EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1001

A STUDY ON THE IMPACT OF BALANCING THE NUMBER OF ELEMENTS OF THE CLUSTERS ON THE UNCAPACITED P-MEDIANS LOCATION PROBLEM USING GRASP WITH PATH-RELINKING

Caroline Parajara[(1)], Gustavo Libotte[(2)], Gustavo Platt[(3)], Geraldo Galdino[(4)]

[(1)]Universidade do Estado do Rio de Janeiro, Brazil
carolparajara@gmail.com

[(2)]Rio de Janeiro State University, Brazil
gustavolibotte@gmail.com

[(3)]Universidade Federal do Rio Grande (FURG), Brazil
gusplatt@gmail.com

[(4)]UENF, Brazil
gpaula.junior@gmail.com

Keywords: GRASP,Path-Relinking,facility location.

Abstract: Facilities installation have been a subject of interest in the production engineering, business management, communities of operational research, transport engineering and logistics companies. The studies of facility location problems deal with questions of minimization of costs in the logistics chain. In many situations, these problems are subject to limitations in the capacity of the facility. Due to these restrictions, logistics demands must be satisfied in order to comply with certain financial interests and meet the service level agreements. In this context, this work aims to evaluate the doubly reactive GRASP procedure integrated with the path-relinking technique, designed to solve the generalized uncapacitated p-medians location problem, using the balanced-sized clusters creation approach, in order to verify the impact of this balance in the context of the total cost of transportation service. The p-median problem refers to locate simultaneously the facilities at different areas, in order to minimize the total transportation distance (and therefore the cost), among each distribution center and the facilities allocated in a certain cluster, for satisfying the demands of its customers. Two reaction parameters are used to control the search for solutions in the GRASP construction phase. The simultaneous use of the two reactive parameters allows the creation of a discipline for the allocation of the customers to the clusters: in general, the nearest customers are allocated first. It was also investigated a relation between the size of the clusters and the median vocation index – an index that establishes how close each province is to each other provinces – of each median, which are the centers of distribution of each cluster. Besides that, it is verified that the clusters that contains medians with better median vocation index tends to have more provinces assigned to it. For the evaluation of the algorithm and the effectiveness of the balancing of the clusters and the median vocation index, the data concerning the distances among all the provinces of Spain were used.

Abstract ID 1002

A GENERALIZED SNC-BESO METHOD FOR MULTI-OBJECTIVE TOPOLOGY OPTIMIZATION

David Munk[1], Timoleon Kipouros[2], Gareth Vio[1]

[1]The University of Sydney, Australia
david.munk@sydney.edu.au, gareth.vio@sydney.edu.au

[2]University of Cambridge, United Kingdom
tk291@eng.cam.ac.uk

Keywords: Smart Normal Constraints; Topology optimization; Multi-objectives

Abstract: Multi-objective optimization plays a vital role in any engineering design problem. Ultimately, a designer must make a trade-off between contrasting and conflicting design objectives. The current approach to facilitate this trade-off is to solve an optimization problem, which yields a candidate solution. This optimization problem usually entails the minimization of a given objective function subjected to a number of constraints. Topology optimization has become a highly developed tool for solving optimization problems, extensively used in the mechanical, automotive and aerospace industries (Sigmund (2011)). Furthermore, gradient-based topology optimization has been proven to efficiently solve fine-resolution problems, having thousands or even millions of design variables, with only a few hundred function evaluations. However, the literature of topology optimization shows a lack of multi-objective algorithms, limiting their application to single objective problems. Recently, Munk et al (2017) introduced the smart normal constraints bi-directional evolutionary structural optimization (SNC-BESO) method, showing that the method is able to produce smart Pareto sets in an effective and efficient manner. However, the method is restricted to bi-objective optimization problems and cannot yet handle multiple constraints. Therefore, if the method is to be successful, the generated Pareto set must truly be representative of the complete optimal design space. Hence, the Pareto set must not over represent one region of the design space, or neglect other regions. This study offers a new development in the SNC-BESO method, which is a simple method for generating smart Pareto solutions that are evenly distributed in the design space. An even distribution of Pareto solutions facilitates the task of choosing the most desirable final design from the set of smart Pareto solutions. The developments presented in this work are namely the ability to generate a set of evenly distributed Pareto solutions over the complete Pareto frontier for multi-objective problems with any number of objectives. Examples will be provided that show the SNC-BESO method applied to n-objective problems, showing its ability to capture all regions of the feasible design space. Therefore, generalizing the SNC-BESO method to all types of multi-objective topology optimization problems.

References

(1) Sigmund O. (2011) On the usefulness of non-gradient approaches in topology optimization, Struct Multidiscip Optim 43, 589-596.
(2) Munk D.J., Kipouros T., Vio G.A., Parks G.T. and Steven G.P. (2017) Multiobjective and multi-physics topology optimization using an updated smart normal constraint bi-directional evolutionary structural optimization method, Struct Multidiscip Optim https://doi.org/10.1007/s00158-017-1781-6.

Abstract ID 1003

TOPOLOGY OPTIMIZATION OF REINFORCED CONCRETE STRUCTURE USING TRUSS-LIKE MATERIAL MODEL

Kemin Zhou, Zhiyi Yang

Huaqiao University, China
zhoukm@hqu.edu.cn, romerome2828@163.com

Keywords: topology optimization,truss-like continuum,steel,concrete

Abstract: Topology optimization of steel and concrete composite based on truss-like material model is presented. The initial design domain is filled with steel and concrete continuously. Structure is analyzed by finite element method. The densities and the orientation of steel at nodes are taken as design variables. The densities of steel are adjusted according to stress ratio method of fully-stressed criterion; the orientation of steel are aligned along maximum principal stress directions. The continuous material distribution field in every element is formed by the interpolation of the material at the nodes belonging the element. Optimizing distributed field of steel, the volume of steel material is minimized under stress constraint. The truss-like continuum constituted with steel and concrete composite is optimized. Several numerical results indicate the numerical instability. More details of manufacture and construction can be presented based on the truss-like material model. The position and orientations of reinforcement of concrete are suggested by the optimization result. Hence, the truss-like material model of steel and concrete is efficient to establish the distribution of steel material in concrete.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1004

OPTIMIZATION OF INFILL STRUCTURES WITH COUPLED HOMOGENIZATION AND LEVEL-SET METHODS

Perle Geoffroy Donders

Safran Tech, France
perle.geoffroy@polytechnique.edu

Keywords: Infill structures,Topology optimization,level-set,homogenization

Abstract: Lattice structures are becoming increasingly popular in the context of additive manufacturing. Thanks to the homogenization method, the topology optimization of such designs is reduced to a more manageable parametric optimization problem. Since the resulting optimized solution remains theoretical, several post-processing methods have been proposed to generate an actual shape. However, the external border of these structures is generally ill-defined, which is a strong limitation for industrial applications. Besides, in order to obtain a functional part, designs featuring a protective external skin would often be privileged. Modeling such structures involves to define on the one hand the global external shape, which can be implicitly described by a level-set function, and on the other hand the inner distribution of the lattice, classically represented by a homogenized material. We propose here to optimize simultaneously the distribution of the inner lattice material and the external shape. The proposed strategy relies on coupling two well-known methods in topology optimization, level-set and homogenization, while taking into account the interface between the skin and the infill of the structure. We present several results in elasticity, in the case of minimization of the compliance. Moreover, we emphasize the fact that this method enables to consider a new range of loads on lattice structures, as hydrostatic pressure.

Abstract ID 1006

MITIGATION OF RAILWAY WHEEL ROLLING NOISE BY USING ADVANCED OPTIMIZATION TECHNIQUES

Jorge Gutiérrez-Gil, Xavier Garcia-Andrés, Jose Martínez-Casas, Enrique Nadal, Francisco Denia

Universitat Politècnica de València, Spain
jorgugi1@etsid.upv.es, xagaran@upv.es, jomarc12@mcm.upv.es, ennaso@upvnet.upv.es, fdenia@mcm.upv.es

Keywords: Rolling noise,optimization,railway wheel,acoustic radiation analysis,evolutive algorithms,finite element method

Abstract: Rolling noise emitted by railway wheels is a problem that affects human health and limits the expansion of the railway network. This problem is caused by the wheel-rail contact, and it is predominant over the rest of noise sources from the vehicle/track system for the usual speed conditions in urban areas. The minimization of rolling noise through changes on the wheel shape by means of the finite element method is discussed in this work, which focuses on potential shape modifications in existing wheels in the form of an optimal wheel web perforation distribution. Such a modification is a cost-effective solution that can be performed in a relatively short term in already manufactured and operating railway wheels. To this end, two objective functions with different computational costs are studied and analysed with several configurations of a genetic algorithm-based optimizer. Both approaches focus on minimizing rolling noise. Approach 1 is based on the minimization of the area below the sound power vs. frequency curve of the wheel, and thus requires solving the system dynamics. On the other hand, Approach 2 is based on the maximization of the natural frequencies of the wheel in order to shift its resonances out of the excitation range, and therefore it only requires a modal analysis. The acoustic radiation analysis is performed through the computation of the normal surface velocities, using a time-domain approach and including a contact filter applied in the track roughness, considered as excitation. Moreover, the structural requirements for fatigue strength in wheels proposed by the optimizer are ensured according to actual standards. Results using Approach 1 reflect that an optimized distribution of perforations on the web of a railway wheel, can reduce significantly the sound power level in the entire studied frequency domain (0 - 5 kHz). This is related to the high sensitivity of the acoustic radiation response with the perforation pattern. Such a phenomenon appears to have a higher impact on noise minimization than that associated with the reduction of the radiating surface due to perforations. The high reduction of the radiated sound power is primarily due to the fact that certain wheel vibration modes with high acoustic contribution are shifted out of the excitation range corresponding to the contact force, this effect being observed in the best solution of Approach 1. Less significant sound power reduction is obtained with Approach 2, although its associated computational cost is considerably lower.

Abstract ID 1007

ADVANCED METHODOLOGIES FOR TOPOLOGY AND GEOMETRY OPTIMIZATION OF NOISE CONTROL DEVICES

Borja Ferrándiz, Jose Martínez-Casas, Enrique Nadal, Juan J. Ródenas, Francisco Denia

Universitat Politècnica de València, Spain
borferca@upvnet.upv.es, jomarc12@mcm.upv.es, ennaso@upvnet.upv.es, jjrodena@mcm.upv.es, fdenia@mcm.upv.es

Keywords: Topology and geometry optimization,silencer,acoustic attenuation,moving asymptotes,finite element method

Abstract: Regarding acoustic attenuation, reactive silencers show a good behaviour at low to mid frequencies, whereas dissipative silencers, i.e., those containing absorbent material, are used in exhaust system applications due to their good performance in wide frequency bands, essentially at high frequencies. The combination of both types of configurations results in the hybrid silencer concept, which shows considerable attenuation in almost all the frequency range of interest. As an initial approach, plane wave models with low computation cost can be employed for acoustic attenuation prediction mainly at low frequencies. However, for more general problems with complex geometries and heterogeneous absorbent material it is necessary the use of multidimensional numerical analysis methods, such as the Finite Element Method (FEM). In the present work, an axisymmetric acoustic model based on a FEM pressure formulation [1] is used in order to predict sound attenuation in dissipative and hybrid silencers in terms of transmission loss (TL). Next, a Topology Optimization (TO) gradient-based algorithm is implemented in order to get the maximum attenuation in a certain target frequency range, assigning a different filling density to each element of the central chamber, while keeping constant the total mass of absorbent material. The adjoint method is used during the TO process in order to speed up the computation of the objective function sensitivities with respect to the design variables (bulk density of each element or group of elements). This TO method is combined with the geometry optimization of the dissipative and reactive chambers. Thus, the implemented algorithm is capable of obtaining not only the optimal absorbent material layout but also the optimal geometry of both chambers (radius and length) which maximizes the silencer transmission loss. In order to combine both techniques, the Method of the Moving Asymptotes (MMA) described in reference [2] is implemented. The FEM solver algorithm is validated with experimental results available in the bibliography. Finally, it is demonstrated that the optimization process results in substantial improvement of the silencer sound attenuation at the target frequency range.

References

(1) A. G. Antebas, F. D. Denia, A. M. Pedrosa, F. J. Fuenmayor. A finite element approach for the acoustic modeling of perforated dissipative silencers with nonhomogeneous properties. Mathematical and Computer Modelling, 57, 1970–1978, 2013.

(2) K. Svanberg. The method of moving asymptotes - a new method for structural optimization. International Journal for Numerical Methods in Engineering, 24, 359–373, 1987.

Abstract ID 1008

AN OPTIMAL STRATEGY FOR TREATING ALZHEIMER'S DISEASE

Samuel Moskowitz

The Hebrew University of Jerusalem, Israel
mosk@mail.huji.ac.il

Keywords: Biomedical,Optimal therapy,Alzheimer's disease

Abstract: Alzheimer's disease is a progressive neurodegenerative dementia in which the brain accumulates amyloid plaques and generates neurofibrillary tangles. The disorder is common among the elderly; hence, it is associated with the process of aging. Dementias impair memory and cognitive skills. Imaging technologies of Positron Emission Tomography and Computed Tomography can reveal the existence of plaques and tangles, which have become hallmarks of the disease. Amyloid beta is cleaved from a precursor molecule in two stages. Normal amounts of protein amyloid beta have beneficial value. An excess is toxic to neurons. In healthy individuals, amyloid beta is cleared from the brain during sleep. With Alzheimer disease, clearance is inefficient resulting in clumping of amyloid beta fragments into plaques. Current and future drug treatments of Alzheimer are directed at curtailing production of amyloid beta, and relieving interference of signals between neurons. Two drugs that are currently in clinical trials are designed to block the activity of beta-secretase, an enzyme, to prevent cleavage. Another medication is aimed at mediating glutamate, a neurotransmitter, necessary for memory and learning that controls the introduction of calcium in nerve cells. From immunotherapy experience, a pill releases antibodies against amyloid beta to enhance clearance through the dura. Eli Lilly announced failure of solanezumab which prevents the formation of plaques. When compared with symptom-free volunteers who took a placebo and whose initial scans revealed high levels of amyloid beta, there was no improvement in the decline of cognitive abilities. The drug company concluded that amyloid beta may not be the cause of Alzheimer's disease, challenging the amyloid hypothesis. Microglia cells reside throughout the brain and spinal column. They scavenge the central system for plaques and dead neurons. Overexpression damages neurons, while their effectiveness diminishes with age. We shall discuss a therapy that utilizes an optimal protocol: that which minimizes deviations from homeostasis. The loss of microglia efficacy resulting from aging observed in a brain scan is compensated by an increase in dosage of the drug employed to remove amyloid beta. We let Δ represent the incremental rate of amyloid beta resulting from inefficient clearance, which is equal to aging rate a. Further, δ defines the optimal dosage used for protein removal. Then, $\Delta/c = a/c = \delta$, where c is a constant. Following this strategy, any benefit derived from normal levels of amyloid would be preserved, side effects avoided, and microglia would still be active removing plaques that remain.

Abstract ID 1009

EVALUATION OF RESIDENTIAL WATER DEMAND CROSS-CORRELATION IN THE CITY OF TRIPOLI

Salah Saleh

University of Tripoli, Libya
ssaleh1974@yahoo.com

Keywords: Water supply systems,demand cross correlation,hydraulic performance,demand allocation.

Abstract: Water supply systems represent an essential component of the infrastructure in urban populations worldwide. Water distribution systems are designed by sizing system components so that they meet current and future demands to be provided at minimum required levels of water pressure and quality. The cost of establishing newly-designed water supply systems is largely dedicated to the supply and placement of pipelines. The sizing of pipelines is highly dependent on the amount of water demands allocated to distribution nodes of the system under consideration. The current demand allocation practices normally imply that there is perfect spatial correlation among the aggregated demands, which is not essentially the case in practice. This assumption indicates that most users follow a single diurnal pattern, which means that such users react simultaneously and in exactly the same way during normal and peak demand conditions. However, the way users react in real-world systems highly depends on many factors that differ from one user to another such as social habits and financial constraints. Recent studies anticipated that low levels of spatial demand correlation can result in significant savings of the capital cost of water supply systems. In this paper, an investigation on the actual demand spatial correlation is carried out using field measurements of diurnal demand patterns for different users in a residential area located in the city of Tripoli. Results showed that users react independently and the correlation is far away from the perfect case.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1010

DISTRIBUTION OF WORKLOAD IN IMA SYSTEMS BY SOLVING A MODIFIED MULTIPLE KNAPSACK PROBLEM

Vasily Balashov, Ekaterina Antipina

Lomonosov Moscow State University, Russian Federation
hbd@cs.msu.su, antipantipovych@gmail.com

Keywords: real-time systems,integrated modular avionics,workload distribution,branch and bound algorithm,scheduling

Abstract: Integrated Modular Avionics (IMA) systems are distributed real-time systems consisting of computing modules connected by a communications network. A typical IMA system utilizes several types of unified modules. Each module runs a set of periodic computational tasks on its central processor (CPU). The tasks are grouped into partitions according to their criticality and data coupling. Each partition is bound to a specific module. Data are transferred between partitions as messages. Frequency of message transfer equals to frequency of the message's sender task. Workload for an IMA system is the set of partitions to be executed on it. CPU load for a task is the multiple of its worst-case execution time (WCET) and frequency. Network load for a message is the multiple of its transfer time and frequency. CPU load for a partition is the sum of CPU loads for its tasks. As different modules can use different CPUs, a task generally has a specific WCET for every module, so CPU load by a partition depends on the module. If two partitions are bound to the same module, messages between them do not create network load. For each module, there is a specific upper limit on CPU load. Binding of some partitions can be restricted to a subset of modules, e.g. those with graphical co-processors. To ensure schedulability and scalability of an IMA system, the workload distribution problem is stated as follows: assign partitions to modules so that the total network load is minimized, and the constraints on CPU loads and partitions binding are met. In this paper, we represent this problem as a modified version of the Multiple Knapsack Problem (MKP). Modules correspond to knapsacks, partitions to items, CPU loads by partitions to item volumes, CPU load limits to knapsack capacities. Item's volume depends on the choice of knapsack. Difference from the original MKP is that profit is assigned to pairs of items (reflecting the network load by a pair of partitions); profit is considered zero if the two items are packed in different knapsacks. The goal is to maximize the total profit. We present a branch and bound algorithm for solving the modified MKP, including a new scheme for upper bounds calculation and heuristics for search space reduction. Algorithm scalability is analyzed on data from real IMA systems. The algorithm is implemented in a scheduling tool accepted for operation by one of the leading Russian aircraft design companies.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1011

SHAPE OPTIMIZATION OF STRAINED GRIDSHELLS

Jef Rombouts[(1)], Geert Lombaert[(1)], Lars De Laet[(2)], Mattias Schevenels[(1)]

[(1)]KU Leuven, Belgium
jef.rombouts@kuleuven.be, geert.lombaert@kuleuven.be, mattias.schevenels@kuleuven.be

[(2)]Vrije Universiteit Brussel, Belgium
lars.de.laet@vub.be

Keywords: Shape optimization,method of moving asymptotes,gridshell

Abstract: Strained gridshells are reticulated shell structures that are erected from a flat grid of initially straight laths. This construction method allows complex curved shapes to be built without requiring specialized off-site manufacturing techniques. The design of strained gridshells is usually subdivided in different stages. First, the overall shape is chosen by the designer. Next, a geometrical technique is used to map a grid on the target surface. Subsequently, material and section properties are assigned to the members of the grid and the bending of the laths is simulated. Finally, loads are applied to the model and a structural analysis is carried out. These design stages have to be performed iteratively to reach a satisfying design. In this paper, an optimization procedure is proposed that optimizes the shape of a strained gridshell for a given grid of straight laths. The erection forces are chosen as the design variables. These erection forces are optimized to minimize the so-called end-compliance, which is defined as the inner product of the external loads and the resulting displacements. The method of moving asymptotes is adopted and implicit dynamic relaxation [1] is used to solve the nonlinear equilibrium equations, ensuring that the required computation time is acceptable. Nonlinear effects such as buckling are taken into account by using co-rotational beam elements to model the gridshell laths. It is shown that this approach allows the structure to be optimized to satisfy safety and serviceability criteria for different load cases. Moreover, it is possible to account for practical building constraints, such as a limitation of the number of nodes to be pushed or pulled during the erection phase. Finally, also designer's preferences can be taken into account via constraint equations. In conclusion, the proposed optimization approach leads to an optimized design while satisfying the designer's preferences and potential buildability constraints. Moreover, the proposed optimization approach simplifies the design process, as it is not necessary to iterate between different design stages.

References

(1) J. Rombouts, G. Lombaert, L. De Laet, and M. Schevenels. On the equivalence of dynamic relaxation and the Newton-Raphson method. International Journal for Numerical Methods in Engineering, 113(9):1531- 1539, 2017.

Abstract ID 1014

SURROGATE-ASSISTED OPTIMIZATION WITH ONLINE SELECTION OR AGGREGATION OF MODELS

Charlotte Beauthier, Caroline Sainvitu, Tariq Benamara

Cenaero, Belgium
charlotte.beauthier@cenaero.be, caroline.sainvitu@cenaero.be, tariq.benamara@cenaero.be

Keywords: Surrogate-based optimization Surrogate models Selection of models Ensemble of models

Abstract: A globally effective approach to high-fidelity optimization problems based on computationally expensive analysis lies in the exploitation of surrogate models. They act as cheap-to-evaluate alternatives to the original high-fidelity models reducing the computational cost, while still providing improved designs. Since several surrogate types can be available, a priori choosing the most suitable one for a given problem is a difficult task for the user. Therefore, the aim of this work is to investigate some online strategies that can help to select the ``best'' surrogate model, or to aggregate several surrogate models by combining them. These strategies of selection and ensemble of models allow to overcome the a priori choice of the type of surrogate model. Indeed, one unique choice of surrogate model can not be suited to all kind of problems. Moreover, the same choice for all responses (objective(s) and constraint(s)) can be inadequate since the different responses can have very different behaviors and therefore require different types of approximation. Either in selective or combined approaches, it is important to define adequate performance measures of the surrogate models. The quality indicators used in this work are the ''Determination Coefficient (R^2)`` and the ''Ranking/Relation Preservation (RP)``. The metric R^2 gives a quantitative measure of the predictability of a surrogate while the RP metric refers to the ability of a surrogate model to preserve the same rank of the solutions with respect to the real function. Surrogate model selection methods consist in assessing the performance of various surrogate models and select one of them. Our considered selection strategy is based on the sum of these performance metrics. One drawback of a selection approach is that it does not take into account complete advantage of the computational resources used to train the different surrogate models. Therefore, the second approach consists in considering a combination of surrogate models. The performances of the online selection and aggregation strategies have been demonstrated in a Surrogate-Based Optimization (SBO) process in comparison with a classical SBO process exploiting a static a priori chosen surrogate model. The results reveal that the selection and aggregation strategies give globally better results in terms of convergence than a static surrogate model that would be chosen a priori. Finally, being able to select a surrogate model or aggregate several ones for each response (objective(s) and constraint(s)) at each iteration is a definite advantage of the considered approaches.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1015

TWO-SCALE TOPOLOGY OPTIMIZATION USING NEURAL NETWORK SURROGATE MODELS

Daniel White(1), Bill Arrighi(2), Jun Kudo(1), Seth Watts(2)

(1)Lawrence Livermore National Laboratory, United States
white37@llnl.gov, kudo4@llnl.gov

(2)LLNL, United States
arrighi2@llnl.gov, watts24@llnl.gov

Keywords: structural mechanics,topology optimization,surrogate model,neural network

Abstract: Due to advances in manufacturing, particularly additive manufacturing, there is significant interest in the design and optimization of macro-scale structures that are realized via spatially-varying micro-scale lattices. Because the micro-scale feature size is 100x to 1000x smaller than the macro-scale dimensions, a fully resolved optimization of the spatially-varying micro-scale lattice is not feasible. Instead, a two scale off-line, on-line approach is proposed. The off-line step consists of highly resolved finite element simulations of lattices with known topology, this is achieved using adaptive mesh refinement to resolve the small features of the lattice. The results of these off-line simulations are used to construct a surrogate model of the elastic response of the lattice. The on-line step consists of a density-like topology optimization of the macro-scale structure, but with N decision variables per element. These N decision variables define the variation of the lattice. If the lattice of interest consists of rods, the decision variables are the radii of the rods. If the lattice of interest consists of spherical inclusions e.g. a foam-like material, the decision variables are the location and radii of the spherical inclusions. As another example, the decision variables can be the density and orientation of carbon fiber for a chopped fiber 3D printer. The surrogate model must accurately capture the effective stiffness of the lattice, including the most general forms of anisotropy. But it must also be efficient to evaluate. Radial basis function approximation is well suited for approximating surfaces and fields in higher dimensions. Radial basis function approximation can be of either interpolatory or regression form, and for this this particular application the regression form is more suitable because it provides smoother results with accurate derivatives which are essential for optimization. The regression form, also known as a least-square fit, is a special type of neural network called a radial basis function network. Results are presented for standard test problems such as cantilever beams, as well as for real-world problems such as optimization of civil and aerospace structures. We quantify the benefits of spatially varying versus uniform lattices, and anisotropic versus isotropic lattices.

Abstract ID 1016

COMPUTATIONAL OPTIMIZATION TOOLS FOR MATERIAL DESIGN OF ELASTIC PROBLEMS USING INVERSE HOMOGENIZATION

Juan Podesta(1), Carlos Méndez(2), Sebastián Toro(2), Alfredo Huespe(2), Javier Oliver(2)

(1)Department of Applied Mechanics - Faculty of Engineering - Northeast National University, Argentina
jmapodesta@gmail.com

(2)CIMEC-UNL-CONICET, Argentina
cgmendez@cimec.unl.edu.ar, sebatm@gmail.com, ahuespe@intec.unl.edu.ar, oliver@cimne.upc.edu

Keywords: Inverse homogenization,topology optimization,symmetry,topological derivate.

Abstract: The objective of this work is to present new computational optimization tools which can be applied to obtain solutions of inverse homogenization problems related to elastic material design satisfying structural requirements. The specific problem that is studied in this work consists of determining the material micro-architecture, such that the elastic effective properties of this heterogeneous material copy those of a target elasticity tensor. The spatial distribution of the hard material phase within a given unit cell that satisfies the sought requirement is found through a rather conventional topology optimization problem [1]. In particular, we use a methodology that is based on a topology optimization algorithm using topological derivative and the level set function [2]. And the specific tools that we have developed in this computational context exploit two aspects of this problem: i) the symmetry of the target elastic tensor, and ii) the shape of the unit cell in where the optimum topology is sought [3]. Therefore, we present a comprehensive analysis of the connection between the target tensor physical features, i.e. its symmetry properties, and the material distribution in the microstructure. According to this idea and assuming periodic micro-architectures, we analyze several Bravais lattices and the plane wallpaper groups in order to study the way in which the symmetries of these patterns are reflected in the homogenized elasticity tensor. We analyze the Wigner-Seitz cells, i.e. the primitive cells, of the subjacent Bravais lattices that preserve all the symmetries and the corresponding implementation of the plane wallpaper groups. Finally, using the connection between physical properties and micro-structural patters, we propose a procedure for the inverse problem that selects the most convenient external boundary shape of the unit cell in where the topology optimization problem is solved, as well as the necessary geometrical symmetries to be imposed to the material distribution within the unit cell that guarantee the symmetry of the homogenized elastic tensor of the designed micro-architecture material. In the search of new extreme material classes, the proposed tools aim to facilitate the inverse design by obtaining simple micro-architecture solutions. [1] Bendsoe, M. P.,

Abstract ID 1017

SHAPE DERIVATIVES OF GEOMETRIC CONSTRAINTS WITHOUT INTEGRATION ALONG RAYS

Florian Feppon[1], Grégoire Allaire[1], Felipe Bordeu[2], Julien Cortial[2], Charles Dapogny[3]

[1]Ecole polytechnique, France
florian.feppon@polytechnique.edu, gregoire.allaire@polytechnique.fr

[2]SAFRAN TECH, France
felipe.bordeu@safrangroup.com, julien.cortial@safrangroup.com

[3]Université Joseph Fourier, Grenoble, France
charles.dapogny@univ-grenoble-alpes.fr

Keywords: Topology optimization, level set method, signed distance function, thickness constraints, advection operator

Abstract: A variational method is proposed to compute integral quantities along the characteristic curves of a velocity field without the need for computing these curves explicitly on the spatial discretization. Such needs occur for instance whencomputing shape derivatives of geometric constraints built upon the sign distance function, which involves integration along normal rays of the optimized shape. Here, we rely on a symmetric variational problem that can be solved conveniently with the finite element method. The well-posedness of the formulation is established through a detailed analysis of weighted graph spaces of the advection operator for C1 velocity fields. Our working assumptions are fulfilled in the context of shape optimization of C2 domains, for which the velocity field is a unit extension of the outward normal. The variational method is compared numerically to direct integration along rays on several analytical examples. Implementation issues such as curvature estimation or taking the skeleton of the ape into account are discussed. Finally, we illustrate the use of our method to enforce conveniently maximum and minimum thickness constraints in structural shape optimization.

Abstract ID 1018

OPTIMAL DESIGN OF ADAPTIVE TOOTHED VARIATOR (CVT)

Konstantin Ivanov

Almaty University of Power Engineering and Telecommunication, Institute of Mechanics and Machine Science of MON RK, Kazakhstan
ivanovgreek@mail.ru

Keywords: toothed variator,force adaptation,test-bed,technique of testing.

Abstract: The adaptive toothed variator represents the planetary gear mechanism with constant engagement of cogwheels and with the variable transfer ratio. The variator is self-regulated mechanism and it works without a control system. Basic difference of a gear variator is the mechanism has two degrees of freedom and only one input. Definability of motion provides the planetary four-bar closed contour creating additional power constraint with circulation of energy. The variator is created on the basis of a discovery of Professor Ivanov K.S. «Effect of force adaptation in mechanics». The essence of the discovery is a planetary kinematic chain with two degrees of freedom in which cogwheels form the mobile closed contour, adapts for variable loading by an independent regulation of motion speed of cogwheels in a contour under the influence of loading. For creation of gear variator it is necessary to use brand new principle of act of the mechanism providing the variable transfer ratio. This principle of act is based on energy circulation in the kinematic chain with two degree of freedom. Energy circulation is provided with the toothed wheels forming a mobile closed contour placed between input and output links of a mechanism. Intensity of circulation of energy depends on variable output loading. This key property of the closed contour defines additional constraint which will neutralize superfluous mobility of the closed contour. As a result the variable transfer ratio is provided with variable output loading. Thus the gear variator will provide not only the variable transfer ratio but also adaptation to a variable load. Adaptation is brand new property of the mechanism allowing to work without a control system. The gear variator is the adaptive self-controlled mechanism. The purpose of the present work to create the optimum design of an adaptive toothed variator performing both necessary and sufficient conditions of adaptation and independent reliable start. The basic theoretical regularities of creation of a gear variator, the description of a development type of a variator and the test-bed, technique of conducting of tests and results of tests of the adaptive gear variator are presented. The adaptive gear variator is the optimal on all parameters highly effective self-controlled connecting gear which can be used for machines with variable technological resistance in all branches of engineering from motor industry to a robotics.

Abstract ID 1020

PARALLEL ROBOTS LIKE A PORTABLE REORIENTATION SYSTEM FOR TRACKING SATELLITES

Jhonatan Eulopa Hernandez[1], Eusebio Eduardo Hernández Martínez[2], Jorge L. Garrido Téllez[2]

[1]Aerospace Development Center-National Polytechnic Institute, Mexico
jhonatan.eulopa@gmail.com

[2]Sección de Estudios de Posgrado e Investigación de la Escuela Superior de Ingeniería Mecánica y Eléctrica U.P. Ticomán, Instituto Politécnic, Mexico
euhernandezm@ipn.mx, jgarrido@ipn.mx

Keywords: Stewart platform,Satellite tracking,Numerical simulations,Precision,Sensitivity analysis.

Abstract: The conventional systems of reorientation of a satellite tracking antenna in portable satellite communications stations are based on serials robots, serial robots have three degrees of freedom and are composed of several kinematic chains joined by rotational articulations. These characteristics can affect the performance of satellite tracking since they limit their movements. For this reason, it is proposed a Stewart platform towards the reorientation system that can accept accelerations and higher speeds during its movement, support large loads that have a higher rigidity and precision to be considered by six actors in parallel and finally, have a better follow-up of your six degrees of freedom. The demand for precision for satellite tracking is high, to determine the accuracy of the Stewart platform, a sensitivity analysis is performed that requires information on the design parameters that must be considered to perform a task with precision. Through the numerical simulations with the Matlab® software, it was found a range for maximum tolerances, varying the geometric parameters and varying the definition of the design applications to satisfy the demand in the accuracy of the application.

Abstract ID 1022

ALTERNATIVES TO EVOLUTIONARY OPTIMIZATION ALGORITHMS IN THE CONTEXT OF TRADITIONAL STOCHASTIC OPTIMIZATION METHODS IN THE SMART AREA TECHNICAL EQUIPMENT APPLICATION

Bohumír Garlík

Czech Technical University in Prague, Czech Republic
bohumir.garlik@fsv.cvut.cz

Keywords: Evolutionary Optimization Algorithms,Stochastic Optimization Methods,Smart Area,Technical Equipment

Abstract: In recent years, the use of evolutionary computational techniques has become widespread in many technical disciplines including, but not limited, neural networks and evolutionary algorithms. From these techniques, in the field of global optimization, mainly the evolutionary optimization algorithms are used. Because of this biological inspiration, the principle of genetic algorithms is easily understood by non-mathematicians as well. However, from the mathematical point of view, the evolutionary and genetic algorithms are just another representatives of stochastic optimization algorithms. The aim of our research was to describe the basic properties of stochastic algorithms including genetic algorithms, to select suitable candidates from the class of traditional stochastic algorithms and to compare their behaviour with the genetic algorithms. The stochastic optimization algorithms provide the advantage of efficient working even with such functions. An important criterion for optimization is also the ability to parallelize a task. The optimization algorithms can be implemented as a parallel system – we calculate the value of a purpose function at several points at the same time. We can use this for some tasks (for example, if we have a device that can perform multiple measurements at a time), but there are tasks, where this process does not provide any acceleration. This feature of the task will be called the ability to parallelize a task. The paper will also describe the specific described implementation and testing of selected algorithms on analytical functions as well as functions mediated by artificial neural networks, which have been learned on practice data and are intended, therefore, to simulate real problems in practice. Furthermore, the aim of our research was also to select those representatives of traditional stochastic algorithms that would be able to compete with the genetic algorithms by their accuracy or speed, to implement these algorithms and to test them on specific data. The paper will provide description of the algorithms where the algorithms will be compared from the theoretical point of view and such algorithms that are suitable for comparison with the genetic algorithms will be selected. In addition, we will describe how the specific methods have been implemented, how they have been modified compared to the basic version, and how the constants of these algorithms have been set. Last but not least, the results of testing of each algorithm on the practice data will be presented and, in the final phase, these results will be analysed.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1023

VEHICLE CONFIGURATION DESIGN USING CELLULAR-DIVISION AND LEVEL-SET BASED TOPOLOGY OPTIMIZATION

RAMANA GRANDHI[(1)], Hao Li[(1)], Marcelo Kobayashi[(2)], RAYMOND M. KOLONAY[(3)]

[(1)]Wright State University, United States
Ramana.Grandhi@wright.edu, li.138@wright.edu

[(2)]University of Hawaii, United States
marcelok@hawaii.edu

[(3)]Wright Patterson Air Force, Base, United States

Keywords: Topology Optimization,Global Optimization,Level-set method

Abstract: While developing new aircraft configurations, the designers have to consider the mission performance based on the requirements on payloads, thermal boundaries, dynamic stability, control effectiveness, and propulsion cycles limitations. Creation of conceptual geometries from simple straight surfaces requires extensive design space exploration for achieving an optimal performance while satisfying multidisciplinary requirements. Always innovative tools are needed for realizing potential configurations with limited computer and manpower resources. In this research a combination of modern optimization methods are integrated for shape and topology evolution of structural components. A combination of global-local optimization with the possibility of multi-objective trade-off solutions is considered. Cellular-division concept is inspired by the division of biological cells in living organisms. The approach starts by taking the Genetic Algorithm (GA) generated binary string (chromosome) for creating the base-line structural topologies using edge production rules and geometric properties. Based on the edge production rules that are developed in cellular-division with dynamic equilibrium, initial edges break points and regions are created. The approach facilitates creation of several conceptual topologies that need to be optimized further, for meeting the multi-physics design requirements. Based on the GA generated populations, many innovative configurations have the potential to be candidate vehicles. Recently level-set based topology optimization has gained popularity due to its advantages in providing smoother boundaries for complex shapes, and also precisely satisfying the local constraints. The implicit boundary definition allows complicated shape changes with a smooth description of structural boundaries, which avoids the ambiguities of intermediate elements within the material domain as appeared in density based method. Cellular-division created geometries need to be optimized for local constraints using an optimization scheme. The proposed design framework integrates level-set method into the cellular-division framework as a local optimizer to form a global-local design scheme with GA. At the global-level, many potential configurations are created using the cellular-division as the initial designs and at the local-level level-set method optimizes these initial designs for strict constraint satisfaction. A combination of these two approaches with their individual strengths are synergistically integrated for evolving a configuration from an open-ended design space. The presentation demonstrates the framework using several benchmark problems of topology optimization and air vehicle structural problems.

Abstract ID 1024

A SURROGATE-ASSISTED COOPERATIVE CO-EVOLUTIONARY ALGORITHM FOR SOLVING HIGH DIMENSIONAL, EXPENSIVE AND BLACK BOX OPTIMIZATION PROBLEMS

Julien Blanchard[1], Charlotte Beauthier[2], Timeteo Carletti[1]

[1]University of Namur, Belgium
julien.blanchard@unamur.be, timoteo.carletti@unamur.be

[2]Cenaero, Belgium
charlotte.beauthier@cenaero.be

Keywords: global optimization; large-scale optimization; surrogate-assisted optimization; high dimensional,expensive and black-box functions; cooperative co-evolutionary algorithm; random grouping; genetic algorithm; evolutionary algorithm;

Abstract: Many research efforts have been recently put to solve large-scale global optimization (LSGO) problems by means of evolutionary algorithms (EAs). Unfortunately, standard EAs are usually not well-suited for such LSGO problems and their performance declines once the number of variables increases. This issue is mainly explained by the exponential growth of the search space and is referred as the "curse of dimensionality". Cooperative co-evolution has been proposed to solve such problems involving thousand of variables. This methodology consists in dividing the LSGO problems into several subproblems, each of them being optimized in a round-robin fashion with an EA. The latter has proved to be very efficient to solve a wide range of LSGO problems. Nevertheless, it often requires a huge number of function evaluations to reach a suitable solution. This is somewhat problematic when the function evaluation is computationally expensive. To overcome this costly issue and still get suitable precision accuracy, one can take advantage of surrogate models. They act as cheap-to-evaluate alternatives to the original high-fidelity models reducing the computational cost, while still providing improved designs. This kind of optimization process, called surrogate-assisted optimization, has been shown to be very efficient on small-dimensional problems but suffers from the curse of dimensionality to solve LSGO problems. Indeed, this curse affects the EA optimization but also affects the quality of the surrogate models. In this paper, cooperative co-evolution relying on dynamic random decompositions is combined with surrogate-assisted optimization in order to efficiently solve high dimensional, expensive and black-box (HEB) problems. The proposed algorithm is based on two pillars: on the one hand, the achievement, in a limited number of function evaluations, of a satisfactory solution required by the HEB nature of the studied problems; on the other hand, its potentially scalable architecture by means of parallel function evaluations. Our study provides good results when solving a wide set of benchmark problems with 100, 500 and 1000 variables. The benefit of the parallel architecture is shown very attractive when comparing with a standard surrogate-assisted algorithm. Furthermore, the presented algorithm is compared with the state-of-the-art algorithm SACCJADE. The comparison has shown that our algorithm is very efficient to find a satisfactory solution with a very small budget in terms of function evaluations.

Abstract ID 1025

DISCUSSION ON BUCKLING LOAD OPTIMIZATION FOR CONTINUUM MODELS SUBJECTED TO ECCENTRIC LOADS

Pauli Pedersen[1], Niels Pedersen[2]

[1]Technical University of Denmark, Mechanical Engineering, Solid Mechanics, Denmark
pauli@mek.dtu.dk

[2]Department of Mechanical Engineering, Technical University of Denmark, Denmark
nlp@mek.dtu.dk

Keywords: Buckling estimation,Eigenvalue formulations,Sensitivities,Analytical,FE

Abstract: Buckling load estimation of continua modeled by finite element (FE) should be based on non-linear equilibrium. When such equilibrium is obtained by incremental solutions and when sensitivity analysis as well as iterative redesigns are included, the computational demands are large especially due to optimization. Therefore, examples presented in the literature relate to few design variables and/or few degrees of freedom. In the present discussion a non-incremental analysis is suggested, and a simple sensitivity analysis as well as recursive redesign is proposed. The implicit geometrical non-linear analysis, based on Green-Lagrange strains, apply the secant stiffness matrix as well as the tangent stiffness matrix, both determined for the equilibrium corresponding to a given reference load, obtained by the Newton-Raphson method. For the formulated eigenvalue problem, which solution give the estimated buckling load, the tangential stiffness matrix is of major importance. In contrast to formulations based on incremental solutions, the tangent stiffness matrix is here divided into two matrices, the stress stiffness matrix that is linear depending on stresses and the remaining part of the tangent stiffness matrix. Examples verify the effectiveness of the proposed procedure. Buckling of homogeneous (uniform density) 2D finite element models are in agreement with available analytical 1D results. The obtained optimized density distribution for a cantilever with central load corresponds to improved bending stiffness, as expected. Then influence from eccentric load on a frame is reported, and in addition to stiffness improvement the redesigns also stabilize by change of eccentricity.

Reference:
Pedersen, N.L., and Pedersen, P. : ''Local analytical sensitivity analysis for design of continua with optimized 3{D} buckling behaviour'' Struct. Multidisc. Optim., 57:293--304, {2018}

Abstract ID 1026

RELIABILITY-BASED DESIGN OPTIMIZATION OF WARPING INCLUDED CURVED ON PLANE BEAM WITH CHAIN HOIST LOAD

Mariusz Poński, Andrzej Sluzalec

Czestochowa University of Technology, Poland
mponski@bud.pcz.czest.pl, sluzalec@bud.pcz.czest.pl

Keywords: reliability,warping,optimization,genetic algorithm

Abstract: The paper presents reliability-based design optimization of curved on plane I-section beam with chain hoist load. This type of structures is one of the most common in industrial buildings. In case of such an element stiffness against warping, which depends on the lateral bending resistance of the flanges plays important role and have to be included in analysis. Such an analysis is made incorporating Vlasov beam theory and large displacement formulation (second order theory). Material parameters such as axial stiffness, flexural and torsional rigidity, transverse shear stiffness and warping stiffness are assumed as random, as well as chain hoist load. Two approaches of uncertainty quantification are considered. First, a standard way, in which parameters are modeled as random variables with log-normal distribution and second, in which parameters are modeled as Gaussian random fields. Second approach can be used when length varying properties are considered. Two-stages reliability-based design optimization method is used. To compute the probability of failure reliability index method with Hasofer-Lind index is adopted. Design point is computed with Abdo-Rackwitz-Fiessler algorithm. Constrained optimization problem is solved using Genetic Algorithm.

Abstract ID 1027

FINITE ELEMENT MESH SIZE OPTIMIZATION FOR STEEL BOLTED CONNECTION

Mario Galic, Hrvoje Draganic, Tihomir Doksanovic

Faculty of Civil Engineering Osijek, Croatia
mgalic@gfos.hr, draganic@gfos.hr, tdoksanovic@gfos.hr

Keywords: nonlinear optimization,artificial neural network,computational time,bolt-hole elongation

Abstract: Bolted connections are important components of steel structures and as such must be based on good design and detailing. Popularity of bolted connections entails that their failure mechanisms are thoroughly researched and adequately analytically described. A prerequisite for a robust and reliable analytical description of a failure mode is a large base of results, collected experimentally or numerically, usually via finite element analysis. FEM simulations are a common approach for research purposes, but the modelling procedure can significantly influence result accuracy. One of the most important parameters for successful convergence and accuracy is spatial discretization, i.e. mesh size. Mesh size presents a delicate balance between accuracy, efficiency and convergence issues, especially in bolted connection analysis where mesh quality amplifies these effects, through contact, material and geometric nonlinearity. Sensitivity studies are, due to increased complexity of nonlinear behaviour, often difficulty to interpret and time expensive, which is why in this study, based on previous research, a mesh size optimization procedure is presented. This optimization is based on a previously verified and validated numerical model parametric study, which produced a large enough dataset of results. The numerical model is of a single-bolt lap connection, as such a connection represents challenging problems in modelling, such as complex boundary conditions (rotation due to longitudinal eccentricity), contact formulation, several possible failure mechanisms. Two-stage optimization was performed in order to determine for which mesh size results of the numerical analysis (bolt-hole elongation and load) converge to those obtained experimentally. The first step included forming of an optimization model based on an artificial neural network (ANN). Results were extrapolated and compared to those attained experimentally, which indicated that the mesh size of 0.87 mm would provide near optimal (experimental) results. However, estimated solving wall time was significantly longer. In the second step, a nonlinear optimization model was structured in order to find a mesh size for which the difference between experimental and optimization results would be equal, whilst the optimization objective was to find a mesh size which requires minimal solving wall time. The optimization model provided insights into mesh size quality to efficiency ratios and rendered that the minimal difference between experimental and numerical results (1.57 %) can be obtained with a mesh size of 2.19 mm. For this mesh size, the model estimated a solving wall time of 1.3 hours, instead of the step one optimization modelling estimated 36 hours.

Abstract ID 1028

DESIGN OF A COMPOSITE STRUCTURE WITH MANUFACTURING CONSTRAINTS

Samih Zein, David Dumas

Cenaero, Belgium
samih.zein@cenaero.be, david.dumas@cenaero.be

Keywords: Genetic Algorithms; Repair Operator; Constraint Satisfaction Programming; Manufacturable Composite Structures.

Abstract: Composite structures are mechanical structures composed of fibers (carbon) and resin. In the recent years, composite structures have taken a growing importance in the aeronautical industry. Because they exhibit high performance properties and lead to a considerable weight reduction, they can be an alternative choice in the design of many aircraft parts. The paper presents a methodology to design such structure. A composite structure is made of a stacking of plies and the fibers in each ply can be oriented in a specific direction (0°, 45°, 90° and 135°). If the structure is divided into zones, the design variables will be the number of plies per orientation per zone. The mechanical performance of the structure depends on the total number of plies and the percentage of plies per orientation in each zone. The objective is to reduce its weight while satisfying some structural integrity constraints. Moreover the stacking sequence of the plies must also satisfy some manufacturing rules. These constraints are of combinatorial nature with respect to the design variables. A stacking sequence generator is used to compute admissible stacking sequences with respect to these rules and which correspond to the design variables. Given that an admissible stacking sequence does not exist for every set of values of the design variables, a repair operator is proposed to cope with this problem. It aims at changing the values of the number of plies in each orientations in order to guarantee the existence of admissible stacking sequences with respect to the manufacturing rules. The approach to solve this optimization problem using a surrogate based genetic algorithm. A repair operator, which is the main focus of the talk, is presented to handle the manufacturing rules. An engineering application is presented to show the advantages of this approach in terms of constraint satisfaction and computational time. The application represents the design of an aircraft wing. The objective function is the weight of the wing. The constraints are the stability of the wing, the Tsai-Wu failure criteria and the manufacturing rules which are handled by the proposed repair operator.

Abstract ID 1030

POWER LOSS REDUCTION THROUGH NETWORK RECONFIGURATION AND DISTRIBUTED GENERATION BY MEANS OF FEASIBILITY-PRESERVING EVOLUTIONARY OPTIMIZATION

Slawomir Koziel(1), Alberto Rojas(1), Szczepan Moskwa(2), Mohamed Abdel-Fattah(1)

(1)Reykjavik University, Iceland
koziel@ru.is, alberto16@ru.is, abdelfattah@ru.is

(2)AGH University of Science and Technology, Poland
szczepan.moskwa@agh.edu.pl

Keywords: Distribution network reconfiguration,distributed generation,smart grids,power loss reduction,mixed-integer optimization,evolutionary algorithms,design feasibility

Abstract: Reduction of power losses and improvement of voltage profile in power distribution networks has been often approached by methodologies such as distribution network reconfiguration (DNR), capacitor bank placement and Volt/Var control [1]. Recently, optimal allocation of distributed generation (DG) has been taken into consideration as a method for grid support due to its attributions towards frequency drop stabilization [2], power loss reduction and voltage profile improvement [3]. Combination of multiple methodologies such as distribution reconfiguration and optimal allocation of DGs have been proposed to increase the benefits [4], [5]; however, the practical complexity of implementing such combination of methodologies increases significantly. The paper proposes a novel algorithm for power loss reduction through DNR and optimization-based allocation of DG sources. In this work, DNR is solved simultaneously with DG allocation. The problem at hand is a complex mixed-integer task. A customized evolutionary algorithm has been developed with recombination operators preserving a radial structure of the network, integer-based operators for DG placement, and floating-point operators for handling their power output capacities. Comprehensive numerical validation performed on standard IEEE 33- and 69-bus systems indicates that our methodology outperforms state-of-the-art algorithms available in the literature in terms of the obtained power loss reduction. Furthermore, it features good repeatability of results as demonstrated through statistical analysis of multiple algorithm runs.

Refrences:

[1] G. Gutiérrez-Alcaraz and J. H. Tovar-Hernández, "Two-stage heuristic methodology for optimal reconfiguration and Volt/VAr control in the operation of electrical distribution systems," IET Generation, Transmissio

[2] A. A. A. El-Ela, S. M. Allam, and M. M. Shatla, “Maximal optimal benefits of distributed generation using genetic algorithms,” Electr. Power Syst. Res., vol. 80, no. 7, pp. 869–877, Jul. 2010

[3] N. A. M. Khairuddin and L. M. Cipcigan, "Optimal placement and capacity of distributed generators in medium voltage generic UK network," 2016 51st International Universities Power Engineering Conference (UPEC), Coimbra, 2016, pp. 1-6.

[4] R. Rakesh, P. VenkataPapana and S. Keerthi, "A hybrid algorithm for optimal allocation of DG in radial distribution system," 2017 IEEE Region 10 Symposium (TENSYMP), Cochin, 2017, pp. 1-5.

[5] R. S. Rao, K. Ravindra, K. Satish and S. V. L. Narasimham, "Power Loss Minimization in Distribution System Using Network Reconfiguration in the Presence of Distributed Generation," in IEEE Transactions on Power Systems, vol. 28, no. 1, pp. 317-325, Feb. 2013.

Abstract ID 1031

STUDY OF POWDERS HANDLING WITH DISCRETE ELEMENT METHOD: HOW OPTIMIZATION SHOULD AND CAN BE USED

Riccardo Cenni

SACMI IMOLA S.C., Italy
riccardo.cenni@sacmi.it

Keywords: Discrete Element Method,Calibration,Surrogate Models,Shape Optimization

Abstract: According to current estimations, a large amount of industrial capacity is get lost due to solids handling problems while the energy consumption of solids handling consumes around 10% of the annual global energy utilization. In such a framework, industries are thus looking more and more into computational methods to study bulk materials and design better processes. Thanks to increasing computer capabilities and more readily useable codes, Discrete Element Method (DEM) is nowadays an available tool for industries. Even if DEM can treat also other powders processes like agglomeration and fluidization, the present work focuses on powders handling and how can optimization techniques help in studying this kind of processes through DEM. Optimization is always required to perform a DEM analysis. In fact, due to the lack of powders rheological data and the number of parameters that characterize the particles interaction models, a calibration step is a requisite to achieve significant results from DEM. A methodology based on surrogate models to calibrate DEM using experimental data measured in bulk physical tests is here detailed. It consists in the DEM reproduction of experimental tests and the creation of suitable response surfaces of this virtualization. The proposed approach reduces the calibration to experimental tests and optimization on surrogate models by avoiding DEM simulations in the calibration stage each time a new powder is studied. Optimization can also be part of a DEM based design process of a handling machine. There are few works in literature on shape optimization coupled with DEM mainly due to computational efforts. A coarse-grained approach to perform shape optimization with DEM is also proposed and applied to an industrial component.

Abstract ID 1032

MATHEMATICAL MODELLING FOR AN OPTIMAL MONITORING DESIGN IN QUALITY CONTROL OF TRAFFIC

Miguel Vázquez-Méndez(1), Lino Alvarez-Vazquez(2), Gerardo Casal(1), Néstor García-Chan(3), Aurea Martínez(2)

(1)Universidade de Santiago de Compostela, Spain
miguelernesto.vazquez@usc.es, xerardo.casal@usc.es

(2)Universidade de Vigo, Spain
lino@dma.uvigo.es, aurea@dma.uvigo.es

(3)Universidad de Guadalajara, Mexico
nestor.gchan@academicos.udg.mx

Keywords: Monitoring,Quality Control,Optimal design,Mathematical modelling

Abstract: Monitoring consists of carrying out surveillance on and/or recording any variable under study. It is not only a very useful technique in medicine (observation of a disease or any medical parameters over time), but also in computing, social sciences, environment, industry, etc. Particularly, it is an essential tool in the Quality Control (QC) of any process. For example, pollution monitoring in a river can be very useful to locate any illegal discharge. In a similar way, traffic flow monitoring can help to detect accidents or cars failed on the road. The design of a monitoring system is a very important task in the QC process. In many cases, reliable estimations of the variables under study can be obtained by using mathematical modelling (numerical simulation). If estimations are available, a monitoring strategy giving representative measurement of these variables can be obtained by solving a multi-objective optimization problem. The usefulness of this procedure can be shown, for example, by designing a river quality monitoring system, using a 1D hyperbolic-parabolic system for the numerical simulation. Another useful application of previous procedure consists of designing a road monitoring strategy. In this case, the mathematical model is the 1D Lighthill-Whitham-Richards (LWR) model, which can be combined with a 2D pollution model if air quality is also being monitored.

This work was supported by funding from project MTM2015-65570-P of Ministerio de Economía y Competitividad (Spain)/FEDER. The fourth author also thanks the support from Sistema Nacional de Investigadores SNI-52768 and Programa para el Desarrollo Profesional Docente PRODEP/103.5/16/8066 (Mexico).)

Abstract ID 1033

SURROGATE BASED SHAPE OPTIMIZATION OF LIGHTENING HOLES IN AIRCRAFT FUSELAGE BEAMS

Erdem Acar[(1)], Yiğit Anıl Yücesan[(2)]

[(1)]TOBB University of Economics and Technology, Turkey
erdem.acar@gmail.com

[(2)]Turkish Aerospace Industry, Turkey
yigitanilyucesan@gmail.com

Keywords: Aircraft Structure,Finite Element Analysis,Lightening Holes,Structural Shape Optimization,Surrogate Models

Abstract: Weight saving from aircraft structures has always been important in aircraft industry. Introducing flanged lightening holes to the primary aircraft structures (e.g., wing ribs, fuselage frame webs, and fuselage longerons) is a way to achieve weight savings. Cutting a hole on the structure leads to a weight reduction but diminishes its strength. Therefore, forming the edge of the hole as a flange is a common practice to regain the strength of the structure. In this study, lateral metallic beam from the upper deck of Turkish Light Utility Helicopter (TLUH) with a predetermined geometry, loading, and edge conditions is considered. Since sharp edges would cause undesirable stress concentrations, the lightening hole geometry is considered to be an ellipse. The radii in the two axes of the ellipse, the curvature coefficient, and center-to-center hole distances are taken as design variables. The optimal values of these geometrical properties are sought by minimizing the structural weight as the objective function, while maintaining the structural strength and stability at certain levels. Since structural responses are computed through computationally expensive finite element analyses, surrogate based optimization approach is followed. In this study, polynomial response surfaces, Kriging and radial basis functions are considered as potential surrogate models. Kriging models with linear trend function is found to be more accurate than other surrogate models to predict the structural responses of interest. In preliminary design, the geometries of the all lightening holes are assumed to be identical. The optimization resulted in 6.9% weight reduction compared to the initial design, without sacrificing structural strength or stability. In the final paper, the geometric properties of the holes are not assumed to be identical and further weight savings will be investigated.

Abstract ID 1034

OPTIMAL CONTROL OF PHYTOREMEDIATION TECHNIQUES FOR HEAVY METALS REMOVAL IN SHALLOW WATER

Lino Alvarez-Vazquez[1], Aurea Martínez[1], Carmen Rodriguez[2], Miguel Vázquez-Méndez[2], Miguel A. Vilar[2]

[1]Universidade de Vigo, Spain
lino@dma.uvigo.es, aurea@dma.uvigo.es

[2]Universidade de Santiago de Compostela, Spain
carmen.rodriguez@usc.es, miguelernesto.vazquez@usc.es, miguel.vilar@usc.es

Keywords: Optimal control,Heavy metals,Phytoremediation,Shallow water.

Abstract: Term "heavy metal" usually denotes any dense metal that is marked for its potential toxicity, especially within environmental contexts. Heavy metals can be found naturally in the earth, but they usually become hazardous as a result of anthropogenic activities. Toxic metals tend to accumulate in living organisms as they are hard to metabolize and cannot be biodegraded. One of the main methods for remediation of heavy metal-contaminated waters is phytoremediation, that refers to the use of plants (algae in this particular case) to clean up water contaminated with hazardous chemicals. Phytoremediation takes advantage of the ability of algae to adsorb toxic heavy metals from the environment, resulting in higher concentrations than those in the surrounding water. In this work we deal with the optimization of different issues related to phytoremediation techniques, by combining mathematical modelling, optimal control of partial differential equations and numerical optimization (in the spirit of several previous works of the authors devoted to similar environmental control problems). In particular, we present a 2D mathematical model coupling the system for shallow water hydrodynamics with the system of nonlinear equations modelling the concentrations of heavy metals, algae and nutrients in large waterbodies. We also propose a full algorithm for computing the numerical solution of the system. In this paper we are interested in two main aspects: (i) determining the minimal quantity of algae to be used in the phytoremediation process, and (ii) locating the optimal place for such algae mass. These questions are formulated as optimal control problems for this scenario, and several numerical results for a realistic problem posed in "Ría de Vigo" (NW Spain) are presented.

(The authors thank the funding from project MTM2015-65570-P of MINECO/FEDER (Spain). The support provided by DHI with MIKE21 modelling system is also appreciated.)

Abstract ID 1035

INTEGRATED MULTICOMPONENT TOPOLOGY OPTIMIZATION OF OPTOMECHANICAL SYSTEMS

Stijn Koppen[1], Max van der Kolk[2], Floris van Kempen[3], Jan de Vreugd[3], Matthijs Langelaar[2]

[1]Delft University of Technology, Netherlands
s.koppen@tudelft.nl

[2]TU Delft, Netherlands
m.vanderkolk@tudelft.nl, m.langelaar@tudelft.nl

[3]TNO, Netherlands
floris.vankempen@tno.nl, jan.devreugd@tno.nl

Keywords: Topology optimization,Multidisciplinary design optimization,system optimization,optical instrumentation,optomechanics,thermoelasticity,structural-thermal-optical-performance analysis

Abstract: The ever increasing need for higher resolution and quality imagery imposes stringent and conflicting requirements on opto-mechanical instruments. In the state-of-the-art system engineering thermo-mechanical design process, the optical performance is not considered directly. Each component is designed and optimized separately to meet a priori defined deformation limits. To further improve the system optical performance, the design space should be expanded by a tightly integrated system design and optimization approach. This contribution uses gradient-based Multidisciplinary Design Optimization (MDO) to couple all interacting subsystems as well as engineering disciplines. We propose system-level optical performance metrics that drive the thermo-mechanical optimization process, simultaneous optimization of all components for the combined metrics and, the replacement of component-level constraints by equivalent system-level constraints. The work focuses on the reduction of optical performance errors of multicomponent reflective optical systems induced by (quasi)-static thermal loads. The thermo-mechanical design and structural topology optimization of all components is driven by system-level optical performance metrics using a full structural-thermal-optical performance (STOP) analysis. To determine system-level optical performance, we use a simplified version of geometric ray tracing by constructing a linear operator that describes the behavior of the optical system. The deformed surfaces are approximated by polynomial least-square fits, from which optical errors and accompanying adjoint sensitivities are derived. We optimize the material layout within given design domains using topology optimization, providing a systematic, bottom-up approach with maximum design freedom without any prior knowledge of the design. To demonstrate the benefit of our approach, we present a two-mirror case study under thermo-mechanical disturbances. The integrated STOP design optimization procedure taking into account all system components is compared to individual component optimization, while subjected to the same (or equivalent) design constraints. In this case study, our proposed approach resulted in a 95% spot size error reduction. The globally optimal performance of the coupled system is always better or equal to the uncoupled optimization approach, as the feasible design space of the system-level optimization completely encapsulates that of the individual component optimization. To satisfy future multidisciplinary system requirements one should aim for considering and integrating multiple components and physics simultaneously in the optimization process.

Abstract ID 1036

OPTIMIZATION OF FILLET STRESS CONCENTRATION UNDER COMBINED LOADING

Niels Pedersen

Department of Mechanical Engineering, Technical University of Denmark, Denmark
nlp@mek.dtu.dk

Keywords: Shaft fillet,Optimization,Axial load,Bending,Torsion

Abstract: For shafts there are typically four failure modes taken into consideration during design, these are; maximum allowable stress, fatigue, deflection and critical speed. Shafts are typically loaded by three different load types; axial, bending and torsion separately or more generally in combinations. In practical shaft design we have abrupt diameter changes where a fillet is applied. For fillets we don't have infinite stresses but a stress concentration described by the stress concentration factor. The stress concentration factor is typically available in charts in textbooks. The charts are given for circular fillets and for the three different loading situations separately. Many charts are based on experimental results from photo elasticity. The typical procedure for a combined load case is to find the maximum stress resulting from each loading and from these maximum values calculate a reference stress (e.g. von Mises). This is done although the maximum stress is not found in the same point for the different load cases. Using this procedure we obtain a conservative estimate of the maximum stress. Structural optimization is a mature science and optimization has been performed on shafts, but the result of optimization has had limited impact on the practical shaft design. Also very few references are found with optimization of shafts for combined load cases. The stress concentration evaluation is in the present research performed using the FE method. For a successful application of shape optimization a couple of points are important. The main aspect is that the shape (with the high stress) parameterization is done separately from the design domain FE meshing, i.e. the nodal position in the FE mesh should not be used as design variables. The shape can be described either analytically or numerically. Which methods selected is not important for a successful optimization. In the present research we use the ANSYS program and utilize the harmonic elements. This allows for 2D axisymmetric models that can handle the non-axisymmetric loads or out of plane loading associated with bending and torsion. The harmonic elements can also handle the in-plane loading associated with axial load so the same model can be used for all three load cases.

Abstract ID 1037

COMBINED LENGTH SCALE AND OVERHANG ANGLE CONTROL IN MINIMUM COMPLIANCE TOPOLOGY OPTIMIZATION FOR ADDITIVE MANUFACTURING.

Jeroen Pellens[1], Geert Lombaert[1], Boyan Lazarov[2], Mattias Schevenels[1]

[1]KU Leuven, Belgium
jeroen.pellens@kuleuven.be, geert.lombaert@kuleuven.be, mattias.schevenels@kuleuven.be

[2]The University of Manchester, United Kingdom
bslazarov@gmail.com

Keywords: Topology optimization,Additive manufacturing,Length scale control,Overhang angle control,Manufacturing constraints.

Abstract: This contribution focusses on topology optimization for additive manufacturing. In order to ensure that the optimized design is immediately manufacturable, it is essential to take into account the appropriate geometric constraints during the optimization. Two important constraints are minimum length scale and maximum overhang angle. A minimum length scale is needed to ensure that the condition on minimal printable feature sizes is satisfied, while an imposed overhang angle eliminates the need for a temporary support structure. This contribution first shows that both constraints cannot simultaneously be met by a straightforward coupling of existing methods for length scale and overhang control. Next, a new filtering scheme is introduced, based on a specific combination of spatial filters, which allows direct control over these constraints in a minimum compliance topology optimization problem. A 2D benchmark problem and a complex 3D case study are presented to demonstrate that the proposed filtering scheme successfully imposes a target length scale in both the solid and the void phase of the design domain, while simultaneously allowing control over the overhang angle.

Abstract ID 1039

CARTESIAN GENETIC PROGRAMING APPLIED TO EQUIVALENT ELECTRIC CIRCUIT IDENTIFICATION

Marco André Kappel[1], Roberto Domingos[2], Ivan Napoleão Bastos[2]

[1]Centro Federal de Educação Tecnológica Celso Suckow da Fonseca – CEFET/RJ, Brazil
marco.kappel@cefet-rj.br

[2]Universidade do Estado do Rio de Janeiro - UERJ, Brazil
hruodber@gmail.com, inbastos@iprj.uerj.br

Keywords: Complex nonlinear optimization,Equivalent electric circuit identification,Cartesian genetic Programming,Differential evolution

Abstract: Equivalent electric circuits are widely used in electrochemical impedance spectroscopy (EIS) data modeling. EIS modeling involves the identification of an electrical circuit physically equivalent to the system under analysis. This equivalence is based on the assumption that each phenomenon of the electrode interface and the electrolyte is represented by electrical components such as resistors, capacitors and inductors. This analogy allows impedance data to be used in simulations and predictions related to corrosion and electrochemistry. However, when no prior knowledge of the inner workings of the process under analysis is available, the identification of the circuit model is not a trivial task. The main objective of this work is to improve both the equivalent circuit topology identification and the parameter estimation by using a different approach than the usual Genetic Programming. In order to accomplish this goal, a methodology was developed to unify the application of Cartesian Genetic Programming to tackle system topology identification and Differential Evolution for optimization of the circuit parameters. The performance and effectiveness of this methodology were tested by performing the circuit identification on four different known systems, using numerically simulated impedance data. Results showed that the applied methodology was able to identify with satisfactory precision both the circuits and the values of the components. Results also indicated the necessity of using a stochastic method in the optimization process, since more than one electric circuit can fit the same dataset. The use of evolutionary adaptive metaheuristics such as the Cartesian Genetic Programming allows not only the estimation of the model parameters, but also the identification of its optimal topology. However, due to the possibility of multiple solutions, its application must be done with caution. Whenever possible, restrictions on the search space should be added, bearing in mind the correspondence of the model to the studied physical phenomena.

Abstract ID 1041

AN ALTERNATIVE REPRESENTATION FOR DENSITY BASED TOPOLOGY OPTIMIZATION OF FLUID FLOWS

Casper Andreasen

DTU Mechanical Engineering, Denmark
csan@mek.dtu.dk

Keywords: Topology Optimization,fluid flow,Navier-Stokes equations,density based

Abstract: Density based topology optimization for fluid flows is commonly modeled using a porous media approach i.e. either as a mixed Darcy-Stokes model or a Brinkman model. The solid material phase (wall) is modeled by considering a porous media with vanishing permeability penalizing the fluid velocity efficiently. The pressure is traditionally not represented equally well leading to problems with defining proper pressure loads on interfaces and leakage over thin solid structures[1]. Furthermore, the leakage is proportional to the permeability leading to ill-conditioning of the governing equation system. The optimization problem is also affected by the vanishing permeability which increase the non-linearity of response due to design changes. This paper presents an alternative to the porosity models in terms of representing the solid phase by imposing boundary conditions for all edges of the solid inclusion. The no-slip Dirichlet condition is imposed weakly using Nitsche's method[2] to model the solid phase and boundary. The influence of the stabilization parameter and design interpolation is investigated and the flow and pressure representation near the boundary is compared towards classical density based and boundary fitted methods. A benchmark using classical flow topology optimization problems posed in the literature is setup and the strength and weaknesses are studied in detail.

References:

[1] *Kreissl, S., Pingen, G., & Maute, K. (2011). An explicit level set approach for generalized shape optimization of fluids with the lattice Boltzmann method. International Journal for Numerical Methods in Fluids, 65(5), 496–519. http://doi.org/10.1002/fld.2193*

[2] *Nitsche, J. (1971). Über ein Variationsprinzip zur Lösung von Dirichlet-Problemen bei Verwendung von Teilräumen, die keinen Randbedingungen unterworfen sind. Abhandlungen Aus Dem Mathematischen Seminar Der Universität Hamburg, 36(1), 9–15. http://doi.org/10.1007/BF02995904*

Abstract ID 1042

NETWORK'S TRIP DEMAND ESTIMATION AS A PROBLEM OF COMBINATORIAL OPTIMIZATION

Alexander Krylatov, Anastasiya Shirokolobova

Saint Petersburg State University, Russian Federation
aykrylatov@yandex.ru, a.shirokolobova@spbu.ru

Keywords: combinatorial optimization,trip demand estimation,OD-matrix estimation,network equilibrium problem

Abstract: The paper is devoted to the problem of trip demand estimation in a road network. Commonly, when solving trip demand estimation problem researchers suppose the presence of so-called a prior origin-destination matrix. Unlike such an approach we assume that the only input data for trip demand estimation problem is traffic load on arcs. Thus, in this paper we intend to avoid using a prior origin-destination matrix for trip demand estimation and show that in such a case one is faced with the problem of combinatorial optimization. Computational complexity of appeared problem is discussed. Heuristic procedure for solving the problem is proposed and it is applied to the test example.

Abstract ID 1044

ELASTO-PLASTIC TOPOLOGY OPTIMIZATION UNDER STOCHASTIC LOADING CONDITIONS

Janos Logo[(1)], Bartlomiej Blachowski[(2)], Piotr Tauzowski[(2)]

[(1)]Budapest University of Technology and Economics, Hungary
logo.janos.bme@gmail.com

[(2)]Institute of Fundamental Technological Research, Warsaw, Poland, Poland
bblach@ippt.pan.pl, ptauzow@ippt.pan.pl

Keywords: topology optimization,plasticity,probabilistic loading,reliability design

Abstract: Advances in 3D printing technology make that structural optimization attracts recently a lot of attention in many research and scientific centers around the world. Nowadays, researchers' efforts are oriented rather towards structural topology optimization under deterministic forces with single load conditions, however the design is based on linearly or nonlinearly elastic material. The last two issues are critical in engineering practice since many deterministic optimal solutions are very sensitive to changes in loading conditions and multiple loading conditions are more realistic. As it is known the multiple loading conditions and the stochastic loading can lead for the same surrogate model. For that reason topology optimization of the structures subjected to stochastic loading is one part of the current research topic. Another issue is related to material properties, which often have to take into consideration plastic characteristics of the applied materials and the load carrying capacity is limited. A practical method for topology optimization of elastoplastic structures has been proposed by the authors recently. One of the major advantages of the method is its straightforward applicability to real engineering problems. Instead of traditionally used structural weight minimization subjected to compliance constraint in our method constraints are imposed directly on stresses. The purpose of the present study is to extend this method to the case of elasto-plastic topology optimization with some probabilistic constraints. To this end, we assume that external loading acting on the structural system under consideration is having stochastic nature, defined by its distribution type, mean value and standard deviation. With the aim of our method the above problem is solved in a way, which assures safety of the structures with given probability value. Although in the past there were some attempts to solve the above mentioned problems analytically, they concerned rather simple academic examples. The approach applied in the present study fully relies on computational methods in particular Finite Element (FE) method and reliability methodology such as FORM, SORM or Monte Carlo. Additionally since the number of FE analyses required to obtain optimal solution is enormous, some aspects of multi-core computing will be discussed. The effectiveness of the proposed stochastic/elasto-plastic topology optimization method will be demonstrated on benchmark problems including cantilever structure and simply supported beam. Moreover, both structural systems will be represented by plane stress finite elements and they will be subjected to stochastic load and linearly elastic-perfectly plastic material.

Abstract ID 1045

ON THE USE OF COMPLEX INPUT POWER IN TOPOLOGY OPTIMIZATION OF ONE-MATERIAL VIBRATING STRUCTURES FOR OBTAINING DISPLACEMENT ANTI-RESONANCES CLOSE TO FREQUENCIES OF INTEREST

Olavo Silva[1], Miguel Neves[2], Arcanjo Lenzi[1]

[1]Federal University of Santa Catarina, Brazil
olavus@gmail.com, arcanjo.lenzi@ufsc.br

[2]IDMEC - Instituto Superior Tecnico - Universidade de Lisboa, Portugal
maneves@dem.ist.utl.pt

Keywords: topology optimization,complex input power,harmonic vibration,anti-resonance

Abstract: Authors present a topology optimization procedure where a weighted sum between active input power and static compliance is used to obtain anti-resonances of displacement at load points in vibrating structures, at frequencies close to those of interest. The reactive input power, converted to a relation between kinetic energy and potential energy, helps to improve the procedure. Several examples are presented to illustrate the potential of the proposed method.

Abstract ID 1046

APPLICATION OF CFD MODEL PARAMETER OPTIMISATION FOR GAS EXPLOSIONS

Anna-Lena Both

Gexcon AS, University of Bergen, Norway
anna-lena.both@gexcon.com

Keywords: parameter optimisation,CFD modelling,sub-grid models,validation,gas explosions.

Abstract: This paper reports the application of a method for optimising the predictive capabilities of a computational fluid dynamics (CFD) tool used for consequence analysis in the process industries. The objective is to investigate whether the procedure for surrogate-based optimisation of empirically determined sub-grid model parameters is applicable to the gas explosion application of a CFD tool. Furthermore, employing optimisation may detect model limitations, supporting the development of complex CFD models. The optimisation problem is formulated to yield the best fit between relevant outputs of a CFD model and corresponding experimental values for selected gas explosion experiments. The wide range of experiments are organised in categories such that experiments from each category represent similar physical phenomena. Optimisation for several campaigns within one validation category was conducted successfully in former work (Braatz and Hisken, 2017; Both et. al., 2017). However, in the application of the CFD tool, it might be impractical if for each category, there exist different optimal parameter values. Running a simulation for a new gas explosion scenario with the correct optimal parameter values would require identifying beforehand the category the scenario belongs to. Hence, in the present paper, results of optimising for several experiments across different validation categories are presented and discussed. It is shown that the optimisation process improves the model predictions satisfactorily. Both, A.-L., Hisken, H., Rückmann, J.-J., & Steihaug, T. (2017). Surrogate-based model parameter optimization based on gas explosion experimental data. Submitted to and accepted by Engineering Optimization. https://doi.org/10.1080/0305215X.2018.1450399 Braatz, A.-L., & Hisken, H. (2017). Response surfaces for advanced consequence models: Two approaches. Journal of Loss Prevention in the Process Industries, 49, Part B, 683-699.

Abstract ID 1049

BIOMIMETIC TOPOLOGY OPTIMIZATION WITH MULTIPLE LOAD CASES

Michal Nowak

Poznan University of technology, Poland
michal.nowak@put.poznan.pl

Keywords: structural optimization,topology optimization,biomimetics

Abstract: Michał Nowak, Chair of Virtual Engineering, Poznan University of Technology, Poland Jan Sokołowski, Institut Elie Cartan, Laboratoire de Mathématiques Université Henri Poincaré, France Antoni Żochowski, Systems Research Institute of the Polish Academy of Sciences, Poland Biomimetic topology optimization with multiple load cases The trabecular bone adapts its form to mechanical loads and is able to form structures that are both lightweight but very stiff. In this sense, it is a problem (for the Nature or living entities) similar to the structural optimization, especially the topology optimization. The presented structural topology optimization method is based on the trabecular bone remodeling phenomenon. The developed biomimetic topology optimization method [1] do not need a volume constraint. Instead of imposing volume constraint shapes are parameterized by the assumed strain energy density on the structural surface. Using this approach also the problem of compliance optimization for multiple load cases can be efficiently solved. The results obtained from the multiple load cases analysis are different than those for only one case. Due to unique features of the presented biomimetic optimization method it is possible to find the solution, the stiffest structural configuration directly for the multiple load cases problem. The stiffest design is obtained by adding or removal material on the structural surface in the virtual space. The assumed value of the strain energy density on the part of the boundary subjected to modification is related to the material properties. The results of the 3D structural topology optimization for multiple load cases using the biomimetic approach will be presented.

Reference

[1] Nowak M., Sokołowski J., Żochowski A., Justification of a certain algorithm for shape optimization in 3D elasticity, Structural and Multidisciplinary Optimization DOI 10.1007/s00158-017-1780-7, February 2018, Volume 57, Issue 2, pp. 721–734, 2018

Abstract ID 1051

BIO-INSPIRED OPTIMIZATION ALGORITHMS FOR LIMIT ANALYSIS OF FRAME STRUCTURES

Alessandro Pluchino[1], Annalisa Greco[2], Francesco Cannizzaro[2], Ilaria Fiore[2]

[1]Department of Physics and Astronomy, University of Catania, Italy
alessandro.pluchino@ct.infn.it

[2]Department of Civil Engineering and Architecture, University of Catania, Italy
agreco@dica.unict.it, fcannizz@dica.unict.it, ilariafiore28@gmail.com

Keywords: Limit analysis; Seismic behaviour; Elementary mechanisms method; Ant colony system optimization; Genetic algorithms; Immune algorithms

Abstract: The present study applies the method of combination of elementary mechanisms to the evaluation of collapse conditions of planar frames. The col- lapse load is evaluated seeking the absolute lowest value among all the mecha- nisms that can be obtained combining the elementary ones. The optimization procedure is developed through three different bio-inspired optimization algo-rithms. In particular, genetic, immune and ant colony algorithms are considered. Original codes developed in the agent-based programming language NetLogo allow building into a virtual metrical space and visualizing in the user interface every single mechanism and the correspondent collapse load. The elementary mechanisms are then combined and the minimum collapse load, together with the corresponding collapse mechanism, is obtained. Several applications have been performed with reference to frames of different size subjected to a seismic load scenario consisting of horizontal forces with increasing magnitude acting on each floor, and permanent vertical loads applied to the beams. The collapse loads and related mechanisms, obtained by means of the proposed optimization procedures, have been compared to the correspondent ones provided by nonlin- ear push over analysis, showing a very good correspondence.

Abstract ID 1053

TOPOLOGY OPTIMIZATION OF NON-LINEAR STRUCTURES

Mathias Wallin[(1)], Niklas Ivarsson[(1)], Daniel Tortorelli[(2)]

[(1)]Lund University, Sweden
mathias.wallin@solid.lth.se, niklas.ivarsson@solid.lth.se

[(2)]Center for Design and Optimization, Lawrence Livermore National Laboratory, United States
tortorelli2@llnl.gov

Keywords: Topology optimization,Hyper-elastic structures,Stability,Buckling

Abstract: In this talk we combine topology optimization with constraints on the stability. Large strains are considered and consequently we implement a hyper-elastic constitutive model. To trace the load-path, the Crisfield path following method is used and in each load step we detect critical points. In most topology optimization procedures the detection is performed by solving a linearized problems which renders an eigenvalue problem. Another route is to solve an extended system where the conditions forthe critical point directly is included. Both approaches will be considered in the presentation. In void or nearly void regions, spurious buckling modes can be triggered which compromises the solution. A common approach to overcome this problem is to modify the stiffness matrix such that these buckling modes are eliminated. This modification comes with the risk of loosing convergence rate in the Newton iterations. In this talk we will discuss a consistent scheme that is able to reduce the risk of spurious buckling without compromising the convergence rate of the Newton scheme. To demonstrate the procedure, numerical examples where structures are optimized for maximum end-tangent stiffness and constrained in terms of stability are presented. This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore Laboratory under Contract DE-AC52-07NA27344.

Abstract ID 1054

DESIGNING COMPLIANT MECHANISMS FOR ADDITIVE MANUFACTURING. CONTROLLING THE MANUFACTURABILITY/FUNCTIONALITY RATIO THROUGH A FLEXIBLE OVERHANG CONSTRAINT.

Alain Garaigordobil, Rubén Ansola

University of the Basque Country, Spain
alain.garaigordobil@ehu.eus, ruben.ansola@ehu.eus

Keywords: Overhang Constraint,Topology Optimization,Additive Manufacturing,Compliant Mechanisms,3D printing.

Abstract: The concept "Topology Optimization for Additive Manufacturing" is a recently coined concept that refers to the complete engagement of topology optimization problems and additive manufacturing processes. The idea of coupling both technologies through a specific overhang constraint lies in the idea of a total design freedom, which classic manufacturing processes are unable to reach. If any design can be build, this will enable a continuum "design manufacturing" process eliminating prost-processing and any interference with the optimized geometry. In the field of structures there are already some ground-breaking approaches, there aren't however any regarding the optimization of compliant mechanisms. The introduction of the overhang constraint within the topology optimization formulation of compliant mechanisms yields a compromise or inverse relation of functionality and manufacturability. The hinges of the flexible mechanisms are formed by a sharp thinning of the material members and describe a shape that possesses many tangents with different slopes, some of them showing not self supported contours. There is an inverse relation there for functionality and manufacturability. If the hinge is to be corrected so that a direct 3D printing of the mechanisms is possible, the global objective function will be harmed as the optimum-functional shape of the hinge is set aside. This paper introduces the advantages of a flexible overhang constraint for a more accurate topology optimization of 3D printed compliant mechanisms enabling intermediate design for different manufacturability/functionality ratios, and analyses the consequences of fully restricting scaffold structures respect to controlling and reducing them.

Abstract ID 1055

THE ADAPTATION OF THE "EXPRESS-3D" CODE FOR THE HYPERSONIC FLOWS SIMULATION

Evgeny Shilnikov

Keldysh Institute of Applied Mathematics RAS, Russian Federation
evvlash@mail.ru

Keywords: Hypersonic flows,Quasi gas dynamic equations,Separated flows,Shock wave/boundary layer interaction,Non-orthogonal grid

Abstract: The paper presents the experience of using the parallel program complex "Express-3D", which implements an explicit finite-difference scheme, based on the quasi-gas-dynamic (QGD) equations system, for modeling hypersonic gas flows. The last version of the code uses multi-block non-orthogonal hexahedral grids [1]. Modeling of high-speed gas flows has some peculiarities. The modeling of hypersonic flows around compression corners for different values of both the angle itself and the angle of attack, showed that in the case of a continuous flow the calculation can be carried out with the same parameters of the method as for the flows with moderate velocities. However, the artificial viscosity, which allows calculations in the presence of strong shock waves (high Mach numbers), can significantly distort the flow field in the subsonic region. To obtain the correct size of the separation zone, it is necessary to modify the regularizers in the QGD system. Calculations showed that the desired result can be achieved by optimizing the relationship between regularizers, analogous to shear and bulk viscosities. In addition, at least at the beginning of calculations, it is preferable to use the flux relaxation approach [2]. As a result, the algorithm allows to simulate gas flows in a wide range of Mach numbers. Some results of using this code for the problems of the hypersonic flow / boundary layer interaction are presented. The simulation results are discussed and compared with the known experimental data. Parallel programs are realized for both the standard x86 architecture, and the architecture of the CUDA graphics processors. A parallel implementation uses MPI, shmem and CUDA libraries. The efficiency of parallel implementation is investigated. The accelerations obtained on different types of GPU are compared. Calculations showed that the increased volume of exchanges in the case of non-orthogonal grids in comparison with rectangular grids leads to a significant drop in acceleration on GPU's of the Tesla C20xx type. However, modern calculators with Kepler architecture allow to achieve good acceleration without changes in the program code.

References

(1) Alexander Davydov and Evgeny Shilnikov. Program Complex for Fluid Dynamic Problems Simulation on GPU-Based Computer Systems. Proceedings of ICNAAM 2014, 4 p., AIP Conference Proceedings, 2015, T. 1648, № 1, 850071, DOI: 10.1063/1.4913126.
(2) Boris Chetverushkin and Evgeny Shilnikov. Flux Relaxation as an Approach to the Stability Improvement for Explicit Finite Difference Schemes. CD proceedings of the II International conference on Engineering Optimization (EngOpt-2010), Lisbon, Portugal, September 2010.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1056

AN ADAPTIVE FEASIBILITY APPROACH FOR CONSTRAINED BAYESIAN OPTIMIZATION WITH APPLICATION IN AIRCRAFT DESIGN.

Remy Priem[1], Nathalie Bartoli[1], Youssef Diouane[2], Sylvain Dubreuil[1], Thierry Lefebvre[1]

[1]ONERA, France
remy.priem@onera.fr, nathalie.bartoli@onera.fr, sylvain.dubreuil@onera.fr, thierry.lefebvre@onera.fr

[2]ISAE-Supaero, France
youssef.diouane@isae-supaero.fr

Keywords: Bayesian Optimization. Constrained Optimization. Aircraft Design. Feasibility Probability.

Abstract: The multidisciplinary optimization of new aircraft configurations involves numerous design variables and constraints. In this context, ONERA (the french aerospace Lab) developed a new constrained bayesian optimizer, named Super Efficient Global Optimization (SEGO) based on Mixture of experts (MOE). The latter employs gaussian processes to set surrogate models for the objective function and the constraints taking into account both exploration (sampling from areas of high uncertainty) as well as exploitation (sampling areas likely to offer improvement over the current best observation). Concerning the constraints, only the prediction of these models is taken into account during the optimization process. Thus, due to the error made by the surrogate model, the estimated feasible domain can be not well approximated and hence leading to poor optimization results in some cases. This issue is amplified once large-scale constrained optimization problems are regarded. In this work, we propose different criteria for constraint handling based on feasibility probabilities (estimated using gaussian processes). In fact, instead of using only constraints predictors the new criteria allow the optimizer to explore unfeasible areas in terms of the constraints predictors. An adaptive mechanism is also included to manage the minimum feasibility acceptance of possible enrichment points.The obtained optimization strategy based on the use of the feasibility probabilities explores better the feasible domain. Numerical experiments are carried out on a set of known test problems as well as an industrial optimization problem.

Abstract ID 1057

OPTIMAL MULTIOBJECTIVE DESIGN OF A HEAD PROTECTION HELMET: A LIMITING PERFORMANCE ANALYSIS

Paulo Moita[(1)], Aníbal Valido[(1)], José Madeira[(2)], João Barradas[(3)], Miguel Antunes[(4)]

[(1)]ESTSetúbal/IPS; CENTEC; CDP2T, Portugal
paulo.moita@estsetubal.ips.pt, anibal.valido@estsetubal.ips.pt

[(2)]ISEL; IDMEC, Portugal
jaguilar@dem.ist.utl.pt

[(3)]IDMEC, Portugal
barradas@ist.utl.pt

[(4)]ESTSetúbal/IPS; CDP2T, Portugal
miguel.antunes@estsetubal.ips.pt

Keywords: Multiobjective optimization,Direct Multisearch algorithm,Injury prevention,Impact,Space-time finite elements,Pareto front

Abstract: In this paper the limiting performance analysis of a head protection helmet is performed. A discrete model of the human head is used. A multiobjective optimum design problem is formulated in order to minimize the risk of injuries in case of impact. Several injury criteria are minimized and are required to remain below a safety threshold value. The optimal control force acting on the head is found. The optimal control force is determined by the Direct MultiSearch (DMS) derivative-free algorithm. The equations of motion are integrated at-once, as it is typical for static response, instead of the traditional step-by-step integration. This fashion, displacement, velocity and acceleration conditions can be imposed easily at any point in time.

Abstract ID 1060

THE COMBINATION OF THREE-DIMENSION INVERSE DESIGN AND OPTIMIZATION METHODS FOR HELIUM CIRCULATOR'S IMPELLER OPTIMIZATION IN HTR

Xing Xie[1], Hong Wang[2], Zhenlin Li[3], Baoshan Zhu[4]

[1]College of Mechanical and Transportation Engineering,China University of petroleum(Beijing), China
xiexing_cup@163.com

[2]Institute of Nuclear and New Energy Technology, Tsinghua University, Beijing, 100084, China, China
hongw@mail.tsinghua.edu.cn

[3]College of Mechanical and Transportation Engineering, China university of petroleum (Beijing), Beijing 102249, China, China
zhenlinli@263.net

[4]State Key Laboratory of Hydroscience and Engineering, Department of Thermal Engineering, Tsinghua University, Beijing 100084, China, China
bszhu@mail.tsinghua.edu.cn

Keywords: Helium Circulator；Inverse Design；Optimization Methods；Efficiency

Abstract: The working environment for Helium Circulator in HTR (high temperature gas-cooled reactor) is especial, high temperature about 523K and high pressure about 7MPa. So the efficiency of the Helium Circulator's impeller is extremely important. In the optimization process, the key is how to choose the optimization parameters. At present, the blade loading parameters and meridional geometry parameters are obtained easily through the 3D inverse design methods and the widely used Bessel curves. The optimization design strategy was built by combining the Three-dimension inverse design method, CFD analyses, Design of Experiment (DOE), Response Surface Methodology (RSM), Multi-Island Genetic Algorithm (MIGA) on the basis of the isight platform. The optimization objective is the impeller efficiency at the design condition. The input parameters are related to the blade loading, blade lean angle at high pressure side and the meridional channel shape. For simplification, the optimization was divided in two steps. In the first step, Blade loading parameters and blade lean angle at high pressure side were selected as the input parameters to find the main influencing factors. Then, the main influencing factors with the meridional channel shape parameters were set as the independent variables. And the optimized impeller is obtained through the RSM model and MIGA optimization method. The results show that the SLOPEH, NCH and THETA1 are the main blade loading influencing factors. And YH and THETA2 are the main meridional geometry influencing factors. The best blade loading distribution is the positive SLOPEH of high value combined with the negative SLOPES. The positive NCH on the hub and shroud will improve the blade loading at the blade leading edge. Small blade lean angle at high pressure side will promote the work at the trailing edge of the impeller. The curve with the relative reduced curvature on the shroud is beneficial to the performance of the impeller. The efficiency of the optimized impeller is 0.93% higher than the original impeller and blade loading distribution on the blades is more uniform. So, the coupled methods turns to be an efficient way for the complicated rotating machinery optimization.

Abstract ID 1061

CONSIDERING LINEAR BUCKLING FOR 3D DENSITY BASED TOPOLOGY OPTIMIZATION

Robert Dienemann[(1)], Axel Schumacher[(1)], Sierk Fiebig[(2)]

[(1)]University of Wuppertal, Germany
dienemann@uni-wuppertal.de, schumacher@uni-wuppertal.de

[(2)]Volkswagen AG, Germany
sierk.fiebig@volkswagen.de

Keywords: Linear Buckling,Topology Optimization,Density Method

Abstract: Stability is an important issue in topology optimization, since results of the optimization are often framework structures. If some trusses of these structures are subjected to compression, they maybe buckle and the structure fails. Since Neves et al., Rahmatalla and Swan as well as Bendsøe and Sigmund demonstrated the use of linear buckling as structure response for the density method, this application was not improved significantly. Their problems were -they used a material interpolation scheme, which was not continuously differentiable, so that a smooth convergence was not ensured (Neves et al.). -they have not treated spurious modes, which are buckling modes in low density regions (Rahmatalla and Swan). -they have not considered or not allowed mode switching (Neves et al., Rahmatalla and Swan, Bendsøe and Sigmund). The first buckling mode of the initial design does not need to be the first buckling mode of the optimized design. During the optimization other modes can be become the critical one. -they have not considered duplicated eigenvalues (Neves et al., Rahmatalla and Swan). If two eigenvalues are the same, their sensitivities cannot be calculated separately. and for all of them the lack of computing power to show realistic 3D applications. In this contribution a continuously differentiable material interpolation scheme is explained to avoid spurious modes. It is shown how to cope with several modes (mode switching, duplicated eigenvalues) and how to use buckling safety as objective or constraint. The optimized structures are compared with results for compliance design. It is shown, that it is not useful to use buckling and mass as the only structure responses, because substructures subjected to tension can become very thin without a negative influence on the buckling safety. Thus tensile stresses are not limited. Buckling and mass have to be combined with other structure responses, like stress or compliance, to achieve a useful structure. Also the combination with manufacturing constraints for deep drawing, as shown by Dienemann et al., is discussed in this contribution. Therefore 3D structures with up to a million design variables are presented. Neves MM, Rodrigues H, Guedes JM(1995) Generalized topology design of structures with a buckling load criterion. StructOptim10:71–78 Rahmatalla S, Swan CC(2003) Form Finding of Sparse Structures with Continuum Topology Optimization. JStructEng129:1707–1716 Bendsøe MP, Sigmund O(2004) Topology Optimization: Theory, Methods and Applications. Springer Dienemann R, Schumacher A, Fiebig S(2017) Topology optimization for finding shell structures manufactured by deep drawing. StructMultidiscipOptim56:473–485

Abstract ID 1062

ON SOLVING LARGE-SCALE PLASTIC LAYOUT OPTIMIZATION OF TRUSSES BY INTERIOR POINT METHODS

Alemseged Weldeyesus

The University of Edinburgh, United Kingdom
a.weldeyesus@ed.ac.uk

Keywords: Interior point method,Linear programming,Semidefinite programming,Truss optimization

Abstract: We are concerned with solving the plastic design formulation traditionally written as a linear program and its extension that belongs to the so-called semidefinite programming to address linear buckling. The optimization problems are modelled following the well-known ground structure approach in which a finite set of nodes are distributed in the design domain and all the possible interconnecting bars are generated. The main goal is then to determine the optimal cross-sectional areas of these bars and obtain the lightest structure that can sustain a given set of applied loads. The excessive connectivity of the nodes results in a huge number of potential bars making the optimization problems computationally difficult for standard solution techniques. Therefore, we propose a specialized primal-dual interior point method in which we employ several novel techniques. We apply a member adding procedure where the problems are initially solved for minimal connecting bars and subsequently members are added until the final optimal design is obtained. We additionally exploit the algebraic structure of the problems to reduce the normal equations system originating from the interior point algorithm, which are often assumed as the smallest possible linear systems by any standard primal-dual interior point algorithms, to much smaller systems. Moreover, the already reduced linear systems are solved using iterative methods instead of the more expensive direct methods. Finally, due to high degree of similarity among the subsequent sub-problems in the last few member adding iterations, we use a warm-start strategy to determine initial point and achieve convergence within fewer interior point iterations. The efficiency and robustness of the method is supported with several numerical experiments.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1063

OPTIMIZATION OF POROUS STRUCTURE EFFECTIVE ELASTIC PROPERTIES BY THE FAST MULTIPOLE BOUNDARY ELEMENT METHOD AND AN ARTIFICIAL IMMUNE SYSTEM

Jacek Ptaszny, Arkadiusz Poteralski

Silesian University of Technology, Institute of Computational Mechanics and Engineering, Poland
jacek.ptaszny@polsl.pl, arkadiusz.poteralski@polsl.pl

Keywords: Optimization,Porous Structure,Effective Elastic Properties,Fast Multipole Boundary Element Method,Artificial Immune System

Abstract: Porous structures include natural porous bodies (e.g. bones, wood, etc.) and artificial porous bodies. The latter group is a class of functional-structural materials with the optimal index of physical and mechanical properties due to their porous structure, including porous metals, porous ceramics and polymer foams. The paper presents an application of the fast multipole boundary element method (FMBEM) coupled with an artificial immune system (AIS) to the optimization of porous structure effective elastic properties. 3D representative volume elements (RVE) of linear elastic porous materials are modelled by the FMBEM, that only requires the discretization of the boundary. The FMBEM allows one to model complex geometries with much lower number of degrees of freedom in comparison to the finite element method that is usually applied in computational homogenization. Furthermore, the computational complexity of the FMBEM is reduced in relation to the conventional BEM. In the present research, 8-node Serendipity boundary elements with adaptive integration scheme are applied. The FMBEM code is parallelized by the OpenMP standard. On the RVE external boundary, displacement boundary conditions are applied, corresponding to a given strain state in the macro scale. Averaged stresses are calculated by the integration over the external boundary. Effective elastic constants of the material are calculated by using the averaged strains and stresses. Design variables considered in the optimization problem, with appropriate constraints, describe the pore geometry. The minimized objective function involves a metric that allows one to calculate the distance between two elasticity tensors: a current solution and a reference tensor that defines the desired properties. The optimization problem is solved by an AIS that is a computational adaptive system inspired by the principles, processes and mechanisms of biological immune systems. AIS algorithms use the ability of the immune systems to learn and detect pathogents in the solution of optimization problems in a computational manner. The AIS does not need any information on the objective function gradient and is suitable for multimodal problems. The algorithm is composed of the following stages: random generation of memory cells, memory cells proliferation and hypermutation, B-cell objective function evaluation, selection and crowding mechanism. Respective operations are performed iteratively until a stop condition is satisfied. Details of the methods and optimization problem will be described in the full paper.

Acknowledgment. The scientific research was funded by National Science Centre, Poland, grant no. 2015/19/B/ST8/02629.

Abstract ID 1066

APPLICATIONS OF ITERATIVE NON-DIFFERENTIABLE OPTIMIZATION TO SOME ENGINEERING APPROXIMATION PROBLEMS

Stefan Stefanov

South-West University "Neofit Rilski", Bulgaria
stefm@swu.bg

Keywords: Convex optimization,nondifferentiable (nonsmooth) optimization,separable programming,subgradient methods,approximation,weighted discrete least squares,minimax problems,overdetermined (inconsistent) systems of linear algebraic equations.

Abstract: The data fitting problem, that is, the problem of approximating a function of several variables, given by tabulated data, and the corresponding problem for inconsistent (overdetermined) systems of linear algebraic equations are considered. Such problems, connected with measurement of physical quantities, arise, for example, in engineering, physics, etc. A traditional approach for solving these two problems is the discrete least squares data fitting method. In this paper, an alternative approach is proposed: with each of these problems, we associate a nondifferentiable (nonsmooth) unconstrained minimization problem with an objective function, based on discrete absolute deviation norm and/or uniform norm (sup-norm), respectively, that is, the problems under consideration are solved by minimizing the residual using these two norms. Respective subgradients are calculated, and a subgradient method is used for solving these two problems. The emphasis is on implementation of the proposed approach. Some computational results, obtained by an appropriate iterative method, are presented, and these results are compared with the results, obtained by the iterative gradient method for the corresponding "differentiable" least squares problems.

Abstract ID 1067

PERFORMANCE ASSESSMENT OF METAHEURISTIC ALGORITHMS FOR STRUCTURAL OPTIMIZATION TAKING INTO ACCOUNT THE INFLUENCE OF CONTROL PARAMETERS

Wouter Dillen, Geert Lombaert, Nathalie Voeten, Mattias Schevenels

KU Leuven, Belgium
wout.dillen@kuleuven.be, geert.lombaert@kuleuven.be, nathalie.voeten@student.kuleuven.be, mattias.schevenels@kuleuven.be

Keywords: structural optimization, metaheuristic optimization, metaheuristic algorithm, stochastic algorithm, statistical analysis, performance assessment, control parameters, parameter selection, parameter tuning, Monte Carlo simulation

Abstract: Metaheuristic optimization algorithms are characterized by stochastic behavior, making each optimization run unique. In addition, metaheuristic algorithms are usually governed by a number of control parameters that require problem-specific tuning. Many publications on metaheuristic algorithms lack the kind of rigorous statistical convergence assessment that is needed to compensate for the above uncertainties, making it impossible to assess the optimality of the resulting design or the effectiveness of the optimization method. In this contribution, we propose a method to assess the performance (i.e. the ability to find the best known solution and the associated computational cost) of a metaheuristic algorithm that takes into account the influence of its control parameters. First, a large number of simulations (independent optimization runs) are performed, where the values of the control parameters are randomly selected from predefined sets of realistic possibilities. Next, for every value of every control parameter, the corresponding subset of simulations is considered in order to infer the relevant conditional performance statistics. As a example, the approach is used to assess the performance of the genetic algorithm built into matlab for a 25-bar truss test case. It is observed that, for the algorithm and the test case considered, the majority of the control parameters have little influence on algorithm performance.

Abstract ID 1068

MID-SECTION STRUCTURE OPTIMIZATION OF OIL TANKER BASED ON CSR PRESCRIPTIVE ANALYSIS

Yuan Wang, Jia-meng Wu

Marine Design & Research Institute of China, China
wytantar@163.com, wujm_maric@sina.cn

Keywords: CSR prescriptive analysis,mid-section,structure optimization,DOE,approximate model

Abstract: Common Structural Rules for Bulk Carriers and Oil Tankers (CSR) issued by IACS provides requirements for loads, hull girder strength, hull local scantling, prescriptive buckling, etc. Literatures show that there are lots of studies on mid-section structure optimization of Oil tanker. However the design constraints in these studies are usually simple instead of considering a wide variety of requirements in CSR, thus the optimization results are not very practical for engineering applications. Since the requirements in CSR are complicated and updated continuously, software by classification societies is designed and used to assess the prescriptive requirements of the CSR. In this paper, MARS2000 by BV is integrated and combined with methods of design of experiment (DOE) and approximate model, to carry out a mid-section structure optimization of Oil tanker. The above strategy and procedure provide an available and effective method for the mid-section structure optimization of Oil tanker based on CSR prescriptive analysis.

Abstract ID 1069

A DIFFERENTIAL EVOLUTION TO FIND THE BEST MATERIAL GROUPINGS IN TRUSS OPTIMIZATION

AFONSO LEMONGE, José Pedro Gonçalves Carvalho, Patrícia Habib Hallak

Federal University of Juiz de Fora, Brazil
afonso.lemonge@ufjf.edu.br, jose.carvalho@engenharia.ufjf.br, patricia.hallak@ufjf.edu.br

Keywords: Multi-material combination Automatic member grouping Cardinality constraints

Abstract: Recently, the structural optimization has received a strong emphasis that leads in the formulation of the objective function questions regarding the possible combination of various materials. That is, the multi-material optimization in which these materials present different characteristics between them. For example, those referring to the behavior of the material that can be physically linear or non-linear, linear behaviors with different moduli of elasticity, different costs depending on the volume to be used, different behaviors in tension and compression, and so on. The topology structural optimization, particularly, has been receiving efforts in this direction and is extremely adequate to address this type of problem. Another issue in this process is to include the possibility of limiting the number of different materials to be used in the optimized final design. This is an interesting aspect where the designer has the freedom to define a priori the maximum number of materials to be used. In that sense, it will be possible to construct curves where the decision-maker can choose between various possibilities, the one or those that are more interesting. That is, the solution or solutions that present one, two, three, and so on, different type of materials. On the other hand, this is not a trivial task and would require numerous tentatives to be made by the designer making it virtually impossible to discover the desired solutions. The objective of this paper is to propose a strategy to obtain solutions to structural optimization problems in sizing, shape and topology, where the use of different materials will be incorporated in the formulation of the problem, besides the possibility of the designer choosing the maximum number of these materials. The search algorithm to be employed is the Differential Evolution and the control of the maximum number of materials to be used is done through the use of cardinality constraints.

Abstract ID 1070

MULTI-CRITERIA OPTIMIZATION OF PRESSURE SCREEN SYSTEMS IN PAPER RECYCLING – BALANCING QUALITY, YIELD, ENERGY CONSUMPTION AND SYSTEM COMPLEXITY.

Tim Müller[1], Lena Altherr[1], Marja Ahola[2], Samuel Schabel[2], Peter Pelz[1]

[1]Chair of Fluid Systems, Technische Universität Darmstadt, Germany
Tim.Mueller@fst.tu-darmstadt.de, lena.altherr@fst.tu-darmstadt.de, peter.pelz@fst.tu-darmstadt.de

[2]Paper Technology and Mechanical Process Engineering, Technische Universität Darmstadt., Germany
ahola@papier.tu-darmstadt.de, schabel@papier.tu-darmstadt.de

Keywords: Global Optimization,Multi-Criteria Optimization,Exact Optimization,MINLP,Mixed-Integer Nonlinear Problem,SCIP,Optimal Design and Control,Paper Recycling,Screening Systems,Process Engineering,Graphical User Interface,Decision-Support.

Abstract: Paper for recycling is the most important raw material for the German paper industry. In 2016, 16.9 million tons of paper for recycling were used in Germany [1]. In addition to fibers and chemicals, the production of paper requires large amounts of process water and energy. The recycling material has a heterogeneous composition and needs to be purified before new paper can be produced. In particular tacky contaminants, so-called stickies, lead to problems in the papermaking process and reduce the quality of the product. For separating stickies from valuable fibres, fine screening systems are used. The fine screening system typically consists of multiple interconnected pressure screens. The design of such systems is highly complex, as many different system configurations are possible and conflicting objectives need to be considered. A mathematical optimization of the configuration and operational parameters was first done by Fügenschuh et al. [2] in 2014. A mixed-integer nonlinear program was used to optimize the configuration and operational parameters simultaneously. In this work, our goal is to extend this model and to provide practitioners with access to our optimization approach. We extend the model of Fügenschuh by: (i) The volume flow of the pulp suspensions is modeled to gain a more realistic representation and to be able to assess the energy consumption. (ii) More system configurations are considered by allowing a splitting of the connection between the different screens. (iii) The design parameters, e.g. slot width of a screen, are taken into account in a dimensionless screen model. Thus, they can be included in the optimization problem. Additional objectives, besides the quality and fibre yield, are the resource-consumption and complexity of the system. The resulting mixed-integer nonlinear program is solved to global optimality using exact methods. A software tool with graphical user interface is developed. It allows for a simple formulation and adaptation of the optimization problem as well as a graphical presentation of the results. Our tool can be seen as a decision support for engineers during planning and operation of such systems and comparable industrial separation processes.

Reference

[1] Verband Deutscher Papierfabriken e.V. (2017): Papier 2017 - Ein Leistungsbericht. Bonn. [2] Fügenschuh, A.; Hayn, C.; Michaels, D.: Mixed-integer linear methods for layout optimization of screening systems in recovered paper production. In: Optimization and Engineering 15(2), 533–573

Abstract ID 1071

ON THE OPTIMIZATION OF RECIRCULATED AQUACULTURE SYSTEMS

Stepan Papacek[(1)], Karel Petera[(2)]

[(1)]University of South Bohemia, Czech Republic
spapacek@seznam.cz

[(2)]Czech Technical University in Prague, Faculty of Mechanical Engineering, Technicka 4, 166 07 Prague 6, Czech Republic, Czech Republic
karel.petera@fs.cvut.cz

Keywords: CFD,aquaculture tank design,optimization,recirculated aquaculture systems

Abstract: The improved design of recirculated aquaculture systems (RAS) is needed facing the demand for increased fish production as well as increased concern of fish wellbeing. Here, we make a step towards use of computational fluid dynamics (CFD) for optimizing the design of fish tanks. The proposed CFD based methodology allows the modeler (the designer) to manipulate both the tank geometry and operating conditions, in order to minimize an appropriate objective function. The objective function is quantifying multiple criteria, dealing mainly with the rearing conditions for fish (a determined average velocity, low velocity variance and fast biosolids removal), and the cost of energy and place. As an example of our methodology, we present one case study involving the CFD analysis of three different RAS: (i) circular, (ii) rectangular multivortex without baffle, and (iii) rectangular multivortex with an additional geometrical element, being the plate baffle between two water inlets. Based on the simplified description of the flow field within each RAS geometry, the optimization of either design and operating parameters is performed.

Abstract ID 1072

ADAPTIVE DRIVE FOR SPACE TECHNOLOGY– DRIVE OF SOLAR PANEL

Dana Tulekenova[1], Konstantin Ivanov[2]

[1]Al-Farabi Kazakh National University, Kazakhstan
dana_tul@mail.ru

[2]Almaty University of Power Engineering and Telecommunication, Institute of Mechanics and Machine Science of MON RK, Kazakhstan
ivanovgreek@mail.ru

Keywords: Gear systems,Adaptive Drive,Vibration,Solar panel,Design,Simulation

Abstract: The adaptive vibration drive of solar panel contains input carrier, output carrier, input satellite, input epicycles gear, output satellite and the internal block with two sun gears. In each block, gears are connected by an elastic shaft. During operation, the elastic shafts transmit vibrational fluctuations to the output carrier. The vibration drive provides reliable overcoming operational overloads. The test-bed contains the motor connected through a compound shaft with the adaptive drive of the solar panel, torque measuring instruments at the exit of the electric motor and an angle of rotation of a shaft. The technical result consists in increase in accuracy of modeling of influence of the solar panel with the drive on the spacecraft. In the proposed work, a vibration drive is synthesized according to a given vibrational action, design and simulation of adaptive drive. The work is based on the laws of mechanics.

Abstract ID 1074

UNCERTAINTY QUANTIFICATION AND MODEL IDENTIFICATION IN A BAYESIAN AND METAHEURISTIC FRAMEWORK

Alexandre Löw[1], Herbert Gomes[2]

[1]UFRGS, Brazil
alexandre.low@ufrgs.br

[2]Federal university of Rio Grande do Sul, Brazil
herbert@mecanica.ufrgs.br

Keywords: system identification,uncertainty quantification,model updating,modal analysis.

Abstract: Uncertainty quantification of identified parameters is an important feature when some quality assessment of the results of model updating procedure is necessary, or when important decisions depend upon these values. In this work, a modification of the conventional sensitivity method is tested along with a Bayesian Monte Carlo framework for identification of system parameters from experimental data, and their probability distributions. First, the updating procedure uses a metaheuristic algorithm (derivative-free) and the Euclidean norm metric. Then, a modification of Markov Chain Monte Carlo method called Transitional MCMC is applied to obtain an approximation of the mean values and probability distributions of the updated parameters based on the scattering of the experimental data. An example is presented with real structure experimental data for updating discrete mass, stiffness and damping parameters, as well as a comparison with previous results yielded by different methods, suggesting equivalent levels of agreement in the updated parameters, but with the advantage of MCMC formulation being practically independent of parameters vectors.

Abstract ID 1075

BAYESION OPTIMAL EXPERIMENTAL DESIGN FOR PARAMETER IDENTIFICATION IN MECHANISED TUNNELLING

Raoul Hoelter

Ruhr-University Bochum, Germany
raoul.hoelter@rub.de

Keywords: Mechnanised tunneling,Bayes' theorem,optimal experimental design,finite-element modeling

Abstract: Modern demands for safe and efficient infrastructure in urban areas make the construction of tunnels unavoidable. However, tunnel construction is facing challenges due to complex ground conditions and small depths of cover. Therefore, a finite-element- model based simulation of the system behaviour is helpful to predict settlements induced by the construction what enables to perform suitable countermeasures. Such simulation models needsto be validated with in-situ data. Besides soil sampling, that allows a preliminary design of the ground conditions, it is helpful to install sensors that will record the tunneling induced system response and to use this data for a back analysis of the system parameters. Two issues have to receive sufficient attention in such a case namely (i) how to use measurement data of an ongoing tunnel excavation to predict the system response in the forthcoming cross sections in the same tunnel line; and (ii) how to design the measurement system in a matter that it optimally allows to identify the relevant soil parameters. To address both aspects, the present works applies the method of Bayesian Optimal Experimental Design (Bayesian OED) to a synthetic Finite-Element model that simulates the construction of a shallow tunnel nearby a surface structure. In the framework of a probabilistic scenario, the soil parameters are assumed to be initially known as probability distributions. To identify their real values, synthetic noisy settlement data is generated in positions that are defined according to the principles of OED, i.e. in a way that allows to identify the relevant parameters with least possible uncertainty. As the tunnel excavation proceeds gradually, after each excavation step a new situation (stress state, deformations, etc.) is faced. The obtained data is used to update the knowledge about the parameters according to the principle of Bayes' theorem. Using this updated model and considering the next excavation step which is about to take place, the initially defined OED is most likely to be not optimal anymore. Therefore, a new design of the measurement set-up is needed that is defined again using the Bayesian approach: Considering the current knowledge of the system, which measurement set-up will allow in the next step most reduction of uncertainty after performing a parameter identification? This procedure is continuously repeated, as long as the tunnel excavation is taking place in areas that may have a critical impact on nearby infrastructure. Thereby, the parameters can be identified most precisely and efficiently.

Abstract ID 1077

TRANSITION OPTIMIZATION OF A TILT-WING ELECTRIC VERTICAL TAKEOFF AND LANDING AIRCRAFT

Shamsheer Chauhan[1], John Hwang[2], Joaquim Martins[1]

[1]University of Michigan, United States
sschau@umich.edu, jrram@umich.edu

[2]Peerless Technologies Corp. (NASA Glenn Research Center), United States
john.hwang@epeerless.com

Keywords: eVTOL,transition,distributed propulsion,CFD

Abstract: Electric vertical takeoff and landing (eVTOL) aircraft for urban mobility are currently receiving considerable attention due to their potential to change the way we move within and between cities. Although electric aircraft are not a new concept, improvements in technologies like batteries and autonomous control have made them significantly more feasible for short distance on-demand transportation. However, this sector of the aviation industry is still in its infancy and there is a lot of scope for development. In this work we focus on the trajectory of a distributed propulsion tilt-wing eVTOL aircraft. Optimizing the trajectory of a tilt-wing aircraft provides an interesting challenge because the transition from vertical to horizontal flight is a delicate balancing act in which the fans need to provide sufficient thrust to maintain lift and accelerate while transferring the burden of lift to the wings. Additionally, optimizing this phase is a unique design challenge because it requires considering states in which the flow over the wing is separated. We use gradient-based optimization methods and high-fidelity CFD, with actuator disk models for the fans to model the aerodynamics, and optimize the trajectory of a selected eVTOL aircraft configuration.

Abstract ID 1078

LOW-FIDELITY AEROSTRUCTURAL OPTIMIZATION OF AIRCRAFT WINGS WITH A SIMPLIFIED WINGBOX MODEL USING OPENAEROSTRUCT

Shamsheer Chauhan, Joaquim Martins

University of Michigan, United States
sschau@umich.edu, jrram@umich.edu

Keywords: aerostructural,FEM,OpenAeroStruct,VLM,wingbox

Abstract: It is common for aircraft design studies to begin with low-fidelity tools and move to higher-fidelity tools at later stages. After early conceptual design stages, designers can take advantage of developments in high-fidelity aerodynamic shape optimization, and more recently, coupled aerostructural optimization to improve their designs. Over the past few years, our research group has developed a framework that allows carrying out high-fidelity aerostructural optimization by coupling a RANS CFD solver to an FEM solver that uses shell elements. In addition, we have recently developed OpenAeroStruct, a light-weight and open-source tool for low-fidelity aerostructural optimization that couples a VLM code to an FEM code that uses spatial beam elements. Due to their low cost, such low-fidelity tools remain useful for design studies. In this paper, we present results from OpenAeroStruct for the optimization of a transport aircraft wing and compare them to results from our group's high-fidelity framework. Additionally, we describe the simplified wingbox model developed and implemented with OpenAeroStruct for this work.

Abstract ID 1079

HYDRAULIC DESIGN AND OPTIMIZATION OF A LNG HYDRAULIC TURBINE RUNNER

Ning Huang(1), Zhenlin Li(2)

(1)China University of Petroleum （Beijing）, China
1191827524@qq.com

(2)China university of petroleum (Beijing), China
1045068849@qq.com

Keywords: LNG hydraulic turbines,DOE,RSM,NSGA-II,Optimization

Abstract: LNG hydraulic turbines used as the replacements of J-T valves play an important role in the LNG industry chain. In this study, an optimization method for hydraulic turbine impeller was established based on experimental design theory, the response surface approximation and genetic algorithm. This study focused on design optimization for the improvement of the performance of a LNG hydraulic turbine impeller by combining numerical analysis with DOE. The design variables of impeller are selected for the optimization process, and their effects were analyzed through Latin Hypercube Sampling method to select the final design variables that has major effects on the performance. Based on the chosen design variables, the design optimization is performed to select an optimized model through the RSM （response surface method） and NSGA-Ⅱ genetic algorithm.The structured grid system is generated through the ANSYS ICEM program. The dependence of the numerical predictions with respect to grid is analysed. When the mesh number is beyond 2.57 million, the head becomes stable. Thus the final grid number for calculation is selected as 2.89 million. The grid numbers for the computational domains are: guide vane 1.37 million, rotor 1.2 million, inlet and outlet 0.16 million, respectively.The CFD software ANSYS FLUENT 14.0 is used to calculate the 3D turbulence flow field of the hydraulic turbine. The flow is assumed to be steady, and the medium LNG is incompressible and viscous. The turbulence model RNG k-ε is chosen, and the interaction between rotor and guide vane is considered with the multiple reference frames (MRF) method. The coupling of pressure and the velocity is calculated with SIMPLEC algorithm, and the convection terms are discretized with the two order upwind scheme. The boundary conditions of the total pressure at inlet and mass flow at outlet were adopted.The efficient and head were chosen as objective functions, in the first step, the sensitivity of design parameters about hydraulic efficiency and head were analyzed, respectively. Then, the design parameters are chosen for the further optimization analysis. Response surface method (RSM) is used to obtain the explicit expression between the design parameters and the objective functions, then the NSGA-II genetic algorithm is used to obtain the Pareto Optimal Set of Multi-Objective Optimization. Finally, the head and hydraulic efficiency of the optimized model rise by 1.5% and 3.2%, respectively.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1081

DEVELOPMENT OF AERODYNAMIC SHAPE OPTIMIZATION METHODS FOR AEROELASTIC WING DESIGN

Cian Conlan-Smith(1), Casper Andreasen(2), Néstor Ramos-García(1), Ole Sigmund(1)

(1)Technical University of Denmark, Denmark
cicosm@mek.dtu.dk, nerga@dtu.dk, sigmund@mek.dtu.dk

(2)DTU Mechanical Engineering, Denmark
csan@mek.dtu.dk

Keywords: Shape Optimization; Wing Parameterization; Panel Methods; Adjoint Sensitivities

Abstract: Aerodynamic shape optimization studies will be presented with a primary focus on aircraft wing design. Naturally, shape optimization problems experience drastic changes in geometry, which means versatile parameterization techniques are required to maximise the available design space. Different methods of parameterization will be presented including standard aerofoil definitions and nodal control methods. These methods will be compared based on their ability to achieve complex geometry from initial basic wing configurations (e.g. rectangular wing) and the performance of subsequent designs. A typical objective function is to minimize the drag to lift ratio integrated over the wing surface subject to geometric constraints. The aerodynamic problem is solved using a modified version of MIRAS [1]. MIRAS is a software developed for wind turbine performance analysis based on a three-dimensional panel method. Our analysis assumes the flow is inviscid, steady and incompressible. The code is modified to calculate the gradients necessary for sensitivity analysis which is based on an adjoint formulation. The motivation for this work is to develop shape optimization tools that can be applied to future aeroelastic studies within the TopOpt research group. The long-term goal is to combine these tools with structural optimization techniques to simultaneously produce external geometric and internal structural designs with optimized aerodynamic and structural performance. [1] Ramos-García N, Sørensen JN, Shen WZ (2016) Three-Dimensional Viscous-Inviscid coupling method for wind turbine computations. Wind Energy 19:67-93

Abstract ID 1082

GLOBAL OPTIMIZED SHAPES OF AEROSPACE VEHICLE MODELS

ADRIANA NASTASE

RWTH, Aachen University, Germany, Germany
nastase@lafaero.rwth-aachen.de

Keywords: Supersonic flow,Global shape optimization,Enlarged variational problems with free boundaries,Hyperbolic PDEs of second order,Meshless solutions,The iterative optimum-optimorum strategy.

Abstract: The classical variational problem of the aerodynamic optimization of the shape of a flying configuration (FC) consists in the determination of the shape of its surface with fixed planform, in order to have a minimum drag at cruise. This elitary FC has a fixed set of similarity parameters of its planform, The global optimized (GO) shape of a FC consists in the simultaneous determination of its optimal camber, twist thickness and also of the similarity parameters of its planform in order to have a minimum drag, at cruise.This enlarged variational problem with free boundaries was solved by the author by introducing a lower limit hypersurface of the drag coefficients of the elitary FCs belonging to a class defined by their common properties This optimum-optimorum strategy of the author was used for the determination of the GO shapes of three models, namely: the delta wing alone ADELA and of two fully-integrated FCs Fadet I and FADET II, which are of minimum drag at cruising Mach numbers 2, 2.2 and respectively 3. The GO shapes of FADET I and FADET II are here usedl for the design of two GO space vehicle models for a suborbital touristic flight in space. A smaller and more rapid GO model can up and go on the surface of a much greater and slower one and can be considered like a Saenger GO variant.

Abstract ID 1083

OPTIMIZATION OF PARALLEL COMPUTATIONS FOR SIMULATING WATER PURIFICATION PROCESSES BY ELECTROMAGNETIC METHOD

Tatiana Kudryashova

Keldysh Institute of Applied Mathematics RAS, Russian Federation
takud_imamod@mail.ru

Keywords: water purification; finite volume method; parallel realization

Abstract: The problems of computer simulating of technological processes are currently relevant and demanded practice. Computer and supercomputer simulating allows you to explore the details of complex technological processes with the necessary degree of detailing. However, the effective use of high performance equipment is not a trivial matter. In the present paper, the problem of implementing parallel computations for simulating the process of water purification by an electromagnetic method is discussed. The problem of water purification is actual in many areas of the economy, including the food and the medical industry. To solve it, natural experiments and mathematical modeling based on hydrodynamic models are applied. In our study, the electromagnetic purification process is described by a complex hydrodynamic model. The model includes the dynamics of charged ions of iron and its salts that move in the water flow of the purification system. The task is solved in a complete three-dimensional non-stationary formulation for real geometry conditions. The resulting system of equations (obtained from the system of Navier-Stokes equations) is formulated in terms of the vector potential of flow, the vortex, the concentration of impurity particles, and the potential of the electric field. As the main numerical approach, an explicit scheme on time and a finite volume method are used. The main numerical approach is realized on non-uniform triangular-prismatic grid. A discrete model has a large volume of spatial mesh (several million cells and more), as well as the complexity of real geometry. Therefore, the use of parallel computations on high-performance multiprocessor systems becomes relevant. For parallel realization of the developed numerical approach, the domain decomposition technique for area and load balancing for calculators are used. As parallel programming technologies, MPI and OpenMP libraries were used. Approbation of the parallel code was carried out on systems with central and vector processors Intel Xeon and Intel Xeon Phi. Studies of efficiency and acceleration during parallel processing helped to determine the optimum calculated configurations. The large volume of calculations of the simulated process was carried out for several characteristic geometric forms of the purification system, and also for several values of the water flow velocity and constant magnetic field. Within the framework of the computer experiments, the flow features in the purification system were obtained and also the final value of impurity concentration in a purified aqueous medium.

Abstract ID 1084

TOPOLOGY OPTIMIZATION INVOLVING HIGH-CYCLE FATIGUE

Shyam Suresh[1], Stefan Lindström[1], Carl-Johan Thore[2], Bo Torstenfelt[1], Anders Klarbring[1]

[1]Linköping University, Sweden
shyam.suresh@liu.se, stefan.lindstrom@liu.se, bo.torstenfelt@liu.se, anders.klarbring@liu.se

[2]Division of Solid Mechanics, Sweden
carl-johan.thore@liu.se

Keywords: Topology optimization,High-cycle fatigue,Endurance Surface,Adjoint sensitivity analysis,Aggregation function

Abstract: The focus of this work is to develop a topology optimization method including high-cycle fatigue as a constraint. The fatigue model is based on a continuum approach, which uses the concept of a moving endurance surface being a function of the stress history and back stress evolution. The development of damage only occurs when the stress state lies outside the endurance surface. The added advantage of using such a model is that, non-proportional loading histories can be used for predicting fatigue quantities without involvement of any cycle-counting algorithms such as rainflow counting. Furthermore, an aggregation function, which approximates the maximum fatigue value, is derived and implemented. As the optimization workflow is sensitivity based, the fatigue sensitivities are determined using an adjoint sensitivity analysis. By using this fatigue model, the predicted damage has a history dependence, which is similar to elasto-plasticity and thus the adjoint solutions are solved stepwise. The sensitivities obtained from the adjoint sensitivity analysis are verified by comparing them to the sensitivities determined by global finite difference. The capabilities of the presented approach are tested on several numerical models where a typical optimization problem is to maximize the stiffness subject to high-cycle fatigue constraints.

Abstract ID 1085

OPTIMIZING THE DESIGN AND CONTROL OF DECENTRALIZED WATER SUPPLY SYSTEMS – A CASE-STUDY OF A HOTEL BUILDING

Philipp Leise[(1)], Lena Altherr[(2)]

[(1)]Institut für Fluidsystemtechnik - TU Darmstadt, Germany
philipp.leise@fst.tu-darmstadt.de

[(2)]Chair of Fluid Systems, Technische Universität Darmstadt, Germany
lena.altherr@fst.tu-darmstadt.de

Keywords: Engineering Optimization,Global Optimization,Energy Effi ciency,Water,Network,Pump,System,Latin Hypercube Sampling

Abstract: Booster stations are used in buildings to supply higher floors with the needed pressure and volume flow, if the supply pressure of the water supplier does not suffice. In high buildings, like skyscrapers, they are usually needed to supply all floors with water. The energy efficiency of these systems can be improved compared to currently used centralized systems by a decentralized topology approach. To design these systems, mathematical optimization based on Mixed-Integer Nonlinear Programming (MINLP) is a promising tool, which allows computing optimal topologies. In this paper, we investigate the optimal topologies of decentralized water supply systems for skyscrapers, which can be modeled by a tree-structured graph. We consider a multi-objective optimization problem. One objective is the total sum of investment costs. The second is the power consumption of the whole system. The underlying model consists of a two-stage variable system, where the binary first stage variables represent the investment decisions, and the second stage variables represent integer and continuous variables for the optimal control of the bought pumps. For optimizing the power consumption, we use the rotating speed of pumps as the key variable to control the energy efficiency. The selection of pumps and pipes are modeled by first stage binary variables. As an input to the optimization program, we use a predefined set of pumps. For modeling the technical characteristics of these pumps, we use polynomial functions and regression analysis. The underlying MINLP is solved by state-of-the-art nonlinear solvers, like SCIP 4.0. As an example use-case, we apply the method to the water supply of a specific real-world high-rise hotel building. We investigate the effects of different sets of available pumps and compare the optimal topologies for different expected runtimes of the system.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1086

SIMULTANEOUS OPTIMIZATION OF ACTUATORS' PLACEMENTS, CONTROL PARAMETERS AND STRUCTURAL TOPOLOGY OF PIEZOELECTRIC COMPOSITE STRUCTURES FOR STATIC SHAPE CONTROL

Kaike YANG, Jihong Zhu, Weihong Zhang

Northwestern Polytechnical University, China
yangkaike29@mail.nwpu.edu.cn, jh.zhu@nwpu.edu.cn, zhangwh@nwpu.edu.cn

Keywords: Simultaneous optimization, Piezoelectric composite structures, Multi-point Constraint; Desired deformations

Abstract: This paper investigates the simultaneous optimization of actuators' placements, control parameters and structural topology of piezoelectric composite structures with surface attached piezoceramic patches. Considering the fragile property that piezoelectric ceramics have, only regular-shaped patch actuators are used here, which greatly facilitate the manufacturing process. Uniform electrical voltages applied on each piezoelectric patch are taken as the voltage design variables for simplifying the complexity of control system. Three kinds of design variables, i.e., the actuators' locations, applied electrical voltages and host structural pseudo-densities, are optimized simultaneously to improve the overall deformation precision. To freely place piezoelectric actuator on the host structure surface regardless of coincident finite element in classic lamination theory (CLT), the multi-point constraints (MPC) method is used here to simulate the perfect bonding between actuator layer and host layer, which inherits the advantages of avoidance of remeshing process, analytical sensitivity as well as efficient lamination description during the movement of actuators in optimization iterations. For applying to spatially complex shape control, a modified shape error function based on the relative error between computed and desired surfaces is used. The finite circle method (FCM) is implemented to prevent the overlaps among the actuators and those between actuators and boundaries of the global design domain. Finally, numerical examples with plane or curved host structure are tested and discussed to demonstrate the validity and efficiency of this method.

Abstract ID 1087

MULTIOBJECTIVE OPTIMIZATION OF COMPOSITE MATERIALS FOR CONTINUOUS FIBER ORIENTATION

Pedro Bührer Santana[1], Ewerton Grotti[1], Marcos Awruch[2], Herbert Gomes[3]

[1]UFRGS, Brazil
pedrobs66@gmail.com, ewerton.grotti@ufrgs.br

[2]UFSM, Brazil
marcos.dfa@gmail.com

[3]Federal university of Rio Grande do Sul, Brazil
herbert@mecanica.ufrgs.br

Keywords: multiobjective optimization,composite material,natural frequencies,QPSO,continuous fiber orientation.

Abstract: Composite materials have gained prominence as an intensively used material in the aerospace and mechanical industry due to their characteristics of stiffness and low weight. The possibility of designing composite material specimens with continuous orientation of the fibers at the ply level, following smooth contours, makes this material even more attractive, as it assess, in a more rational way, the whole reserve of fiber stiffness in the directions of main loadings. This work presents a methodology for the optimization of the dynamic behavior of composite materials by the definition of a continuous fiber orientation. Parameterized curves are used to define the continuous orientation of the fibers and the control points are assumed as design parameters during optimization. A Multi-Objective Quantum Particle Swarm Optimization (MOQPSO) algorithm is used as an optimizer due to desirable characteristics of good convergence and lower likelihood of being stuck in local minima. An example of a composite plate is used to maximize the relationship between the first two natural frequencies (mode veering) and the results compared to solutions assumed optimal. Another example of multi-objective optimization of the composite plate material is presented and compared with literature solutions (which uses an improved NSGA-II algorithm) taking into account the Tsai-Wu index and the Practicality index (a value that defines the ease of execution of the continuous orientations of the fibers). In the end, the results of the orientation of the fibers found in the composite material were very similar to those reported in the literature, confirming the validity of the proposed methodology.

Abstract ID 1088

MULTIOBJECTIVE OPTIMIZATION OF VEHICLE SUSPENSION FOR ROAD IRREGULARITIES BY MOQPSO

Ewerton Grotti[1], Marcos Awruch[2], Herbert Gomes[3], Artur Dieguez Backes[1]

[1]UFRGS, Brazil
ewerton.grotti@ufrgs.br, arturbackes@gmail.com

[2]UFSM, Brazil
marcos.dfa@gmail.com

[3]Federal university of Rio Grande do Sul, Brazil
herbert@mecanica.ufrgs.br

Keywords: Multiobjective optimization,QPSO,vehicular suspension.

Abstract: This paper describes a study on optimization of a half-car suspension model using a novel Multi-Objective Optimization based on Quantum Particle Swarm Algorithm (MOQPSO). Features like diversity, convergence, and spread of solutions are desirable characteristics in obtaining the Pareto front when performing Multi-Objective Optimization. The novelty of the algorithm relies on the main advantages of the Quantum Particle Swarm metaheuristic that allows robustness, speed, and accuracy of the solutions. Leader particles, an external archive for Pareto front and cluster avoidance by a tolerance distance are implemented in the proposed algorithm. The algorithm is used in the multiobjective optimization of a vehicle suspension and compared with a traditional algorithm (NSGA-II). It is used simple sinusoidal bumps and road profile irregularities, which are generated following ISO 8606 recommendations based on a model with spectral densities. Seat acceleration, suspension working-space, and ground reaction forces are the multiobjective functions. Suspension stiffness, damping, seat position are the assumed design variables. Comparisons with other authors are presented and similar results are obtained. Some remarks are reported related to the extreme solutions found on the Pareto front.

Abstract ID 1089

OPTIMALITY CONDITIONS FOR SPARSE QUADRATIC OPTIMIZATION PROBLEM

Duygu ÜÇÜNCÜ[(1)], Süreyya Akyüz[(2)], Erdal Gül[(3)], Gerhard Wilhelm Weber[(4)]

[(1)]Yıldız Technical University and Bahcesehir University, Turkey
duygu.ucuncu@eng.bau.edu.tr

[(2)]Bahcesehir University, Turkey
sureyya.akyuz@eng.bau.edu.tr

[(3)]Yıldız Technical University, Turkey
gul@yildiz.edu.tr

[(4)]Poznan University of Technology, Poland
gerhard.weber@put.poznan.pl

Keywords: Ensemble Pruning,Machine Learning,Sparse Constraints,Difference of Convex Functions

Abstract: Sparse models are preferred in machine learning problems because of their computational interpretability and it is seen in many applications such as in Google Page Rank, classification and regression problems, in the method of Principal Component Analysis (PCA) that finds the most important features and further applications in graphical models. In this study, we derive optimality conditions for the quadratic problem which has cardinality constraint imposing sparse solution. Our Quadratic model is a special application of ensemble pruning model in ensemble learning algorithms. Here, we refer to our previous study on this application in ensemble selection for clustering problems. The quadratic model proposed in this study optimizes trade-off between accuracy and diversity of discriminant functions (classifiers) simultaneously so that the best candidates of ensemble are selected for prediction step. The selection of the best classifiers in the ensemble is crucial for the overall performance of ensemble learning algorithms since redundant/outlier solutions in the ensemble library will decrease the overall prediction accuracy. In order to eliminate such candidates, both accuracy and diversity are taken into account when selecting the best subset of the ensemble. The cardinality constraint is further relaxed by considering various approximations such as L1 norm regularization and student t-log likelihood approximations. Under these considerations and approximations, we build optimality criteria for our quadratic optimization problem with a cardinality constraint.

Abstract ID 1090

OPTIMUM ADAPTIVE SLICING CONSIDERING THE LAYER STRENGTH OF FUSED DEPOSITION MODELLING PARTS

Gokulakrishnan J[(1)], Gurunathan Saravana Kumar[(2)]

[(1)]Indian Institute of Technology,Madras, India
jgokul.krishnan28@gmail.com

[(2)]IIT Madras, India
gsaravana@iitm.ac.in

Keywords: Additive manufacturing,FDM,Optimization,FEM

Abstract: Fused deposition modelling (FDM) is an Additive manufacturing (AM) process where the part tensile strength depends on process parameters like layer thickness, part build orientation and infill density to name a few. Layer thickness is an important parameter and in this work, experiments were conducted using specimens build as per ASTM D638 and ASTM D695 specification to find the effect of layer thickness on the tensile strength and compressive strength respectively. A constitutive model in finite element (FE) based on composite laminate theory was then developed using the experimental data that considers the layer effect. An optimization framework was built using this FE model to find optimal layer thickness for each layer without changing the total layer count. The design variables were the layer thickness and the objective function was chosen to minimize the displacement with dimensional constraint for the given loading condition. Sequential quadratic programming was used for search. Example case studies are presented to illustrate the methodology and results.

Abstract ID 1091

CORRELATION ANALYSIS BETWEEN THE VIBROACOUSTIC BEHAVIOR OF STEERING GEAR AND BALL NUT ASSEMBLIES IN THE AUTOMOTIVE INDUSTRY

Paul Bucur[1], Klaus Frick[2], Philipp Hungerländer[3]

[1]Alpen Adria Universität Klagenfurt, Austria
pabucur@edu.aau.at

[2]NTB Buchs, China
klaus.frick@ntb.ch

[3]Alpen-Adria Universität Klagenfurt, Austria
philipp.hungerlaender@aau.at

Keywords: deep canonical correlation analysis,CCA,neural networks,automotive,acoustics,correlation

Abstract: The development and incorporation of novel technologies in the automotive industry such as autonomous driving or steer-by-wire systems have accelerated technological change, increasing the system complexity significantly and posing new engineering challenges. The simultaneous increase in quality standards requires strict specifications to be propagated across the supply chain, from the carmaker companies down to the automotive component suppliers. This challenge is exacerbated in domains where the quality of a product can be subjective, such as in automotive acoustics. In particular, the design and production of steering systems thus ceases to be a matter of simple functionality, with considerable efforts dedicated to the understanding of the vibroacoustic interaction of steering components. In the current work, we use optimization techniques to deal with a situation encountered in the daily operations of one of the world's leading steering system suppliers, ThyssenKrupp Presta AG, where quality requirements imposed on the vibroacoustic quality of the steering gear need to be passed down to its subcomponents. Furthermore, only one subcomponent, the ball nut assembly (BNA), is subject to an own vibroacoustical quality test, equivalent to the one of the steering gear. In our work we quantify the BNA influence on the assembled steering gear by finding optimal, low dimensional representations of their respective vibroacoustic signals in the equivalent quality test. This is achieved by iteratively maximizing the correlation of projections of BNA and steering gear order spectra under orthogonality constraints. The new, maximally correlated representations for their characteristic order spectra allow an analysis of the BNA's contribution to the steering gear's vibroacoustic behaviour. A first estimate on the attainable correlation is achieved by linear Canonical Correlation Analysis (CCA). The estimate is updated using non-linear methods, such as Kernel CCA (KCCA), which uses the kernel trick to solve the non-linear KCCA optimization problem. Due to their high suitability as non-linear function approximators, deep neural networks can also be used to find new, maximally correlated representations which are not restricted to reproducing kernel Hilbert spaces with the corresponding kernels. We explore the performance of different neural network architectures, optimize their hyperparameter via the Tree-structured Parzen Estimator approach and establish the superiority of the Deep CCA technique in terms of attainable correlation. Furthermore, the weight visualization enables the identification of key influence areas for which BNA quality thresholds can be set, leading to a joint optimization of the monetary costs originating from misclassified parts in both quality tests.

Abstract ID 1092

REDUCED PARAMETER SET SURFACE CONSTRUCTION FROM A GENERIC B-SPLINE SURFACES

Ivo Marinić-Kragić, Damir Vucina

FESB, University of Split, Croatia
imarinic@fesb.hr, vucina@fesb.hr

Keywords: B-spline,Shape optimization

Abstract: Shape optimization is a rather complex undertaking which involves many challenges but nevertheless becomes a necessity in several industries. In shape optimization, the system subject to optimization is usually described by partial differential equations. In engineering application of shape optimization, the optimization problems usually contain multiple mutually conflicting objectives functions, modeled by very different computational methods. This causes difficulties in engineering applications of methods developed specially for solving a specific type of partial differential equations. A generic method for solving such problems is to construct a numerical workflow with various interconnected software. The optimizer controlling the shape variations within the numerical workflow is also a major concern. Depending on the optimization problem, a different optimization algorithm (genetic algorithm, gradient method,…) may be appropriate. In engineering shpe optimization, the notions of geometry and shape are the 'common denominator' shared by all the components of the engineering analysis and synthesis procedures. With an adequate geometry parameterization, the number of shape variables can be reduced therby decreese the optimization complexity. For engineering application, the obtained shape needs to be manufacturable. This means that a generic shape described by for example B-spline surface is not fully applicanble and the constraints can be implemented directly in the shape representation therby reducing the number of variables. To obtain a simplified shape, it can be segmented into multiple patches described by simple analytical functions. The aim of this paper is to develop a simplified geometry representation of a generic shape (usually represented by a B-spline surface) as sets of simple partial shape portions. At first, this was conducted using the results from an optimization procedure where a B-spline surface was used. The optimized object was the blade of a vertical axis wind turbine. The shape in the optimization procedure was described by a B-spline surface and the result is a complex shape which cannot be described by a simple analytical function. The shape was subsequently partitioned by several methods using approximation techniques. The performance (as defined by the optimization procedure) of the initial shape (B-spline) is compared to the shape obtained by the simplified geometry represented by a set of simple partitions. The same procedure was also analysed for using a point cloud obtained from a 3D scanning. The promising results were discussed regarding the possible reduction of shape variables.

Abstract ID 1093

STRESS CONSTRAINED OPTIMIZATION OF PLATES WITH NONLINEAR MATERIAL BEHAVIOUR

Bence Balogh(1), Matteo Bruggi(2), Janos Logo(3)

(1)Budapest University of Technolgy and Economics, Hungary
balogh.bence@epito.bme.hu

(2)Politecnico di Milano, Italy
matteo.bruggi@polimi.it

(3)Budapest University of Technology and Economics, Hungary
logo.janos.bme@gmail.com

Keywords: stress,constraint,EFG,FEM,nonlinear material,plate,shell,optimization

Abstract: The goal of the study is to develop numerical algorithms for the optimization of plated structures. The formulation of the optimization problem is based on the global or local weak form of a 2D continuum, giving rise to the usage of either the finite element method or another. The results are illustrated by the application of FEM and the element free Galerkin (EFG) method. In the latter, the moving least squares (MLS) method is used to construct shape functions with compactly supported weight functions, to achieve meshless approximations of system state equations. The direct method is included to enforce the essential boundary conditions because of the lack of the Kronecker delta function property of MLS meshless shape functions. Methods are compared in terms of computational time, numerical issues, advantages and shortcomings, and overall applicability in general. From optimization point of view, the goal is to minimize the volume, while ensuring a certain level of stiffness and stresses. The solution is obtained by using both the homogenization method and mathematical programming. The study is enclosed by illustrative examples of isotropic plates with linear and nonlinear material behaviour.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1094

2-DIMENSIONAL OUTLINE SHAPE REPRESENTATION FOR GENERATIVE DESIGN WITH EVOLUTIONARY ALGORITHMS

Paul Lapok, Alistair Lawson, Ben Paechter

Edinburgh Napier University, United Kingdom
p.lapok@napier.ac.uk, a.lawson@napier.ac.uk, b.paechter@napier.ac.uk

Keywords: Genetic Representation,Shape Representation,Shape Optimisation,Genetic Algorithm,Evolutionary Algorithm

Abstract: In this paper, we investigate the ability of genetic representation methods to describe two-dimensional outline shapes, in order to use them in a generative design system. A specific area of mechanical design focuses on planar mechanisms. These are assembled of mechanical components, e.g. multiple levers, which transmit forces and torques over their contour. The shape of the contour influences the performance of the overall system. The genetic representations are based on floating-point chromosomes, where each value maps to a specific parameter of a resulting shape. In order to evaluate the performance of each representation method, a set of target shapes was defined. These consist of simple symmetric and asymmetric shapes with edges and curves, and also of more complex mechanical lever shapes, extracted from an automotive device. An evolutionary algorithm with crossover and mutation operators is used to search for the best approximation of these target shapes. The fitness function is based on two penalty values: first, calculated by comparing the area of a candidate solution with the area of a target shape; and second, based on the intersection area between a candidate solution and a target shape compared to the entire area of the target. Experiments were undertaken to investigate the capabilities of the representations in terms of search space coverage; compatibility with evolutionary operators; and the ability to produce shapes with mechanical characteristics. The results show the benefits and drawbacks of using each of selected methods of representation, and their suitability of reassembling different outline shapes.

Abstract ID 1096

OPTIMAL SEARCH STRATEGIES FOR RESCUE DRONES BASED ON SWARM BEHAVIOUR WITH DIFFERENT ETHICS

Alexander Struck, Ronny Hartanto, Florian Roesner, Clein Sarmiento Castrillón

Rhein-Waal University of Applied Sciences, Germany
alexander.struck@hsrw.eu, ronny.hartanto@hsrw.eu, florian.roesner@hsrw.org, cleinsarmiento@hotmail.com

Keywords: swarm optimisation,autonomous agents,multi-objective optimisation,cultural algorithms,evolutionary computation

Abstract: Search and rescue of people in need after catastrophic events like earth quake areas, large scale wildfires, hurricane zones or flood districts is dangerous and challenging for the rescue personnel. Limited resources and reduced accessibility to danger zones even prevent rescue attempts in total. New technologies to assist and keep safe the search and rescue teams while maintaining maximal success rate are therefore desired. Autonomous drones and robots can provide helpful assistance in locating and supporting injured persons. A particularly powerful aid can be expected if the rescue drones act as a swarm of autonomous agents. Each agent follows a certain search protocol and decides based on sensor input and information exchange with other agents and central command which action it will take, for instance delivering first aid kits and utilities for victims still capable to help themselves, requiring a rescue team for persons in severe danger or reporting casualties. In this context, a rescue scenario based on simulated swarms of agents which can exchange data and energy via charge transfer between their drive battery is discussed, including recharge and information transfer at a base camp/central command. Agents in the swarm follow a certain ethical protocol. For instance, they can act fully altruistically and give up all of their remaining charge when convinced that a victim can be saved by their self-abandonment. The other extreme is maximal selfishness, the agent only communicating the location of victims while preserving always enough energy to recharge at the operation center or through altruistic robots. The protocol furthermore includes inter-agent interactions and communications which will influence the individual agent decisions. We discuss the optimal swarm ethics and its efficiency compared to standard rescue protocols. We also examine limits and benefits in real world technical applications.

Abstract ID 1098

FIRE RISK MODELING USING ARTIFICIAL NEURAL NETWORKS

Luiza Fernandes[1], Marcelo Nero[1], Rosangela Cintra[2], Plinio da Costa Temba[1]

[1]UFMG, Brazil
luizacintraf@gmail.com, marcelo.nero@gmail.com, temba.mobile@gmail.com

[2]Nacional Institute for Space Research, Brazil
rocintra@gmail.com

Keywords: fire risk,neural artificial networks,inverse problems

Abstract: Forest fires cause many changes in environment and in climate, becoming a huge concern related with environment, as your prevention and control. The fire risk calculation supports the planning of activities to prevent forest fire, as it determines the probability of fire occurrence in certain place. This article has the aim of mapping fire risk areas of Belo Horizonte city. The proposed modeling is to create an artificial neural network with supervised training. A neural network to do the prediction of most propitious fire areas is expected, where it can be introduced the input variables at any period that desire to be determined. This estimate will provide the outline of priority areas for prevention activities and allocation of brigade teams, seeking to minimize possible damages caused by fires.

Abstract ID 1099

3D TOPOLOGY OPTIMIZATION WITH H-ADAPTIVE REFINEMENT BASED ON THE CARTESIAN GRIDS FINITE ELEMENT METHOD (CGFEM)

David Pellicer, Juan J. Ródenas, Enrique Nadal, José Albelda

Universitat Politècnica de València, Spain
damuopel@upv.es, jjrodena@mcm.upv.es, ennaso@upvnet.upv.es, jalbelda@mcm.upv.es

Keywords: topology optimization,cartesian grids finite element method,cgFEM,refinement,h-adaptative,3D,SIMP

Abstract: Regarding optimization of structural components, topology optimization has become one of the most popular methods to achieve significant reductions in mass and volume. The topology optimization algorithm considered in this paper, the SIMP method, is described in Bendsøe 1989 [1]. Topology optimization is an iterative process, which requires the Finite Element Method (FEM) to obtain the objective function and gradients. A better performance of FEM can be achieved if all the elements have a uniform shape. This is usually impossible with standard FEM where elements must fit the boundary of the working space. In this work, we propose the use of the Cartesian grid FEM (cgFEM) [2], instead of the standard FEM. The main features of this method are the use of Cartesian FE grids independent of geometry and an efficient hierarchical data structure. The SIMP method has been adequately adapted to the cgFEM framework, where elements can be cut by the boundary. In addition, we propose the use of h-adaptative mesh refinement in the optimization loop as a way to improve the accuracy in the definition of the contour of the component provided by optimization. The iterative process begins with a mesh of uniform element size. SIMP convergence requirements are relaxed to avoid a large number of iterations. Once this process reaches the prescribed convergence level, the elements with intermediate density levels are refined, halving their element sizes, and a new SIMP loop will then start. This process will be repeated until a minimum prescribed element size is reached. The use of h-adaptative refinement leads to solutions that, being topologically similar to those obtained with the initial coarse uniform mesh, have a high contour definition. This high quality definition of the contour, where intermediate values of density are practically nonexistent, noticeably simplifies the manufacturing of the topology-optimized geometries. [1] M. P. Bendsøe, 1989. Optimal shape design as a material distribution problem. Structural Optimization 1, 193-202. [2] E. Nadal, 2014. Cartesian grid FEM (cgFEM): High performance h-adaptive FE analysis with efficient error control: application to structural shape optimization. Ph.D. Thesis, Universitat Politècnica de València.

Abstract ID 1100

ALGORITHMIC SYSTEM DESIGN OF THERMOFLUID SYSTEMS

Jonas Weber, Ulf Lorenz

University of Siegen, Germany
jonas.weber@uni-siegen.de, ulf.lorenz@uni-siegen.de

Keywords: Technical Operations Research (TOR),Mixed-Integer Linear Programming,Thermofluid System,Thermalfluid System,System Synthesis,System Design Problem,Dynamic System,Continuous-Time

Abstract: Technical components are usually well optimized regarding soft characteristics, such as energy efficiency or reliability. However, simply combining these optimized components in a technical system does not necessarily lead to optimal systems. Therefore, focusing on a system perspective reveals new potential for optimization. To make use of this potential, we investigate an algorithmic system design approach associated with the novel research area ‘Technical Operations Research’ (TOR). It is originated from engineering and developed in cooperation with mathematicians as a part of the German Research Foundation (DFG) founded Collaborative Research Center (CRC) 805 ’Control of Uncertainties in Load-Carrying Structures in Mechanical Engineering’. TOR was developed to combine technical and mathematical know-how in order to design optimal systems given a defined objective, such as energy consumption or lifetime cost. These systems are not only designed to operate in one fixed scenario which is usually associated with the maximum load. Rather, a full load profile is taken into consideration. Following the insight of previous research results on fluid systems, we examine thermofluid systems which can be interpreted as a fluid system with superimposed heat transfer. The structure of such a system can be abstracted as a graph – more specifically, a flow network. We translate the underlying optimization problem into a mixed-integer linear program which is designed to obey the physical laws of thermofluid mechanics. Typically, fluid systems can be considered as quasi stationary systems since their dynamic effects are mostly negligible. However, for thermofluid systems this assumption does not hold because time-dependency is an issue as storage tanks for the heated fluid gain importance. In order to handle the dynamic effects induced by the storage tanks, we further introduce a continuous-time representation based on a global event-based formulation.

Abstract ID 1101

TOPOLOGY OPTIMIZATION FOR ADSORBED SYSTEM WITH CONDENSED PCM BODIES

Diego Prado, Emílio Carlos Nelli Silva

Universidade de São Paulo, Brazil
disprado@usp.br, ecnsilva@usp.br

Keywords: Topology Optimization,Adsorption,Phase Change Materials,Finite Elements,Gas Storage

Abstract: Gas transport and storage are just two vital elements to be considered when analyzing potential solutions involving gas employment. The system efficacy and capacity usually figure out how profitable the gas solution is. A known method for gas storage and transport is the adsorbed natural gas (ANG). It consists in the adhesion of gas at a porous matrix by the adsorption phenomena. Adsorption is an exothermic phenomenon, thus, when gas is adsorbed, heat is generated, heating the system up. One issue regarding ANG engineering is the fact that increasing temperatures cause adsorption capacity to diminish. To solve this issue, processes of controlling the temperature within the vessel can be seen in literature. A temperature control method consists in placing phase change materials (PCM) bodies inside the vessel. In literature, it is confirmed that placing PCM in an adsorption vessel may improve its adsorption and desorption capability by lessening the overall thermal amplitude throughout the cycle. Results vary by altering the total amount and position of PCM bodies at the vessel interior. Employing an effective tool for optimized material distribution, for example, Topology Optimization Method (TOM) is an increasingly attractive answer. Several studies have been conducted about TOM abilities and implementations and it is currently known to be a flexible method for material distribution inside a domain. In this work, it is studied the employment of a topology optimization formulation capable of increasing efficiency of ANG tanks by optimizing PCM distribution at the container inside. The modeled vessel includes a cylindrical vessel with adsorbent substance in its interior that is vulnerable to a pressure growth at the inlet. The FEniCS library is used to manage the differential equations problem and the routine is built in python. Sensitivities calculation are performed by dolfin-adjoint libraries. For TOM, the Project Variable is the distribution of PCM inside the vessel. By tackling the non-linearity caused by phase change periods, an analytic solution to the phase change is linearized and implemented for the numerical process. Helmholtz filter is implemented to remove intermediate values of PCM distribution. This implementation benefits TOM when it avoids the necessity of adaptive mesh solutions, often essential when tackling phase shift problems. By employing TOM, an ANG vessel with PCM is optimized. Optimization results are presented and benefits that the optimization brings are discussed.

Abstract ID 1102

ADVANCES IN HOMOGENIZATION-BASED TOPOLOGY OPTIMIZATION FOR HIGH-RESOLUTION MICROSTRUCTURES

Jeroen Groen, Ole Sigmund

Technical University of Denmark, Denmark
jergro@mek.dtu.dk, sigmund@mek.dtu.dk

Keywords: topology optimization,homogenization,microstructures,additive manufacturing

Abstract: The objective of this work is to present recent advances in projection methods to obtain high-resolution manufacturable structures from efficient and coarse-scale, homogenization-based topology optimization results [1,2]. The focus of this work is on compliance minimization of linear-elasticity problems, for which it is known that the optimal solution is in the space of layered materials. In a very appealing approach Pantz and Trabelsi introduced a method to project the rank-2 microstructures from homogenization-based topology optimization, to obtain a solid-void design with finite length-scale [3]. The microstructures are oriented along the directions of lamination such that a well-connected design is achieved. This approach paves the way for coarse-scale topology optimization where the projection can be performed on a high-resolution mesh, without a need for cumbersome and expensive multi-scale formulations. In a recent work we have simplified the projection procedure, and introduced procedures for controlling the shape of the projected design [1]. This allowed for high-resolution (~1 million elements in 2D), near-optimal and manufacturable designs, obtained within a few minutes on a standard PC. In the current work we will demonstrate extensions of the method into three dimensions, and discuss the potential of the method over standard topology optimization methods. Especially, with regard to the large savings in computational cost. Furthermore, the application of the method in the context of infill design for coated structures will be discussed.

References

[1] J.P. Groen and O. Sigmund. Homogenization-based topology optimization for high-resolution manufacturable micro-structures. International Journal of Numerical Methods in Engineering 2018; 113(8):1148–1163, doi: 10.1002/nme.5575

[2] S.D. Larsen, O. Sigmund and J.P. Groen. Optimal truss and frame design from projected homogenization-based topology optimization. Structural and Multidisciplinary Optimization 2018;:1-14, doi: 10.1007/s00158-018-1948-9

[3] O. Pantz and K. Trabelsi. A post-treatment of the homogenization method for shape optimization. SIAM Journal on Control and Optimization 2008; 47(3):1380–1398, doi:10.1137/070688900

Abstract ID 1103

EFFECT OF DIFFERENT AGENT-BEHAVIOUR ON A TRAFFIC SIMULATION FRAMEWORK

Ronny Hartanto[(1)], Alexander Struck[(1)], Anoshan Indreswaran[(2)], Arindam Mahanta[(2)], Yu-Jeng Kuo[(2)]

[(1)]Rhein-Waal University of Applied Sciences, Germany
ronny.hartanto@hsrw.eu, alexander.struck@hsrw.eu

[(2)]Rhine-Waal University of Applied Sciences, Germany
indreswaran.anoshan@gmail.com, arindam.mahanta@live.com, yu-jeng.kuo@hsrw.org

Keywords: Simulation Framework,Traffic Simulation,Agent behaviour,Optimization

Abstract: Simulation is a helpful tool for analysing and optimising certain problems in various different scenarios. In urban area, traffic simulation could help optimising the placement of the traffic lights or traffic signs. Typically, the simulation based mostly on the linear approximation of the distances and speed. However, drivers' behaviour could also influence the traffic situation resulting in traffic jam which lead to delay on the arrival time on other drivers. In this work, a simulation framework that focusses on the drivers' behaviour is presented. Each driver is modelled as an agent which has some driving attitude varying from careless driver to careful one. The simulation model a daily activity of each agent, where it has a place to live and an office to work. The agents will then do their daily activities which can be an ordinary day or some free day by visiting friends, cinema or shopping center. Based on the daily activity situation the driving style will be influenced from a patient driver which drives carefully to an angered driver that tends to become more careless. In this context, the population and size of the city in addition to the drivers' behaviour is discussed and the effects are compared to the same population with normal driving behaviour as control group. Furthermore, the simulation framework could be applied to different domain such as emergency situation like fire on a building or a sinking ship. In these domain, agents' behaviour could influence the whole rescue situation based on the number of causalities. The simulation could help design optimal rescue path and layout of the building as well as number of rescue boat and their placement on the ships.

Abstract ID 1104

A MACRO-SCALE TOPOLOGY OPTIMIZATION METHOD FOR FLOWS THROUGH SOLID STRUCTURE ARRAYS

Paul Lacko, Geert Buckinx, Martine Baelmans

KU Leuven, Belgium
paul.lacko@kuleuven.be, geert.buckinx@kuleuven.be, martine.baelmans@kuleuven.be

Keywords: topology optimization; micro-size flow device; macro-scale modeling

Abstract: Periodic arrays of solid structures such as pin fins are being included in more and more micro-size fluid flow and heat transfer devices. Such arrays are beneficial towards device performance since, in comparison to microchannel devices, they are able to further reduce the pressure drop and increase the heat transfer rate between a flow and solid. In recent years, mathematical optimization strategies such as topology optimization are increasingly being applied to microchannel flow devices in order to pursue innovative designs with superior performance. These techniques optimize the material placement of either solid wall or void channel in the entire design domain. Current topology optimization methods require direct numerical simulation (DNS) of the flow and conjugate heat transfer for proper resolution of the physics, which for large problems can become computationally very costly. From a manufacturing point of view, devices containing periodic solid structure arrays are more easily fabricated than optimized microchannel design topologies. However, at present no comparable optimization methodologies exist to optimize the size or placement of solid structure arrays in flow devices, with the aim of improving performance. In this research, we present a macro-scale topology optimization method for flow systems consisting of an array of solid structures with fixed position and shape, but varying size. The hydraulic performance of these devices is maximized by optimizing the size of each individual solid structure. Since DNS of microscale features in a flow device is computationally infeasible, the presented macro-scale method relies on solving the spatially filtered Navier-Stokes flow equations. This allows us to capture the average flow features without solving all of the detailed flow phenomena. To this end, the effect of the solid structures is modeled via an interfacial force. The results of our method are compared to traditional cases of topology optimization of fluid flow problems, and DNS is used to validate our designs and verify the accuracy of the assumption of the interfacial force replacing the actual microstructures.

Abstract ID 1105

OPTIMIZATION OF OBJECT-RELATIONAL DATABASE STRUCTURE

Ainars Auzins, Janis Eiduks

Riga Technical University, Latvia
ainars.auzins@rtu.lv, zane_matematika@inbox.lv

Keywords: object-relational database,structure optimization,multicriterial optimization

Abstract: Object-relational database is a hybrid solution. During its constructing (physical projection), problems are caused by three factors: ambiguity of transformations of conceptual model, multiplicity of criteria in quality assessment, and a lack of constructive model. The authors of various engineering developments have tried to understand the existing problems deeper and to offer their solutions. Object-relational database structure S is formed by basic containers Ki i=1,...,k (object, relational, XML tables) , data objects Oj j=1,...,z, object methods Mr r=1,...,m, object linking mechanisms Rt t=1,...,h, constraints Cl l=1,...,g and object types hierarchies components Ht t=1,...,u. The designer of a database must examine and assess a large variety of various potential solutions. The following database structure optimisation problem must be formulated and solved. The object-relational database structure S(K, O, M, R, C, H) needs to be optimized in admissible variation space G of database structures. With the variation of these structural elements, it is possible to obtain various object-relational database solutions with different qualities. For the automation of this process, a constructive structure model is necessary that can be used in software. XML language is used for such model development. The experience in the optimisation of topologies and forms has revealed the disadvantages of parametric optimisation in the operation with structures. There is the analysis provided of a set of parameters rather than the structure. In many cases it is not the same. It is necessary that structure S variation space Ω is created by possible structures rather than their parametric models. When moving in this space from one structure to the next structure, there would be the structures and not their parametric models analysed. It would permit better use of both formal and informal assessments. It is necessary to define structure variation space Ω to see it. For this in work is used Transformation rules database. Various algorithms and approaches have been developed for solving multicriterial optimisation problem. The most corresponding approach to design processes is adaptive or interactive approach. Sequential, directed analysis of database structures is performed in dialogue regime. At the end of each iteration, the designer provides the structure assessment and wishes. A great deal is being devoted to the effective presentation of different type of sub results (graphical and values) to the database designer (decision maker).

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1109

A COMPARATIVE STUDY ON THE AERODYNAMIC MODEL FIDELITY EFFECTS IN PRELIMINARY AIRCRAFT DESIGN OPTIMIZATION

Jose Lobo do Vale(1), Nuno Alves de Sousa(1), Martin Sohst(1), Afzal Suleman(2), Sid Banerjee(3), Graham Potter(3)

(1)University of Victoria, Canada
joselobodovale.cfar@gmail.com; nunoalvesdesousa@me.com; martin.shost@tum.de

(2)IDMEC and University of Victoria, Portugal
suleman@tecnico.ulisboa.pt

(3)Bombardier Aerospace, Canada
sid.banerjee@aero.bombardier.com, graham.potter@aero.bombardier.com

Keywords: Multidisciplinary Design Optimization,Aircraft preliminary design,Fluid-Structure Interaction,Multy-fidelity analysis comparison

Abstract: A comparative study between the multidisciplinary design optimization results of a regional jet transport aircraft based on different fidelity aerodynamic models is presented. The optimization of the wing structure of the aircraft is based on surrogate models of performance parameters for both the objective function and constraints, for which the parameterized design configuration is used as input. The performance parameters include mission fuel consumption, structural stress under specified load cases, balanced field length for take-off and climb performance. A fluid-structure interaction procedure is used to couple the aerodynamic and structural models and generate databases with information about aerodynamic forces and moments accounting for aircraft deformation and stress. The structural model consists of an equivalent beam model representing a wingbox structure with varying thickness along span. The aerodynamic models consist of a potential flow model with viscous drag corrections for the low/medium fidelity analysis and a commercial CFD RANS code for comparison. A representative fuselage and tail configuration is use as a baseline configuration of the aircraft. Systems mass distribution is also provided for the baseline aircraft configuration. Propulsion is modeled using a provided engine database. A quasi-static calculation of several operating points along the mission profile is used for integration of fuel consumption and assessment of mission fuel consumption for configurations respecting the load cases and take-off performance constraints. Results obtained for the two aerodynamic models are compared both at the database generation phase as well as in the performance parameters, allowing for the understanding of the influence of the aerodynamic model fidelity in the final optimized design. For the database generation phase, deformation obtained from the different fidelity models will be compared in terms of both displacement and wing twist, in order to understand if the coupling of differences in aerodynamic predictions and corresponding deformations cause significant differences in the aerodynamic efficiency and structural weight, particularly in an optimization context where the structure flexibility has an increasing trend. In the mission analysis phase, the accumulated effects of the previous results are compared in order to quantify the end line effect of the different fidelity models in terms of operating costs (fuel consumption) and production costs (wing structural mass).

Abstract ID 1110

IMPOSING 5-AXIS MILLING CONSTRAINTS IN DENSITY-BASED TOPOLOGY OPTIMIZATION

Matthijs Langelaar[(1)], David Weinberg[(2)], Nam H. Kim[(3)]

[(1)]TU Delft, Netherlands
m.langelaar@tudelft.nl

[(2)]AutoDesk, Inc., United States
david.weinberg@autodesk.com

[(3)]University of Florida, United States
nkim@ufl.edu

Keywords: topology optimization,manufacturing constraints,milling constraints,SIMP

Abstract: This contribution presents a formulation to guarantee manufacturability by 5-axis milling processes in density-based topology optimization, and aspects of its implementation in a commercial topology optimization environment. Considering manufacturing restrictions at an early stage in the design process is important, as designs generated without such restrictions are likely to lead towards design concepts that prove highly suboptimal when manufacturing considerations are introduced at a later design stage. Various manufacturing constraints have already been developed for topology optimization, for operations ranging from casting to rolling to additive manufacturing. However, for 5-axis milling, which represents one of the most prominent and often used manufacturing techniques for metal components, thus far no adequate approach was available. In this process, 3 relative translations and 2 rotations are possible between a cutting tool and the workpiece. The amount of possible operations forms a challenge in formulating an efficient manufacturing constraint for use in topology optimization. In this contribution, we present our method to impose 5-axis milling restrictions, using a filtering approach in a density-based (SIMP) topology optimization setting. Next to presenting its formulation, we discuss ways to control the tool orientations and cutter geometry, as well as implementation considerations for arbitrary meshes in a commercial software environment. Numerical examples will be presented in 2D (3-axis milling) and 3D for the full 5-axis case, using Autodesk Nastran.

Abstract ID 1113

INVESTIGATION OF INITIAL DESIGN INFLUENCE IN TOPOLOGY OPTIMIZATION

Jimmy Schoubroeck, Matthijs Langelaar, Deepak Gupta

TU Delft, Netherlands
jimmy@vanschoubroeck.com, m.langelaar@tudelft.nl, d.k.gupta@tudelft.nl

Keywords: Topology optimization,initial design,starting guess.

Abstract: Topology optimization problems are large-scale and non-convex, in which the initial design plays an important role. Functioning as the starting point for the optimization algorithm, it influences the quality and the computational cost of the final design. Although this is well known in the topology optimization community, a homogeneous density distribution is traditionally chosen. As topology optimization problems contain an abundant amount of local minima, problem specific initial designs potentially yield better results. Soild-void designs results in slowly occurring and only slight modifications by the optimizer. Generating an initial design using an evolutionary approach [1] proves initial designs that outperform a homogeneous distribution exist, at a high computational cost. Thus far, the influence of the initial design on the quality and total cost of the final design has not been studied systematically. Furthermore, problem dependent initial designs are hardly used. A reason for this might be the lack of a common, systematic method to investigate the relative initial design quality differences. In this contribution, we present three novel ideas to address this gap. First, we define a method to compare and rank the performance of different initial designs in a quantitative manner, inspired on a method previously proposed for ranking optimization algorithms [2]. Second, we compare two new initial design types that require little computational effort to generate, with the conventional homogeneous distribution. The first consists of optimizing the unpenalized problem on a coarsened grid. The second is physics-based, originating from Constructal Theory [3] Third, we investigate the robustness of optimizers by initiating them with an explicitly chosen poor initial design. The comparison of initial designs is performed using three standard optimizers (OC, MMA, IPOPT) using a large set of established mechanical and thermal problems. However, the method can also be extended to other problem types. As the initial designs are tested using a large problem set, their performance ratio can be compared in great detail. One practical result is that for the IPOPT optimizer, initial designs that outperform the homogeneous distribution in the objective exist for all investigated problem cases. Another result is that OC performs poorly when starting from a poor initial design.

References

[1] Lohan DJ, Dede EM, Allison JT (2015), 11th World Congress Structural Multidisciplinary Optimization, June, pp 2–7
[2] Rojas-Labanda S, Stolpe M (2015), Structural Multidisciplinary Optimization 52(6):1205–1221
[3] Bejan A (1997), International Journal Heat Mass Transfer 40(4):799–816

Abstract ID 1114

SECOND-ORDER INVERSE RELIABILITY ANALYSIS: A NEW METHODOLOGY TO THE TREATMENT OF RELIABILITY IN ENGINEERING SYSTEM

Gustavo Libotte[1], Fran Sérgio Lobato[2], Gustavo Platt[3], Francisco Neto[1]

[1]Rio de Janeiro State University, Brazil
gustavolibotte@gmail.com

[2]Federal University of Uberlândia, Brazil
fslobato@ufu.br

[3]Universidade Federal do Rio Grande (FURG), Brazil
gusplatt@gmail.com

Keywords: Reliability-based optimization; Inverse reliability analysis; Engineering system design

Abstract: Reliability-Based methods have been established to take into account, in a rigorous manner, the uncertainties involved in the analysis of engineering systems. The failure probability and the reliability index are used to quantify risks and therefore evaluate the consequences of failure. First/second-order reliability method (FORM/SORM) is considered to be one of the most reliable computational methods to deal with reliability in engineering systems. Basically, the idea is to overcome the computational difficulties in the determination of the reliability index and approximating the constraints. In this contribution, a new methodology for the treatment of uncertainties in engineering systems is proposed. This approach, called Second-Order Inverse Reliability Analysis (SOIRA), consists in the use of first and second order derivatives in order to reduce the number of objective function evaluations in relation to other classical approaches to deal with reliability. In order to evaluate the proposed methodology, three reliability approaches (FORM, SORM and IRA) are applied in two test cases: i) W16X31 steel beam problem and ii) beam problem. The obtained results demonstrated that the proposed strategy represents an interesting alternative in the treatment of reliability, in terms of results and number of objective function evaluations, in comparison with those obtained by other classical approaches.

Abstract ID 1115

MULTIGLODS: CLEVER MULTISTART IN MULTIOBJECTIVE DIRECTIONAL DIRECT SEARCH

Ana Custodio[(1)], José Madeira[(2)]

[(1)]Universidade Nova de Lisboa, Portugal
alcustodio@fct.unl.pt

[(2)]ISEL; IDMEC, Portugal
jaguilar@dem.ist.utl.pt

Keywords: Global optimization,derivative-free optimization,multiobjective optimization,multistart strategies,direct search methods.

Abstract: The optimization of multimodal functions is a challenging task, in particular when derivatives are not available for use. Recently, in a directional direct search framework, a clever multistart strategy was proposed for global derivative-free optimization of single objective functions. The goal of the current work is to generalize this approach to the computation of global Pareto fronts for multiobjective multimodal derivative-free optimization problems. The proposed algorithm alternates between initializing new searches, using a multistart strategy, and exploring promising subregions, resorting to directional direct search. Components of the objective function are not aggregated and new points are accepted using the concept of Pareto dominance. The initialized searches are not all conducted until the end, merging when start to be close to each other. We will describe the algorithmic structure considered, present the main associated theoretical results, and report related numerical experience that evidences the quality of the final solutions generated by the new algorithm and its capability in identifying approximations to global and local Pareto fronts of a given problem.

Abstract ID 1117

THICKNESS CONSTRAINTS FOR TOPOLOGY OPTIMIZATION USING THE FICTITIOUS PHYSICAL MODEL

Takayuki Yamada

Kyoto University, Japan
takayuki@me.kyoto-u.ac.jp

Keywords: fictitious physical model,geometrical constraint,thickness,dispersive coefficient,high order homogenization,topology optimization

Abstract: Thickness constraint is an important geometrical constraint in topology optimization methods. We present a novel approach of the thickness constraint based on the Fictitious Physical Model (FPM). The FPM is formulated using the similarity of the dispersive coefficient in high order homogenization [1]. The thickness constraint is represented using the solutions of the liner partial deferential equation system. Its design sensitivity is derived using the adjoint variable method. Several numerical examples are shown to confirm the validity and utility of the proposed method using the level set-based topology optimization method [2]. The main advantage of the proposed method is the allowance of thickness constraint violations during the optimization procedure. Furthermore, the thickness is computed without computing minimum distances from the boundaries of target shape. [1] G. Allaire, T. Yamada, Optimization of dispersive coefficients in the homogenization of the wave equation in periodic structures, hal-01341082. [2] T. Yamada, K. Izui, S. Nishiwaki, A. Takezawa, A topology optimization method based on the level set method incorporating a fictitious interface energy, Computer Methods in Applied Mechanics and Engineering, Vol.199, No.45-48, pp.2876-2891 (2010).

Abstract ID 1120

MODELLING AND SIMULATION OF A RACE-CAR FRAME USING GRAPH-BASED DESIGN LANGUAGES

Manuel Ramsaier(1), Ralf Stetter(1), Markus Till(1), Stephan Rudolph(2)

(1)Ravensburg-Weingarten University of Applied Sciences, Germany
ramsaier@hs-weingarten.de, stetter@hs-weingarten.de, tillm@hs-weingarten.de

(2)University of Stuttgart, Germany
stephan.rudolph@isd.uni-stuttgart.de

Keywords: Design Automation,Design Language,Sizing Optimization

Abstract: Graph-based design languages aim at the holistic digital description of industrial products. Such languages are based on the structure of natural languages, in which vocabulary and rules define a language. Meanwhile, on the basis of such languages, a powerful engineering framework is now available. This framework aims at computer processing rules and reuse of design and production knowledge. Thus, it relieves product development engineers of routine work by generative means: Domain-specific models such as finite element models and CAD geometry models are generated with scripts (automatically) based on a central data model. The central data model is the core of the design language and holds all information necessary to generate all domain-specific models specified in the design language. This paper describes the use of this kind of design language for the embodiment and dimensioning of a frame for a Formula Student racing car. In the Formula Student regulations, certain load cases are specified and certain design rules are given by regulations. By representing the frame geometry in a design language, it is possible to automatically perform a digital function proof which always complies to the Formula Student regulations. The design can be automatically analyzed by generating a finite element analysis (FEA) with regard to the load cases in the regulations. As a first of its kind implementation, a sizing optimization for the tubes and plates of the car frame is automatically performed. This implementation extends the optimization design language, which has been presented at the WCSMO12 [1]. Being able to define both, topology optimization models and sizing optimization models, the outlook describes future applications of the optimization design language. [1] Ramsaier, M., Stetter, R., Till, M., Rudolph, S., Schumacher, A.: Automatic Definition of density-driven Topology Optimization with graph-based Design Languages, Proceedings of the 12th World Congress on Structural and Multidisciplinary Optimisation, Braunschweig, 5th -9th June, 2017

Abstract ID 1121

OPTIMIZATION OF POLYACRYLAMIDE BASED MULTICOMPONENT HYDROGELS SYNTHESIS USING A NEURO-EVOLUTIONARY STRATEGY

Elena Dragoi[(1)], Gabriel Dan Suditu[(2)], Silvia Curteanu[(2)]

[(1)]"Gh. Asachi" Technical University, Romania
elenan.dragoi@gmail.com

[(2)]"Gh Asachi" Technical University, Iasi, Romania
suditu_g@yahoo.com, silvia_curteanu@yahoo.com

Keywords: Differential Evolution,Artificial Neural Networks,Process optimization,Multicomponent hydrogels

Abstract: In this work, the synthesis of polyacrylamide based multicomponent hydrogels is modelled using a neuro-evolutive technique which combines Differential Evolution (DE) algoritm and Artificial Neural Networks (ANNs). The neural model is developed in an optimal form applying the DE procedure, meaning the optimization of the weights, biases and architecture (number of hidden layers, neurons in each hidden layer and their activation function). The data set used in modelling action contains experimental data obtained in our laboratory. Based on the neural model, the process is further optimized with DE algorithm in order to determine the optimum conditions of the synthesis (time, temperature, monomer concentration, initiator, crosslinking agent, inclusion polymer, and type of the polymer added) leading to the maximization of the reaction yield. In order to improve the performance of the DE algorithm, different research directions were followed in this work: i) the use of self-adaptability to automatically determine the optimum values for the control parameters of the optimization algorithm; ii) the modification at step level of DE (chaotic maps for the initial population and a modified mutation strategy that has a higher probability of providing better individuals); iii) hybridization with Backpropagation and/or Local Search algorithm for the best solution found so far. The simulation results indicated that the best model, as individual multilayer perceptron, has a (7:10:1) structure, where 7 indicates the number of inputs (process parameters), 10 the number of neurons in the hidden layer and 1 the number of outputs (reaction yield). The obtained errors are: 7.54% average absolute error (AARE), 0.96 correlation (COREL) and 0.36 mean squared error (MSE) for training and 9.23% AARE, 0.967 COREL, 0.722 MSE for testing. Even this model can be considered satisfactory, a stack neural network was developed, composed from three simple individual networks, also applying the optimization with DE algorithm. In this way, the errors were reduced with more than 4%. The optimization of the process, using the stack neural model, provides the working conditions that lead to a reaction yield of 96%. Some restrictions were imposed to the reaction conditions for reducing the material and time consumption. From the points of view of result accuracy and method accessibility, the optimization method based on ANN and DE, applied both to model and process, can be considered appropriate for the approach system, capturing in an efficient way the dynamic of the process.

Abstract ID 1122

ADAPTIVE TOPOLOGY AND SHAPE OPTIMIZATION WITH INTEGRATED CASTING SIMULATION

Thilo Franke[(1)], Ronald Bartz[(1)], Sierk Fiebig[(1)], Thomas Vietor[(2)], Julian Hage[(3)], Anneke vom Hofe[(3)]

[(1)]Volkswagen AG, Germany
thilo.franke@volkswagen.de, ronald.bartz@volkswagen.de, sierk.fiebig@volkswagen.de

[(2)]TU Braunschweig, Germany
t.vietor@tu-braunschweig.de

[(3)]ARkentec, Germany
julian.hage@arkentec.de, anneke.vom.hofe@arkentec.de

Keywords: topology optimization,casting simulation,castability,shape optimization,smoothing,CAD conversion

Abstract: The automotive future demands light and affordable designs and components. Stricter regulations, worldwide competition and environmental aims push on this trend. To develop lighter parts in a decreased time structural optimization is used in many R&D departments. To ensure an ideal design of cast parts in the topology optimization a casting simulation is integrated in the optimization procedure. With this additional simulation the castability can be optimized in parallel to the mechanical properties and the weight. Several manufacturing restriction such as the draft angle, minimum member, hole and pocket size, smooth parting line and the reduction of cold run, turbulence as well as shrinkage porosity are implemented. The result is a manufacturable and light structure, which can be transferred into a real part easily. To describe the geometry a regular voxel mesh in combination with a binary design variable per element was used in the past. For the simulations it was converted to an equilateral hexahedron mesh. While this modelling has advantages respective the implementation of manufacturing restrictions and nonlinear load cases, its disadvantages is the rough description of the surface in the FEM simulation or the CAD conversion after the optimization. Also small changes in the geometry are not possible. In this paper an approach is shown to use the available routines of the topology optimization to optimize the shape of the part on a small scale, too, and provide a smooth optimization result. This is done by using a design variable per element, which can be continuous between zero and one in the surface layer. In this way all implemented functions and manufacturing restrictions can be used for both topology and shape optimization. To avoid numerical difficulties the FEM simulations are done with a converted tetrahedron mesh. This increases the quality of the simulation by guaranteeing a smooth surface and avoiding sharp edges. The CFD based casting process simulation is done with the very fast, structured hexahedron elements. The results of the simulations are mapped on the optimization model to change the part design again. Beside the increased degrees of freedom for doing shape optimization and the higher simulation quality with adapted meshes this optimization procedure allows the smoothing of the surface. In summary this approach features better optimization results, which are light and castable with a smooth surface, decreases the development time and enables the next step of an automatically development process, the CAD conversion.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1123

INVERSE AND ITERATIVE APPROACHES IN NUMERICAL INJECTION MOLD DESIGN

Florian Zwicke, Stefanie Elgeti

RWTH Aachen University, Germany
zwicke@cats.rwth-aachen.de, elgeti@cats.rwth-aachen.de

Keywords: inverse design numerical optimization injection molding

Abstract: In order to reduce defects in injection molded parts, as well as to reduce costs and manual work in the mold design process, we develop a numerical approach for the design of injection molding cavities. The idea is to simulate the injection molding process as reliably as possible and to use the predictions yielded by such simulations to automatically determine a suitable mold cavity shape. Our primary goal in this respect is the reduction of geometric faults in the finished part. The quality of the simulation-based design method clearly depends on the quality of the simulation itself. Therefore, the development of an accurate simulation method that uses state-of-the-art as well as newly developed material models is a key component of such a method. While keeping in mind that the simulation must remain suitable for an optimization in terms of, e.g., computational efficiency, we work on models to more accurately describe the material behavior of polymers during their solidification. A special focus is placed on transitional states of amorphous polymers, when they can neither be described as completely liquid nor completely solid. In specific terms, we combine viscoelastic fluid models and nonlinear solid models to be able to simulate both fluid and solid aspects of material behavior simultaneously. For the design of an optimized mold cavity, we follow multiple approaches. While we aim for an efficient inverse design mechanism, we also utilize concepts of mathematical optimization. This requires the formulation of the design process as a minimization problem. A challenge is presented by the suitable representation of geometric deficiencies in a single scalar objective function. Since any iterative procedures will require many runs of the computationally costly molding simulation, we also look for more efficient methods that can aid the iterative process or even replace it completely. We have already been successful in developing an inverse procedure that can be applied to a part of the simulation and will show how this can be used to speed up the optimization process.

Abstract ID 1124

TOPOLOGY OPTIMIZATION USING THE HYBRID FINITE ELEMENT-WAVE BASED METHOD FOR STRUCTURAL-ACOUSTIC PROBLEMS

Seongyeol Goo, Semyung Wang

Gwangju Institute of Science and Technology, South Korea
ksy1124@gist.ac.kr, smwang@gist.ac.kr

Keywords: wave-based method,finite element method,mixed-formulation,structural-acoustic problems

Abstract: In this work, we present an efficient topology optimization method for structural-acoustic problems. A mixed-formulation that interpolate the pressure and displacement field simultaneously is the effective way for topology optimization of structural-acoustic problems. In this method, a linear shape function is used for the pressure interpolation to represent continuous pressure field while quadratic shape function is used for displacement interpolation to ensure numerical stability. This leads to a heavy computational cost in high frequency range or large-scale problem which require a fine discretization. In this regard, we present an efficient topology optimization using the hybrid finite element-wave based method. The wave-based method which uses an exact solutions for field variable approximation is an efficient and accurate numerical prediction method. In the non-design domain, the wave-based method is applied to reduce computational cost. In the design domain, finite element method with mixed-formulation is used to design parameterization. We use the gradient-based optimizer and design sensitivities are computed by the adjoint variable method. Numerical examples are presented to validate the propose method. Result of optimization confirms that the proposed method is able to reduce computational cost compared to conventional method. Acknowledgement This work was supported by a National Research Foundation of Korea (NRF) grant funded by the Korean government (NRF-2017R1A2A1A05001326).

Abstract ID 1125

ADJOINT METHOD FOR TOPOLOGICAL DERIVATIVES FOR OPTIMIZATION TASKS WITH MATERIAL AND GEOMETRICAL NONLINEARITIES

Katrin Weider, Axel Schumacher

University of Wuppertal, Germany
weider@uni-wuppertal.de, schumacher@uni-wuppertal.de

Keywords: Topological Derivative,adjoint sensitivity analysis,crashworthiness

Abstract: The Topological Derivative (TD) is the sensitivity of a functional for the introduction of an infinitesimal hole into the mechanical body. For linear elasticity problems in structural mechanics the TD is known in a closed analytical form for various functionals. In this contribution, the TD for crash loaded structures is derived with the adjoint sensitivity analysis. Wherever the analytical derivation is limited, a numerical, so-called microscale, investigation cf. [1] and [2] completes the TD. The goal is to get a sensitivity for topology changes dealing with material and geometrical nonlinearities, inertial effects and time dependency. The main idea of the adjoint sensitivity analysis is to circumvent the direct calculation of the sensitivity of the displacement field. Instead, the adjoint equilibrium equation has to be solved. In this approach, material derivation [3] and partial integration in the time domain cf. [4] are applied to the TD. This ensures, that the inertial effects are kept, as they are important for a reliable crash simulation. The result is a backward integration scheme for the adjoint state. For the calculation of the TD, only the boundary integral on the introduced hole remains. This integral contains terms of the functional and the weak equilibrium condition. Corresponding to [1], a microscale investigation for each term replaces the analytical form with meta-models. The presented scheme to derive the TD will be illustrated with an academic example. For a functional that copes with crash relevant requirements, the TD is shown and compared with the sensitivities derived with numerical differentiation. The numerical effort and the storage requirement will be outlined, as well as the chances and limitations dealing with crash software for the calculation of the adjoint state.

References

[1] *K. Weider and A. Schumacher, On the calculation of Topological Derivatives considering an exemplary nonlinear material model, PAMM, Vol. 16(1), 717-718 (2016).*

[2] *K. Weider and A. Schumacher, A topology optimization scheme for crash loaded structures using Topological Derivatives, Advances in Structural and Multidisciplinary Optimization, WCSMO 2017, 1601-1614 (2018).*

[3] *A. A. Novotny, J. Sokolowski, Topological Derivatives in Shape Optimization, Springer-Verlag Berlin Heidelberg (2013).*

[4] *J. Dahl, J. S. Jensen, O. Sigmund, Topology optimization for transient wave propagation problems in one dimension, Struct Multidisc Optim, Vol. 36, 585-595 (2008).*

Abstract ID 1126

INDUSTRIAL CHALLENGES FOR LEVEL-SET-DRIVEN MESH-EVOLUTION-BASED TOPOLOGY OPTIMIZATION

Felipe Bordeu[(1)], Julien Cortial[(1)], Florian Feppon[(2)]

[(1)]SAFRAN TECH, France
felipe.bordeu@safrangroup.com, julien.cortial@safrangroup.com

[(2)]Ecole polytechnique, France
florian.feppon@polytechnique.edu

Keywords: topology optimization,level set,industrial application,body-fitted mesh

Abstract: Many variants of level-set topology optimization have been proposed in the scientific literature. One key differentiating aspect is the physical interpretation of the implicitly defined solid-void interface. One possibility among others is to rely on body-fitted spatial discretization of the computational domain. This approach possesses many attractive features, in particular providing at all time an unambiguously-defined solid-void interface, not requiring level-set-aware mechanical solver and offering a seamless transition to fine-tuning, mesh-deformation-based shape optimization. However, the relevance of this ambitious technology in an industrial context remains unproven. Indeed, it has essentially been applied on academic problems characterized by a limited set of well-behaved optimization criteria, elementary geometries, and coincident computational and design domains. On the other hand, industrial problems typically feature a rich set of optimization criteria including manufacturing constraints, involved design domain geometries due to integration constraints arising from the part environment, and the presence of functional interfaces that must be preserved to connect adjacent parts. This contribution aims at illustrating the associated challenges as well as recent progress towards the treatment of industrial-grade test cases.

Abstract ID 1127

DESIGN OPTIMIZATION OF COVER PANEL OF ENGINE-INCLUDED SYSTEM USING TOPOGRAPHY OPTIMIZATION

Hyun-Guk Kim[(1)], Nerse Can[(2)], Seongyeol Goo[(3)], Semyung Wang[(3)]

[(1)]Gwangju Institute of Science and Technology (GIST), South Korea
hkkim88@gist.ac.kr

[(2)]Gwangju Institute of Science and Technology, Afghanistan
can@gist.ac.kr

[(3)]Gwangju Institute of Science and Technology, South Korea
ksy1124@gist.ac.kr, smwang@gist.ac.kr

Keywords: Topography optimization Engine-included system Equivalent radiated power

Abstract: As the power usage of the home appliances gradually increases, research on a high-efficient mechanical system has been focused. In order to develop a high-efficient system with high performance, a gas engine was used as a power source. The engine-included system has much higher energy efficiency than a conventional system powered by the electromagnetic motor. However, if the gas engine was adopted as a power source, the energy efficiency and power of the system are improved while the radiation noise is increased. To overcome this drawback, we design a shell structure including optimal bead pattern that reduces the sound radiation using the topography optimization to the cover panel of the system. In this study, the vibration behavior of the system was measured with the engine speed sweep. Using this result, the target frequency band is determined. In this research, the objective function is an equivalent radiated power (ERP), which is the radiation power calculated from only the structural velocity. In addition, a shell structure with bead pattern is designed to minimize the equivalent radiated power in a given target frequency band using topography optimization. The shape change of the panel bring the change of stiffness. Finally, equivalent radiated power is also changed. Using the topography optimization, the optimal bead pattern on the panel to minimize the equivalent radiated power could found.

Acknowledgements This work was supported by a National Research Foundation of Korea (NRF) grant funded by the Korean government (NRF-2017R1A2A1A05001326).

Abstract ID 1128

NODE TO NODE REQUIREMENTS ON THE SYNTHESIS OF MECHANISMS USING MINIMUM DISTANCE APPROACH

Igor Fernandez de Bustos[(1)], Vanessa García Marina[(2)], Gorka Urkullu[(2)], Haritz Uriarte[(2)]

[(1)]Escuela de Ingeniería de Bilbao (UPV/EHU), Spain
impfedei@ehu.es

[(2)]ES de Ingeniería de Bilbao (UPV/EHU), Spain
vanessa.garcia@ehu.es, gorka.urkullu@ehu.es, huriarte004@ehu.es

Keywords: Linkages,Optimization,SQP

Abstract: The minimum distance method for the synthesis of mechanism is a versatile method able to help in the dimensional design of mechanisms with any kind of requirements. In previous work, this method was designed with node to point and node to line requirements, which allows one to afford function generation, path generation, solid guidance and any combination of them. It can also tackle problems with prescribed and unprescribed timing. The method is based on the minimum distance problem, which can be defined as obtaining the configuration of the mechanism (position of all the elements) which delivers the lower distance to the requirements. This problem is solved for each of the precision points defined for the synthesis and, the summation of all the minimized distances is used as the error function for the mechanism synthesis. This is, thus, a two-scale minimization problem, where the error function itself consists on several optimization problems. The aim of this presentation is to show a method for the introduction of node to node requirements in the dimensional synthesis of mechanisms when using the minimum distance approach. The presented method allows one to introduce a requirement on the distance of two points belonging to different elements of the linkage, which has multiple practical applications such as the design of grippers. In order to do so, the minimum distance into both nodes is included in the error function for each synthesis point including these kind of requirements. The minimization of the minimum distance function is performed with a sequential quadratic programming algorithm. The required derivatives are obtained analytically to reduce computational cost and improve on convergence. The minimization of the synthesis problem is also solved here using an SQP method, but the error function has been developed taking into account the possibility of applying other methods such as genetic algorithms. The requirement is introduced as an additional term in the minimum distance function, thus allowing one to combine it to other types of requirements, such as node to point or node to line. Although in an initial stage of development, the method shows a good behavior in terms of convergence and computational efficiency. In order to demonstrate this, several examples of both the minimum distance problem resolution and also the synthesis resolution are presented.

Abstract ID 1129

MULTI-OBJECTIVE CONTROL PROBLEMS FOR OPTIMAL ISOLATION OF ELASTIC STRUCTURES FROM VIBRATION

Mark Kogan[1], Dmitry Balandin[2], Ruslan Biryukov[3]

[1]Architecture & Civil Engineering University, Russian Federation
mkogan@nngasu.ru

[2]Lobachevsky Nizhnii Novgorod State University, Russian Federation
dbalandin@yandex.ru

[3]Architecture and Civil Engineering State University, Russian Federation
biryukovrs@gmail.com

Keywords: Multi-objective optimization,Pareto optimal control,optimal vibration isolation.

Abstract: The problems of designing devices that provide effective protection of complex structures, instruments, equipment, and the man himself from the harmful effects of vibrations, and at the same time possessing limited sizes, continue to attract attention of scientists and engineers. In engineering practice, such devices are called vibration isolators. It is known that the vibration isolation problem is conveniently considered as a control problem in which the regulator acts as a vibration isolator. The main performance indices characterizing an efficiency of vibration isolators usually involve the value determining the maximal course of this device and the maximal deformations or stresses that arise in the elastic object to be protected. The reasonable choice of a suitable vibration isolating device is, as a rule, a search for a some trade-off between these two important indices: the less the maximal course of the vibration isolator, the more maximal deformations and vice versa. Taking into account this circumstance, it may be expedient to set a two-objective problem of synthesizing the control or, in other words, to choose an appropriate vibration isolator minimizing these performance objectives in Pareto sense. If several vibration isolation devices are involved into the process of protection, there is possibility to consider a multi-objective control problem instead of the two-objective one. In this paper, a general approach to multi-objective vibration protection is proposed. By using a scalar multi-objective cost function in the form of Germeyer convolution we derive necessary conditions for Pareto optimality and characterize Pareto optimal controllers in terms of linear matrix inequalities (LMIs) as optimal solutions for this function. As an example, the two-objective problem of seismic protection of twenty-story building is discussed in detail. The performance objectives are the maximum of the maximal intersectional deformations and the maximal displacement of the building relative to the foundation. The problem under consideration is complicated by the fact that the external seismic disturbances is unknown in advance, so the synthesis of vibration isolation device is carried out on the "worst-case", i.e. for the most dangerous excitation from a some class of disturbances.

Abstract ID 1130

ON COMPARISON OF SOLUTION METHODS FOR 3D CONTACT SHAPE OPTIMIZATION PROBLEMS WITH FRICTION

Petr Beremlijski

VŠB-Technical University of Ostrava, Czech Republic
petr.beremlijski@vsb.cz

Keywords: shape optimization,contact problem,Coulomb friction,nonsmooth optimization,bundle methods

Abstract: The shape optimization of 3D elastic body in contact with rigid obstacle with Coulomb friction can be modelled as minimization of composite function generated by the objective and the control-state mapping. It has been shown that for small coefficients of friction the discretized contact problem with Coulomb friction has a unique solution and this solution is Lipschitzian as a function of a control variable describing the shape of the elastic body. It means that the control-state mapping is single-valued and the 3D contact shape optimization problem with Coulomb friction leads to a minimization of nondifferentiable (nonsmooth) single-valued function. There are several possibilities how to solve the problem. The easiest one is to neglect the friction and find the optimal shape of the optimized body as the solution of the shape optimization problem of 3D elastic body in contact without friction. The advantage is that we solve the optimization problem with differentiable function. Unfortunately, we find the optimized shape which does not solve the original problem exactly. Another possibility is to solve the whole problem with Coulomb friction. This leads to optimization of nonsmooth function. For this case we have to use methods which are working with calculus of Clarke. The most reliable of the nonsmooth methods for this kind of problem are bundle methods. We use bundle trust method proposed by Schramm and Zowe and proximal bundle method proposed by Mäkelä and Neittaanmäki. In each step of the iteration process, we must be able to find the solution of the state problem (contact problem with Coulomb friction) and to compute one arbitrary Clarke subgradient. To get subgradient information needed in the used numerical method we use the differential calculus of Mordukhovich. The aim of the contribution is to compute the optimized shape of 3D elastic body in contact with rigid obstacle by all previous mentioned solution methods and their comparison.

Abstract ID 1131

ACOUSTIC RAINBOWS - PASSIVE SHAPING OF FREE SPACE SOUND EMISSION

Rasmus Christiansen(1), Ole Sigmund(2), Efren Fernandez-Grande(2)

(1)The Technical University of Denmark, Denmark
raelch@mek.dtu.dk

(2)Technical University of Denmark, Denmark
sigmund@mek.dtu.dk, efg@elektro.dtu.dk

Keywords: wave acoustics,passive device,acoustic rainbow,spatial-spectral separation

Abstract: The optical rainbow is a well understood phenomenon which is easily reproducible on a macroscopic scale by guiding sunlight through a prism. The underlying mechanism of the rainbow is the dispersive nature of visible light as it is reflected and refracted through different media, such as water and glass. Sound-waves in the audible spectrum are however not subject to significant dispersion in most homogeneous media. Thus acoustic rainbows are not readily observable in nature. This work, meanwhile, demonstrates that it is possible to design devices, yielding a spectral separation of sound analogous to that of light seen in the optical rainbow. This work presents a passive, single material device, tailored for controlling the free space emission pattern of an acoustic point source by angularly separating its frequency content across a $\pm 25\%$ frequency band around a central frequency, f_c. In addition other devices tailored to exhibit different emission patterns are presented demonstrating the versatility of the underlying design methodology. The characteristic dimensions of the presented devices are on the order of the wavelength, a region which is problematic when using traditional methods, such as ray tracing. Both numerical and experimental results are presented, demonstrating the real world feasibility of the proposed devices. The device design has been carried out using the topology optimization based approach detailed in [1]. Here a 2D model problem is formulated in the frequency domain with the acoustics modelled using the Helmholtz equation. The design goal is to identify a distribution of solid material in a bounded region of space which creates a desired emission pattern into free space for a targeted frequency band. The design problem is formulated as an optimization problem where the objective function depends on the difference between a prescribed desired sound field and the solution to the model problem for a given material distribution. The Globally Convergent Method of Moving Asymptotes is used to perform the optimization [2].

References

[1] Christiansen, R. E. and Efren Fernandez-Grande, Design of passive directional acoustic devices using Topology Optimization - from method to experimental validation. J. Acoust. Soc. Am. 140, p. 3862-3873, 2016.

[2] Svanberg Krister, A class of globally convergent optimization methods based on conservative convex seperable approximations. SIAM Journal of Optimization 12, p. 555-573, 2002.

Abstract ID 1132

OPTIMAL DESIGN OF ROTOR BLADES FOR AN AXIAL COMPRESSOR USING GRADIENT BASED METHOD

Hyung-Jin, Youn-Jea Kim

Sungkyunkwan University, South Korea
wimzzz@skku.edu, yjkim@skku.edu

Keywords: Optimization,Axial compressor,CFD,Stacking line

Abstract: Design optimization methods for rotor blades of an axial compressor have been developed by using the Computational Fluid Dynamics (CFD). In order to improve the aerodynamic performances, such as pressure ratio and adiabatic efficiency, three-dimensional Reynolds averaged Navier-Stokes analysis was used for the single stage axial compressor. The optimum design process considering the aerodynamic characteristics consists of designing the shape using the Non-Uniform Rational B-Spline (NURBS) function and performing the optimum design with Gradient-Based Optimization Method (GBOM). For the proceeding of automated optimization, the commercial code ANSYS CFX ver. 16.1 and Design Exploration were applied. Results show that the newly designed model demonstrated better performance than the reference model. In particular, the pressure ratio was found to be higher than that of the reference model.

Abstract ID 1133

OPTIMAL BATCH CREATION FOR BELL-TYPE INDUSTRIAL BATCH ANNEALING FURNACE WITH AN ANNEALING TIME PREDICTION MODEL

Adil Orta[(1)], İskender Kayabasi[(1)], Onur Saka[(1)], Ali Öztürk[(1)], Kenan Aghayev[(1)], Ali Gözay[(2)], Taner Göçen[(2)], Erdoğan Özdemir[(2)], Eda Kızıltaş[(2)]

[(1)]Borusan R&D, Turkey
aorta@borusan.com, ikayabasi@borusan.com, osaka@borusan.com, aliozturk@borusan.com, kaghayev@borusan.com

[(2)]Borcelik Celik Sanayii Ticaret A.S., Turkey
agozay@borcelik.com, tgocen@borcelik.com, erozdemir@borcelik.com, eckiziltas@borcelik.com

Keywords: batch annealing,coil loading,artificial neural network,mixed integer programming,process optimization

Abstract: Batch annealing process is highly automated and commonly used heat treatment process which is eligible for industrial applications. In this process, steel coils are vertically stacked one on top of each other and heated up to 720°C between 13-25 hours. Temperature distribution and annealing time of each coil depend on weight, thickness, outer diameter, height, vertical position, etc. Having an optimal combination of coil batches increases the productivity of the process. and to create the optimal batches, annealing times of each combination should be predicted. For this purpose, a validated heat transfer model is used to simulate past 2 years' processes. More than 29,000 data are obtained which covers different coil parameters and annealing programs. A neural network model is constructed to predict the annealing time. Error rates of annealing time prediction model are between 30 to 50 minutes which is quite successful. After the validation of the annealing time prediction model, an Integer Programming formulation is developed for the optimal batch creation problem. An alternative approach is proposed for selecting the best batch combinations in a dynamic production environment. Increase in production efficiency is demonstrated in the computational study.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1134

EXPLORING THE FITNESS LANDSCAPE OF A REALISTIC TURBOFAN ROTOR BLADE OPTIMIZATION

Jakub Kmec[(1)], Sebastian Schmitt[(2)]

[(1)]Palacký University, Czech Republic
Kjuba.na.druhou@seznam.cz

[(2)]Honda Research Institute, Germany
sebastian.schmitt@honda-ri.de

Keywords: Shape optimization,CFD,CMA-ES,PSO,Free form deformation,Hicks-Henne bumb functions

Abstract: Aerodynamic shape optimization has established itself as a valuable tool in the engineering design process to achieve highly efficient results. A central aspect for such approaches is the mapping from the design parameters which encode the geometry of the shape to be improved to the quality criteria which describe its performance. The choices made in the setup of the optimization process strongly influence this mapping and thus are expected to have a profound influence on the achievable result. In this work we explore the influence of such choices on the effects on the shape optimization of a turbofan rotor blade as it can be realized within an aircraft engine design process. The blade quality is assessed by realistic three dimensional computational fluid dynamics (CFD) simulations. We compare the results from the covariance matrix adaptation evolutionary strategy (CMA-ES) with the outcome of a particle swarm optimization (PSO). We also investigate the changes induced by a different initialization of the CMA-ES and a variation of its population size. A particular focus is put on the changes in the results by increasing the number of parameters for the blade geometry representation. For all such variations, we generally find that the achievable improvement of the blade quality is comparable for most settings and thus rather insensitive to the details of the setup. On the other hand, even supposedly minor changes in the settings, such as using a different random seed for the initialization of the optimizer algorithm, lead to very different shapes. Optimized shapes which show comparable performance usually differ quite strongly in their geometries over the complete blade shape. Our analysis indicates that the fitness landscape for such a realistic turbofan rotor blade optimization is highly multi-modal with many local optima, where very different shapes show similar performance.

Abstract ID 1136

ONE GOOD REASON FOR EARLY TERMINATION OF KRYLOV SOLVERS IN TOPOLOGY OPTIMIZATION

Asger Limkilde[(1)], Anton Evgrafov[(2)], Jens Gravesen[(3)]

[(1)]Technical University of Denmark, Denmark
asgl@dtu.dk

[(2)]DTU Mechanical Engineering, Denmark
aaev@mek.dtu.dk

[(3)]DTU, Denmark
jgra@dtu.dk

Keywords: Topology optimization,Nested approach,Approximations,Krylov solvers

Abstract: In topology optimization, and structural optimization in general, a common methodology is to perform the optimization on design variables only, treating the solution of the underlying PDE constraints as a function call. With this approach, often referred to as the nested approach, the process of repeatedly solving the state and adjoint equations will dominate the computational effort. One attempt to reduce this effort, is to solve the state and adjoint systems less accurately. Previous work on such approximate approaches is based on early termination of an iterative solver. It demonstrates that seemingly rough approximate solutions obtained after few iterations of a Krylov solver are often sufficient for solving the topology optimization problem. In this work we develop on this idea by looking at the problem from a PDE-based angle. Namely we utilize a posteriori FEM error estimates to give a quantitative measure of when to terminate the iterative solver. We illustrate the proposed method with benchmark examples from linear elasticity. Our main observation is that the discretization error dominates the residual after few iterations. Utilizing this observation for an approximate approach, we find that the optimization algorithm behaves similarly to what one expects from ``exact'' solves. But the number of iterations is significantly reduced, even compared to previously suggested heuristics for approximate solves. The proposed method requires estimation of the residual during the iterations. Hence for large problems the method is impractical to utilize as it is presented in this work. Nevertheless we believe that it provides valuable insight into why approximate approaches yield accurate results. Additionally it provides quantitative guidelines for premature termination of iterative solvers and our experiments suggest that when combined with an efficient error estimate, a lot of computational effort can be saved, by solving the discrete problem just accurately enough.

Abstract ID 1138

OPTIMIZATION OF TWO-STAGE CENTRIFUGAL PUMP OF ROCKET ENGINE

Vasilii Zubanov[(1)], Andrei Volkov[(1)], Valeriy Matveev[(1)], Grigorii Popov[(1)], Oleg Baturin[(1)], Yulia Novikova[(2)]

[(1)]Samara National Research University, Russian Federation
waskes91@gmail.com, a44rey@gmail.com, valeriym2008@rambler.ru, grishatty@gmail.com, oleg.v.baturin@gmail.com

[(2)]Samara University, Russian Federation
y.d.novikova@gmail.com

Keywords: screw centrifugal pump,blade,CFD,optimization

Abstract: The article presents a method for improving the characteristics of fuel pump of rocket engine by the joint usage of mathematical optimization software IOSO, meshing complex NUMECA and CFD programm ANSYS CFX. The optimization software was used for automatic change of the geometry of low-pressure impeller, transition duct and high-pressure impeller to find the optimal design. the original variant of the remaining parts of the pump was keeped. For this reason, only geometrical parameters of the blades were varied without changing the contours of the pump meridional flow part. The investigated pump consists of five parts: inlet duct, low-pressure screw centrifugal stage, transition duct, high-pressure screw centrifugal stage and volute outlet duct. The pump main parameters with water as the working fluid (based on experiment data) were the following: high-pressure stage rotor speed was 13300 rpm; low-pressure rotor speed was 3617 rpm by gearbox; inlet total pressure was 0.4 MPa; outlet mass flow was 132.6 kg/s at the nominal mode. Creation of vane unit mesh (rotors and stator transition duct) was performed using NUMECA AutoGrid5. Sector models were used for the calculation simplification. The flow around only one blade or screw was considered. Setting up and solution of the task were carried out in the ANSYS CFX solver. Comparison of calculated characteristics of the basic pump with the experimental data was performed before the optimization. The analysis of characteristics for the obtained optimized pump geometry was carried out. It was found that pump with optimized geometry has greater efficiency in comparison with the original pump variant. The obtained reserve can be used to boost the rocket engine, and/or to reduce the loading of the main turbine, which operates in aggressive oxidizing environment.

Abstract ID 1140

REVERSIBLE COLD MILLING PROCESS TIME OPTIMIZATION FOR AN INDUSTRIAL APPLICATION

Kanan Aghayev(1), Ali Öztürk(1), Selim İlker(2), Adil Orta(1), Kaan Esendağ(1), Eda Kızıltaş(2)

(1)Borusan R&D, Turkey
knn.agayv@gmail.com, aliozturk@borusan.com, aorta@borusan.com, kesendag@borusan.com

(2)Borcelik Celik Sanayii Ticaret A.S., Turkey
silker@borcelik.com, eckiziltas@borcelik.com

Keywords: Genetic algorithms (GA),Optimization,Reversible Cold Milling,Advanced Statistical Model,Artificial neural network

Abstract: Reversible cold milling is a widely used industrial process for metal forming. It consists of backward and forward motion of the sheet metals between the rolling mills. As the process is highly automated, optimization of the process parameters is essential for cost minimization. However, it is a complex optimization problem because maximization of the rolling speed increases the motor mill currents and rolling force, and physical constraints of the line may not allow to achieve that. For optimization process, rolling speed, rolling force and motor mill currents of the line should be predicted to check whether they are in physical limits or not. These parameters strongly depend on sheet metal properties (width, thickness, reduction ratio), material properties (yield strength, tensile strength), and other line parameters (oil types, mill radius, front and back tension). For the prediction of the line parameters, neural networks and advanced statistical methods are used. Layer structure, backpropagation functions, and regression methods are changed to increase the precision and the speed of the models. Then, the prediction models are tested and compared with the measured data for verification. After the prediction process, a genetic algorithm (GA) is developed to minimize the total process time by determining the reduction ratio of the sheet metal in each pass process. In each iteration of GA with the fitness function based on an advanced statistical model, reduction ratio of the sheet metal in each pass process is changed while satisfying physical constraints. Thus, the processing time of the reversible cold rolling process is minimized without violating the physical constraints of the line. The results show that the combining of GA and statistical models is an effective tool for process parameter optimization of reversible cold milling.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1141

A HEURISTIC APPROACH TO SUBDOMAIN ORIENTED MULTI-MATERIAL TOPOLOGY OPTIMIZATION

Katarzyna Tajs-Zielinska, Bogdan Bochenek

Cracow University of Technology, Poland
katarzyna.tajs-zielinska@pk.edu.pl, bogdan.bochenek@pk.edu.pl

Keywords: MULTI-MATERIAL TOPOLOGY OPTIMIZATION,CELLULAR AUTOMATA

Abstract: Developing novel methods, approaches and computational techniques is essential for solving engineering problems efficiently. This is important issue especially nowadays when emerging problems become more and more demanding. As the example of a fast and intensively developed optimization tool may serve a topology optimization, which allows to develop new, innovative layouts of considered designs. The idea is to find within a defined design domain the distribution of material that is optimal according to the assumed criterion or criteria. The optimized structure gains new shape and material layout, since some parts of material are relocated and others are selectively removed. The vast majority of reported in literature solutions regard structures made of one material. On the other hand, allowing for implementation of multi-material structures may open new possibilities for improving existing solutions. The typical approach is a redistribution of materials within a whole design domain. This conventional concept of topology optimization is extended in the present paper by introducing the idea of 'subdomain oriented multi-material topology optimization'. The design domain is divided into regions for which different types of material are defined and through this procedure the multi-material structure is created. The challenge of the present research is to find optimal topologies, under restriction that redistribution of material can be performed only within subdomains selected for employed materials. What is very important, in terms of practical applications, it is possible to impose constraints on volume fraction of each defined material. Obtained results of preliminary numerical studies show, that this approach produces different results as compared with classical single-material problems. The effectiveness of topology optimization process is determined by proper choice of numerical optimization algorithm. This paper utilises very efficient and versatile heuristic method called Cellular Automata (CA). The main advantage of the CA algorithm is that, it is an easy to implement, fast convergent technique and usually requires less iterations as compared to other approaches to achieve the optimal solution. There are also not many parameters to adjust what is important for practical applications. In addition, included self-weight loading makes considered design problems more practical and realistic. The implementation of self-weight loading has a significant influence on the final results of topology optimization process, what is very important especially when dealing with the optimization of massive engineering structures.

Abstract ID 1144

TOPOLOGY OPTIMIZATION FOR COMPLIANCE MINIMIZATION AND ACTUATOR LAYOUT TO VIBRATION SUPPRESS

Juliano Gonçalves, Daniel De Leon, Eduardo Perondi

Federal University of Rio Grande do Sul, Brazil
juliano.fagundes@ufrgs.br, daniel.leon@ufrgs.br, perondi@mecanica.ufrgs.br

Keywords: Topology optimization,PEMAP-P,Piezoelectric actuator,Controllability Gramian

Abstract: This article addresses the compliance problem along with the piezoelectric actuator design for active vibration control. The structure layout is obtained by solving a compliance minimization problem while the actuators topology is found by the maximization of a controllability index written in terms of the controllability Gramian, which is a measure that describes the ability of the actuators input to move the system state from an initial condition to a desired final state, at rest for instance, in a finite time interval. Also, the polarization direction of each actuator is defined according to the distribution of an additional design variable. Therefore, it is possible to produce both tensile and compressive fields in different points of the structure using the same applied control voltage. In order to achieve this goal, a material interpolation scheme based on the Piezoelectric Material with Penalization and Polarization (PEMAP-P) model is employed and both the optimum structure/actuator layout and polarization profile are obtained simultaneously. The sensitivities with respect to the polarization and design variables are calculated analytically. Numerical examples are presented considering the control of bending vibration modes for a cantilever beam and a simply supported beam in order to show the efficiency of the proposed formulation. The control performance of the designed structures are analyzed by means of a Linear-Quadratic Regulator (LQR) simulation and these results are compared to the ones obtained by a formulation that does not take into account the actuator polarity in the optimization problem, i.e., the polarization profile is stated a priori.

Abstract ID 1145

THE PERFORMANCE OF A MODIFIED HARMONY SEARCH ALGORITHM IN THE STRUCTURAL IDENTIFICATION AND DAMAGE DETECTION OF A SCALED OFFSHORE WIND TURBINE LABORATORY MODEL

Mahmoud Jahjouh, Raimund Rolfes

Institute of Structural Analysis - Leibniz Universität Hannover, Germany
m.jahjouh@isd.uni-hannover.de, r.rolfes@isd.uni-hannover.de

Keywords: Optimization,Inverse Problems,Model-Updating,Wind Energy,Offshore Wind Turbines,Damage Detection,Structural Health Monitoring,Structural Identification

Abstract: Offshore wind turbines are subjected to harsh environmental and operational conditions that affect their dynamic properties and cause damage. Visual checks are, for economic reasons, kept as low as possible, thus making the ability to detect damage via transmitted measurements a vital issue. Identifying a structure is considered in essence an inverse problem in which the stiffness, mass and damping properties are determined based on the measured outputs, i.e. vibration response. Amongst other structural identification techniques, model-updating methods based on vibration data have proven to fit well for the identification of such structures. Such model-updating schemes treat the identification problem as an optimization problem, which can be well-solved using meta-heuristic optimization schemes. The objective of this study is to investigate the performance of the harmony search algorithm, both basic and modified, in identifying a scaled laboratory model of an offshore wind turbine supporting structure and detect its damage. The laboratory model is tested in a wave basin and is subjected to a variety of damage and marine growth levels. The harmony search algorithm variants that are investigated include the basic harmony search algorithm, a modified adaptive harmony search algorithm, and the later with a modified search space reduction scheme. The investigation shows promising results, especially for the case of harmony search coupled with a search space reduction scheme, and provides further suggestions on how to improve the performance even further.

Abstract ID 1146

OPTIMIZATION OF METAL FIN DISTRIBUTIONS IN LATENT HEAT STORAGES

Bart Peremans, Maarten Blommaert, Martine Baelmans

KU Leuven, Belgium
bart.peremans@kuleuven.be, maarten.blommaert@kuleuven.be, martine.baelmans@kuleuven.be

Keywords: Latent heat storage,adjoint-based optimization,metal fins

Abstract: Over the past years, latent heat storages have gained increased interest due to their superior storage capacity. High storage capacities are achieved as a result of the high latent heat of melting of Phase Change Materials (PCMs) [1]. However, the low thermal conductivity of PCMs limits the charging and discharging performance significantly, causing long charging and discharging times. Heat transfer enhancement techniques for PCM storages are extensively studied both experimentally and numerically [1]. Highly conductive fin structures are often employed as they extract the heat from the heat transfer fluid and easily conduct it into the PCM domain. However, it has been observed that the charging power steeply drops in time [2]. As the PCM melts gradually its ability of absorbing heat from the heat transfer fluid decreases as a result of increased thermal diffusion lengths. Moreover, due to the limited input power and limited convection of the heat transfer fluid, the PCM does not melt uniformly. Therefore, uniform fin distributions can be outperformed by new designs with irregular fin distributions, as some spots could benefit from a higher fin density. In this research, the performance of PCM storages is optimized by optimally spacing the highly conductive metal fins in the PCM storage. The fin shapes are rectangular and their size is kept constant, whereas the fin positions are altered. An adjoint-based optimization strategy is used for efficient gradient calculations combined with consecutive BFGS updates. The optimization procedure is performed for different fin widths, fin amounts, and input powers. It is shown that the optimal fin distribution strongly depends on the fin widths and higher performances are reached with smaller fin structures. The optimal fin positioning shows a trend towards reduced fin spacing, i.e. higher fin density, towards the exit of the heat transfer fluid channel. Decreasing the input heat generates optimal designs with more densely spaced fins.

References

[1] B. Zalba, J. M. Marín, L. F. Cabeza and H. Mehling, "Review on thermal energy storage with phase change: materials, heat transfer analysis and applications," Applied Thermal Engineering, vol. 23, pp. 251-283, 2003.

[2] J. Gasia, J. Diriken, M. Bourke, J. Van Bael and L. F. Cabeza, "Comparative study of the thermal performance of four different shell-and-tube heat exchangers used as latent heat thermal energy storage systems," Renewable Energy, vol. 144, pp. 934-944, 2017.

Abstract ID 1147

META-HEURISTIC ALGORITHM FOR COLLABORATIVE ROBOT SWARM APPLIED TO POLLUTION SCANNING UNDERWATER MISSIONS

Itziar Landa, Diana Manjarres, Sonia Bilbao

Tecnalia Research & Innovation, Spain
itziar.landa@tecnalia.com, diana.manjarres@tecnalia.com, sonia.bilbao@tecnalia.com

Keywords: Heuristic; Robotic Swarms; Optimization; Underwater robots; Scheduling

Abstract: In the last years robotic swarms have attracted high attention in the research community for the intelligent designing and planning of specific missions or operations. In this context, the so-called mission consists of the optimal design of task schedules and the intelligent allocation of resources subjected to certain operational conditions or environmental constraints. Nevertheless, the study of underwater robotic swarms has been very limited and therefore, the development of new strategies for the cooperation between robots are necessary in this field. This manuscript focuses on this issue by devising an evolutionary heuristic algorithm aimed at efficiently scheduling in robotic swarms, which cooperate to accomplish the scanning of an area. Concretely, the final goal is focused on monitoring a stain of salinity and pollution over a real-based scenario in the underwater environment. For that purpose, the algorithm will use a simulated software which models in real-time the levels of salinity and pollution in the specific location. Therefore, the proposed algorithm must be designed to 1) detect the stain within the specified location, 2) accurately model the stain in the time-dependent environment by means of a collaborative algorithm that minimizes price and cost (measured in terms of battery cost and time) of the overall mission. Moreover, realistic conditions are imposed, i.e., the robots have not the same capabilities to perform the tasks and the price, speed and the cost of executing a certain task depends on each robot. It is important to note that the normal scanning task for collaborative robotic swarms in the underwater field consists of dividing the global area into subareas in which each robot works, yielding to a faster inspection of the whole area. This paper focuses on the real collaboration between robotic swarms, i.e. the real-time scheduling of tasks based on the robots' positions and the evolution of the stain. Therefore, the robotic swarm is constantly reorganized depending on the above-mentioned conditions by means of calling other robots for reinforcing the scanning, changing the robots' positions or assigning new tasks to certain robots to optimally accomplish the mission.

Abstract ID 1148

BEYOND THE HARRIS' MODEL TO OPTIMALLY DEFINE LOT SIZES IN A MAKE-TO-STOCK MULTI-LINE PRODUCTION SYSTEM

Marco Bortolini[(1)], Silvia Errani[(1)], Mauro Gamberi[(1)], Francesco Pilati[(2)], Alberto Regattieri[(1)], Alberto Regattieri[(1)]

[(1)]Alma Mater Studiorum - University of Bologna, Italy
marco.bortolini3@unibo.it, silvia.errani3@unibo.it, mauro.gamberi@unibo.it, alberto.regattieri@unibo.it, alberto.regattieri@unibo.it

[(2)]University of Bologna - Department of Industrial Engineering, Italy
francesco.pilati3@unibo.it

Keywords: Economic order quantity,make-to-stock,multi-line production system,lot sizing problem,lot optimization,production planning

Abstract: Since 1913, the Harris' model is adopted within intermittent production sys-tems to size the batches to produce and purchase. For each product, the model sets the so-called Economic Order Quantity (EOQ) as the quantity op-timally trading-off the cost of orders and the average stock cost. Traditional-ly, the EOQ from the Harris' model is a milestone for make-to-stock (MTS) production systems. In addition, existing extensions of the base model are in the direction of including multiple actors of the supply chain, i.e. joint eco-nomic lot size, and tailored product management policies, i.e. consignment stock. A basic hypothesis behind the lot size models is that the production line productivity is higher than the average market demand so that a dynamic equilibrium becomes feasible. Nevertheless, in the case of permanent or temporary high product request, the productivity of a single production line can be insufficient. This case makes of interest the adoption of multi-line production systems. Such systems are made of parallel production lines able to produce the same product at the same final qualitative standards so that the output is a unique batch of identical products. This paper investigates MTS multi-line systems presenting two formulations of the EOQ model for the case of identical lines (1) and the case of lines with different productivity and setup cost[(2)]. Finally, an application of the model is done with data taken from a leading company operating in the bev-erage packaging sector.

Abstract ID 1149

FULL-FIELD MULTI-FIDELITY SURROGATE ASSISTED OPTIMIZATION AND THEIR APPLICATION TO THE OPTIMAL DESIGN OF TURBOMACHINES

Tariq Benamara[1], Hanane Khatouri[2], Caroline Sainvitu[1], Charlotte Beauthier[1], Piotr Breitkopf[2]

[1]Cenaero, Belgium
tariq.benamara@cenaero.be, caroline.sainvitu@cenaero.be, charlotte.beauthier@cenaero.be

[2]Université de Technologie de Compiègne, France
hanane.khatouri@utc.fr, piotr.breitkopf@utc.fr

Keywords: Online Surrogate-Based Optimization,Reduced Order Modeling,Proper Orthogonal Decomposition,Multi-fidelity,Infill strategy

Abstract: The design of complex engineering systems relies more and more on Multi-Disciplinary Optimization. Surrogate-Based Optimization methodologies have been considered for the past decades as a potential solution to alleviate the computational burden of modern optimization campaigns. Nevertheless, the usage of high-fidelity simulations within Surrogate-Based Optimization loops can be unaffordable especially for high-dimensional problems. Multi-fidelity surrogate modeling can be an excellent way to improve the quality of surrogates while maintaining the computational cost of the training phase within acceptable limits. In this contribution, we propose an infill strategy dedicated to optimizations accelerated by recent multi-fidelity non-intrusive proper orthogonal decomposition based surrogate models. These surrogates allow for a fast prediction of the vectorial information associated to the behavior of a given configuration. They take roots in the re-interpretation of the concept of the constrained POD (CPOD) to enrich the reduced order model of the high-dimensional output space, obtained from precise albeit costly high-fidelity simulations, with abundant yet less accurate lower-fidelity data. Multi-fidelity surrogate models on the obtained POD projection coefficients are then used to link, at virtually no extra cost, any parameter set in the design space to its high-dimensional response. To integrate these surrogate models into efficient Surrogate-Based Optimization loops, we propose an infill strategy targeting the selection of promising zones in the design space while restraining the computation burden affordable. This strategy selects not only the potentially efficient sets of parameters depending on their objectives and feasibility, but also tries to identify the level of fidelity necessary to equilibrate the CPU cost ratio between the available solvers. Both the POD bases and the surrogate models on the projection coefficients are improved along the optimization process to reach a satisfactory compromise. The performances of the proposed algorithm are discussed and compared with contributions using the aforementioned multi-fidelity POD based surrogate models on both analytical and industrial optimization problems.

Abstract ID 1150

USING MULTICRITERION OPTIMIZATION METHODS TO OPTIMIZE THE 3D SHAPE OF AXIAL COMPRESSOR BLADES

Grigorii Popov[(1)], Evgenii Goriachkin[(1)], Yulia Novikova[(1)], Daria Kolmakova[(1)], Andrei Volkov[(2)]

[(1)]Samara University, Russian Federation
grishatty@gmail.com, goriachkin.e.s@gmail.com, y.d.novikova@gmail.com, kolmakova.daria@gmail.com

[(2)]Samara National Research University, Russian Federation
a44rey@gmail.com

Keywords: Compressor,optimization,shape,blades

Abstract: Multicriterion optimization methods are widely use in many types of design process. This is because the using of optimization tools allows in an automated mode to find such a combination of design parameters of the investigated unit, in the implementation of which all the requirements are best met. One of the applications of such methods in turbomachinery is to optimize the 3D shape of the compressor blades. The article presents developed optimization methods for improving the working process of an axial compressor of gas turbine engine. Developed method allows performing the search for the best 3D geometry of compressor blades automatically by using optimization software IOSO and CFD software NUMECA Fine/Turbo. The algorithm of developed method is described below. The optimization software IOSO generates vector of input parameters describing the geometry of compressor blades in parametric form. Then “in-house” software Profiler generates files containing information about the new geometry of blades. Generated files are loaded into a numerical model of the compressor which is using to calculate the parameters of the working process in CFD software NUMECA Fine/Turbo using 3D Navier-Stokes solver. A vector of output parameters and restrictions is formed after the end of the calculation and is returned to IOSO to select the best variant of blade geometry and to form a new set of input parameters. This cycle is repeated until the desired result is achieved. Optimization was performed by changing the form of the camber line in three sections of each blade and by shifting three sections of the guide vanes in the circumferential and axial directions. The calculation of the compressor parameters was performed for work and stall points of its performance map at each optimization step. The study was carried out for seven-stage high-pressure compressor and two three-stage low-pressure compressors. Optimization problems was solved in a two-criteria formulation. To ensure that the position of the operating point on the characteristics of the compresses did not change, limitations were set on the amount of flow of the working fluid and the ration of total pressure in the process of optimization. As the result of optimization, improvement of efficiency was achieved for all investigated compressors. For HPC was found variant of blades that provides an increase in the efficiency by 1.2% and for LPC was found variant of blades that provides an increase in the efficiency by 1.3%.

Abstract ID 1154

TOWARDS SIMULATION-AIDED DESIGN OF SINGLE-SCREW EXTRUDERS

Sebastian Eusterholz

CATS – RWTH Aachen University, Germany
eusterholz@cats.rwth-aachen.de

Keywords: Single-Screw Extruder,Shape Optimization,Numerical Design,Geometry Parameterization

Abstract: In this talk we present novel concepts for the simulation-based design of single-screw extruders. While single-screw extruders are widely used because of their low operating costs, the produced melt often suffers from an inhomogeneous material distribution. This is enhanced by inadequate process design. Therefore, extensive running-in trials are carried out to enhance the extruder's design until the produced melt is sufficiently conditioned for further processing. It is our aim to develop techniques that support the currently experience-based design process by numerical design. Based on a method already used in die design, we propose concepts for the method's extension towards the numerical design of mixing-elements in single-screw extruders. We assume that we start the design process with a functional, but possibly inefficient initial design. The novelty in our method is to determine a suitable geometry that provides sufficient mixing by reformulating the mixing problem into a shape-optimization problem. Instead of solving the inverse problem, we try to circumvent problems that this may involve by applying iterative black-box optimization based on an efficient low-order parameterization of the geometry. Our setup consists of four fundamental steps: (1) definition of a suitable objective function,(2)flexible parameterization of the geometry,(3)flow simulation, and (4) geometry modification based on an optimization algorithm. We conduct non-isothermal flow simulations modeling the melt as an incompressible shear-thinning fluid. By utilizing the shear-slip mesh update method we resolve the screw's and barrel's relative motion on boundary-conforming grids. Since the success of this black-box optimization approach is largely reliant on a small number of optimization parameters, our current work is focused on new ideas to parameterize extruder screws in a flexible yet efficient way. We discuss techniques based on global NURBS representation of the geometry – as previously used in die design – and contrast those with new ideas developed for the extruder optimization. Limitations inherent in the new approach are outlined, as well as its ability to exploit parallelization in an HPC environment. This work covers two aspects: (1) We review the application of the developed optimization framework to the shape optimization of extrusion dies, and(2)we detail the extension of the framework towards the optimization of mixing elements in single-screw extruders. Special focus is put on suitable geometry parameterizations reflecting the assumed limitation on the number of optimization parameters.

Abstract ID 1155

EXPERIMENTAL COMPRESSOR MULTIDISCIPLINARY OPTIMIZATION USING DIFFERENT PARAMETERIZATION SCHEMES

Tatiana Buyukli[1], Igor Egorov[2], Grigorii Popov[3], Evgenii Goriachkin[3], Anton Salnikov[1]

[1]Central Institute of Aviation Motors, Russian Federation
buyukly@mail.ru, salnikov_anton_vlad@mail.ru

[2]Lyulka Design Bureau, Russian Federation
egorov300657@yandex.ru

[3]Samara National Research University, Russian Federation
grishatty@gmail.com, goriachkin.e.s@gmail.com

Keywords: Compressor,optimization,blades,shape

Abstract: The present-day compressors development is a labor-intensive problem, because compressor structure should meet different requirements to the design characteristics (aerodynamic, strength, weight, design constraints, processing limits etc.). In order to make this task easier, it's reasonable to find optimal combination of compressor design parameters using the mathematical optimization resources. The optimization problem formulation is very important in optimization. The optimization problem formulation includes development of parameterized grid-model, parameterization scheme and designers' decision about which parameters and what number of parameters they should vary. In this paper the multi-criteria and multidisciplinary optimization of the rotor and stator blades of the experimental compressor stage NASA Rotor 37 is carried out. For the optimization the unified parameterized multidisciplinary 3D model was used. This model includes the air-gas channel of the compressor stage and the finite element model of the rotor blade. This approach allows the consideration of different requirements for the aerodynamic, strength, and mass characteristics within one coupled optimization problem in unified computational space. The goal of this work is the analysis of different blade parameterization schemes and determination of optimum number of variable parameters for compressor stage aerodynamic characteristics improvement with respect to rotor blade static and dynamic strength. As an optimization criterions compressor stage efficiency and the blade mass minimization were used. Aerodynamic limits are: flow rate and pressure ratio values should not exceed base values more than ±0.5%. A static and dynamic strength limits are: maximum stress level should not exceed base level (the original design stress level) and the relative distance between the four natural frequencies and the nearest harmonics should not be less than 20%. In order to research an effect of the number of variables to the optimization results, the four parameterized models were created. The optimization of the NASA Rotor 37 was carried out using all created parametric models. The models are characterized by number of variables, which describe the blade pressure and suction sides. As a result of optimization the NASA Rotor 37 version was found, which provide the efficiency increasing by approximately 2% and the blade centrifugal load decreasing by approximately 9%, while all aerodynamic and strength requirements are satisfied. It was also found, that increasing of the blade profile number of variables more than 7 is not rational.

Abstract ID 1156

TOPOLOGY OPTIMIZATION OF PERIODIC 3D HEAT TRANSFER PROBLEMS WITH A 2D DESIGN

Jonas Lundgren[1], Anders Klarbring[1], Jan-Erik Lundgren[2], Carl-Johan Thore[3]

[1]Linköping University, Sweden
jonas.lundgren@liu.se, anders.klarbring@liu.se

[2]Siemens Industrial Turbomachinery AB, Germany
jan-erik.lundgren@siemens.com

[3]Division of Solid Mechanics, Sweden
carl-johan.thore@liu.se

Keywords: topology optimization,heat transfer,design-dependent convection,internal convection,periodic boundary conditions,maximum temperature

Abstract: In this paper we consider a model for density-based topology optimization of stationary heat transfer problems in 3D structures with periodic design, subjected to design-dependent internal convection. The internal convection discussed in the paper takes place at the interface between a solid material and a cooling fluid flowing in internal channels through the design domain. The periodic design calls for use of periodic boundary conditions (BC). In addition to the periodic BC, there are given BC of prescribed temperature and convection. The objective is to minimize the maximum temperature, which is approximated by means of an L_p-norm. A continuous formulation of the state and optimization problem is derived and discretized by the finite element method. The internal convection is modelled to be proportional to the design variable gradient in the continuous problem. In discrete form, it is approximated as proportional to the difference in design densities of two adjacent elements in the finite element mesh. Additionally, the design is considered to be a 2D design, extruded in 3D. This is achieved through a filtering process, which means that the number of design variables are reduced to the number of elements in one plane of the structure. The resulting optimization problem is solved using gradient-based methods. The problem is illustrated through some numerical examples on geometries related to gas turbine applications, where we show the basic behaviour and characteristics of the model. In addition, we investigate different parameter settings, such as the exponent in the L_p-norm.

Abstract ID 1157

ON THE RELATION BETWEEN LENGTH SCALE CONTROL AND STRESS CONSTRAINTS IN DENSITY BASED TOPOLOGY OPTIMIZATION

Boyan Lazarov[(1)], Oded Amir[(2)]

[(1)]The University of Manchester, United Kingdom
bslazarov@gmail.com

[(2)]Technion - Israel Institute of Technology, Israel
odedamir@technion.ac.il

Keywords: Topology Optimization; Stress Constraints; Length Scale

Abstract: The goal of this work is to present a new set of computational procedures for stress-constrained continuum topology optimization. The formulation exploits the link between strictly enforced length scale and stress concentration in solid bodies. The connection allows for automatic control of the maximum value of the von Mises stress by the length scale parameters. The reformulated optimization process does not require more than a single constraint, and standard optimality criteria algorithm can drive the actual solution. From a computational perspective, the proposed procedures offer a significant simplification compared to common approaches to stress constraints. Essentially, stress-constrained topology optimization is reduced to a minimum compliance problem with the additional treatment of the length scale.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1158

ADAPTIVE STRATEGIES FOR FAIL-SAFE TOPOLOGY OPTIMIZATION

Olaf Ambrozkiewicz, Benedikt Kriegesmann

Hamburg University of Technology, Germany
olaf.ambrozkiewicz@tuhh.de, benedikt.kriegesmann@tuhh.de

Keywords: Topology optimization,fail-safe design

Abstract: For components which are critical for safety, it is desirable that the structure is tolerant to partial damage, i.e. that multiple, redundant load paths exist and the structure is fail-safe. A method to embed a fail-safe requirement in topology optimization using the SIMP approach has first been proposed by Jansen et al. [Struct Multidisc Optim, 2013]. Their approach consists of removing single isolated patches from the design domain. However, the number of patches to consider is very high in order to make sure that all possible damage scenarios are covered. Since for each patch the equilibrium system is solved, the number of patches drives the computational cost and makes the approach unfeasible for practical applications. Zhou and Fleury [Struct Multidisc Optim, 2016] suggested to only consider a subset of all possible damage patches arranged such, that a minimal hideout volume for the possible damage is achieved. Still, a regular grid of the damage patches is used and only the denseness of the spatial distribution of the patches is reduced. In order to achieve a further reduction of damage cases, two strategies can be pursued: Either an Active-Set strategy which only considers the most critical patches out of the full set of patches according to a certain criterion, or an adaptive placement of damage patches. In the current contribution, two approaches that follow these strategies are implemented and compared to existing approaches. The first approach is referred to as threshold method. It consists of reducing the number of patches simply by considering only patches with densities above a certain threshold. The computational effort especially at the beginning of the simulation can be significantly reduced. For the overall simulation the effort could be reduced by about 50%, without sacrificing performance of the final design. The second approach makes use of the fact, that following the approach of Jansen et al. the maximum compliance of all damage scenarios is minimized. Therefore the optimization is driven by the worst-case scenarios and the influence of the non-critical patches is close to zero, and hence, they need not to be considered. This motivates the method of an adaptive placement of worst-case patches. The optimization task is modified to a nested optimization, where the location and shape of the most critical patches is determined and the compliance is only determined for these worst-case patches.

Abstract ID 1159

AERODYNAMIC OPTIMIZATION OF TURBINE AIRFOILS USING MULTI-FIDELITY SURROGATE MODELS

Bernhard Poethke[(1)], Stefan Voelker[(1)], Konrad Vogeler[(2)]

[(1)]Siemens AG, Germany
bernhard.poethke.ext@siemens.com, voelker.stefan@siemens.com

[(2)]Technical University of Dresden, Germany
konrad.vogeler@tu-dresden.de

Keywords: Multi-Fidelity Surrogate Models,co-Kriging,Proper Orthogonal Decomposition,Airfoil Optimization

Abstract: For many applications numerical simulations are available in a varying degree of fidelity and computational expense. On the one hand, in an accurate and time-consuming high-fidelity (HiFi) version, that is used as a reference for design and optimization, and on the other hand, in a low-fidelity (LoFi) version that is faster but less accurate. In the field of computational fluid dynamics (CFD), for example the flow simulation of turbine airfoils, an accurate 3D solver accounts for the HiFi model and a faster 2D solver for the LoFi model, where the 2D simulations are performed on multiple radially stacked airfoil sections (quasi 3D). Assuming the LoFi model captures the basic effects reasonably well, a great quantity of inexpensive LoFi data may be coupled with a small amount of expensive HiFi data to enhance the accuracy of a surrogate model in comparison to a surrogate model that relies solely on the HiFi data. Used in a surrogate based optimization these multi-fidelity surrogate models can be used to speed up the optimization. Conventional multi-fidelity surrogate models approximate the HiFi objective function by aligning the low-fidelity predictions to the high-fidelity results. This is commonly achieved by interpolating the error between both fidelity models, e.g. in form of a kriging based interpolation. The design space variables are the independent variables of this interpolation. In this paper a different approach is presented. Instead of using the design space variables directly, LoFi coordinates in a low-dimensional subspace are used for the interpolation of the HiFi objective values. The low-dimensional subspace representation is obtained by Proper Orthogonal Decomposition (POD) of the LoFi computational domain to identify the most important modes of variation. In comparison to a kriging surface based on design space variables, the advantages are a lower-dimensional kriging model and a simpler, i.e. smoother, response surface. The multi-fidelity surrogate models are applied to predicting aerodynamic performance of a second stage gas turbine vane. Comparing the surrogate prediction to the actual objective value from the HiFi model, the multi-fidelity models are found to be more accurate than a single-fidelity kriging model. Based on these surrogates multi-fidelity optimizations are carried out utilizing a kriging based Expected Improvement strategy. Especially the POD based method shows a fast convergence and outperforms a single-fidelity optimization.

Abstract ID 1160

DESIGN OF FINITE SIZE OPTICAL CAVITIES USING TOPOLOGY OPTIMIZATION

Fengwen Wang(1), Rasmus Christiansen(2), Ole Sigmund(1)

(1)Technical University of Denmark, Denmark
fwan@mek.dtu.dk, sigmund@mek.dtu.dk

(2)The Technical University of Denmark, Denmark
raelch@mek.dtu.dk

Keywords: Topology optimization,finite size,optical cavities,Purcell factor

Abstract: Optical cavities have unique properties by confining light in a wavelength-size volume with very small loss. They exhibit high quality factor (Q) and small mode volume (V). This makes them promising building blocks for future integrated photonic circuits [1]. Previously, several studies were presented to design optical cavities based on photonic crystal platform to increase the Q factor while decreasing the modal volume (V), i.e. to enhance the Purcell factor, which is proportional to Q/V. Most of the studies focused on shape optimization of photonic crystal cavities using geometrical perturbations. The Purcell factor was enhanced by trial-and-error approaches through extensive simulations by changing locations or radii of air holes in photonic crystals [2]. More recently, an optimization formulation was presented to design optical cavities with enhanced Purcell factor using topology optimization. However, the optimized cavities presented in [3] were hardly manufacturable due to lack of length scale. In this study, we employ the optimization formulation presented in Ref [3] to design optical cavities with enhanced Purcell factor. The optimization problem is formulated to maximize a frequency-averaged local density of state (LDOS) [3]. To ensure manufacturability, length-scale and design robustness, the robust formulation presented in [4] is employed by considering different design realizations simulating manufacturing errors. The optimization problem for designing manufacturable optical cavities is recast to maximize the minimum LDOS among the different design realizations considered. Both 2D and 3D slab cavities with different sizes will be systematically designed. Based on the optimized cavities, influence of cavity size on the cavity performance will be further investigated.

References

[1] Nozaki, K., Shinya, A., Matsuo, S., Suzaki, Y., Segawa, T., Sato, T. and Notomi, M. (2012), Ultralow-power all-optical RAM based on nanocavities, Nature Photonics, 6(4), 248-252.
[2] Dharanipathy, U. P., Minkov, M., Tonin, M., Savona, V. and Houdré, R. (2014), High-Q silicon photonic crystal cavity for enhanced optical nonlinearities, Applied Physics Letters, 105(10), 101101.
[3] Liang, X. and Johnson, S. G. (2013), Formulation for scalable optimization of microcavities via the frequency-averaged local density of states, Optics express, 21(25), 30812-30841.
[4] Wang, F., Lazarov, B. S. and Sigmund, O. (2011), On projection methods, convergence and robust formulations in topology optimization, Structural and Multidisciplinary Optimization, 43(6), 767-784.

Abstract ID 1161

DESIGN AND MANAGEMENT OF RENEWABLE SMART ENERGY SYSTEMS: AN OPTIMIZATION MODEL AND ITALIAN CASE STUDY

Francesco Pilati[(1)], Marco Bortolini[(2)], Mauro Gamberi[(2)], Alberto Regattieri[(2)]

[(1)]University of Bologna - Department of Industrial Engineering, Italy
francesco.pilati3@unibo.it

[(2)]Alma Mater Studiorum - University of Bologna, Italy
marco.bortolini3@unibo.it, mauro.gamberi@unibo.it, alberto.regattieri@unibo.it

Keywords: Smart energy,hybrid power system,plant design optimization,renewable energy,industrial application,sustainability.

Abstract: Smart and distributed energy micro-production is the new pattern for the electric energy supply, joining high service level and sustainability issues. Within such a context, the renewables, i.e. solar photovoltaic (PV), micro-wind, etc., play an increasing role as part of the source mix because of their capillary presence and the decrease of the required initial technology investments. On the contrary, the renewable intermittence is the key weakness to overcome to make a turning point to their final spread. To this purpose, hybrid energy systems join the plus of having renewable modules to the plus of having backup traditional units activated in the case of lack of energy. This study presents and applies to an Italian rural context a linear programming model to best design and manage a local off-grid renewable smart energy system. The power system may include PV and micro-wind technologies together with a battery bank and diesel generator as the backup system. Starting from the expected average load profile, the environmental conditions and the technical features of the energy modules, the model selects the most suitable energy sources, optimizes the power rates of each unit and manages the energy flows within the system. The final goal to achieve is to minimize the levelized cost of the produced electricity (LCOE) making such a system competitive respect to fully fossil fuel based energy systems. The aforementioned case study exemplifies the model application focusing on a remote scientific center requiring electric energy for its daily research activities. The area where the center is located is badly connected to the national grid and, actually, a fossil fuel generator is used, only, to provide electricity. An as-is vs. to-be differential analysis assesses the effect of introducing a dedicated renewable smart energy system finding its economic feasibility over a 15 year lifetime. Evidences show the convenience of exploiting the solar source, while little convenience is for micro-wind installation because of low available wind power and the increasing system complexity. Globally, the LCOE is close to 0.14 €/kWh making competitive the hybrid energy solution, close to the evident environmental benefit.

Abstract ID 1162

BILEVEL JOINT OPTIMIZATION FOR PRODUCT FAMILY ARCHITECTING CONSIDERING RECYCLE DISASSEMBLING

Gang Du, Jing Zhao, Xiaojie Liu

Tianjin University, China
tddg@tju.edu.cn, zhaojing_jane@tju.edu.cn, jliu@tju.edu.cn

Keywords: product family architecting,recycle disassembling,leader-follower joint optimization,bilevel programming,nested genetic algorithm

Abstract: For effective product disassembly and recovery in the stage of product retirement, the problem of recycle disassembly design should be considered at the early stage of product development. This paper proposes a bilevel joint optimization model for the leader-follower decision-making of product family architecture and disassembly co-design by a Stackelberg game. The upper-level architecture design aims to optimization the product family modular architecture for maximizing the customer utility per cost, in which the total product cost includes design costs and disassembly costs. The lower-level disassembly design seeks for the optimal selection of disassembly scheme with the objective of maximizing the total cost utility, in which the disassembly cost includes the direct cost and indirect cost derived by environment and risk factors. The nested genetic algorithm with coding strategy is developed for this 0-1 nonlinear bilevel programming model with engineering background. A case study of automatic dishwasher product family architecting is presented to demonstrate the feasibility and potential of our proposed model and algorithm.

Abstract ID 1163

ADAPTIVE MESH REFINEMENT AND EFFICIENT PRECONDITIONING FOR TOPOLOGY OPTIMIZATION WITH DISCRETE GEOMETRIC COMPONENTS

Julián Norato, Shanglong Zhang

University of Connecticut, United States
julian.norato@uconn.edu, shanglong.zhang@uconn.edu

Keywords: Topology optimization,geometry projection,parallel computing

Abstract: Traditional density-based and level set methods for topology optimization render very efficient, organic designs. These designs, however, are often difficult to fabricate with available manufacturing processes. The geometry projection method recently advanced by our group accommodates a specific but common fabrication technique, namely assembly of stock material such as bars and plates. This method maps parameterized geometric primitives onto a fixed finite element mesh for the primal and sensitivity analyses, and renders optimal topologies that distinctly consist of these primitives. Since the ensuing optimal designs more closely resemble the final fabricated structure, this approach leads to significant savings in resources otherwise spent in translating an organic topology into a manufacturable concept. Moreover, the resulting designs are more structurally efficient than the translated organic designs. In addition to these advantages, the availability of a parametric primitives provides a direct computer aided design (CAD) representation. Practical structures made of stock material typically exhibit a low volume fraction with respect to the volume of the design region they occupy. The geometry projection requires that the element size is such that there is more than one element across the thinnest dimension of the primitive for accuracy and robustness of the sensitivity analysis. If a uniform element size mesh is used, this requirement leads to very high numbers of elements for practical applications (e.g., welded plate structures), making the cost of the optimization impractical. A strategy to alleviate this computational cost is to use adaptive mesh refinement. A fine mesh that satisfies the element size requirements of the geometry projection is only needed within a vicinity of the boundaries of the geometric components. Elsewhere, we can employ a much coarser mesh. In our method, for every design produced by the optimizer, we perform adaptive refinement and coarsening of the mesh using the projected density as a refinement indicator. We use quadrilateral and hexahedral elements in 2-D and 3-D respectively, and the refinement strategy consists of iterative subdivision/combination of elements, which results in hanging nodes. Through numerical examples, we demonstrate the effectiveness of the proposed method and show that, when used in conjunction with efficient geometric multigrid preconditioners, the proposed strategy drastically increases the efficiency of the optimization for industry-size problems.

Abstract ID 1165

A BRANCH AND BOUND METHOD FOR GLOBALLY OPTIMISING VALVE LOCATIONS IN WATER DISTRIBUTION NETWORKS

Filippo Pecci[(1)], Edo Abraham[(2)], Ivan Stoianov[(1)]

[(1)]Imperial College London, United Kingdom
f.pecci14@imperial.ac.uk, ivan.stoianov@imperial.ac.uk

[(2)]TU Delft, Netherlands
e.abraham@tudelft.nl

Keywords: Global optimisation; valve placement; pressure management; water distribution networks

Abstract: The optimal control of pressure is critical for the management of water distribution networks (WDNs). In fact, significant leakage reductions can be realised by continuously operating pressure control valves to maintain average zone pressure (AZP), under stochastic changes in demand, close to a minimum level defined by regulations [1]. This work investigates the problem of optimal placement of control valves in WDNs, where the objective is to minimise AZP. The problem formulation results in a nonconvex mixed integer nonlinear program (MINLP). Due to its complex mathematical structure, in previous literature, this nonconvex MINLP has been solved by heuristics [2] or local optimisation methods [3]. However, such approaches do not provide theoretical guarantee on the global optimality of the computed valve configurations. Here, we implement a branch and bound method to obtain certified bounds on the optimality gap of the solutions. The algorithm generates a sequence of lower and upper bounds to the optimal value. The lower bounds are computed solving mixed integer linear programs whose formulations include linear relaxations of the nonconvex constraints. Such polyhedral relaxations are defined by extending the derivation in [4] to the nonconvex terms considered here. In addition, a tailored domain reduction procedure is implemented to tighten the relaxations. The developed methods are numerically evaluated using case studies, including an operational WDN from the UK. The branch and bound algorithm converged to good quality feasible solutions in all instances, with bounds on the optimality gap comparable to the level of uncertainty usually experienced in water network models. Future work should investigate the inclusion of valid linear inequalities within the formulation of the relaxed MILPs, to further reduce the optimality bounds.

References

[1] *R. Wright, E. Abraham, P. Parpas, and I. Stoianov, "Control of water distribution networks with dynamic DMA topology using strictly feasible sequential convex programming," Water Resour. Res., vol. 51, no. 12, pp. 9925–9941, 2015.*

[2] *L. S. Araujo, H. Ramos, and S. T. Coelho, "Pressure Control for Leakage Minimisation in Water Distribution Systems Management," Water Resour. Manag., vol. 20, no. 1, pp. 133–149, 2006.*

[3] *P. D. Dai and P. Li, "Optimal Localization of Pressure Reducing Valves in Water Distribution Systems by a Reformulation Approach," Water Resour. Manag., vol. 28, no. 10, pp. 3057–3074, 2014.*

[4] *L. Liberti and C. C. Pantelides, "Convex envelopes of monomials of odd degree," J. Glob. Optim., vol. 25, no. 2, pp. 157–168, 2003.*

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1166

FINITE ELEMENT MODEL UPDATING OF A WIND TURBINE BLADE - A COMPARATIVE STUDY

Marlene Bruns

Leibniz Universität Hannover, Germany
m.bruns@isd.uni-hannover.de

Keywords: structural health monitoring,damage localization,model updating,optimization

Abstract: As one of the main renewable energy sources, wind energy has gained an important role in the generation of sustainable energy. For this reason, the aim to achieve a high degree of utilization as well as the aim to enhance the durability of wind turbines became vital research topics. Therefore, the ability to identify structural damage and consequently prevent component failure is a signifi-cant tool of interest in relation to flexible service intervals and condition-based maintenance of wind turbines. As rotor blades are related to about twenty percent of the overall costs of a wind turbine, monitoring their condition is of high interest for the reduction of operation and mainte-nance costs. Thus, the focus of this contribution is on the detection, localization and quantification of structural damage of wind turbine blades. There has been a development of many different non-destructive damage localization techniques over the past decades, whereby vibration-based damage localization techniques have successfully been used to monitor wind turbine blades. Vibration-based methods assume that damage-induced variations in the structural properties, namely mass, stiffness and damping, cause detectable changes in the structural behavior. In the presented work, a reference model of a parameterized offshore rotor blade is created. In order to predict damages in this reference model, the stiffness of certain cross sections is reduced. The simulation of the corresponding structural behavior creates a data set, representing the measured response of a damaged state. To detect, locate and quantify these changes, the structural properties of the reference model are adapted to the 'measured' response by comparing modal parameters. Then, cross sections with varied properties indicate the area where damage has occurred. To analyze the considered model updating procedure, different sets of sensor positions and different numbers of design variables are compared utilizing various optimization algorithms.

Abstract ID 1167

CRITICAL PLANE APPROACH FOR FATIGUE RESISTANCE USING STRESS-BASED TOPOLOGY OPTIMIZATION

Maxime Collet[(1)], Simon Bauduin[(2)], Eduardo Fernández Sánchez[(2)], Pablo Alarcón Soto[(2)], Pierre Duysinx[(3)]

[(1)]Univeristy of Liège, Belgium
maxime.collet@uliege.be

[(2)]University of Liège, Belgium
s.bauduin@uliege.be, efsanchez@uliege.be, palarcon@uliege.be

[(3)]University of Liege, Belgium
p.duysinx@uliege.be

Keywords: topology optimization,fatigue failure,stress constraints

Abstract: Fatigue is responsible for almost 80% of the overall breakages in mechanical components. Such a failure phenomenon must be prevented as soon as the early stage of design. Since the seminal works by Augut Wöhler, the literature counts various methods able to prevent fatigue failure. In the automotive industry, the components undergo a high number of cycles leading to consider the stresses as variables into the fatigue criteria. Topology optimization has become a valuable tool used to propose preliminary designs as attested by several commercial software on the market. Combining fatigue design with a stress-based topology optimization procedure is therefore natural. In this work, the coupling of the Dang Van criterion within a topology optimization code is investigated to provide fatigue resistant layouts. The choice of the Dang Van criterion is encouraged by its wide usage in the automotive industry . The former is based on the concept of critical plane in the vicinity of which plastic yielding occurs. With the hypothesis of reaching the elastic shakedown state, the criterion establishes that crack initiation is prevented if the microscopic stress state remains below a prescribed threshold. Following the framework proposed by Dang Van, the fatigue failure procedure is introduced into a density-based topology optimization code embedding stress constraints. The first step of the procedure is to construct the microscopic stress using a regular finite element analysis and evaluate a damage value in the sense of Dang Van. A sub-optimization routine is necessary to solve a min-max problem in order to find the residual stress tensor to construct the microscopic stresses. This sub-optimization might be time consuming and must be dealt with care. In a second step, this work shows how the fatigue resistance procedure is implemented into a density-based topology optimization using stress constraints and in particular how the sensitivity analysis is performed using the adjoint approach. The optimization process is carried out with the Method of Moving Assymptotes along the qp-relaxation to overcome the singularity phenomenon of the stress constraints. The proposed optimization framework is evaluated in terms of its numerical performances and is compared to classical results obtained by a regular stress-based topology optimization on several benchmarks.

Abstract ID 1168

MISALIGNMENT TOPOLOGY OPTIMIZATION

Simon Bauduin[1], Pablo Alarcón Soto[1], Eduardo Fernández Sánchez[1], Maxime Collet[2], Satoru Ishikawa[3], Pierre Duysinx[4]

[1]University of Liège, Belgium
s.bauduin@uliege.be, palarcon@uliege.be, efsanchez@uliege.be

[2]Univeristy of Liège, Belgium
maxime.collet@uliege.be

[3]Toyota Motor Corporation, Japan
satoru_ishikawa@mail.toyota.co.jp

[4]University of Liege, Belgium
p.duysinx@uliege.be

Keywords: Topology Optimization,Misalignment

Abstract: Topology optimization problems aims at the minimization of an objective function while satisfying various constraints. This objective function has been based on "compliance formulation" since Bendsøe and Kikuchi (1988) as it provides solutions where the displacements are globally controlled. However, this formulation doesn't take into account special needs over local displacements or even relative displacements such as the misalignment between two gears. This point is of paramount importance to achieve the best efficiency. Although critical, this domain is especially challenging as very few contributions exist on the subject. Coupling topology optimization with the misalignment minimization can provide promising results once chosen the right formulation. The misalignment can be expressed in various ways. In this work a small amount of formulations were tested on a simple case study composed of two axes to be align. This allowed us to choose a promising expression for the misalignment and furthermore to investigate its efficiency on a 2D problem. The former consists of a box clamped on both sides where a load is applied in its center. The objective is to minimize the misalignment between two horizontal bars located at the middle of each clamped edges. This optimization problem was implemented in our in-house MATLAB code. Different issues were already highlighted during this simple test. The first one was an unclear optimized material distribution as well as a non-converged solution. This typical result of topology optimization has been investigated throughout the years and interesting methods were developed to tackle this issue. For our case study we have chosen to impose a constraint on the measure of discreteness in our optimization formulation to impose a more black-and-white solution with actual engineering meaning. The second issue was a disconnection of the structure coming from an ill-posed optimization formulation as only local constraints are taken into account and no global performance of the problem is required. This issue is furthermore emphasized by imposing a constraint on the measure of discreteness. Thusly a natural way to deal with it is to introduce a constraint on the global compliance of the solution. According to our tests we obtained interesting and engineering meaningful solutions on a 2D case. Our formulation of misalignment and our side constraints were furthermore also tested on a 3D torsion problem.

Abstract ID 1169

DEVELOPMENT OF A TOPOLOGICAL OPTIMIZATION FRAMEWORK FOR 2D PROBLEMS USING OPENFOAM

Pablo Alarcón Soto(1), Eduardo Fernández Sánchez(1), Simon Bauduin(1), Maxime Collet(2), Pierre Duysinx(3)

(1)University of Liège, Belgium
palarcon@uliege.be, efsanchez@uliege.be, s.bauduin@uliege.be

(2)Univeristy of Liège, Belgium
maxime.collet@uliege.be

(3)University of Liege, Belgium
p.duysinx@uliege.be

Keywords: OpenFOAM,Topology Optimization,Fluid Mechanics,Fuel Cells

Abstract: Proton-Exchange Membrane Fuel Cells (PEMFC) are systems that directly convert chemicals into electricity by means of an electro-chemical reaction between hydrogen and oxygen. Following the concerns related to climate change and the search for cleaner, safer and more efficient power sources, Hydrogen PEMFC looks like a promising option. Indeed, PEMFC have the silent operation, high reliability, low working temperature and they only produce water as waste. Nevertheless, to rival the Internal Combustion Engine (ICE), PEMFC shall decrease their manufacturing cost, increase their lifetime and their efficiency as well as improve the thermal management. To achieve such revolution, Topology Optimization techniques are used to propose innovative designs of the gas channel network of bipolar plates made by steel forming. This work defines the channel network layout of a Fuel Cell using Fluid Flow Topology Optimization (FFTO) subject to design constraints. To achieve this goal, a simulation environment has been developed to couple OpenFOAM (to simulate the fluid flow) with Optimization Algorithms. The mathematical framework considers the simulation of the flow using the Stokes equations in steady-state condition. These equations combined with Darcy's law by means of the Brinkman penalization results in a density-based method which is used to perform the topology optimization. The state equations are completed with the continuity equation and a constraint on the volume. We present two different results: first, a minimization problem of the dissipated power subject to a volume constraint is performed in order to validate the coupling between OpenFOAM and the Optimization Algorithms in 2D applications. This part aims at comparing the results with the vastly available literature, following the version of the objective function proposed in [1]. The second part considers the implementation of manufacturing constraints into the previously solved optimization problem such as minimum gap and maximum size, which will help us to better reflect the practical and industrial applications that can be obtained with the proposed method [2].

References

[1] Niels Aage, Thomas H. Poulsen, Allan Gersborg- Hansen, and Ole Sigmund. Topology optimization of large scale stokes flow problems. Structural and Multidisciplinary Optimization, 35(2):175–180, 2008.

[2] Fernández E., Collet M., Bauduin S., Lemaire E., Duysinx P. Contributions to Handle Maximum Size Constraints in Density-Based Topology Optimization. Advances in Structural and Multidisciplinary Optimization. WCSMO 2017.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1170

CONSTRAINT AGGREGATION IN TOPOLOGY OPTIMIZATION

Eduardo Fernández Sánchez[1], Maxime Collet[2], Simon Bauduin[1], Pablo Alarcón Soto[1], Pierre Duysinx[3]

[1]University of Liège, Belgium
efsanchez@uliege.be, s.bauduin@uliege.be, palarcon@uliege.be

[2]Univeristy of Liège, Belgium
maxime.collet@uliege.be

[3]University of Liege, Belgium
p.duysinx@uliege.be

Keywords: Local Constraints,Aggregation,p-mean,p-norm,Manufacturing Constraints

Abstract: A vast amount of the methods that address local design requirements introduce a wide set of constraints within the optimization problem. This local formulation calls for the use of aggregation functions in order to avoid the computational burden on the optimizer. This step of collecting the constraints within a few representative ones seems as a simple implementation detail coming at the final stage of the formulation. Therefore it is often neglected in the discussion. However if this aggregation step is not well treated the success of the whole method may be compromised, and in many cases the simplest part of the constraint becomes time-consuming or even, the hardest point of the formulation. Aggregation functions are built to be smooth and differentiable approximations of the max function. In addition their sensitivity information should be smooth in order to be used in efficient continuous optimization algorithms. They have also to catch accurately the most critical constraints to mimic the locally constrained problem. The classical application is in the field of stress constraints, where a large amount of contributions have been made on the subject. Most of the research contributes with new aggregation techniques, which are adapted to the context of topology optimization with stress constraints. However, to tailor high quality global manufacturing constraints, we need to make further progress in the understanding of the aggregation functions when used in the topology optimization. To this end, we perform a deep theoretical investigation and a quantitative numerical assessment of the behavior of these functions when being used in different formulations of manufacturing and mechanical constraints. Specifically, we focus the study on p-mean and p–norm functions within the framework of density methods. We include in the analysis methods to introduce: i) maximum size control, ii) minimum gap between solid members, iii) minimum size, iii) overhang control for additive manufacturing and iv) stress constraints. Some important observations obtained from this study are: p-norm depends on the amount of data that is being aggregated, making it more unstable under mesh refinement. On the other hand, p-mean is less dependent on mesh modifications but it is likely to produce results that do not satisfy every local constraint. In addition, by looking at the sensitivities it is possible to have an insight of the nonlinearity of a method, which could be used as a criterion to know whether it is necessary or not to alter the aggregation function.

Abstract ID 1172

EFFICIENT TRANSIENT TOPOLOGY OPTIMIZATION THROUGH DYNAMIC SUBSTRUCTURING

Gore Lukas Bluhm, Niels Aage

Technical University of Denmark, Denmark
glubluh@mek.dtu.dk, naage@mek.dtu.dk

Keywords: Topology optimization,Transient problems,Model order reduction,Component mode synthesis,Consistent adjoint sensitivity analysis

Abstract: Transient topology optimization is known to be computationally expensive and thus less attractive than its steady state counterparts. A large portion of the execution time is spent on the transient analysis, including both the time integration of the governing finite element equations and the additional terminal value problem, which is required by the sensitivity analysis using the adjoint method. This work develops a methodology for reducing the computational effort through the usage of dynamic substructuring methods. For achieving this, a component mode synthesis, namely the Craig-Bampton method, is applied to reduce the degrees of freedom of the system. The reduced system gained by the substructuring is utilized both for the computation of the state vectors and the sensitivities. The main idea of the substructuring method is to decompose the design domain into a number of substructures, or components, and hence avoiding a global assembly. The system matrices of these substructures are reduced in size, by describing the dynamic behaviour of the internal degrees of freedoms both by their static response subject to a unit displacement of each degree of freedom on the boundary to the other substructures, and a number of vibrational modes with fixed boundary. Then, the reduced system matrices are assembled from the reduced substructure matrices, whereby the system can be reduced by orders of magnitude compared to the original and global system, and the same is true for the computational expense of the transient analysis. But this comes with the cost of computing a set of reduction bases in every iteration of the optimization. Furthermore, the reduced system only represents an approximation of the full system, and hence there will be an error, when the substructuring is applied. This deviation from the full system is well understood when it comes to the state vectors. But this work will also perform a study on the consistency of the sensitivities by taking the dependency of the reduction bases on the design variable into account when formulating the expression for the sensitivities. This topic has not gotten any attention in the literature so far. Results show that using dynamic substructuring methods, the computational effort can be reduced significantly, while at the same time achieving similar results in terms of the optimized density distribution to the ones from the optimization bases on the full system.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1173

STATIC AEROELASTIC SCALING WITH NON-SIMILAR FLOW THROUGH MULTIDISCIPLINARY OPTIMIZATION

Joan Mas Colomer[1], Nathalie Bartoli[1], Thierry Lefebvre[1], Joseph Morlier[2]

[1]ONERA, France
joan.mas_colomer@onera.fr, nathalie.bartoli@onera.fr, thierry.lefebvre@onera.fr

[2]ISAE, France
joseph.morlier@isae.fr

Keywords: Multidisciplinary Optimization,Aeroelasticity,Similarity,Aircraft Scaling

Abstract: The use of aeroelastically scaled flying demonstrators is a means of experimentally testing new aircraft concepts while reducing the risks (both economical and operational) of developing, building and testing a full scale aircraft. Traditional aeroelastic scaling of flying models assumes either that flow similarity exists between the two aircraft, or that the difference in the flow conditions has negligible effects. By using this hypothesis, the similarity in the static deflection is achieved by matching the stiffness of the wing while preserving the aerodynamic shape of the wing. However, if this difference is not negligible, the similarity of the static deflection cannot be achieved, in general, only by matching the stiffness, as the pressure distribution changes with the flow conditions. This can be the case, for example, of an airliner flying around Mach 0.85 and its equivalent scaled model flying at a clearly subsonic regime. In this paper, we will focus on the static aeroelastic scaling despite non-negligible differences in the flow compressibility (i.e., Mach number). We will present an approach based on aerostructural analysis and optimization to design both the structure of the wing and its aerodynamic shape to match the static deflection between two aircraft flying at different Mach numbers. The optimization problem consists in minimizing the static deflection of the wing with respect to the structure thicknesses, the wing chord, and the wing twist at several sections along the span. To test this methodology, we will use NASA's CRM wing model flying at Mach 0.85 as the reference aircraft. For that purpose, we use an aeroelastic coupling between a structural solver (an open-source version of Nastran95) and a 3D panel method including compressibility corrections (Panair). All the multidisciplinary analysis and optimizations are assembled using the OpenMDAO framework.

Abstract ID 1174

TOPOLOGY OPTIMIZATION FOR ENGINEERED FLOW BATTERY ELECTRODES

Victor Beck, Todd Weisgraber, Anna Ivanovskaya, Swetha Chandrasekaran, Bryan Moran, Seth Watts, Daniel Tortorelli, Eric Duoss, Juergen Biener

Lawrence Livermore National Laboratory, United States
beck33@llnl.gov, weisgraber2@llnl.gov, ivanovskaya1@llnl.gov, chandrasekar2@llnl.gov, moran5@llnl.gov, watts24@llnl.gov, tortorelli2@llnl.gov, duoss1@llnl.gov, biener2@llnl.gov

Keywords: Topology optimization,flow batteries,electrochemistry,multidisciplinary optimization

Abstract: Flow batteries are a promising technology for large scale energy storage and load balancing from intermittent power sources, but their viability hinges on our ability to attain high-power outputs while minimizing costs and meeting performance constraints. Effective engineering of these systems is further complicated both by limitations on the control of the electrochemical cell component morphologies across scales and accurate modeling of the multiple, simultaneous physical processes. At Lawrence Livermore National Lab, we have pioneered a potential solution to this problem using additive manufacturing techniques which enable hierarchical structures controlled from the sub-micron through the centimeter length scales. Yet, even with this expanded design space, the complexity and tight coupling of the underlying physical processes remains as an obstacle to effective design: Apparently obvious choices can nevertheless lead to an unexpected adverse performance impact. To address this challenge, we present an automatic design methodology to optimize the electrode topology over precisely defined performance criteria. We combine forward physics solvers for the full, multidisciplinary electrochemical problem, including fluid flow, electrochemistry and mass transfer, with adjoint solvers to determine topological sensitivities. Our algorithms compute optimal electrochemical cell geometries which are then physically created using additive manufacturing techniques and post-processed to create carbon electrodes. Our work provides a systematic path toward rational design of cost-effective, high-power flow batteries.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Abstract ID 1175

ON THE POTENTIAL AND CHALLENGES OF NEURAL STYLE TRANSFER FOR THREE-DIMENSIONAL SHAPE DATA

Timo Friedrich, Nikola Aulig, Stefan Menzel

Honda Research Institute Europe, Germany
timo.friedrich@honda-ri.de, nikola.aulig@honda-ri.de, stefan.menzel@honda-ri.de

Keywords: Style Transfer,Deep Learning,Shape Representations

Abstract: In the field of two-dimensional image and video processing, convolutional neural networks have been successfully applied to generate novel images by composing content and style of two different sources, a process called artistic or neural style transfer. However a usage of these methods for three-dimensional objects is not straightforward due to the unstructured mesh representations of typical shape data. Hence efficient geometry representations are required to use neural network based style transfer concepts for three-dimensional shapes and to enable the fast creation of style options for instance in a product ideation process. In this paper an overview of current state-of-the-art shape representations is presented with respect to their applicability of neural style transfer on three-dimensional shape data. Combinations of three-dimensional geometric representations with deep neural network architectures are evaluated towards their capability to store and reproduce content and style information based on previously proposed reconstruction tests.

Abstract ID 1176

TRANSIENT TOPOLOGY OPTIMIZATION OF VIBRO-ACOUSTIC PROBLEMS

Cetin Dilgen, Niels Aage

Technical University of Denmark, Denmark
cedil@mek.dtu.dk, naage@mek.dtu.dk

Keywords: Topology optimization,Acoustic-mechanical interaction,Transient optimization

Abstract: The need for improved performance of small acoustic devices such as hearing aids and smartphones is ever increasing. As the devices become smaller they are becoming subject to more complex signals while experiencing strong transient coupling between acoustic pressure and structural vibrations. Transient finite element simulations and topology optimization are the essential elements to improve and meet future demands of coupled acoustic-mechanical systems. The aim of this work is to demonstrate the possibilities of applying transient topology optimization to acoustic-mechanical interaction problems. Topology optimization is an iterative procedure which optimizes material distribution in a design domain while minimizing an objective function. Usually, frequency domain analysis is considered the current state-of-the-art for the optimization of vibro-acoustic problems. However, this approach causes issues especially when large-scale models are considered, due to the indefiniteness of the resulting linear systems. Employing transient analysis for the modeling and optimization is a promising alternative to overcome these issues. In this work, mixed Finite Element Method is utilized for the modeling of the coupled acoustic-structural system which is particularly suited for topology optimization since standard design parametrization can be utilized to interpolate between acoustics and structural mediums. Transient optimization of acoustic-mechanical interaction problems allows us the design efficient structures where acoustic pressure signals are tailored as a result of the optimization. Several optimization cases are presented which demonstrates the advantages of transient optimization including acoustic pulse envelope shaping using the Hilbert transform.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1177

IMPLEMENTATION OF MAXIMUM LENGTH SCALE CONTROL WITHIN THE CONTEXT OF AN INDUSTRIAL TOPOLOGY OPTIMIZATION SOFTWARE

Frédéric Duboeuf(1), Alain Remouchamps(2), Eduardo Fernández(3), Etienne Lemaire(1)

(1)SIEMENS LMS Samtech, Belgium
frederic.duboeuf@siemens.com, etienne.lemaire@siemens.com

(2)SIEMENS Samtech, Belgium
alain.remouchamps@siemens.com

(3)University of Liège, Belgium
efsanchez@ulg.ac.be

Keywords: Maximum length scale,density-based topology optimization,manufacturing constraint

Abstract: In structural design, some issues relevant to a manufacturing process, a functional design, or purely aesthetic conditions may require a proper control of the allowable member sizes of structures. A maximum length scale may be introduced as manufacturing constraint to avoid overheating in the bulk of a 3D printed part. Conversely, imposing minimum length scale limits impracticable small details and prevents also numerical issues related to checkerboard patterns and mesh dependency. Suitable formulations of these conditions must be provided in order to define a well posed topology optimization problem. In the SIEMENS topology optimization tools (Samcef Topol, NX Nastran SOL 200), several manufacturing constraints have been implemented (symmetry, casting, extrusion, etc). Among them, the enforcement of a minimum length scale is available, based on filtering techniques. With the aim to provide additional control of the maximum allowed thickness of a structure, dedicated formal constraints have been proposed in the literature [1]. This scheme limits dependency on parameters with regard to other alternatives (e.g. using penalization). Imposing a maximum fraction of material in the neighborhood of each point of the structure, this approach results in as much additional constraints as local controls provided. In the context of FE density-based topology optimization, each element may be subject to maximum length scale control, for which as many sensitivities as design variables are involved. This leads to a computational burden for the optimizer which becomes unbearable in industrial applications. Combining several strategies to improve performance of the local approach (i.e. active set strategy, continuation method), this work achieved the industrialization of the method. Thanks to agglomeration techniques classically used for stress constraints, local constraints are condensed into a single one. Furthermore, in line with [2] modifying the neighborhoods used for local constraint computation, a strategy is proposed to enforce the maximum length scale with accuracy. Finally, dedicated treatments of the elements located near the boundaries of the design domain and with non-optimizable elements are introduced, providing a robust control of the maximum length scale everywhere in the design space. Performance, accuracy and robustness of the resulting approach are validated on industrial applications.

References

[1] J. K. Guest, Imposing maximum length scale in topology optimization, Struct. Multidiscip. Optim. 37(5), 2009, 463–473.
[2] E. Fernández, M. Collet, S. Bauduin, E. Lemaire, and P. Duysinx, Contributions to handle maximum size constraints in density-based topology optimization, Advances in Structural and Multidisciplinary Optimization (WCSMO12), 2017, 1054–1068.

Abstract ID 1178

LEVEL SET TOPOLOGY OPTIMIZATION OF COUPLED MECHANICAL-ACOUSTIC PROBLEMS

Sumer Dilgen, Jakob Jense

Technical University of Denmark, Denmark
sydil@elektro.dtu.dk, json@mek.dtu.dk

Keywords: Topology Optimization,Level set methods,Acoustic-mechanical interaction,Cutfem

Abstract: Many acoustic devices such as hearing aids and loudspeakers exhibit strong interaction between mechanical vibrations and acoustic pressure due to high internal pressure levels coupled with lightweight flexible materials. Density-based topology optimization using the mixed formulation has been proposed to design such coupled systems and has been successfully applied to 2D systems [1]. However, high computational costs make an extension of the approach to realistic complex 3D geometries challenging. The level-set approach with body-fitted meshes and design updates based on the Hamilton-Jacobi equation has also been employed to the coupled mechanical-acoustic optimization problem [2], but suffers also from high computational costs due to re-meshing in each design iteration. Recently, a BESO approach combined with heuristic sensitivity analysis has appeared also [3] but the heuristics make the approach unsuitable for system exhibiting strong coupling. The present work employs the level set design parametrization with the geometry of the interface between the vibrating solid and the acoustic region described via the zero contour of an explicit level set function. The immersed boundary method is used to capture the geometry on a fixed and un-fitted mesh using the cutFEM method [4]. The level-set values are explicitly used as design variables allowing the use of efficient math programming tools facilitating the development of a computationally efficient framework for optimizing strongly-coupled mechanical acoustic interaction problems. The developed framework is demonstrated with optimization examples where the minimization of acoustic pressure in certain objective domain is considered.

References

[1] *Yoon GH, Jensen JS, Sigmund O 2007 Topology optimization of acoustic–structure interaction problems using a mixed finite element formulation. International Journal for Numerical Methods in Engineering 70, 1049-1075.*

[2] *Shu L, Wang MY, Ma Z 2014 Level set based topology optimization of vibrating structures for coupled acoustic-structural dynamics. Computers & Structures 132, 34-42.*

[3] *Vicente WM, Picelli R, Pavanello R, Xie YM 2015 Topology optimization of frequency responses of fluid-structure interaction systems, Finite Elements in Analysis and Design 98, 1-13.*

[4] *Burman E, Claus S, Hansbo P, Larson MG, Massing A 2015 CutFEM: Discretizing geometry and partial differential equations, International Journal for Numerical Methods in Engineering 104, 472-501.*

Abstract ID 1179

OPTIMIZATION OF HEAT EXCHANGER FLOW PATHS USING A NOVEL INTEGER PERMUTATION BASED GENETIC ALGORITHM

Vikrant Aute, Zhenning Li

University of Maryland, United States
vikrant@umd.edu, znli@umd.edu

Keywords: Genetic Algorithm,Integer Permutation,Tube-fin Heat Exchanger,Circuitry Optimization

Abstract: Tube-fin heat exchangers (HXs) are widely used in air-conditioning and heat pump applications. The performance of these heat exchangers is strongly influenced by the refrigerant circuitry, i.e. the refrigerant flow path along the different tubes in the HX core. For a given number of tubes, the number of possible circuitries is exponentially large, and the traditional optimization algorithms cannot be used to optimize the circuitry for a given application. One of the challenges is that the thermodynamically feasible design space is a very small fraction of the total design space. Researchers have previously used Genetic Algorithms (GA) coupled with some variation of symbolic learning to solve this problem, but there is no guarantee that the resulting circuitry can be manufactured in a cost-effective manner. In this paper, we present an integer permutation based Genetic Algorithm (IPGA) for solving the circuitry optimization problem. A finite volume heat exchanger simulation tool is used to simulate the performance of different circuitries generated by the optimizer. A novel approach is developed to represent heat exchanger circuitry as a chromosome in the genetic algorithm. Six genetic operators are designed to operate on these chromosomes. A hybrid population initialization scheme is developed to speed up the efficiency of optimization by increasing feasibility of initial population. This population initialization scheme generates individuals from three sources, which are predefined circuitry generator, Latin Hypercube sampling and optimization of sub-problems with the goal of attaining short adjoining tubes (i.e. U-bends). Furthermore, the manufacturability aspect is handled using a constraint-dominated sorting in the fitness assignment stage of GA. An exhaustive search verification using a small heat exchanger indicates that IPGA is capable of finding optimal or near-optimal refrigerant circuitry designs with relatively low computational cost. The constraint handling technique can effectively improve the manufacturability of the optimal circuitries. The analyses of several test heat exchanger designs show that IPGA can obtain a 2.3-14.6% increase in heat exchange capacity compared with the manually designed counter-flow circuitry. A comparison with other circuitry optimization methods from the literature is also conducted and it is shown that the proposed IPGA approach can find designs which are better in terms of performance and manufacturability than those from the literature.

Abstract ID 1182

FLUID DIODES DESIGN IN PULSATING HEAT PIPES USING TOPOLOGY OPTIMIZATION

Bruno Souza, Emílio Carlos Nelli Silva

University of Sao Paulo, Brazil
bruno.caldas@gmail.com, ecnsilva@usp.br

Keywords: Fluid Diodes,Topology Optimization,Pulsating Heat Pipes

Abstract: The major issue of different modern machines are heat dissipation and the implementation of pulsating heat pipes (PHP) are one of the great promising solutions. Besides that, fluid diodes, which are devices that allow the fluid flow preferentially in one direction without moving parts, have been recently applied in PHP in the literature as good solution on improving thermal resistance and internal fluid flow. Therefore, this work explores how the PHP design can be improved using topology optimization focusing on the fluid diodes, avoiding project time consumption and creating new non-intuitive geometries properly to the PHP. The implementation of the optimization uses interior point optimizer and it is based on python language with FEniCS-Framework helping calculate the objective function and Dolfin-Adjoint Framework estimating the respective gradients. The objective function is the maximization of the heat exchange based on the fluid flow. The fluid material model used is based on the Borrvall and Petterson (2012) approach which makes possible the continuity between solid and fluid. The optimization problem is solved by using an interior point optimization algorithm (IPOPT). Helmholtz equations are used to filter some results in order to control the minimum dimensions of topology. 2D geometries are presented as a result showing the improvements related to the traditional devices.

Abstract ID 1184

DESIGNING ELASTOMERIC 3D PRINTED ARCHITECTURES WITH A MECHANICAL REDUCED ORDER MODEL

Todd Weisgraber, Ward Small, Jeremy Lenhardt, Christopher Spadaccini, Robert Maxwell, Eric Duoss, Thomas Wilson

Lawrence Livermore National Laboratory, United States
tweisgraber@llnl.gov, small3@llnl.gov, lenhardt2@llnl.gov, spadaccini2@llnl.gov, maxwell7@llnl.gov, duoss1@llnl.gov, wilson97@llnl.gov

Keywords: Additive Manufacturing,Reduced Order Model,Parametric Optimization

Abstract: Direct ink writing of silicone elastomers enables printing with precise control of porosity and mechanical properties of ordered cellular solids, suitable for shock absorption and stress mitigation applications. With the ability to manipulate structure and feedstock stiffness, the design space becomes challenging to parse to obtain a solution for a desired non-linear mechanical response. Here we derive an analytical design approach a subset of architectures. Results from finite element simulations and quasi-static mechanical tests of two different parallel strand architectures were analyzed to understand the structure-property relationships under uniaxial compression. Combining effective stiffness-density scaling with least squares optimization of the stress responses yielded general response curves parameterized by resin modulus and strand spacing. An analytical expression of these curves serves as a reduced order model, which, when optimized, provides a rapid design capability for filament-based 3D printed structures. To demonstrate the capability, we present computed optimal architecture designs that satisfy prescribed loading conditions and porosity constraints along with mechanical characterization data to provide validation.

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-747998

Abstract ID 1185

TOPOLOGY OPTIMIZATION WITH THE INERTIA RELIEF METHOD

Carl-Johan Thore

Division of Solid Mechanics, Sweden
carl-johan.thore@liu.se

Keywords: Topology optimization,Unconstrained bodies,Inertia relief,Singular systems

Abstract: In many applications it is of interested to perform static finite element (FE) analyses on unconstrained bodies, including airplanes, helicopters and satellites in flight. This is particularly the case if topology optimization (TO) is to be used, since TO with time-dependent equations can be very computationally expensive. However, since the body is unconstrained it need not be in static equilibrium under the given loading, and therefore it is not a priori clear that a meaningful static analysis can be performed. But if one assumes that the loading is time-independent and the rotational part of the induced rigid body accelerations is small, then the inertial forces associated with such accelerations can be calculated exactly and subtracted from the given loading, making the net force and torque acting on the body equal zero. Neglecting vibrations, the body is now in static equilibrium; the method whereby this was achieved is sometimes called the inertia relief method. The body is still unconstrained however, so the equilibrium equation lacks a unique solution, since an arbitrary (linearized) rigid body motion can be added to one solution to get another. A common way to handle this problem of non-uniqueness is to impose constraints on the displacement (typically by prescribing displacement components at FE nodes) which prevent rigid motions while leaving the deformation unaltered. This method is simple but may have a significant negative impact on the conditioning of the stiffness matrix. Another, less frequently seen, way to avoid non-uniqueness is to add a penalty term to the equilibrium equation that forces any rigid motion to zero. The main drawback of this method is that the resulting system matrix is dense. Fortunately however, the structure of the matrix is such that matrix-vector products used by iterative linear solvers can be computed efficiently. In this work we formulate the inertia relief method for unconstrained, linearly elastic structures in an infinite-dimensional setting and use the model in topology optimization with the goal of maximizing stiffness. Discretization is carried out using the FE method, and convergence of the approximation scheme is shown. The optimization problem is posed in nested form and the FE equilibrium equation is solved using a multi-grid preconditioned conjugate gradient method. Numerical examples illustrate the idea and include comparisons of the above-mentioned methods for handling the singular stiffness matrix and the effect of different material interpolation schemes.

Abstract ID 1186

PENALTY-FREE SELF-ADAPTIVE SEARCH SPACE REDUCTION METHOD FOR MULTI-OBJECTIVE EVOLUTIONARY OPTIMIZATION OF WATER DISTRIBUTION NETWORKS

Tiku Tanyimboh

University of the Witwatersrand, Johannesburg, South Africa
tiku.tanyimboh@wits.ac.za

Keywords: Water distribution system; self-adaptive search space reduction; entropy maximization; multi-objective discrete evolutionary optimization; genetic algorithm

Abstract: Evolutionary optimization approaches such as genetic algorithms (GAs) are being used increasingly in the optimization of water distribution networks. However, the size of the search or solution space is highly dependent on the size of the network and number of commercially available pipe diameters adopted. Consequently, the number of function evaluations or hydraulic simulations required to identify optimal and/or near-optimal solutions can be extremely large. For real-world networks with hundreds of pipes or more, the process can be extremely time-consuming as the GA might require millions of computationally expensive function evaluations or hydraulic simulations. It is, therefore, highly desirable to reduce the search or solution space in order to speed up the optimization process. Hitherto, not much work with valuable results has been done on this aspect and few publications present methods for reducing the GA search space. The new approach developed and assessed was based on the importance of every path through the network, which is included in the entropy function. Unlike the previous approaches in the literature, the method proposed does not involve pre-processing and initializing or setting the reduced solution space of the diameters beforehand. Instead, based on reliability and resilience considerations, the reduced solution space is determined using maximum entropy principles. The new methodology proposed comprises two main phases. In the first phase, the entire solution or search space is explored without restriction until a feasible solution is identified. In the second phase, exploitation is intensified by updating the active solution space in every generation. This is achieved by means of a reference solution that is updated in every generation in the second phase. The reduced set of candidate diameters considered in each generation in the second phase is defined relative to the reference solution. The algorithm has been applied to an established benchmark network previously used in search space reduction studies. Detailed comparisons of the Pareto-optimal fronts from the full and reduced solution spaces (RSS) were carried out. Solutions obtained using RSS dominated and clearly outperformed the solutions based on the full solution space by being less expensive for similar entropy values. Another significant advantage of the proposed maximum entropy based RSS approach is that it limits the search space to the areas that are very close to the boundaries between the feasible and infeasible regions. Consistently good results were achieved in terms of the computational efficiency and quality of solutions as a result.

Abstract ID 1187

A GRADIENT-BASED STRATEGY FOR THE OPTIMIZATION OF STIFFENED COMPOSITE STRUCTURES SUBJECT TO MULTIPLE LOAD CASES AND MULTIPLE FAILURE CRITERIA

Farshad Farzan Nasab, H.J.M. Geijselaers, a. de Boer

University of Twente, Netherlands
f.farzannasab@UTWENTE.NL, h.j.m.geijselaers@utwente.nl, a.deboer@utwente.nl

Keywords: composite structures,structural optimization,blending

Abstract: This work aims at investigating the applicability of the level-set based thickness optimization method, earlier proposed by the authors, to a realistic structure. The design has to have sufficient stiffness and strength while the structural mass is minimized. The concerned composite structure is subjected to multiple load cases. The proposed method guarantees the fulfillment of the design guidelines, namely symmetry, covering ply, disorientation, percentage rule, balance, and contiguity of the layup. The stiffeners divide a composite structure into several smaller panels. The manufacturability of a resulting design is guaranteed as plies are continuous among adjacent panels (the design is blended). The proposed method is successfully applied to the mass minimization problem of the stiffened top and bottom skin of a wing torsion box. The structure, subject to two load cases, is optimized where local buckling and allowable strain are the constraints of the problem.

Abstract ID 1189

INFILL ANALYSIS AND OPTIMIZATION IN ADDITIVE MANUFACTURING APPLICATIONS

Gian Marco Tassi[1], Qiren Gao[2], Alejandro Diaz[2]

[1]Politecnico di Torino, Italy
gmtassi.93@gmail.com

[2]Michigan State University, United States
gaoqiren@msu.edu, diaz@egr.msu.edu

Keywords: Lattice optimization,additive manufacturing,infill design

Abstract: Recent advances in additive manufacturing make possible the manufacture of mechanical components that achieve enhanced performance by means of complex lattice microstructures. In addition to weight reduction and increased stiffness, the lattice can be tailored to satisfy multiple performance specifications, including some that demand multiphysics and multiscale analyses. Spatial variations are no longer limited to simple periodic tilings of a single characteristic cell. Instead, the spatial variation of the lattice, and even its topology, can be controlled to achieve enhanced performance while remaining manufacturable through advanced additive manufacturing technologies. One application of these complex lattice patterns is as “infill” in 3D printed parts. Optionally, the part may have a solid outside shell and solid internal walls, but internal cavities are occupied by a carefully designed lattice infill. The scale of the lattice may be small when compared to the scale of the part itself, even approaching scales that are more typical of a porous material. With recent advances in additive manufacturing, it is possible to design the infill in detail and optimize its (geometric) properties, even at small scales. In this work we investigate the effect of using different micro geometries in (3D) mechanical parts constructed by additive manufacturing. We allow spatial variations of parametric properties, lattice positioning and scaling, and lattice topology. The work includes an investigation of the effective mechanical properties of different lattice micro geometries. We use as our principal examples weight constrained problems involving stiffness maximization, although the methodology can be adapted to other performance criteria.

Abstract ID 1192

ON THE TREATMENT OF MULTIROW INTERFACE IN AERODYNAMIC TURBOMACHINERY ADJOINT SOLVERS

Simão Rodrigues[1], Andre Marta[2]

[1]IDMEC - Institute of Mechanical Engineering, Portugal
simao.rodrigues@tecnico.ulisboa.pt

[2]IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Portugal
andre.marta@tecnico.ulisboa.pt

Keywords: automatic differentiation,derivatives,gradient-based optimization,shape optimization,operating conditions

Abstract: The currently available computational power and improvements of high-fidelity numerical simulations have lead to an increased use of computational fluid dynamics (CFD) in the analysis of turbomachinery flows, particularly in design environments. The optimization cases often contain up to thousands of design variables and gradient-based (GB) optimization algorithms are typically selected due to their efficiency. The adjoint method is key to efficiently compute the derivatives required by the GB algorithms, with a computational cost nearly independent of the number of design variables. In this paper we present the details of the development of an adjoint multirow interface based on the mixing-plane treatment to extend an already existing adjoint solver using the ADjoint approach. The mixing-plane treatment allows the steady simulation of multiple rows, taking their interaction between one another into account and thus providing more realistic results. A stator/rotor turbine stage of a commercial jet engine is analyzed and some representative sensitivity results are presented and discussed.

Abstract ID 1193

THEORY OF GRILLAGE OPTIMIZATION – A DISCRETE SETTING

Karol Bolbotowski

Warsaw University of Technology, Faculty of Civil Engineering, Poland
k.bolbotowski@il.pw.edu.pl

Keywords: Optimum grillage,ground structure,duality

Abstract: Classically, a grillage structure can be viewed as a finite, planar system of beams under bending that meet at joints. An alternative, continuous description revolves around a fibrous plate with the fibers representing infinitely thin beams. The topic of optimum grillages in the latter setting gained interest in the early '70s; numerous analytical solutions have been derived ever since. Meanwhile, a far more popular theory of optimum frameworks called Michell trusses has been extensively studied since the very beginning of the 20th century. An efficient method for discretizing the Michell problem was developed in the '60s and it employed the so-called ground structure - a dense, yet finite network of truss bars that interconnects a fixed grid of nodes. Then the design variables are chosen as the cross-section areas constant per each bar which renders the optimization problem as discrete at its root. Later, this problem, set either as plastic or elastic design, received a thorough mathematical treatment and was reduced to a pair of mutually dual linear programming problems: kinematic and equilibrium forms with, respectively, nodal displacements and with member forces as variables. Hence, due to linearity, the truss optimization problem naturally admits a neat matrix-vector formulation. Since the continuous grillage optimization problem mathematically lies in close proximity to Michell problem, possibility of adopting the ground structure approach for numerical optimization of grillages follows. This was done first in the early '90s combined with FEM for elastic design problem, recently also for large scale plastic design problems. Although the methods developed proved to produce satisfactory numerical grillage layouts, the discrete problem being solved was in fact an approximated version of the true grillage-ground-structure optimization problem. As opposed to truss problem, the optimum width distribution in a grillage may vary along the beams and so may the bending moment function. Hence, reducing the problem to an exact, discrete (finite dimensional) setting is not straightforward and is set as a goal of the present work. In this paper the point of departure is a pair of mutually dual variational problems written for the grillage ground structure: kinematic and equilibrium forms with, respectively, displacement and bending moment functions as variables. The two infinite dimensional problems are then analytically reduced to the two mutually dual discrete forms; the matrix-vector fashion known from truss optimization is preserved. One of the key results is an appearance of the two dual norms defined on the plane.

Abstract ID 1194

IDENTIFICATION OF PARAMETERS FOR MATERIAL DAMAGE MODELS BY INVERSE ANALYSIS AND OPTIMIZATION, USING FINITE ELEMENT SIMULATION

Rui Amaral[(1)], Abel Santos[(2)]

[(1)]INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering, Portugal
ramaral@inegi.up.pt

[(2)]FEUP, Portugal
abael@fe.up.pt

Keywords: Material constitutive models,inverse analysis,finite element,optimization

Abstract: A reliable material behaviour modelling is a key to obtain accurate results when using numerical simulation in automotive industry. To reproduce the material properties, complex constitutive models are required and consequently more parameters have to be identified. Usually, the identification of constitutive model parameters is based in several performed mechanical tests under different loading conditions, however some of the experiments are difficult to carry out and evaluate. This paper presents an alternative approach using an inverse numerical analysis to obtain and determine the parameters of constitutive models and to characterize the material fracture behaviour. The inverse analysis methodology was implemented by programming and connecting a script for the optimization algorithm with a script for the finite element model and having an iterative procedure to find the best fitting parameter values that minimize an objective function defined for this problem. The applicability of implemented inverse approach is evaluated and validated by comparing the results obtained from finite element analysis with the experimental data, from tests with different loading conditions.

Abstract ID 1195

ANALYSIS AND OPTIMIZATION OF FORMABILITY TESTS FOR COMPOSITE SANDWICH METAL-POLYMER MATERIALS

Sara Miranda[1], Abel Santos[2], Rui Amaral[1], Luís Malheiro[3]

[1]INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering, Portugal
smiranda@inegi.up.pt, ramaral@inegi.up.pt

[2]FEUP, Portugal
abel@fe.up.pt

[3]INAPAL Metal, SA, Portugal
lmalheiro@inapalmetal.pt

Keywords: Composite sandwich materials,formability tests,hole expansion,optimization.

Abstract: Lightweight design is a main objective, not only to aeronautical industry, but also nowadays to automotive industry, due to the awareness of environmental problems, current and near-future restrictions. This is the context for extensive research to developing and using lightweight materials, such as the combination of metals with polymers, the so-called composite sandwich materials. However, the combination of steel with other materials poses new challenges, due to their new or different behaviour and non-homogeneity of deformation, needing also different approaches to material characterization and formability analysis. One of these challenges is related with traditional and standard sheet metal formability tests, which did perform well for homogeneous materials but show not being adequate for composite materials. This work defines the problems faced with formability tests, such as hole expansion, KWI and Fukui tests, when using composite sandwich metal/polymer materials and identifies the fundamental geometrical and processing variables for each test. A sensitivity analysis is performed for these variables by developing virtual tests and corresponding finite element models, in order to optimize and find the adequate testing procedures for this new kind of non-homogenous materials.

Abstract ID 1196

STOCHASTIC TOPOLOGY OPTIMIZATION: COMPARING POLYNOMIAL CHAOS APPROACHES TO DIRECT SPARSE QUADRATURE

Geoffrey Oxberry, Andrew Barker, Wong Jonathan, Mark Stowell, Youngsoo Choi, Daniel White, Daniel Tortorelli

Lawrence Livermore National Laboratory, United States
oxberry1@llnl.gov, barker29@llnl.gov, wong125@llnl.gov, stowell1@llnl.gov, choi15@llnl.gov, white37@llnl.gov, tortorelli2@llnl.gov

Keywords: topology optimization,stochastic programming,design under uncertainty,polynomial chaos,sparse quadrature

Abstract: Recent work by Keshavarzzadeh, Meidani, and Tortorelli, and by Keshavarzzadeh, Fernandez, and Tortorelli, illustrates the computational efficiency of polynomial chaos expansions in representing uncertainty in stochastic topology optimization as compared to Monte Carlo approaches. In this polynomial chaos approach, sparse quadrature methods are used to compute coefficients of a series expansion in uncertainty space. However, in many cases, these same quadrature methods could be used to compute objective functions and constraints directly, without passing through a polynomial chaos expansion. We contrast the relative efficiency of these two approaches, tradeoffs, and algorithmic specializations necessary to expose parallelism and improve performance while maintaining numerical stability.

Abstract ID 1197

A MODERN FREE-WAKE PANEL METHOD USING UNSTRUCTURED MESHES

Mario Bras, Curran Crawford, Afzal Suleman

University of Victoria, Canada
mbras@uvic.ca, curranc@uvic.ca, suleman@uvic.ca

Keywords: panel methods; unstructured meshes; half-edge data structures; modern C

Abstract: Panel methods have been the de facto tool for aerodynamic analysis in the conceptual and preliminary design phases of aircraft for decades. The aerospace industry has relied on them, initially, when computing resources were poor, as the only practical way of obtaining aerodynamic solutions of arbitrary configurations, and lately, as a fast alternative to higher order CFD methods. Since panel methods allow a 3-dimensional fluid flow to be solved on a 2-dimensional surface mesh, the computation complexity of a problem is considerably reduced. Panel methods date back to the 1960s, therefore, most currently available codebases carry a legacy with them in the form of old procedural code that cannot be easily extended with extra functionality, strict use of structured meshes, user-prescribed wakes for lifting surfaces, inflexible and outdated input file support and, in addition, they tend to not make use of modern hardware technologies such as CPU vectorization and parallelism. In this work, a 3-dimensional panel method using a free-wake model and unstructured meshes is presented. The method utilizes constant source and doublet panels to define the geometry and vortex sheets for wake representation. A half-edge data structure is implemented to efficiently represent unstructured polygonal meshes. Support for several known mesh file formats is included and a flexible input file format is used to allow the user to easily configure the solution process. This work incorporates modern software development practices, such as unit testing and version control, with a generic and object-oriented approach in a modern portable C 17 header-only template library, laying a solid foundation for future applications.

Abstract ID 1204

IMPROVING COORDINATION IN SUPPLY CHAIN USING ARTIFICIAL NEURAL NETWORKS AND MULTI-AGENT APPROACH

Halima Bousqaoui, Ilham SLIMANI), Said ACHCHAB

Mohammed V University, Morocco
halima.bousqaoui@gmail.com, slimani.ilham@gmail.com, s.achchab@um5s.net.ma

Keywords: Supply chain management,Multi-agent system,Information sharing,Artificial neutral networks,Coordination in supply chain

Abstract: Supply chain is a group of distributed entities interacting with each other and aiming to improve their business strategies. However, due to globalization, supply chain's companies are more and more connected as they are facing challenges related to complexity. Consequently, in order to reach the optimization goal, companies must cooperate and act as a centralized system; this cooperation is mostly accomplished through information sharing. Indeed, information sharing is pivotal in achieving coordination and visibility along the supply chain. Furthermore, effective planning activities in a supply chain depends highly on the sales forecasts, which is a very complex task due to the uncertain character of the costumer's demand and various other internal and external parameters. This paper tackles the issue of information sharing by studying its effect on demand's prediction in the context of a multi-echelon supply chain. Therefore, this paper presents an agent-based approach to model coordination by sharing demand forecasts in a supply chain. Multi-agent system is used to model cooperation among multi-echelon supply chain's members. Moreover, neural network's forecasting ability is applied to train agents in order to predict the costumer's demand of a certain product by demonstrating the importance of information sharing in the case where information is shared or not. The proposed agent-based system models demand forecasts sharing as a coordination tool in a multi-echelon supply chain with a concrete numerical experimentation using real supermarket data. Besides, sales forecasting is presented in details based on different architectures of neural networks including recurrent and feed-forward structures.

Abstract ID 1205

RELIABILITY-BASED DESIGN OPTIMIZATION OF A WIND TURBINE BLADE USING AN EFFICIENT APPROACH

Abdolrasoul Sohouli[1], Afzal Suleman[2]

[1]Instituto Superior Técnico, Portugal
abdolrasoul.sohouli@ist.utl.pt

[2]IDMEC and University of Victoria, Portugal
suleman@tecnico.ulisboa.pt

Keywords: Decoupled discrete material optimization,reliability-based design optimization,sequential optimization and reliability assessment,variable stiffness composite laminates

Abstract: This paper presents an efficient optimization framework to design composite laminates of a wind turbine blade with loading uncertainties. The 10 MW DTU blade is selected as the reference blade design. A decoupled reliability-based design optimization is developed based on the sequence of a decoupled discrete material optimization and the inverse reliability analysis. This reliability-based design optimization approach is named the sequential optimization and reliability assessment method. The inverse reliability analysis is evaluated using a stochastic response surface method and a first order reliability approach. The design variables are the piecewise patch orientations and material properties of the fiber reinforced composites. The candidate materials of the design space are glass fiber and carbon fiber reinforced polymers. In the design process, the composite laminates of the blade's load-carrying component are designed to minimize the material cost by satisfying the constraints. The compliance and eigenfrequency constraints are analyzed for the optimization framework. The deterministic optimal designs are obtained using the decoupled discrete material optimization approach for baseline comparison. The reliability-based designs are dependent to the uncertainties in loads and the target failure probability. This leads to different optimal layouts compared to the deterministic solutions.

Abstract ID 1207

MINIMIZATION OF THE EFFECTIVE THERMAL EXPANSION COEFFICIENT OF COMPOSITE MATERIAL USING A MULTI-SCALE TOPOLOGY OPTIMIZATION METHOD

Lidy Anaya Jaimes[(1)], William Vicente[(2)], Renato Pavanello[(3)]

[(1)]University of Campinas, UNICAMP, Brazil
lidy@fem.unicamp.br

[(2)]University of Campinas, Brazil
william.vicente@feagri.unicamp.br

[(3)]UNICAMP, Brazil
pava@fem.unicamp.br

Keywords: Thermal expansion coefficients,Composite materials,BESO method

Abstract: This article proposes a methodology to design composite materials, considering two distinct materials phases and one void phase simultaneously, in order to minimize the thermal expansion coefficients. The design of composite material is treated as a topology optimization problem with a multi-material and multi-scale approach. The Bi-directional Evolutionary Structural Optimization method (BESO) is used to solve the optimization problem and the homogenization method is applied to obtain the equivalent properties for the designed material. In order to show the suitability of the implemented methodology, it is presented some examples for the minimization of the homogenized thermal expansion coefficients considering two-dimensional state of stress. A setting using two material phases, and void was performed resulting in a set of orthotropic materials with thermal expansion less than 10% of the case composing the domain with any of the material phases used.

Abstract ID 1215

THE METHOD OF FUNDAMENTAL SOLUTIONS FOR POINTWISE SOURCE RECONSTRUCTION ASSOCIATED WITH MODIFIED HELMHOLTZ EQUATION

Jairo de Faria, Thiago Machado, Romulo Lima, Raul Sá

UFPB, Brazil
jairo@ci.ufpb.br, thiagao.matematica@gmail.com, romulo_dasilva@hotmail.com, raulrennerm@gmail.com

Keywords: pointwise sources reconstruction,modified Helmholtz equation,method of fundamental solution,inverse problems,sensitivity analysis.

Abstract: Pointwise source identification presents a great variety of applications in engineering, like location of pollution sources for a given environment, identification of dipoles and monopoles in both electroencephalography and magnetoencephalography and so on. This problem consists of reconstruct sources (quantity, location and intensity), distributed in a domain based on boundary measurements. In particular, in this work we study problems associated with the modified Helmholtz equation, which are of interest in implicit marching schemes for the heat equation and in the linearization of the Poisson–Boltzmann equation, for instance. The strategy adopted for the reconstruction of the point sources is, as usually found in the literature, to rewrite the inverse problem as an optimization one, where the minimization of an appropriated shape functional is associated to the solution of the inverse problem. More specifically, we minimize the L2-distance between the boundary measurements and the correspondent numerical solution of direct problem taking into account some pointwise source distribution. Then, we derive the sensitivity of the shape functional with respect to the set of admissible pointwise sources. From the numerical point of view, we adopt the Method of Fundamental Solutions (MFS) in order to approximate the numerical solutions of the direct problems. In addition to all the known advantages of this meshless method over domain discretization techniques - such as the Finite Element Method (MEF) and Finite Difference Method (MDF) - the MFS allows us to properly represent a pointwise source by a point (a MFS source point), reducing the noise that is inherent when using MEF or MDF in the reconstruction algorithm. The numerical results obtained, for the identification of multiple pointwise sources, even for partial noisy data, indicate that the proposed algorithm is accurate, convergent, stable and efficient.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1218

INTEGRATION OF FLANGE CONNECTIONS IN THE GRAPH AND HEURISTIC BASED TOPOLOGY OPTIMIZATION OF CRASHWORTHINESS STRUCTURES

Simon Link[1], Domink Schneider[1], Axel Schumacher[2], Christopher Ortmann[3]

[1]Bergische Universität Wuppertal, Germany
simon.link@uni-wuppertal.de, dschneider@uni-wuppertal.de

[2]University of Wuppertal, Germany
schumacher@uni-wuppertal.de

[3]Volkswagen AG, Germany
christopher.ortmann@volkswagen.de

Keywords: topology optimization,heuristics,crashworthiness,manufacturing

Abstract: In the simulation of crashworthiness structures different kinds of nonlinearities like large deformations, contact and material nonlinearities appear. In order to optimize the topology of such structures, Olschinka, Ortmann and Schumacher [1,2] introduced the Graph and Heuristic Based Topology Optimization (GHT), which deals with the optimization of crashworthiness profile structures. For changing the topology, heuristics derived from expert knowledge are used. The basic approach of the GHT is limited to profile structures, as the graph syntax, which describes the profile cross-section and the heuristics, that modify the topology, were developed only for the extrusion manufacturing process. Due to the demand for using different manufacturing processes, the approach is extended to sheet metal compound structures. In the extension described in this contribution, the structure is split into multiple less complex parts, which can be independently manufactured and later bonded to the complete structure. Because flanges and bonding have a huge influence on the mechanical behavior, the flanges and the bonding have to be included in the analysis model of the optimization. Therefore, new modeling schemes are used to define the number and positions of the flanges. In general all kind of bonding techniques can be used. In the first extension, the approach is limited to adhesive bonding. Depending on the bonding technique, it is necessary to create flange connections to increase the joining surface area and thus the strength of the bonding. The new optimization procedure is illustrated with the help of an example. The optimization results for different manufacturing processes of the component are compared. The example consists of an automotive rocker (material: steel) and a cross member in a side impact crash load case and different static load cases.

References

[1] Olschinka, C., Schumacher, A.: Graph based topology optimization of crashworthiness structures, PAMM Proc. Applied Math. Mech., Volume 8 Issue 1, Pages 10029-10032, 2008
[2] Ortmann, C., Schumacher, A.: Graph and heuristic based topology optimization of crash loaded structures. Struct. Multidiscip. Optim. 47(6), 839–854 (2013)

Abstract ID 1220

SYNTHESIS OF A NON-GRASHOF SIX-BAR POLYCENTRIC KNEE PROSTHESES USING AN EVOLUTIONARY OPTIMIZATION ALGORITHM

Cuauhtemoc Morales-Cruz, Edgar Alfredo Portilla-Flores, Rosaura Anaíd Suárez-Santillán, Noemi Hernández-Oliva, Maria Bárbara Calva-Yáñez

Instituto Politecnico Nacional, Mexico
cumoralescruz@gmail.com, aportilla@ipn.mx, anaid.suarez@gmail.com, nhernandezo@ipn.mx, b_calva@hotmail.com

Keywords: Mechanism Synthesis,Six-bar Polycentric Knee,Optimization,Non-Grashof,Differential Evolution.

Abstract: The knee prosthesis development has tried many approaches including passive, dynamically damped and powered designs. Nevertheless, the passive approach still has some very important aspects to contribute to this complex design process and must be restudied before applying any powered approach. The synergistic combination of this two perspectives is necessary to conceive the knee prosthesis implementation as biomechatronic design and to take advantage of the best from each approach. The purpose of this study is the dimensional synthesis of a polycentric six-bar mechanism to be implemented as a knee prosthesis. For this reason, a constrained numerical optimization is proposed where the main objective is the minimization of the error when following the desired trajectory, previously obtained as a result of the Mexican anthropometry studies. Additionally, this study adds, as a requirement, the avoidance of the knee hyperextension with the mechanism itself instead of using mechanical stops added them in other stages of the knee design. This work handles this new requirement by applying a set of new constraints in the optimization problem to imposed the desired behavior as well as forcing the synthetized mechanism to be a Non-Grashof mechanism. The optimization problem is solved by using an evolutionary technique, because of its simplicity in the implementation and the good results reported in literature when solving real-world engineering problems. The Differential Evolution algorithm is applied in combination with some simple but efficient rules to handle the constraints. By following this route the obtained mechanism follows the desired trajectory, avoids the hyperextension and its configuration is more compact due to the folding characteristics of a Non-Grashof configuration. Finally, the obtained mechanism simulation is presented and it is modeled using CAD tools.

Abstract ID 1225

FINANCIAL EARLY WARNING SYSTEM MODEL BASED ON NEURAL NETWORKS , PSO AND SA ALGORITHMS

Fatima Zahra Azayite, Said achchab

National School for Computer Science and Systems analysis. Mohammed V University, Morocco
azayitefaty@yahoo.fr, sachchab@gmail.com

Keywords: bankruptcy prediction financial warning system neural network PSO Simulated annealing

Abstract: Predicting bankruptcy is one of the most challenging subjects and research topics in economic and financial areas especially in these last decades. Making a financial early warning systems to evaluate firms failure risk depending on their financial behavior can be a crusial key indicator for making decision . One of the most popular and performer tools to predict financial distress is Artificial Neural Network (ANN) . In this paper, a financial warning system is presented based on a hybrid ANN model to predict bancruptcy and risk scoring, This hybrid model considers the firms' behavior during three years to predict risk failure. Taking into consideration in one hand that ANN is a powerful tool to aproximate non linear function if it is designed with aprpopriate parameters, and in the second hand, the problem of local minima, we propose a topology design algorithm based on an improved Particle swarm optimization and Simulated annealing to define an optimized ANN architecture. Taking in consideration feature selection , a synsitivity analysis in made to catch the relevance of the discriminant variables used in the proposed financial warning system. A comparative performance study is reported. The results showed that the proposed model represents a valid alternative to give an early risk failure warning .

Abstract ID 1227

IMMERSED COMPONENT-DRIVEN SHAPE OPTIMIZATION WITH ADAPTIVE MESH REFINEMENT.

Miguel Salazar de Troya(1), Daniel Tortorelli(2)

(1)University of Illinois at Urbana-Champaign, United States
salazardetro1@llnl.gov

(2)Center for Design and Optimization, Lawrence Livermore National Laboratory, United States
tortorelli2@llnl.gov

Keywords: shape optimization,immersed finite element methods,component-driven design

Abstract: We present a shape optimization framework via an ersatz material approach to design the layout of multiple engineering components within a hold-all domain. We use a level set function and Booleans operations to define the geometry. We approximate these Boolean operations with differentiable functions for our optimization. We then take the sign of this level set function, again using a differentiable function, to define an approximate indicator field which acts as a volume fraction variable in the finite element discretization of the elasticity equation. The gradient of the approximate indicator field is used to define the integrals for the boundary conditions at the material boundary including design dependent loading. We use adaptive mesh refinement to obtain a more efficient and accurate geometry description. Numerical examples with immersed boundary conditions are shown.

Abstract ID 1228

TRUSS LATTICE DESIGN UNDER DYNAMIC LOADS WITH ADAPTIVE TIME STEPPING.

Miguel Salazar de Troya[1], Daniel Tortorelli[2]

[1]University of Illinois at Urbana-Champaign, United States
salazardetro1@llnl.gov

[2]Center for Design and Optimization, Lawrence Livermore National Laboratory, United States
tortorelli2@llnl.gov

Keywords: elastodynamics,truss lattice,adaptive timestepping,optimization,design

Abstract: We develop a design framework for structures comprised of octet-truss lattices subject to impact loads. We design our lattice by changing the struts cross section area and compute the homogenized properties using an analytical model based on slender struts and a periodic microstructure. A constraint in the variation of design variables is imposed to preserve the homogenization assumption. The lattice design goal is the maximization of the mechanical energy at defined regions. We use an adaptive time stepping scheme to avoid having a fixed time step throughout the optimization, as the CFL condition changes due to the changes in design and adaptive time stepping yields a more accurate and efficient simulation. Classic adaptive time stepping schemes are highly discontinuous. They involve conditional statements and often require several attempts for each time step, making them inadequate for optimization. We use instead algorithms based on well-established techniques from linear feedback control theory which behave more smoothly. We use the fifth-order Runge Kutta scheme Dormand-Prince which contains an embedded error estimate. The optimized results are compared in computational time with a fixed time step approach.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1229

RADIAL BASIS FUNCTIONS INFLUENCE IN CORS METODOLOGY APPLIED ON AERODYNAMIC WING OPTIMIZATION PROBLEMS

Nelson Díaz Gautier, Edna Da Silva

UNIFEI, Brazil
ndiazg22@hotmail.com, ednaunifei@yahoo.com.br

Keywords: Radial Basis Functions,Metamodels,Aerodynamics wing,CORS.

Abstract: This paper discusses the influence of different Radial Basis Function (RBF) that use a shape parameter C in metamodel construction to be applied to 3D aerodynamic wing optimization problems using the Constrains Optimization with Response Surface (CORS) methodology in conjunction with a stochastic Controlled Random Search Algorithm (CRSA). The CORS methodology is based on the iterative construction and optimization of response surfaces with a robust search pattern application. In the CORS methodology the response surface may be generate by at least three types of methods: (i) Classical (polynomials and parametric surfaces), (ii) Statistical (K-Nearest, Kriging and Gaussian Processes) and (iii) Advanced (RBF and Neural Network). The response surfaces used in this paper are constructed using three different type of RBF: Gaussian, Hardy's Multiquadric and Inverse Multiquadric, whose shape parameters are automatically, optimized using Leave One Out Cross Validation (LOOCV). The RBF's are directly applied on the response surface construction inside the CORS structure, such that the influence of their shape parameters may be significant for the efficiency of the methodology. The methodology is applied for accelerating the optimization process of wing aerodynamic designs with a solver based on a first order 3D panel method and a 2D boundary layer model. Since the main objective of this paper is of prospective nature, the choice of a relatively low-fidelity flow computation solver is justified. One considers problems of minimizing the aerodynamic coefficient relation (CD/CL) and the inverse of lift coefficient (1/CL). The comparative influence of the RBF choice on the acceleration induced by the CORS methodology is investigated taking into account the number of calls of the objective function to find the minimum value in each problem.

Abstract ID 1232

SENSITIVITY OF SHAPE PARAMETERS OF BRAKE SYSTEMS UNDER SQUEAL NOISE CRITERIA

Mohanasundaram Pradeep[1], Gillot Frederic[2], Besset Sebastien[1], Shimoyama Koji[3]

[1]ECL / LTDS UMR CNRS 5513, France
pradeep.mohanasundaram@ec-lyon.fr, sebastien.besset@ec-lyon.fr

[2]Ecole Centrale de Lyon / LTDS / INRIA Rennes, France
frederic.gillot@inria.fr

[3]Tohoku University, Japan
shimoyama@tohoku.ac.jp

Keywords: sensitivity analysis,shape optimization,brake systems,squeal noise

Abstract: We propose in this paper to deal with squeal noise reduction of brake systems through their shape optimization during the design step. We first expose the FEM model used to generate the stability diagram representing the squeal noise behavior of a given brake system shape. We then propose an objective function able to be included in a minimization problem and based on the stability diagram. We use then a parallel code to browse the objective function response surface through a Latin Hypercube Sampling design of experiment. A Self Organizing Map is then generated to expose the sensibility of our objective function to seven shape parameters of the FEM brake system. We present and analysis the SOM results for further optimization steps.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1236

SUSTAINABLE DESIGN OPTIMIZATION OF REINFORCED CONCRETE FRAMES CONSIDERING CO2 EMISSION MINIMIZATION

Alberto Martins[1], Luís Simões[2], João Negrão[2]

[1]Universidade de Coimbra, Portugal
alberto@dec.uc.pt

[2]University of Coimbra, Portugal
lcsimoes@dec.uc.pt, jhnegrao@dec.uc.pt

Keywords: Optimization; Reinforced concrete; CO2 emissions; Sustainable design

Abstract: Nowadays, the environmental consequences of global warming are of major concern. Worldwide, efforts are being made to reduce the CO2 (carbon dioxide) emissions in order to mitigate the greenhouse effect. Since the environmental impact of construction industry is significant, construction sustainability is gaining increasing relevance in the last years. In this way it is important, in the design of civil engineering structures, to consider besides the construction costs also the environmental costs. The environmental costs are related to the CO2 emissions generated during the production of the construction materials and during building of the structure. Structural design is an iterative process which, through changes in some parameters of the structural system, seeks a solution that satisfies a set of criteria related to safety, serviceability and economy. Nowadays, sustainability criteria should also be included. Although structural optimization is not commonly used in civil engineering practice, the use of optimization tools in the design of reinforced concrete framed structures naturally arises as an efficient way to compute the cross-sectional dimensions of the beams and columns, the amount of reinforcing steel and the concrete grade, aiming at reducing the material and environmental costs and therefore obtaining economical, structurally efficient and "environmentally-friendly" solutions. In this work a numerical model for the design of reinforced concrete frames was developed. The structural analysis includes all the actions and relevant effects, namely, dead and live loads, the time-dependent effects and the geometrical nonlinearities. The structural response to changes in the design variables is done by a discrete direct sensitivity analysis procedure. The design of reinforced concrete frames is formulated as a multi-objective optimization problem with objectives of minimum construction cost, minimum CO2 emissions, minimum deflections and stresses and a Pareto solution is sought. The minimax solution is found by the minimization of a convex scalar function obtained through an entropy-based approach. The displacements and stresses design objectives are established according to the Eurocode 2 recommendations for the design of framed structures. The design variables considered are the beams and columns cross-sectional dimensions, the steel reinforcement area and the concrete grade. The gradient-based optimization algorithm used proved to be efficient to find the continuous optimum solution. Practical solutions from the engineering point of view are achieved by rounding the continuous solution. The features and applicability of the developed numerical model are demonstrated by numerical examples concerning the optimization of real sized reinforced concrete frames.

Abstract ID 1239

TRAJECTORY OPTIMIZATION OF INDUSTRIAL ROBOTS WITH A FEASIBLE DIRECTION INTERIOR POINT ALGORITHM

Jose Herskovits[1], Michel Alba[2], Luiz Ribeiro[3]

[1]IME - Military Institute of Engineering, Brazil
jose@optimize.ufrj.br

[2]Instituto Militar de Engenharia, Brazil
michel.alba@hotmail.com

[3]IME, Brazil
ribeiro@ime.eb.br

Keywords: Industrial Robotics; Trajectory Optimization; Inverse Kinemathics; Industrial Robots Optimization.

Abstract: Trajectory planning is considered a fundamental concern in robotics. In this paper we discuss the use of optimization techniques to obtain optimum trajectories of industrial robots. We use the flexibility of optimization techniques to address different formulations and solve them using the Feasible Direction Interior Point Algorithm (FDIPA). This method essentially solves two linear systems in each iteration to compute a descent and feasible direction of the problem, then performs a line search procedure that assures global convergence and feasibility of all iterates. Initially, it will be discussed point-to-point collision-free paths, that is, given an initial pose of the robot and a final target point, find an optimum trajectory that minimizes time, total displacement, energy or other performance index while avoiding collision with any obstacle. Then we discuss the path-following cases, where, given the desired trajectory of the robot's end-effector, optimum joint trajectories are calculated, concerning objective functions such as minimum velocity or acceleration peaks. In both cases we also deal with joint mechanical limits (maximum displacements, velocities and accelerations) as constraints to the optimization problem. Finally, we use a 4 degrees-of-freedom (DOF) planar manipulator to present numerical examples. Our results prove the effectiveness of the proposed approach and ensure robustness and applicability of the method.

Abstract ID 1240

ROBUST OPTIMIZATION FORMULATIONS FOR WATERFLOODING MANAGEMENT IN RESERVOIR ENGINEERING

Silvana Maria Afonso[1], Jefferson Pinto[2], Ramiro Willmersdorf[3]

[1]Federal University of Pernambuco - UFPE, Brazil
silvanabastos7@gmail.com

[2]UFPE, Brazil
wellano@gmail.com

[3]Federal University of Pernambuco, Brazil
ramiro@willmersdorf.net

Keywords: Robust Optimization,Waterflooding Management,Reservoir Engineering

Abstract: In oil reservoir management, one of the major challenges is the search for the best solution for oil production. In this scenario, the geological characteristics of fields contain uncertainties. One way to conduct optimal management of reservoirs under uncertainty is through robust optimization, which uses a set of realizations to honor the statistics of geological properties. The statistics considered are the mean and the expected value. In this work, such statistics are considered in three different formulations for the optimal robust management in the reservoirs. The first one is a classical uniobjetive problem in which the mean of the NPV (Net Present Liquid) is the objective function and its standard deviation is included in the set of constraints. The second employs also a uniobjective problem formulation, combining in a unique function the expected function and standard deviation of the NPV using a risk factor that considers the trade-off between the expected value and the standard deviation. Finally a classical Multiobjective formulation based on Pareto front technique is employed. Here, the mean and the standard deviation are coupled together to obtain Pareto solutions from which any design can be chosen. The required statistics of the formulations will be computed Monte Carlo (MC) simulations and In order to reduce the procedure processing time, the simulations will be performed into a subset of existing field realizations as the consideration of all reservoir realizations is cost prohibitive. A small subset of realizations is select aiming time processing reduction for the statistics calculations. Two approaches of selecting a representative subset of realizations are done, one ranks the realizations according to the performance of each realization in terms of NPV (Net Present Value), the other is based on clustering the uncertain field, e.g. in terms of permeability field, using a K-means procedure. In order to reduce simulation costs due to several function calls required in the optimization process, data fitting based surrogate models are applied in the Sequential Approximated Optimization strategy. The optimization results based on the realizations subset is then applied to all existing realizations. Finally, the technical applicability of the investigated formulations will be checked against a benchmark example reported in literature.

Abstract ID 1242

RELIABILITY BASED DESIGN OPTIMIZATION BY USING METAMODELS

Niclas Strömberg

Örebro University, Sweden
niclas.stromberg@oru.se

Keywords: FORM,SORM,Metamodels

Abstract: This paper summarize my work so far on reliability based design optimization (RBDO) by using metamodels and present some new ideas on RBDO using support vector machines. Design optimization of complex models, such as non-linear finite element models, are treated by fitting metamodels to computer experiments. A new approach for radial basis function networks (RBFN) using a priori bias is suggested and compared to established RBFN, Kriging, polynomial chaos expansion, support vector machines (SVM), support vector regression (SVR), and least square SVM and SVR. Different types of computer experiments are also investigated such as e.g. S-optimal design of experiments, Halton- and Hammersley sampling, and different adaptive sampling approaches. For instance, SVM-supported sampling is suggested in order to improve the limit surface by putting extra sampling points at the margin of the SVM. Uncertainties in design variables and parameters are included in the design optimization by FORM- and SORM-based RBDO. By establishing the most probable point (MPP) at the limit surface using a Newton method with an inexact Jacobian, Taylor expansions of the metamodels are done at the MPP using intermediate variables defined by the iso-probabilistic transformation for several density distributions such as lognormal, gamma, Gumbel and Weibull. In such manner, LP- and QP-problems are derived which are solved in sequence until convergence. The implementation of the approaches in an in-house toolbox are very robust and efficient. This is demonstrated by solving several examples for a large number of variables and reliability constraints.

Abstract ID 1244

OPTIMAL DESIGN OF NEW STEEL CONNECTIONS

Luigi Palizzolo, Salvatore Benfratello, Pietro Tabbuso

University of Palermo, Italy
luigi.palizzolo@unipa.it, salvatore.benfratello@unipa.it, pietro.tabbuso@unipa.it

Keywords: Steel device,flexural design,computational analisys,elastic and limit behaviour

Abstract: The greater part of the European standards, which regulates the structural design of civil and industrial constructions, prescribes the evaluation of different load conditions and different limit behaviors to be imposed to the structure. So, it is usually defined a serviceability condition, characterized by the presence of quasi static loads and moderate intensity seismic actions, and a limit condition, characterized by the presence of suitably reduced gravity loads and full seismic actions. Correspondingly, it is prescribed that the structure exhibits an elastic or a shakedown behavior in serviceability conditions and that the structure does not collapse under limit load conditions, even suffering a limited amount of damage. Consequently, optimal structures must possess adequate stiffness properties in order to ensure the complete usability in serviceability conditions and good resistance and ductility features in order to respect the imposed limit conditions. In this context, steel structures find their ideal application and, actually, they are more and more utilized in new constructions as well as within restoration interventions. The behavior of the structure depends on the utilized steel profiles and on the way they are joined each other. Usually, the connections are designed so as to ensure very high stiffness and resistance to the nodes, so that the elastic and post elastic response of the structure is governed just by the steel elements features. In other words, the elastic and the limit behaviour of the structure are depending on each other being related to the stiffness of the utilized profiles and to their own limit resistance. On the other side, in many cases of practical interest it can be required that structures exhibit an elastic and a limit behaviour independent of each other. With this aim a special connection, called Limited Resistance Rigid Perfectly Plastic Hinge (LRPH), can be utilized, constituted by two parallel bounding plates, connecting the relevant structure elements, with inside a suitably designed sandwich section. In the present paper, an optimization procedure based on a genetic algorithm approach is utilized in order to design LRPH connections according with appropriate prescribed mechanical, kinematical and technological constraints. The obtained results, even if obtained in the limited field of pure bending, are very encouraging and they represent a fundamental starting point for practical applications related to full stress behavior and more complex structures.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1245

ON CONTACT SHAPE OPTIMIZATION PROBLEMS RELATED TO DISPLACEMENT CONTROL

Istvan Paczelt(1), Zenon Mróz(2)

(1)University of Miskolc, Hungary
paczelt@freemail.hu

(2)Institute of Fundamental Technological Research, Warsaw, Poland, Poland
zmroz@ippt.pan.pl

Keywords: contact shape optimization,deflection control,optimal contact pressure distribution

Abstract: The problem is related to control of same point displacements of a loaded structure by applying the interacting punch loading. As at the controlled points the displacement and the force are prescribed, a new type optimization problem is formulated. The solution method of this problem can be used for the design of robot elements, such as clippers and gardening or plantation tools for mechanical processing. It is assumed that strains are small and the materials of the contacting bodies are linearly elastic. This problem in the lecture will be demonstrated by considering several cases, namely 1. a cantilever beam clamped at its end and loaded at point Q by the force F, 2. the beam and its support are allowed to execute the rigid body vertical displacement, 3. the beam is allowed to execute the rigid body vertical displacement and rotation. In this case, the displacements are prescribed at two points. In all cases, the control of the deflections at given points is made by the lateral stamp action inducing the resultant load. The stamp contact form is specified for a given distribution of contact tractions between the stamp and beam subject to constraints of fixed values of displacements ui and forces Fi at the points Qi of the beam. In the solution of the optimization problem, first, the value of rigid body displacement of the beam is calculated and from contact conditions between the punch and beam the rigid body punch displacement is specified, which may be used in the mechanical technological process. Using the Green function for the beam, the displacements can easily be expressed for different forces and contact stresses. In these contact optimization problems, the initial gap (shape form of the contact surface) is the unknown function. The problem is discretized and the calculation of the contact shape can be performed by applying the iterative procedure described in [1,2].

Acknowledgements The present research was partially supported by the Hungarian Academy of Sciences, by the grant National Research, Development and Innovation Office – NKFIH: K115701

References

[1] I.Páczelt. Iterative methods for solution of contact optimization problems, Arch. Mech., 52, 4-5, 685-711, 2000.
[2] I.Páczelt, A. Baksa and Z. Mróz. Contact optimization problems for stationary and sliding conditions, Springer International Publishing Switzerland 2016, P. Neittaanmaki et al. (eds.), Mathematical Modelling and Optimization of Complex Structures, Computational Methods in Applied Sciences 40, 281-312, DOI 10.1007/978-3-319-23564-6_16.

Abstract ID 1246

FINITE ELEMENT SIMULATION AND TOPOLOGY OPTIMIZATION OF BIOINSPIRED STRUCTURES UNDER LOW-VELOCITY IMPACT

Francisco Ramírez-Gil, Esteban Foronda, Wilfredo Montealegre

Universidad Nacional de Colombia, Colombia
fjramireg@unal.edu.co, eforondao@unal.edu.co, wmontealegrer@unal.edu.co

Keywords: Transient dynamics,Explicit finite element method,Topology optimization,Bioinspired design

Abstract: Nature has proven to be a successful designer of materials and structures. As consequence, humans have tried to replicate this type of structures through the bioinspired design. This led to the development of the functionally graded materials (FGM), a new type of composites in which the microstructure, composition, porosity or other characteristic is changed continuously through one or more directions, allowing a smooth variation of properties over the volume. In this research, the concept of FGM is explored for low-velocity impact applications, in which the objective is to reduce the weight of a plate and enhance (or at least keep) it effective stiffness. Although there are different strategies to design FGMs, in this study the volume density of the structure is changed from surface to core by controlling the porosity through inserting holes. This is a common method used by nature in structures subjected to impact such as bones, teeth, horns and wood, and also by man-made products such as metal foams due to their potential for lightweight and energy absorption. Two approaches are proposed herein to reach the objective. The first one consists in generating several patterns of holes intuitively, and the second one generates these holes' pattern through topology optimization. An explicit finite element analysis is used to simulate the low-velocity impact and the comparison is done with plates without holes. Different load cases are evaluated, studying the effect of subjecting the plate to localized or distributed loads. The results show that it is possible to design the patterns of holes reducing the weight of the plate without having a substantial detriment on their structural response. These results can be used to design components in applications where weight reduction is a priority and it must be balanced with the impact energy absorption capability. Finally, further research should be developed so that this design technique can be applied to components subjected to medium- and high-velocity impacts, including contact, plasticity and failure criteria.

Abstract ID 1247

FATIGUE AND STRESS CONSTRAINED TOPOLOGY OPTIMIZATION OF 3D STRUCTURES SUBJECTED TO MULTIPLE LOAD CASES

Erik Lund, Jacob Oest

Aalborg University, Department of Materials and Production, Denmark
el@mp.aau.dk, oest@mp.aau.dk

Keywords: Fatigue constraints,stress constraints,adjoint sensitivity analysis,topology optimization

Abstract: In this work the authors extend their previous work on 2D topology optimization including finite-life high-cycle fatigue constraints to 3D cases where multiple load cases and stress constraints are also considered. The method takes offset in the standard density approach to the topology problem and qp-approach for stress interpolation and relaxation. The objective is to minimize mass, and the load cases are either static load cases or proportional variable amplitude loading conditions. Linear elastic material behavior is assumed and the fatigue response is computed using quasi-static structural analysis. Fatigue constraints are computed using Palmgren-Miner's linear damage hypothesis, S-N curves, and the Sines fatigue criterion. The large number of local constraints is reduced by use of aggregate functions, and a very efficient adjoint formulation is applied for sensitivity analysis of fatigue constraints where the amount of adjoint problems to be solved is independent of the amount of cycles in the load spectrum. It is demonstrated how the computational cost of sensitivity analysis of fatigue constraints is comparable to the cost of having stress constraints. The 3D problems are solved using the Portable and Extendable Toolkit for Scientific Computing (PETSc) as demonstrated by the topology optimization code made publicly available by the TopOpt group at DTU, www.topopt.dtu.dk/PETSc. A number of examples demonstrate the efficiency of the approach and the necessity of including fatigue constraints for structures subjected to variable amplitude loading conditions, compared to using simplified stress constraints.

Abstract ID 1252

MULTI-FIDELITY APPROACHES FOR CRASHWORTHINESS OPTIMIZATION

Fabian Duddeck

Technical University of Munich (TUM), Germany
duddeck@tum.de

Keywords: Structural optimization,crashworthiness,multi-fidelity approaches,physical and mathematical surrogates,early and late phase development,Solution Space method,industrial applications.

Abstract: Structural optimization for crashworthiness is today an important topic for the automotive industry. Different optimization types (layout, topology, material, shape, size, robustness, reliability, etc.) and algorithms (gradient-based / gradient-free, physical / mathematical surrogates, evolutionary / genetic algorithms, etc.) have been introduced. Methods should be adapted to distinguish between optimization for high energy absorption or for low intrusions (safety cage), and between early and late development phases including the transition between both phases. For late phases, high-fidelity FEM models are normally used while for the concept phase low-fidelity models are more appropriate due to the lack of knowledge of detailed design aspects. For both, a high number of different vehicles, load cases, and disciplines have to be considered simultaneously. This means that the complexity of the optimization problem can only be handled by hybrid and hierarchical approaches establishing a multi-fidelity and partially decoupled methodology. Instead of using a numerical model with the best compromise between accuracy and efficiency, a high-fidelity model (FEM) with high accuracy is combined with often several low-fidelity models (mathematical and physical) with high efficiency. Here, recent results from the author's research groups are presented focusing on a new methodology, called Solution Space approach, for concept development using a sequential multi-fidelity approach. This is based on (i) decoupling a multi-vehicle and multi-disciplinary problem via low-fidelity physical models (e.g. lumped masses) including optimization of the component requirements and (ii) single discipline/vehicle/component optimizations with, as the first step, high-fidelity models. It is then proposed to realize the component optimization with a second multi-fidelity approach where a mathematical surrogate (Kriging, efficient global optimization, EGO) using high-fidelity FE models is enriched by gradients from a second low-fidelity physical surrogate (e.g. equivalent static load method, ESL). Examples for front and side impact cases will be shown. As outlook, these approaches will be embedded into a general overview on possible multi-fidelity optimization schemes for vehicular crashworthiness to motivate future developments and academic and industrial applications. Additional options for low-fidelity crash models will be given.

Abstract ID 1254

WORST CASE OPTIMAL DESIGN USING SMALL AMPLITUDE HOMOGENIZATION

Sergio Gutiérrez

Pontificia Universidad Catolica de Chile, Chile
sgutierr@ing.puc.cl

Keywords: Homogenization,Small Contrast,Robust Optimal Design

Abstract: The Small Amplitude Homogenization idea is used to solve minimization optimal design problems in the worst possible case, when there is uncertainty in some of the information needed to formulate the state equation of the problem. To select the worst possible case, a first order approximation of the objective function in terms of the quantity known with uncertainty is maximized over the set of admissible perturbations. Considering perturbations of bounded norm, the worst posible case becomes explicit and the aforementioned first order approximation is minimized by a gradient method. Numerical examples are provided, first for heat diffusion when the internal heat source is known with uncertainty, and secondly, for shear walls in linear elasticity when the boundary force is perturbed.

Abstract ID 1256

A FEASIBLE DIRECTION ALGORITHM FOR THE GENERALIZED NASH EQUILIBRIUM PROBLEM

Jose Herskovits[1], Carolina Effio[2], Jean-Rodolphe Roche[3]

[1]IME - Military Institute of Engineering, Brazil
jose@optimize.ufrj.br

[2]COPPE/UFRJ, Brazil
carolina@optimize.ufrj.br

[3]Université de Lorraine, France
jean-rodolphe.roche@univ-lorraine.fr

Keywords: Nonlinear Optimization,Nash Equilibrium,Mathematical Programming

Abstract: The Generalized Nash Equilibrium Problem (GNEP) is an extension of the Nash Equilibrium Problem (NEP). This one involves two or more players; each player is associated with a feasible strategy set and a payoff function. It is assumed that there is not collaboration among the players. The difference between GNEP and NEP is that the feasible set of the GNEP depends on the strategies set of the others players. We develop a feasible point Newton-like algorithm for the Generalized Nash Equilibrium problem (GNEP) with shared constraints. For a given interior initial point, we propose an algorithm that generates a feasible sequence converging to the solution of the normalized equilibrium problem. At each iteration, for each player, a feasible descent direction is computed by solving two linear systems with the same matrix. Considering the sum of the Lagrangians corresponding to each player we can generate a pseudo gradient used to perform an Armijo-like line search along each feasible descent direction. The present approach was already employed for several test problems, showing to be very strong and efficient. A set of numerical results is presented to confirm this conclusion.

Abstract ID 1258

OPTIMIZATION OF THE PROPELLER-DRIVEN PROPULSION SYSTEM FOR A SMALL UAV

Nuno Moita[1], Andre Marta[2]

[1]Instituto Superior Técnico, Universidade de Lisboa, Portugal
nuno.moita@tecnico.ulisboa.pt

[2]IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Portugal
andre.marta@tecnico.ulisboa.pt

Keywords: Propeller,Planform shape,Optimization,Efficiency,Thrust,Electrical Power

Abstract: Integrated in the LEEUAV project, a Long Endurance Electric UAV developed by LAETA, the objective of this work was to optimize the propeller-driven propulsion system designed previously. Following a careful selection of the propulsion systems analysis model, a propeller parametrization was made, including the planform and airfoil shape. relevant functions of interest were used to evaluate the performance of the propeller, such as thrust, power and thrust coefficients, and propeller efficiency. Experimental tests were performed to validate the software, which included three different propellers chosen to study how the performance varies for different propeller diameters and pitches, and electric motors. Since it was not known accurately which airfoil was used in each propeller, two different airfoils were assumed. Following the experimental tests and the validation of the software, a planform shape optimization was performed for cruise and climb. At the end of this optimization, a system motor propeller with an higher efficiency for both flight stages was obtained.

Abstract ID 1259

EFFICIENT AERODYNAMIC OPTIMIZATION OF AIRCRAFT WINGS

Pedro Rodrigues[1], Andre Marta[2]

[1]Instituto Superior Técnico, Universidade de Lisboa, Portugal
pedro.miguel.verissimo.rodrigues@tecnico.ulisboa.pt

[2]IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Portugal
andre.marta@tecnico.ulisboa.pt

Keywords: Gradient-based optimization,Aerodynamic design,Sensitivity analysis,Automatic differentiation,Adjoint method.

Abstract: One of the most important keys to the successful design of complex systems is disciplinary inte- gration. Multidisciplinary Design and Optimization is now a promising methodology for the efficient design of such systems, since it combines multidisciplinary analysis with gradient-based optimization techniques. Therefore, this methodology requires the derivatives evaluation of the functions of interest with respect to the design variables, which is the most demanding computational task in the optimization process. Traditionally, those derivatives are calculated inefficiently and inaccurately using approximate methods. Therefore, the objective of this work is to develop an efficient optimization framework to solve aerodynamic design problems using exact gradient information. Firstly, a survey on sensitivity analysis methods is conducted to identify which tools are available and understand their respective merits. Secondly, an aerodynamic model based on the panel method is reformulated into five smaller modules, in which the respective sensitivity analysis blocks are constructed using exact gradient estimation methods: automatic differentiation, symbolic differentiation and the adjoint method. Both the aerodynamic tool and respective sensitivity analysis are validated using a wing design tool and the finite-differences method, respectively. Finally, aerodynamic optimization problems are solved using the new tool with remarkable success since, when compared to the finite-differences method, the optimization time can be reduced by 90%.

Abstract ID 1260

MULTIDISCIPLINARY OPTIMISATION OF FLEXIBLE AIRCRAFT STRUCTURES IN CONSIDERATION OF FLIGHT CONTROL SYSTEM DEMANDS IN THE TIME DOMAIN

Daniel Nussbächer[(1)], Fernass Daoud[(1)], Ögmundur Petersson[(1)], Mirko Hornung[(2)]

[(1)]Airbus Defence and Space GmbH, Germany
daniel.nussbaecher@airbus.com, fernass.daoud@airbus.com, oegmundur.petersson@airbus.com

[(2)]Technische Universität München, Germany
mirko.hornung@tum.de

Keywords: Mutlidisciplinary Design Optimisation Industrial Aircraft Design Aeroservoelasticity Structural Dynamics

Abstract: This paper presents how the major aircraft design disciplines "flight control systems" and "aerostructural design" are coupled through the application of multidisciplinary design optimisation for time domain problems at Airbus Defence and Space. It shows that respecting flight control system demands in a multidisciplinary way is a must for the success of industrial aircraft projects. Today's major customer requirements target extended flight ranges and loitering times on the one side, and higher manoeuvrability of the product on the other side. Both demands increase the importance of aeroelasticity and flight control system during design. To tackle the novel customer requirements, the Airbus in-house optimisation tool Lagrange was enhanced by the possibility of coupling flight control laws with aeroelastic analyses. The governing equations of the aeroservoelastic system are developed. The control laws are given in terms of a discrete controller, as common in industrial development. The monolithic, aeroelastic model, providing external loads, incorporates inertia relief using a mean axes formulation. Structural dynamics are encountered in the time domain and solved with the generalized alpha method. Basic damping models are considered in order to properly face the servostructural dynamics of the system. Based on the governing equations of the analysis model, the optimisation problem is formulated. Structural mass is considered as the primary objective function. Additionally, the dynamic of the controller is encountered as an objective. Constraints are formulated by means of both structural integrity and flight mechanical aspects. Design variables are structural thickness values, ply angles of laminated materials, as well as control variables like gain factors in the control law. In the early stage of aircraft sizing, industrial aircraft models usually consist of hundreds of thousands of structural, and tens of thousands of aerodynamic degrees of freedom. As an application, a flexible, unmanned aerial vehicle with a high aspect ratio is optimised. Results obtained by following the conventional aircraft optimisation approach are compared to results from the enhanced process for this industrial example. A validation of the approach against different aeroelastic solutions is presented. Calculations from higher fidelity aerodynamic solvers are consulted for this purpose. As an engineering outcome, it is shown how the consideration of controlled loads in the optimisation step significantly changes the range of allowable designs. The paper thus presents the methodical shift at Airbus Defence and Space from designing with conservative, passive reserve factors to designing with active ones.

Abstract ID 1262

APPLYING THE MODIFIED CUCKOO SEARCH TO THE CUSTOMISATION OF AN INDUSTRIAL PRE-MIXER

Jennifer Thompson

Swansea University, United Kingdom
jennifer.thompson@swansea.ac.uk

Keywords: Pre-mixer Fluent Cuckoo-Search Customisation Industrial.

Abstract: The Modified Cuckoo Search was used to customise the design of a pre-mixer for use in a pressure let-down station heater. This is a true industrial test application for this novel optimisation algorithm. A commercial-off-the-shelf (COTS) mixer was used as a bench mark to assess the impact of Modified Cuckoo Search. In addition to customisation of the pre-mixer's design using Modified Cuckoo Search, the commercial Ansys Design Exploration v16.0 software was applied to the problem. This package utilises the Non-Dominated Sorted Genetic Algorithm-II (NSGA-II). The results of our study showed that by using these optimisation algorithms at least a 30% improvement in the performance as compared to the COTS design could be achieved. Further to this, it was found that the free and open source Modified Cuckoo Search performed comparatively to the commercial package Ansys. This will be significant for small to medium sized enterprises that are often limited by budget constraints to using off the shelf devices.

Abstract ID 1263

MULTIMATERIAL TOPOLOGY OPTIMIZATION OF A RAVIGNEAUX PLANETARY GEAR

Pierre Duysinx[(1)], Pablo Alarcón Soto[(1)], Simon Bauduin[(1)], Eduardo Fernández Sánchez[(1)], Julie JOSSIEAUX[(2)], Sebastien GOHY[(2)], Michael BRUYNEEL[(3)], Jean-Marc VAASSEN[(4)], Pascal DEVINCENZO[(4)]

[(1)]University of Liège, Belgium
p.duysinx@uliege.be; palarcon@uliege.be, s.bauduin@uliege.be, efsanchez@uliege.be

[(2)]GDTECH, Belgium
julie.jossieaux@gdtech.eu, sebastien.gohy@gdtech.eu

[(3)]GDTECH / ULiege, Belgium
michael.bruyneel@gdtech.eu

[(4)]Open Engineering, Belgium
jm.vaassen@open-engineering.com, p.devincenzo@open-engineering.com

Keywords: Topology optimization,multimaterial,planteray gear,misalignment.

Abstract: To reduce fuel consumption of automobiles, one can reduce the vehicle mass and increase the transmission efficiency of drivetrain components. To this end, topology optimization is a potential great design tool to help engineers in finding new designs exhibiting higher performance for a smaller weight. This research explores the ability of topology optimization to propose new designs of high efficient transmission components. The redesign of a Ravigneaux gear train has been selected to serve as a benchmark to investigate the possible weight savings in a typical transmission component while preserving or improving the energy efficiency. In gear trains, the transmission efficiency is related to the misalignment of gears because it is a source of mechanical losses during operations. While most of topology optimization studies consider compliance minimization, it is interesting to investigate if considering specific performance objective functions can bring an added value compared to the general statement of topology optimization based on compliance design. In addition, to save some further weight, there is also a great interest in considering multimaterial solutions to see if these solutions could bring sufficient improvement compared to the increase of cost and manufacturing complexity that results from these designs. It was observed that design can be blurred so that the convergence procedure can greatly benefit from the introduction non-discreteness indicator as design constraints. The multimaterial optimization is formulated using the Shape Function with Penalization by Bruyneel (2011), a similar approach to the Discrete Material Approach proposed by Stegman and Lund (2005). Non discreteness measure, initially proposed by Sigmund (2007), is introduced here as a design constraint. This constraints is very useful to ensure a stabilization of the convergence process as shown in our numerical experiments. Following the work by Bauduin (2018, this conference), gear misalignement is estimated using the modulus of the cross product of the gear unit vectors. The new formulations and developments have been implemented in the OOFELIE by Open Engineering, which has been used to conduct the numerical experiments. The work is organized as follows: 1/ Presentation of different formulations of the design problem. 2/ Formulation of multimaterial topology optimization using Design Material Optimization and Generalized Shape Function. 3/ Formulation of misalignment constraint and non-discreteness measures. Sensitivity analysis. 4/ Solution scheme. Numerical applications and discussion of the results. 5/ Conclusions and future developments.

Abstract ID 1264

OPTIMIZATION OF UNIDIRECTIONAL HYBRID POLYMER COMPOSITES USING A SPRING ELEMENT MODEL

Fábio Conde[1], Pedro Coelho[2], Rodrigo Tavares[3], José Guedes[1], Hélder Rodrigues[1], Pedro Camanho[3]

[1]Instituto de Engenharia Mecânica (IDMEC), Portugal
f.conde@campus.fct.unl.pt, jmguedes@tecnico.ulisboa.pt, hcr@tecnico.ulisboa.pt

[2]Unidade de Investigação e Desenvolvimento em Engenharia Mecânica e Industrial (UNIDEMI), Portugal
pgc@fct.unl.pt

[3]Instituto de Engenharia Mecânica e Gestão Industrial (INEGI), Portugal
rptavares@inegi.up.pt, pcamanho@fe.up.pt

Keywords: Composites,Pseudo-ductility,Numerical Modelling,Multi-objective,Topology,Optimization

Abstract: Composite materials have met increasingly interest in industry specially in lightweight construction due to their special properties compared to the conventional structural materials. However, they are characterized by having a brittle failure, i.e. typically they have no ductility, which may limit their widespread usage. To overcome this shortcoming, the fibre hybridization method is used to introduce a designated pseudo-ductile behaviour in the fibre reinforced composite material. The present work analyzes and optimizes this hybrid composite material under tensile load based on a Spring Element Model (SEM) proposed in Tavares et al. (2017). In a previous study (Conde et al., 2018), an optimization problem was already formulated in order to find an optimal fibre hybridization using two different analytical models. Despite the employed methodology proved to be effective back then, a new optimization problem formulation is also proposed in this work. This new optimization problem formulation uses the plastic deformation energy per unit of volume as objective function and a new constraint that relates the elastic modulus and the failure strength of a fibre in the frame of continuous optimization. In Conde et al. (2018) analytical models were used and therefore important mechanisms involved in the longitudinal failure of unidirectional composites were not taken into account leading to unrealistic results. The main relevance of the present work has to do with the use of a numerical model of the microstructure which takes into account more failure mechanisms. These new model features enrich the optimization problem such that optimal and more realistic fibre hybridizations are sought. The SEM works here with the definition of a Representative Volume Element (RVE) where a package of two types of fibres embedded in a polymer matrix can be found randomly or periodically distributed. Besides the spatial locations of the scattered fibres regardless their type, it also merits our attention here the possible formation of clusters of fibres of one type or another. In fact, the fibre-type distribution or lay-out impacts the overall composite response and motivates here pursuing a lay-out (topology) optimization problem. A measure of the degree of fibre dispersion in space is proposed here and one uses it to study the sensitivity of the pseudo-ductility behaviour to fibre dispersion or clustering. Ultimately one discovers an optimal mix of fibre materials, as well as, an optimal fibre spatial arrangement for such hybridization which produces a relevant pseudo-ductile behaviour in the composite under uniaxial traction.

Abstract ID 1266

METAHEURISTIC OPTIMIZATION OF NATURAL RESOURCES IN THERMAL CRACKING PROCESS

Fernando Boto, Diana Manjarres, Itziar Landa

Tecnalia Research & Innovation, Spain
fernando.boto@tecnalia.com, diana.manjarres@tecnalia.com, itziar.landa@tecnalia.com

Keywords: evolutionary algorithms; chemical process; cracking; optimization

Abstract: Thermal cracking is one of the most energy-consuming process in the chemical industry and its optimization has become a real challenge for the research community. In this context, this paper proposes two meta-heuristic approaches based on the Genetic Algorithm (GA) and the Harmony Search (HS) algorithms for minimizing the sum of the Energy Consumption and the Water Use in the overall thermal cracking process. Simulation results show that HS achieves best average minimum and mean values than its counterpart GA.

Abstract ID 1267

DESIGN OF LOW-DENSITY RANK STRUCTURES

Yiqiang Wang, Ole Sigmund

Technical University of Denmark, Denmark
ywang@mek.dtu.dk, sigmund@mek.dtu.dk

Keywords: Rank structure; Add up model; Maximum stiffness; Multiple loading

Abstract: Rank structures with closed walls can attain maximum stiffness in theory. This study focuses on finding stiffest rank structures with any number of rank planes for any prescribed multi-loading. The performance of the rank structures are quantified by their limiting stiffness at low densities, and therefore they can include rank features at a single scale level. Moreover, regarding the negligible bending stiffness of the thin-sized planes, a so-called add-up model is used to calculate the effective properties of the rank structures by directly adding up the properties of each individual feature. The optimization can then be established to optimize the plane orientations and thicknesses for minimizing the complementary energies by the given stresses. When applying random stresses, the optimized rank structures would exhibit anisotropic behavior, but by giving the right loading conditions, they can be isotropic. Effectiveness and accuracy of the add-up model will be tested by comparing to the analytic results from rank structure, as well as the finite element analysis, and the optimizations are solved for various numbers of rank planes and for both anisotropic and isotropic rank structures.

Abstract ID 1269

THE USE OF BAYESIAN OPTIMISATION TECHNIQUES FOR THE PANTOGRAPH-CATENARY DYNAMIC INTERACTION STOCHASTIC PROBLEM

Santiago Verdú, Manuel Tur, Javier Fuenmayor

Universitat Politècnica de València, Spain
sangreve@upv.es, manuel.tur@mcm.upv.es, ffuenmay@mcm.upv.es

Keywords: Bayesian optimisation; Stochastic Optimisation; Pantograph-catenary interaction

Abstract: Nowadays, simulation of pantograph-catenary dynamic interaction [1] have become an essential tool for the design of the overhead contact line. This problem entails some challenges from the computational point of view, mainly related to the strong nonlinearities associated to both dropper slackening and pantograph contact loss. With the aid of numerical simulations, it is possible to obtain optimal catenary geometry configurations to reduce, for example, wear on the cabling and therefore, to decrease maintenance costs. Up to date, these kind of optimisations [2] have been performed by means of Genetic Algorithms for very specific operating conditions, such as, for a single train speed or for an ideal initial configuration of the catenary. Nevertheless, in a more realistic scenario, these conditions are much more variable since the locomotive travels at a certain speed range and, due to installation errors, there is uncertainty in determining the geometric configuration of a catenary. Thus, this work is aimed to find optimal catenary configurations, in terms of maintenance, for wider and more realistic operating conditions. To this end, the uncertainty associated with the catenary installation errors is taken into account in the catenary finite element model. This stochastic approach makes more expensive the objective function evaluation in terms of computational cost. For that reason, the use of Bayesian Optimisation techniques seems very suitable for the problem at hand and their application is explored in this work.

ACKNOWLEDGEMENTS The authors would like to acknowledge the financial support received from the Regional Government of Valencia (PROMETEO/2016/007) and the Spanish Ministry of Economy, Industry and Competitiveness (TRA2017-84736-R).

References

[1] S. Bruni, J. Ambrosio, A. Carnicero, Y. H. Cho, L. Finner, M. Ikeda, S. Y. Kwon, J. P. Massat, S. Stichel, M. Tur, et al. "The results of the pantograph-catenary interaction benchmark", Vehicle System Dynamics, vol. 53-3, pp. 412-435, 2015.

[2] S. Gregori, M. Tur, E. Nadal, and F.J. Fuenmayor, "An approach to geometric optimisation of railway catenaries". Vehicle System Dynamics, published online, DOI: 10.1080/00423114.2017.1407434, pp.1-25, 2017.

Abstract ID 1270

CFRP LAYUP OPTIMISATION TO REDUCE RESULTING DISTORTIONS OF RTM-PRODUCED HYBRID STEEL-CFRP PLATES

Stefan Scheiblhofer

LKR Leichtmetallkompetenzzentrum Ranshofen GmbH, Austria
stefan.scheiblhofer@ait.ac.at

Keywords: RTM,cooling simulation,distortion preditiction,distortion management,numerical distortion optimisation,hybrid steel CFRP plates

Abstract: The production of hybrid metal-composite structures is often bound to multi-step-processes. In contrast, it is possible to produce hybrid components in a single-step Resin Transfer Moulding (RTM) process [1], which avoids additional steps to join the metal and the CFRP component. This results in the need for developing special resin systems capable of joining metal to CFRP while being a good binding agent for the dry carbon fibres. Nevertheless, new problems arise, as the different material properties result in residual strains, stresses and final component distortion while cooling the component from the warm RTM process down to room temperature. Finite element simulations help to gain insight and understanding of those problems as well as to reduce their impact. In previous research work [2] it was shown, that it is possible to predict the resulting distortions of a hybrid metal-composite plate, manufactured in a single-step RTM technology,by simulating the cooling phase of the process. In the present study, a parameter optimisation was set up based on previously developed simulation model [2] in order to find an optimised CFRP layup capable of reducing final residual distortions. For the optimisation, plates with dimensions of 500x500 mm² were chosen as geometry, with a 2 mm thick steel and a 2 mm CFRP component. Besides reducing the distortions, the optimisation aimed at a homogenized distortion distribution compared to the saddle shaped distortion geometry of the original plates [2]. For validation and comparison purpose, the resulting, optimized CFRP layup will be manufactured and compared with the original, symmetrical 0°/90° layup. The produced plates will be optically scanned and measured so to evaluate the optimisation results. This paper presents and discusses the optimisation model as well as the analysis and validation with experimental results. For the validation the plates were produced in three different layup configurations to ensure a good comparability of the experiments to one another. The validation through experiments show a good agreement with numerical results and produce promising results. Nevertheless, the simplified modelling technique in the FE model leaves room for improvement which will also be discussed. Future prospects and fields of applications will be discussed and conclude the underlying research. [

References

[1] *E. Fauster, et. Al.. HybridRTM – Quality Controlled Manufacturing of Hybrid Material composites through Resin Transfer Moulding. 21st Symposium on Composites. Bremen, 5-7.July 2017*

[2] *S. Scheiblhofer, S.Ucsnik. Deformation Prediction of RTM Produced Hybrid Metal-carbon Composites. NWC17. Stockholm, 11-14.June 2017*

Abstract ID 1273

TWO-STAGE, MULTI-OBJECTIVE OPTIMISATION FRAMEWORK FOR AN EFFICIENT PATHWAY TO DECARBONISE THE POWER SECTOR

Ruben Bravo[1], Daniel Friedrich[2]

[1]School of Engineering, Institute for Energy Systems, The University of Edinburgh, United Kingdom
r.bravo@ed.ac.uk

[2]School of Engineering, Institute for Energy Systems, The University of Edinburgh, UK, United Kingdom
d.friedrich@ed.ac.uk

Keywords: Multi-objective optimisation,hybrid energy system,energy storage,system flexibility

Abstract: The efficient and flexible design of renewable power plants is key to increase competitiveness of clean technologies and accomplish climate strategies. Hybrid renewable power plants, considering different renewable energy technologies, integrated with energy storage have the potential to provide sustainable, cost competitive and dispatchable energy. However, current renewable power plants are not dispatchable and deliver energy only when the renewable source is available. This results in large fluctuations and increasing cost of integration in the wider electricity system. Flexible design of renewable power plants with energy storage increase reliability and decrease integration cost of sustainable technologies. Nevertheless, the design of flexible, affordable and dispatchable power plants involves a thoughtful balance between technical and financial performance. Moreover, the design of renewable power plants has to handle a larger number of parameters compared with conventional power plants, and the integration of energy storage requires an operational strategy optimisation for every design. The model presented is developed as a two-stage multi-objective optimisation framework for a hybrid power plant. In order to exploit the synergies of hybrid power plants and to promote the best technologies to be chosen in the design, both design and operational optimisation objectives have to be linked. The first stage, i.e. the design optimisation, is performed by genetic algorithms and is focuses on the best definition of the capacities of every subsystem for a cost-competitive supply, handling the trade off between technical and financial performance. Then, as a nested second stage, a linear automated scalarisation method for multi-objective optimisation is performed in order to find the annual optimal hourly operation strategy. In this case, the objectives of the design optimisation include the levelised cost of electricity, investment and system flexibility. These are very closely related with the objectives of the operational optimisation, which include maximisation of the energy, minimisation of the mismatch between supply and demand, and minimisation of greenhouse gases emissions (in the case that a fossil fuelled unit is considered to give more flexibility to the system). Finally, by a post-optimisation sensitivity analysis, a set of optimal designs can be slightly modified to estimate benefits by increasing flexibility. Through the optimisation framework described it is possible to handle different energy generation and storage technologies to design a sustainable, cost competitive, flexible and dispatchable power plant. Besides, the post-optimisation analysis can handle other key performance indicators and provides more detailed information, improving the decision making.

Abstract ID 1274

OPTIMIZATION OF AXIALLY MOVING LAYERED WEB

Nikolay Banichuk(1), Svetlana Ivanova(2), Alexander Sinitsyn(2), Vladislav Afanas'ev(3)

(1)Ishlinsky Institute for Problems in Mechanics RAS, Russian Federation
banichuk@gmail.com

(2)Institute for Problems in Mechanics RAS, Russian Federation
syuivanova@yandex.ru, alexander@sinitsyn.info

(3)Moscow State University of Technology STANKIN, Russian Federation
ciber200hlm500x@yandex.ru

Keywords: Structural optimization,layered structures,moving web

Abstract: The stability analysis and optimization of elastic web travelling between two rollers with a constant velocity are presented. The mathematical model for a layered travelling web (continuous isotropic composite plate) is developed restricting the consideration to one open draw. The layered plate with various mechanical properties of layers is considered and analytical expressions for the effective characteristics are derived. As a result the composed structure can be considered as an isotropic homogeneous plate and the obtained formulas for computation of critical velocity can be applied. Then the isoperimetric optimization problem is formulated and studied. The total mass of the layered plate is considered as an isoperimetric condition. The critical divergence velocity is taken as an optimized quality criterion. To this end consisted in maximization of the web stability and for maximization of the divergence velocity with respect to material distribution, the evolutionary optimization method (genetic algorithm) is applied. The number of materials is supposed to be given. Applying the genetic algorithm we distribute these materials on the plate thickness (provide the optimal plate consisted of some layers of different thickness) and maximize the critical velocity under the constraint on the total mass of the structure. Numerical results are presented for different sets of problem parameters. It is noted that the considered problem and applied approach can be generalized and also used for the cases with incomplete data concerning the properties of materials.

The work was supported by the Russian Science Foundation (project 17-19-01247).

Abstract ID 1275

AN OPTIMIZATION APPROACH FOR AN ULTRA EFFICIENT ELECTRIC RACING VEHICLE'S SUPPORTING SYSTEM BASED ON COMPOSITE SHELL ELEMENTS.

Wojciech Skarka, Tomasz Pabian

Silesian University of Technology, Poland
wojciech.skarka@polsl.pl, tomasz.andrzej.pabian@gmail.com

Keywords: electric vehicle,composite structure,monocoque,supporting structure,topology optimization,energy-efficient vehicle

Abstract: In a process of designing an ultra efficient objects, one of the most important issues is to minimize an overall resistance in each of its components. However, the process is complex and time consuming, as every element should be treated separately and a whole object must be also considered as a unity. With a usage of different optimization tools, a designer is able to obtain the best possible solution with given constraints and conditions. In this paper, an optimization approach for an ultra efficient electric vehicle is presented. The analyzed object is a supporting system for an electric vehicle powered by a hydrogen fuel cell designed by Smart Power Team from the Silesian University of Technology, which is dedicated to participating in Shell Eco-marathon competition, in a UrbanConcept class. During the race, not a total time is taken into consideration, but a total amount of used fuel, with the least, the higher position of a competitor. Therefore each subassembly of a vehicle must be optimized with a consideration of energy efficiency. In case of the supporting system based on shell elements, three main areas of optimization can be distinguished: body's shape, other subassemblies' placements and their connections to the system and an inner and outer structure of shell elements. As the supporting system is not a part of a drivetrain, its impact on the vehicle's total efficiency is not direct and can be analyzed mostly in consideration of its mass but also stiffness, which impacts on other subassemblies performance. Due to the fact that body panels are integrated parts of the supporting system, the shape optimization, mostly due to aerodynamic properties, was already conducted and is not a part of this paper. Moreover, the optimization process, based on topology optimization of the shell structure and laminates' thickness and plies' thickness and sequence was already conducted for the previous iteration of the outer shape of the vehicle, therefore most crucial areas of the structure have been already identified and basic methodology has been already developed. As the vehicle is driven with considerably low velocities and on a proper racetrack, loads introduced to the supporting system are relatively small and a loads structure is simpler than in case of a typical commercial vehicle.

Abstract ID 1276

OPTIMISATION OF A COMPOSITE BEAM-BASED LOAD BEARING STRUCTURE, FOR AN ULTRA-EFFICIENT ELECTRIC VEHICLE.

Wojciech Skarka, Michał Sosnowski

Silesian University of Technology, Poland
wojciech.skarka@polsl.pl, michal.filip.sosnowski@gmail.com

Keywords: electric vehicle,supporting structure optimization,spatial frame,energy-efficient vehicle

Abstract: Continuous development of technologies and state of the environment, as well as emerging from these sources combined market demands, requires creating energy efficient vehicles for the daily commute purposes. The goal of this paper is to present optimisation process of the load bearing structure, which is a part of hydrogen fuel cell powered vehicle, that can be described as a small urban car. Due to its purpose, it is not capable of travelling with high velocities and does not have to cope with major road irregularities. The structure had to obey rules and regulations of Shell Eco-Marathon competition, in which it is going to take part in the custody of Smart Power Team from the Silesian University of Technology in Gliwice. Impact on efficiency, from the structure point of view, comes from aerodynamics, weight and stiffness, which may influence different subassemblies efficiency. The analysed vehicle already possessed shape of the fuselage, which was previously optimised to improve aerodynamics. Therefore, the subject of skin shape optimisation was not taken into consideration in this paper. Nevertheless, deep understanding and familiarity of the outer shape were required, to create efficient supports that transfer loads- for example, aerodynamic loads and ensure fuselage stiffness and mounting to the chassis. As the main goal of the structure was to obtain low weight, materials used in the load bearing system were mainly composite materials like carbon fibre tubes and sandwich structures, but also 3D printed elements. The secondary objective of the conducted work was to develop a structure, which as many parts as possible may be created and assembled by students. As a result of such an approach, costs were reduced significantly and educational value to the project was added. To obtain this goal, without sacrificing the safety of the vehicle and its driver, a special type of joints between carbon fibre tubes was developed in previous work and applied in this design. The methodology used during the optimisation process was based on experiences gathered during simliar structure design by the authors and its main principle is topology optimisation. In order to obtain further improvements, deeper analysis of the structure was required, and as a result number of steps followed during optimization process increased.

Abstract ID 1277

OPTIMISATION OF FIBRE-PATHS IN COMPOSITES PRODUCED BY ADDITIVE MANUFACTURING

Rafael Ferreira[1], Ian Ashcroft[2], Shuguang Li[2], Peng Zhuo[2]

[1]Instituto Tecnológico de Aeronáutica, Brazil
rthiago@ita.br

[2]University of Nottingham, United Kingdom
ezzia@exmail.nottingham.ac.uk, epzsl2@exmail.nottingham.ac.uk, epxpz@exmail.nottingham.ac.uk

Keywords: additive manufacturing,continuous carbon fibre composites,optimisation

Abstract: An innovative research front for composites is their production by additive manufacturing (AM), also referred to as 3D printing. AM, which was previously mainly used for prototyping, is now evolving towards functional components. Part of the motivation in the search for AM developments to fibre composites is to explore the inherent flexibility of the related processes, for example the possibility of laying curved fibre-paths within a component. This work aims to present a variable stiffness curve-based design parametrization to the optimisation of a 3D printed aeronautical lug, made of thermoplastic polymer reinforced by continuous fibres. Results on structural modelling for stiffness and strength show that these quantities behave in different manners for the assumed parametrization. An optimisation problem is proposed, and it is expected that optimised designs for stresses may further enhance the applicability of 3D printed composites in load bearing situations.

Abstract ID 1278

ASSESSMENT OF STANDARDIZATION OF COMPATIBILITY USING GENETIC ALGORITHMS

Luis Sousa(1), Diogo Rechena(2), Virgínia Infante(3)

(1)Instituto Superior Tecnico, Portugal
luis.goncalves.sousa@tecnico.ulisboa.pt

(2)Instituto Superior Técnico, Portugal
diogo.rechena@tecnico.ulisboa.pt

(3)Instituto Superior Técnico, Afghanistan
virginia.infante@tecnico.ulisboa.pt

Keywords: standardization,Genetic Algorithm,local search

Abstract: In manufacturing companies, every time a new product is developed, designers tend to recreate components instead of using the existing designs causing design divergence. This causes manufacturing cost increases as well as increases in time to market for new products. Through Standardization, it is possible to take advantage of the benefits of mass production such as increased reliability, lower lifecycle costs and lower time to market in product development. In firms, during standardization processes, candidates are searched in databases through Shape Similarity Assessment Algorithms (SSAA). While current SSAA provide a means of reducing part proliferation during the development of new products, they are unsuccessful when it comes to assess if any pair of components is standardisable mainly due to their insensitivity to component details such as component interfaces. In this work, a set of standardization compatibility metrics for the selection of standardization candidates is proposed. This is achieved through the development and application of a voxelization algorithm which assesses volumetric commonalities between the assessed geometries. The metrics are dependent on the relative alignment between components, and maximum standardization compatibility is only achieved if the alignment is such that there is a match between interfaces of different components. In this work a local search Genetic Algorithm is applied so as to find the optimal alignment between components for the development of standard designs. Preliminary results indicate that while there are several local optimal results for the proposed metrics, the global solution is attainable using a local search approach as opposed to conventional genetic algorithms, which tend to converge to local optima.

Abstract ID 1279

OPTIMAL FEED TEMPERATURE FOR THE DECOMPOSITION PROCESS OF HYDROGEN PEROXIDE OCCURRING IN THE REACTOR WITH FIXED-BED OF COMMERCIAL CATALASE

Ireneusz Grubecki

UTP University of Science and Technology, Poland
ireneusz.grubecki@utp.edu.pl

Keywords: Optimal feed temperature,Maximum hydrogen peroxide conversion,Parallel deactivation,Immobilized commercial catalase,Diffusional resistances,Fixed-bed reactor

Abstract: Fixed-bed reactors are important workhorses in biochemical industry because of their efficiency, low cost, and type of construction, operation, and maintenance. These (bio)reactors are widely em-ployed since use of immobilized enzymes offers an easy product separation, less enzyme loss, in-crease in thermal and operational enzyme stability, enzyme protection against harmful environmental stress, and a better control of process. Design and optimization of fixed-bed reactors are not an easy task and often involve an inherent trade-off between different and conflicting objectives. Particular-ly, in case of bioprocesses, optimal conditions assurance can be a very challenging task (even if the process model is available) because of enzyme deactivation which is not always taken into account to predict proper bioreactor. The factors responsible for enzyme deactivation characteristics in rela-tionship to the main enzyme catalysed reaction can be decisive in choosing the reactor operating mode and optimal operating conditions for biotransformations course. Biocatalyst deactivation dependent on substrate concentration (parallel deactivation) is the specific one and makes enzyme activity both function of time and position. Such deactivation mechanism is related to catalase which has intensively been applied for elimination of residual hydrogen peroxide in various domains such as textile, food, and semiconductors industries, as well as the waste waters treatment and cosmetics and pharmaceutical formulations in biosensor system. One can notice that the optimal operating conditions in a continuous packed-bed reactor for hydrogen peroxide decomposition are not easy to implement in industrial practice, because of the dependences of state variables being a functions of time and reactor length. Additionally, when working with immobilized enzymes (especially catalase), internal and/or external diffusional resistances are likely to occur regardless method of immobilization used. Practically, in the most simple way, an optimal operating strategy can be accomplished by searching for a suitable feed temperature yielding the maximum bioreactor productivity. Hence, the objective of the present study was to search for – under constant feed flow rate – the optimal feed temperature of the fixed-bed reactor performing hydrogen peroxide decomposition by immobilized onto the non-porous glass beads Terminox Ultra catalase. The optimal feed temperature was obtained by maximizing time-averaged hydrogen peroxide conversion accounting for the lower and upper temperature constraints as well as diffusional resistances expressed by global effective-ness factor. The obtained results can improve the knowledge of the hydrogen peroxide decomposed by catalases from various sources and the selection of operating conditions.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1281

TOPOLOGY OPTIMIZATION OF STRUCTURES IN CONTACT

Luis Fernandez[1], Daniel Tortorelli[2]

[1]UIUC, United States
lfferna2@illinois.edu

[2]Center for Design and Optimization, Lawrence Livermore National Laboratory, United States
tortorelli2@llnl.gov

Keywords: contact,segment-to-segment,topology optimization,B-spline

Abstract: Appropriate modeling of the boundary conditions is crucial to the design of structural components. Poor modeling results in poor designs. Of these conditions, contact is the one that dominates countless physical situations, e.g., crashworthiness, wear, and lubrication, etc. Indeed, contact is present in every structure because loads are transferred from one body to another via contact. However, contact modeling is challenging so it is often replaced by simple traction and/or displacement boundary conditions which compromises the accuracy of the simulation. Works in the Topology Optimization (TO) of structures in contact are primarily restricted to rigid obstacle problems. Contact of bodies with nonconforming mating meshes requires more advance segment-to-segment modeling techniques, which are rarely used. Indeed, most of the numerical examples are two-dimensional. Our research is devoted to the TO of structures in contact using more advanced modeling techniques to address design problems with multiple deformable components in contact. Since the contact problem is computationally expensive, we use efficient optimization algorithms which require sensitivity analysis. Novel features of our proposed work include the use of a general continuum formulation of the contact model, making it suitable for large deformation problems and arbitrary discretizations. Also, we use a mortar segment-to-segment approach to solve the contact problem of two deformable bodies with dissimilar meshes. Moreover, we use a B-spline design parameterization to 1) reduce the number of design variables in comparison to element-wise parameterizations and 2) regularize the TO problem. Additionally, we propose to use the following well-known techniques: penalty and augmented Lagrangian methods to enforce contact constraints, analytical adjoint sensitivity analysis to compute the gradients of general functionals, efficient gradient-based optimization algorithms to effectively transverse the design space, e.g., the Interior Point Optimizer (IPOPT), and the SIMP density method of TO. Finally, we will provide numerical examples to validate our study.

Abstract ID 1282

APPLICATION OF GLOBAL OPTIMIZATION METHODS IN MULTISCALE INVERSE PROBLEM SOLUTION

Waclaw Kus

Silesian University of Technology, Poland
waclaw.kus@polsl.pl

Keywords: numerical homogenization,optimization,inverse problem,biomechanics,FEM

Abstract: The multiscale modelling of materials plays important role in engineering design and biomechanical analysis of tissues. The multiscale methods allow to take into account influence of microstructure of the macro model behaviour. The paper deals with multiscale modelling of hyperelastic biomechanical tissue. The tissue is modelled with use of numerical homogenization technique. The direct problems are solved with use of the Finite Element Method. The mechanical macro parameters of tissue can be obtained on the experimental way, but the properties of microscale sometimes must be determined using inverse problems. The author propose the formulation of the inverse problem as a optimization problem with objective function depended on macro level properties. The design variables describe material properties in micro level. The minimization of objective function leads to design variables values which should correspond with micro level material properties. The nonuniqueness of solutions of the inverse problems are well known problem. The optimization with use of global optimization evolutionary based algorithm is considered, the algorithm is used many times to empirically check the problems with nonuniqueness. The optimization algorithm is implemented in commercial FEM software. The full paper contain information about evolutionary algorithm, implementation of algorithm in FEM software, description of multiscale algorithm, the inverse problem formulation and tests. The material properties in microscale for models of brain tissue are considered as a numerical examples.

Acknowledgement. The research is partially financed from statutory subsidy of the Faculty of Mechanical Engineering of the Silesian University of Technology in 2018 and BK226/RMT4/2018

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1283

OPTIMUM DESIGN OF PARKING-LOTS WITH MULTIPLE VEHICLE TYPES, PARKING FEES AND SERVICE CLASSES

Partha Chakroborty, Parikshit Sharma

Indian Institute of Technology, Kanpur, India
partha@iitk.ac.in; parikshi@iitk.ac.in

Keywords: Parking-lot design,Non-linear mixed-integer problem,Genetic Algorithm

Abstract: Many facilities like airports, train stations, etc. provide parking-lots for vehicles. Vehicles that arrive are of multiple types (with different parking space requirements) and often demand different kinds of parking services – some want long-term parking while others short-term. Parking fees also impact demand for parking. Hence, in addition to the question (i) how big (in terms of capacity) should a parking-lot be, the following questions are also relevant: (ii) how should the total capacity be distributed among the different vehicle types and service classes and (iii) how much should the parking fees be? In this work the authors attempt to answer these questions. The answers depend on what the transport planner wishes to achieve. For example, one planner may want to minimize the probability of not finding space in the parking-lot while another may want to minimize the operator's revenue loss. Here, mathematical programming (MP) formulations for various types of objectives are developed and solved. The constraints to the problems arise out of service quality and space restrictions, and parking fee requirements. A parking-lot behaves as a capacity-constrained, multiple-server queuing system where the capacity and the number of servers are equal to the number of parking-stalls in the parking-lot. In this problem, the state of the system is represented as $n=[n_{1,1},\cdots,n_{(i,j)},\cdots,n_{(I,J)}]$ where $n_{(i,j)}$ is the number of spaces occupied by vehicles of type i and service class, j. P(n), the probability that the system is in state n, turns out to be a non-linear expression (involving finite series sums) of variables like, parking capacity $C_{(i,j)}$, mean arrival-rate $\lambda_{(i,j)}$, mean parking duration $\delta_{(i,j)}$, parking fee, etc. Thus the MP formulations involve constraints and objectives that are non-linear functions of the decision variables of which $C_{(i,j)}$ are integers. This makes the problem a non-linear, mixed integer-programming problem – a problem class that is notoriously difficult to solve using traditional techniques. Consequently, Genetic Algorithms (GA) is used to determine the optimal solutions. In order to establish the quality of these solutions, for some special cases, piece-wise approximations for P(n) are developed and used to obtain optimum solutions using analytical methods. These when compared with GA-based solutions indicate that GA provides good solutions. Finally, based on the optimum solutions obtained here, an attempt is made to develop rules-of-thumb that can be easily employed to arrive at good design solutions for parking-lots with multiple vehicles types, parking fees and service classes.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1284

MULTI-OBJECTIVE MEMETIC ALGORITHM BASED ON LEARNING FOR SUSTAINABLE DESIGN OF FRP COMPOSITE STRUCTURES

Carlos António

LAETA (INEGI), Faculdade de Engenharia, Universidade do Porto, Portugal
cantonio@fe.up.pt

Keywords: Multi-objective optimization,sustainability,hybrid composites,memetic learning,non-domination,co-evolution.

Abstract: An approach for decreasing costs in lightweight structures using FRP composite materials is proposed based on a hybrid construction where expensive and high-stiffness materials performs together with inexpensive and low-stiffness material. The optimal design of hybrid composite stiffened structures is addressed as sizing, topology and sustainable material selection in a multi-objective optimization framework. Minimum weight (cost), minimum strain energy (stiffness) and maximum sensitivity to sustainable factors are the objectives of the proposed structural robust design approach. The model performs the trade-off between the performance targets against sustainability, depending on given stress, displacement and buckling constraints imposed on composite structures. The design variables are ply angles and ply thicknesses of shell laminates, the cross section dimensions of stiffeners and the variables related to material selections' and structural distribution. A Multi-objective Memetic Algorithm (MOMA) searching Pareto-optimal front is proposed. MOMA applies multiple learning procedures exploring the synergy of different cultural transmission rules. These rules are associated with some kind of problem knowledge and learning classified as Lamarckian or Baldwinian. The memetic learning procedures aim to improve the exploitation and exploration capacities of MOMA. It is implemented the selfish gene theory using a fusion of concepts. The age structure performs together with feature-based allele's statistics analysis used in the learning procedure implemented inside a virtual population (VP) using the rules: (i) storage of the ranked solutions aiming to obtain the Pareto front and (ii) evolution as a virtual population of alleles. A self-adaptive genetic search incorporating Pareto dominance and elitism performs together in the proposed MOMA. Two concepts of dominance are used: the first one denoted by local non-dominance performs at the isolation stage of populations and the second one called global non-dominance performs on the age structured VP. The age control emulates the human life cycle and enables to apply the species conservation paradigm. The crossover operator applied to age-structured VP results from the development of new mating and offspring selection mechanisms considering age control and dominance. The concept of species associated with material choice and distribution on composite structures is used. A detailed analysis of solutions/individuals at the Pareto-optimal front reveals that they belong to different species. From this, it concludes that MOMA is successful in preserving the population diversity. Furthermore, MOMA is able to indicate alternative optimal designs based on different species what might be very important for the designers in multi-objective design sustainable optimization of stiffened composite structures.

Abstract ID 1285

OPTIMIZATION OF GRIPPER TRAJECTORIES IN AUTOMATED COMPOSITE DRAPING

Christian Krogh[(1)], Johnny Jakobsen[(1)], James Sherwood[(2)]

[(1)]Aalborg University, Denmark
ck@mp.aau.dk, joj@mp.aau.dk

[(2)]University of Massachusetts, Lowell, United States
james_sherwood@uml.edu

Keywords: Composites,Carbon fiber prepreg,draping,trajectory optimization,automation

Abstract: “FlexDraper” is being developed as an automated solution for the draping of woven carbon fiber prepregs. The “FlexDraper” system is comprised of an array of actuated grippers mounted on an industrial robot. This robotic system cando a one-by-one ply placement (draping) of a set of fabrics onto a mold surface to provide a repeatable and automated composite manufacturing process. A major challenge for this automated draping is to determine the respective movements for each of the grippers such that the draped configuration matches a prescribed boundary and does not induce any out-of-plane wrinkles. In a previous research effort, an advanced nonlinear, rate-dependent Finite Element (FE) model was created and used to study the problem with simple gripper movements. It was found in that study that the placement of the ply is highly dependent on the path taken by the grippers and that wrinkles can easily form during draping. Thus, it was concluded that a concerted effort should be put into determining the optimal gripper trajectories. While the FE model agrees well with experimental results, it is also computationally expensive. Thus, it is not suitable for completing optimization analyses and a faster, approximate model must be developed. In the present study, the fiber ply is modelled by a series of catenaries, i.e. curves that represent the behavior of cables supported at the end points. To match the experimentally measured behavior of the fiber ply, a catenary model with added bending stiffness is employed. An optimization framework is set up such that the respective movements of the grippers from the initial configuration with the ply suspended above the mold, to the final draped configuration, can be determined. The movement of the grippers is divided into steps, where in each step, an optimization problem is solved with move limits imposed on the grippers. In this way, the trajectories of the grippers can be mapped. Before mold contact, the objective is – in addition to minimizing the mold-ply distance – to position the ply such that it will match the prescribed boundary at the end of the placement process. After mold contact, the objective is to minimize the difference between the slopes of the ply and the mold at the contact point. In this manner, the ply will be rolled onto the mold and wrinkling will be mitigated. Ultimately, the generated gripper movements are used in the FE model and compared to experimental results.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1286

IDENTIFICATION OF IMMERSED OBSTACLES VIA EXTENDED BOUNDARY MEASUREMENTS USING A GAME STRATEGY APPROACH

Marwa OUNI[1], Abderrahmane HABBAL[2], Moez KALLEL[1]

[1]University of Tunis El Manar, ENIT-LAMSIN, Tunisia
marwa1ouni@gmail.com, moez.kallel@enit.utm.tn

[2]University of Côte d'Azur, J.A. Dieudonné laboratory,, France
habbal@polytech.unice.fr

Keywords: Data completion,Geometric inverse problem,Stokes problem,Nash game

Abstract: In this work, we consider the identification of one or more obstacles immersed in a viscous and incompressible fluid flow governed by the Stokes equations, from incomplete over-specified measurements at the boundary of the flow. Our purpose is to extend the method introduced in [1], based on a game theory approach, to develop a new algorithm for simultaneous identification of the objects and missing boundary data, of Dirichlet and Neumann type conditions. Consider a bounded open domain, which is filled with a fluid. Its boundary is sufficiently smooth and composed of two connected components. We consider an unknown obstacle immersed in this domain. The inverse problem considered here consists, then, from the given velocity and stress forces on an accessible part of the outer boundary, to determine the unknown obstacle such that the fluid velocity u and the pressure p verified the Stokes system with homogeneous Neumann boundary conditions on the obstacle using the Neumann and Dirichlet data on an accessible part of the outer boundary. This problem is formulated as a Three-player Nash game. The first player takes the known Dirichlet data and uses the Neumann condition on the inaccessible part of the outer boundary as a strategic variable. The second player is given the known Neumann data, and plays with the Dirichlet condition prescribed over the inaccessible boundary. Both of the two players consider a response fixed by the third player, which controls the obstacle shape. We have adopted the level-set method for an implicit representation of the contour of this object. Then, we introduce three objective functions, where each player tries to optimize his own cost by seeking to converge towards an equilibrium that represents a compromise between them. This equilibrium is defined as a solution of the multi-objective optimization problem (Nash equilibrium) and which is expected to approximate the coupled problem solution. In order to test the efficiency and robustness of the proposed approach and to compare with the existing methods, a numerical study is carried out for different forms of the obstacle.

References

[1] A. Habbal and M. Kallel. << Neumann-Dirichlet Nash strategies for the solution of elliptic Cauchy problems >>. SIAM Journal on Control and Optimization, 51:4066–4083, 2013.

Abstract ID 1287

AN OPTIMIZATION APPROACH TO GENERATE ACCURATE AND EFFICIENT LOOKUP TABLES FOR ENGINEERING APPLICATIONS

Hugo Magalhaes[1], Filipe Marques[2], Binbin Liu[3], João Pombo[4], Paulo Flores[2], Jorge Ambrósio[1], Stefano Bruni[3]

[1]LAETA/IDMEC Instituto Superior Técnico, Portugal
hugomagalhaes@tecnico.ulisboa.pt; jorge.ambrosio@tecnico.ulisboa.pt

[2]Universidade do Minho, Portugal
fmarques@dem.uminho.pt, pflores@dem.uminho.pt

[3]Polictenico di Milano, Italy
binbin.liu@polimi.it, stefano.bruni@polimi.it

[4]Heriot-Watt University, United Kingdom
j.c.pombo@hw.ac.uk

Keywords: Lookup table generation; Sequential optimal design; Unidirectional search; Interpolation accuracy; Engineering applications.

Abstract: Lookup tables are used to substitute time-consuming online calculations in many computational dynamics methods, as for instance for the railway wheel-rail interaction. In a wide number of engineering applications, the use of lookup tables can drastically reduce simulation times without greatly compromising accuracy, due to interpolation errors. The generation of a lookup table consists of pre-calculating the set of quantities that are required for the dynamic analysis, which covers the study domain. Thus, the computational cost of calculating these quantities is shifted from the numerical simulation to the generation of the lookup table, which is only performed once. During the dynamic analyses, the tables are interpolated to get all required parameters. The selection of the points that describe the lookup tables domain is of importance to ensure not only that the interpolated values are sufficiently accurate, but also that the number of points used is minimized. Currently, lookup tables are generated without involving measures to make them simpler or without error minimization in mind. To overcome this shortcoming, an optimization approach to automatically generate lookup tables with a prescribed accuracy is presented here. The points of a lookup table domain are grouped in a set of layers. The thicknesses of these layers represent distances between the points. To reach faster interpolations, the minimum size of the lookup table is identified, that is, the minimum number of points that define the lookup table domain. This objective consists of maximizing the layers thicknesses. In turn, to ensure specified accurate interpolations of the lookup table, the thicknesses of the layers are defined such that the deviation between interpolated and exact values at selected control points are kept under specified tolerances. Thus, the automatic lookup table generator tool developed in this work uses a sequential optimization strategy to design the layers of the lookup tables domain. To design the thicknesses of each layer, a dedicated optimization algorithm has been implemented. This algorithm uses a unidirectional search strategy that only considers the growth of the design variables. The optimization procedure reaches the optimal result when a layer cannot be thickened anymore without exceeding the specified tolerances for the interpolation errors. To demonstrate the performance of the proposed approach, lookup tables have been generated for known analytical functions, being adjusted the optimization options to reduce the time consumption. It is demonstrated that this work provides a reliable lookup tables generator to be applied in engineering applications.

Abstract ID 1288

DISCONTINUOUS PETROV-GALERKIN METHODS FOR TOPOLOGY OPTIMIZATION

Anton Evgrafov

DTU Mechanical Engineering, Denmark
aaev@mek.dtu.dk

Keywords: Discontinuous Petrov-Galerkin methods,DPG,topology optimization

Abstract: Discontinuous Petrov-Galerkin (DPG) methods constitute a modern class of finite element methods, which present several advantages when compared with traditional Bubnov-Galerkin methods, especially when the latter is applied to indefinite or non-symmetric problems. For example, under minimal assumptions about the solvability of a given boundary value problem (BVP) the method results in stable, symmetric and positive definite discrete problems for a very wide range of possible finite element approximations of the fields, involved in the problem's formulation. Additionally, as a by-product of the solution procedure, the method produces element-wise residual estimates, which can be utilized for adaptive mesh refinement or simply as a qualitative measure of infeasibility of a current solution approximation with respect to a given BVP. Our goal is to utilize these advantages of DPG methods in the context of topology optimization. Unfortunately, the direct application of DPG discretizations to the BVPs arising in topology optimization is hindered by the very unusual scaling of the residual, caused by the gigantic jumps in the coefficients of the governing differential equations. For example, in the canonical case of linearized elasticity with SIMP model the coefficient ratio between the "stiff" and "soft" phases is held at a billion, which is then further squared by Petrov-Galerkin methods based on minimizing the squared residual. We introduce a DPG method with appropriately scaled residual norm, which allows us to deal with big contrast ratios in the coefficients. We then apply this method to benchmark topology optimization problems appearing in linearized elasticity.

Abstract ID 1289

AN ALGORITHM FOR CONSTRAINED OPTIMIZATION WITH APPLICATIONS TO THE DESIGN OF MECHANICAL STRUCTURES

Cristian Barbarosie[(1)], Sérgio Lopes[(2)], Anca-Maria Toader[(1)]

[(1)]CMAF-CIO, Lisbon University, Portugal
cabarbarosie@fc.ul.pt, atoader@fc.ul.pt

[(2)]CMAF-CIO, Lisbon University and ISEL, Instituto Politécnico de Lisboa, Portugal
slopes@adm.isel.pt

Keywords: constrained minimization,worst case design,minimax problems,active set strategy

Abstract: We propose an algorithm for minimization of a functional under constraints. First, an algorithm for minimization under equality constraints is devised. It uses first-order derivatives of both the objective function and the constraints. The step is computed as a sum between a steepest-descent step (which minimizes the objective functional) and a correction step related to the Newton method (which aims to solve the equality constraints). The linear combination between these two steps involves coefficients similar to Lagrange multipliers which are computed in a natural way based on the Newton condition. The algorithm uses no projection and thus the iterates are not feasible; the constraints are satisfied only in the limit (after convergence). A local convergence result is proven for a general non-linear setting, where both the objective functional and the constraints are not necessarily convex functions. In a second stage, this algorithm is extended, by means of an active set strategy, to the case of inequality constraints. Active constraints are treated as equality constraints. Inequality constraints are activated as soon as they are violated. However, they are not deactivated as soon as they become fullfilled. Instead, a deactivation criterion is used, based on the sign of the associated Lagrange multiplier. As a (trivial) third step, the algorithm is generalized in order to deal with minimax problems, which are relevant for structural optimization. An example of worst case design is discussed in the framework of optimization of mechanical structures with multiple load cases. Numerical results are presented.

Abstract ID 1290

ON RECENT DEVELOPMENTS IN LAYOUT OPTIMIZATION OF LARGE-SCALE TRUSSES

Tomasz Sokół

Warsaw University of Technology, Faculty of Civil Engineering, Poland
t.sokol@il.pw.edu.pl

Keywords: truss topology optimization,Michell structures,adaptive ground structure method

Abstract: The paper deals with a specific ground structure method for topology optimization of large-scale trusses approximating Michell structures. The ground structure methods are expensive but robust. The optimization process consists in finding the optimal subset of active bars from a prescribed set of possible bars connecting nodes. The bars that do not transmit any forces disappear and are eliminated in the final solution. The nodes have fixed positions (coordinates). Therefore, they must be arranged quite densely to obtain good approximations of exact solutions. This leads to huge optimization problems that are expensive and hard to solve in a direct way. This obstacle can be overcome by the adaptive ground structure method proposed by Gilbert and Tyas [1] and later developed by the author [2]. On the other hand, due to fixed positions of nodes the topology optimization problem can be formulated and solved in the framework of linear programming (which is convex and free of local minima). This enables finding a globally optimal solution. In the present paper we discuss different strategies of reducing the size of the optimization problem by applying selective subsets of active bars and nodes. An important improvement to adaptive ground structure methods is proposed. This improvement allows better reduction of the problem size by eliminating greater number of unnecessary bars. This reduction is possible thanks to adjusting adjoint displacement field in empty regions where no material is needed. This adjusting phase requires solving an auxiliary linear programming problem of relatively small size. This improvement is particularly important for multi-load 3D problems because the optimal spatial trusses tend to assume forms of lattice surfaces while most of design space becomes empty. It is worth noting that despite the iterative character, the method guaranties the convergence to the optimal solution because at the end the strains in all potential bars have to satisfy Michell optimality criteria. The newest version of the implemented method allows solving tasks with billions of potential bars and enabled to obtain new important solutions which extend the class of known Michell trusses to 3D space and multiple load conditions.

References

[1] *M. Gilbert, A. Tyas, Layout optimization of large-scale pin-jointed frames, Engineering Computations, 20, 2003.*

[2] *T. Sokół, On the Numerical Approximation of Michell Trusses and the Improved Ground Structure Method. In: Schumacher A., Vietor T., Fiebig S., Bletzinger KU., Maute K. (eds) Advances in Structural and Multidisciplinary Optimization, pp.1411-1417. WCSMO 2017. Springer, 2018.*

Abstract ID 1292

CONSIDERATION OF STRUCTURAL MEMBER DEFORMATION CONSTRAINTS USING LAGRANGE MULTIPLIERS

Luiz Fernando Martha[(1)], Guilherme Barros[(1)], Evandro Parente Junior[(2)]

[(1)]PUC-Rio, Brazil
lfm@tecgraf.puc-rio.br, gbarros@tecgraf.puc-rio.br

[(2)]UFC, Brazil
evandro@ufc.br

Keywords: Matrix Structural Analysis,Educational Software,Rigid Members,Inextensible Members,Strain Constraints,Lagrange multipliers.

Abstract: This paper is concerned with the analysis of framed structures with inextensible and rigid members, i.e. members without axial and bending strains. Rigid and inextensible members may be useful in educational software because they capture the essence of the structural behavior with a reduced the number of variables. In addition, they allow a comparison with results obtained by hand calculation using classical structural analysis methods. There are three main approaches to constraint handling: transformation, penalty function and Lagrange multiplier methods (Zienkiewicz et al., 2013; Cook et al., 2002; Felippa, 2017). The transformation methods, also known as master-slave elimination, use each constraint to eliminate one equilibrium equation, reducing the number of degrees of freedom. However, this approach does not allow the determination of axial forces in inextensible member or bending moments in rigid members. The implementation of the penalty function method is trivial, since physically it corresponds to assign a very large number to the axial stiffness (EA) of inextensible members and a very large number to the bending stiffness (EI) of rigid members. However, as the penalty factor increases, the stiffness matrix becomes increasingly ill-conditioned, leading to large solutions errors. This paper presents a methodology for considering structural member deformation constraints using Lagrange multipliers. It consists of adding strain constraints into the total potential energy minimization, leading to a quadratic programming problem. In addition, this approach is very suitable for computational implementation because it does not affect the generic characteristic of a matrix structural analysis. The solution gives rise to one Lagrange multiplier per constraint, which is essential for computing member internal forces. However, there are situations in which inextensible and rigid member constrains may be redundant, which prevents the determination of dependent Lagrange multipliers. In these cases, it is not possible to determine internal forces in the members with redundant constraints. Although not implemented, a special treatment is indicated for determining member internal forces in these situations.

Abstract ID 1293

ON DESIGN OPTIMIZATION OF HEAT SINKS WITH CURVATURE CONSIDERATIONS FOR ADDITIVE MANUFACTURING

Yoshihiro Tateishi[1], Hiromichi Gohara[2], Ryoichi Kato[2], Yoshinari Ikeda[2], Victor Parque[1], Tomoyuki Miyashita[1], Muhammad Khairi Faiz[1], Makoto Yoshida[1]

[1]Waseda University, Japan
yt-d21tt@fuji.waseda.jp, parque@aoni.waseda.jp, tomo.miyashita@waseda.jp, khairifaiz296@akane.waseda.jp, makoto-yoshida@waseda.jp

[2]Fujielectric Co., Japan
gohara-hiromichi@fujielectric.com, katou-ryouiti@fujielectric.com, ikeda-y@fujielectric.com

Keywords: Heat Sink,Design Optimization

Abstract: As recent power modules and semiconductor devices demand the utmost performance in small and light-weight structures, the design and the manufacturing of heat sinks that offer maximal cooling performance has become a challenge due to continuously evolving miniaturization and smaller cooling areas. In line of the above, and for practical realizations, heat sinks having the ability to operate in limited volume, as well as having simple geometry are highly desirable due to existing limitations in cooling area and machining processes. In this paper, we propose a methodology to design heat sinks that aim at minimizing temperature and pressure loss based on curvature considerations, as well as design of experiments and response surfaces. Exhaustive simulations and sensitivity analyses based on Finite Element Method have shown the improved cooling performance in terms of thermal resistance when compared to the conventional heat sinks with straight fins. Also, our proposed approach maximizes the contact area between the refrigerant and the heat sink, and increases the refrigerant flow velocity when compared to the conventional heat sink. Furthermore, the unique point of our proposed approach lies not only in the simplicity of the geometry of the heat sink, but also in the higher cooling performance, which is key to realize enhanced cooling mechanisms by existing metal-based 3D printers. We believe our approach offers the building blocks to enable the design and realization of heat sinks with manufacturable geometry and utmost cooling performance. As such, our proposed approach has the potential to capitalize on the benefits of metal-based 3D printing technologies, enabling the possibility to realize challenging geometries.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1294

OPTIMAL SCHEDULING OF TUNNEL INSPECTION AND MONITORING FOR LEVELING YEARLY BUDGET

Hiroshige Dan(1), Ayaka Yamamoto(1), Hiroaki Tanaka-Kanekiyo(1), Atushi Sutoh(2), Osamu Maruyama(3), Takashi Satoh(4)

(1)Kansai University, Japan
dan@kansai-u.ac.jp, nyaasu6@gmail.com, hiro.t.k@kansai-u.ac.jp

(2)Tohoku Institute of Technology, Japan
atsu-sutoh@tohtech.ac.jp

(3)Tokyo City University, Japan
omaruya@tcu.ac.jp

(4)Civil Engineering Research Institute for Cold Region, Japan
taka4@ceri.go.jp

Keywords: Scheduling,Tunnel,Inspection,Monitoring,Civil Engineering

Abstract: Many infrastructures were built in 1950's and 60's intensively in Japan, which was the highest economic growth period. They got older in half a century, and now it is an urgent task to inspect and maintain such aging infrastructures. In this research, we focus on the inspection and monitoring schedule of tunnels. In Japan, 130-meter-section of ceiling panels fell at Sasago tunnel (Yamanashi prefecture, Japan) in 2012. Three vehicles were crushed and nine people were killed in the incident. After that, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) renewed the manual of tunnel inspection. The renewed manual instructs that all tunnels must be inspected within every five years and its status of deterioration is graded. Moreover, if the grade of a tunnel falls below the predetermined threshold, the tunnel must be monitored within two years from the last inspection or monitoring. On the other hand, such inspections and monitoring activities need money. Generally, for tunnels which are the property of a local government, inspection and monitoring fee would be paid by that government. Therefore, the government must prepare a budget for such activities. However, if the number or total lengths of inspected and monitored tunnels are biased from year to year, then it is difficult to get enough budget for the year in which there are many inspected and monitored tunnels. In this research, we proposed an optimization model to level the yearly budget for tunnel inspections and monitoring activities. To tell the truth, the manual allows to accelerate the inspection schedule: for example, we can inspect a tunnel within four years. By using this allowance, we can resolve the bias and level the yearly budget gradually. On the other hand, this leveling procedure would increase the aggregate budget of a target period because the total number of inspections and monitoring activities may increase. So, in this research, we proposed an optimization model for making the optimal schedule of tunnel inspection and monitoring for leveling yearly budget within the predetermined aggregate budget in the period. Numerical experiments were conducted in this research: we use the practical data which include 270 tunnels in Hokkaido prefecture. The result shows that our proposed model works well and can find the optimal and practical schedule for Hokkaido area.

Abstract ID 1295

MULTI-OBJECTIVE OPTIMIZATION OF INDUSTRIAL PROCESSES

Dr. Ashish Gujrathi, Zainab Al Ani, G. Reza Vakili-Nezhaad, Talal Al-Wahaibi

Sultan Qaboos University, Oman
ashishg@squ.edu.om, zozaziz79@gmail.com, vakili@squ.edu.om, alwahaib@squ.edu.om

Keywords: Multi-objective optimization,Evolutionary Algorithm,NSGA-II,Industrial Processes

Abstract: Natural gas and sulfuric acid are two of the most widely consumed products around the world. The increased demand for energy leads to fast growth of natural gas. The natural gas processing goes through many stages. Many of these stages have been considered for multi-objective optimization (like liquefaction), while the area of dehydration stage still needs more study. Regarding sulfuric acid importance, in addition to its various uses, it is a part of the production process of many industrial goods such as fertilizers. The production process of sulfuric acid and natural gas generate several gas emissions that are released to atmosphere and are negatively affecting the environment. In addition, during the production, the plant units are losing huge amount of energy. In order to solve these environmental and thermodynamic problems, both processes need to be multi-objectively optimized with respect to the specified objectives. For natural gas production, the considered bi-objective case is the simultaneous minimization of total process physical exergy (EXRGT) and photochemical ozone creation potential (POCP). ProMax® 4.0 was used to simulate the process coupled with excel-based NSGA-II algorithm to carry out optimization. Many decision variables were considered like solvent and gas flow rates, pressure and temperature of inlet streams. Limitations for the final product water content, solvent flow rate were taken into account. It was found that there exists a potential for improving the process and that the pressure of the inlet wet gas stream has the strongest impact on the multi-optimization results. For the sulfuric acid production plant, Aspen Plus was used for simulation and excel-based NSGA-II algorithm was used for optimization. Minimization of acidification potential (AP) and the physical exergy of the process units (EXRGP). Decision variables like columns and reactors operating pressure and raw materials flow rates (air and sulfur) were considered in addition to several constrains regarding the purity of the acid, gas lines water content, etc. Results showed that there is a multi-optimization potential for this process with respect to the thermodynamic and environmental point of view and that process is mainly influenced by the steam flow rate that is used for gas cooling purposes. Both studies provide a better understanding for dehydration and sulfuric acid processes, so that it will help in improving all the related plants all around the world.

Abstract ID 1297

IDENTIFICATION OF VISCOELASTIC PROPERTIES OF MATERIALS BY ADJUSTING FREQUENCY RESPONSE CURVES

Vítor Carvalho[1], Aurelio Araujo[2], Cristóvão Mota Soares[3]

[1]IST/IDMEC, Portugal
vitor.s.carvalho@tecnico.ulisboa.pt

[2]IDMEC, Instituto Superior Tecnico, Portugal
aurelio.araujo@tecnico.ulisboa.pt

[3]IDMEC/IST-Instituto Superior Técnico, Universidade de Lisboa, Portugal
cristovao.mota.soares@tecnico.ulisboa.pt

Keywords: viscoelastic properties; damping; identification; frequency response

Abstract: The suppression of vibrations in structures is an area that has importance not only for structural integrity but also for human comfort. In the last decades several types of materials have been developed to be applied in soft core structures, the main objective is that the core provides a significant amount of damping. In this work we consider an approach that allows for the adjustment of a numerical experimental frequency response function (FRF), obtained with a finite element method of the soft core plate element, to the FRF obtained in the laboratory or in the real service of a structure. The main objective is to estimate the engineering properties considering the real behavior of the high damping materials. The optimization process consists in minimizing the error between resonance peaks, due to the deviation of the theoretical FRF and the experimental FRF, the process variables are the engineering properties of the core material. The properties of the material can be frequency dependent and in that follow-up, the adjustment is done at each resonance peak. In an early stage an evolutionary algorithm is used to approximate a global solution and thereafter that solution is refined by a gradient-based method. This research work has been developed considered a hysteretic damping model for highly damped materials. Hence, the FRF curves do not have defined peaks and so the work focuses on the precision study of the applied optimization algorithm. Some studies will be presented using numerically simulated data but also experimental data.

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1298

TOPOLOGY OPTIMIZATION OF COMPLIANT FLUIDIC CONTROL STRUCTURES UNDERGOING LARGE DEFORMATIONS

Prabhat Kumar(1), Paola Fanzio(1), Luigi Sasso(1), Matthijs Langelaar(2)

(1)Delft University of Technology, Netherlands
p.kumar-3@tudelft.nl, p.fanzio-1@tudelft.nl, l.sasso@tudelft.nl

(2)TU Delft, Netherlands
m.langelaar@tudelft.nl

Keywords: Topology optimization; Compliant mechanisms; Geometrical and material nonlinearity; Nonlinear finite element method;

Abstract: In this work, topology optimization is used to design compliant fluidic control structures (CFCSs). A compliant mechanism which transmits force, motion and/or energy into different output responses at associated different locations within the design space while experiencing large deformation with the purpose of regulating fluid flow, can be termed as a CFCS. Such output responses, herein, are characterized via opening and/or closing of predefined holes having different positions, shapes and sizes. In a CFCS, a hole can be closed if its boundaries move towards each-other in response to the external input actuation. Conversely, in case of opening, they should move apart. A least square error objective with respect to a target boundary shape and/or position is proposed to achieve CFCSs with desired opening and/or closing functions, under selected resource constraints. Such mechanisms can be used as tunable fluidic control devices which can vary their shapes and functions in specific, predetermined ways in response to external loadings while undergoing large deformation. It has been noticed that topology optimization techniques based on gradient search involving large deformation experience numerical instabilities when extreme deformation occurs in lower stiffness finite elements/regions. To avoid such anomalies, we use the approach presented in [1] for the topology optimization. Material and geometrical nonlinearities are considered to cater to large deformation, which proves essential to obtain effective CFCSs. The Newton-Raphson method in association with updated Lagrangian formulation based finite element method is used to solve the mechanical equilibrium equations. The structures are actuated via uniformly displacement (stretching) loads. Various single/multi-functional compliant devices are presented, and their performances are compared with their respective prototypes to show the efficacy of the approach.

References:

[1] F. Wang, B. S. Lazarov, O. Sigmund, and J. S. Jensen, \Interpolation scheme for fictitious domain techniques and topology optimization of finite strain elastic problems," Computer Methods in Applied Mechanics and Engineering, vol. 276, pp. 453-472, 2014.

Abstract ID 1299

ANALYSIS OF SLOPES USING ELITIST DIFFERENTIAL EVOLUTION ALGORITHM

Yagizer Yalcin, Murat Altun, Onur Pekcan

Middle East Technical University, Turkey
yyalcin@metu.edu.tr, mualtun@metu.edu.tr, opekcan@metu.edu.tr

Keywords: Slope stability analysis, limit equilibrium method, non – circular slip surface, optimization, metaheuristics, Differential Evolution algorithm, Elitist Differential Evolution algorithm, Particle Swarm Optimization, Grey Wolf Optimization

Abstract: Analysis of man-made and natural slopes has been a challenge for engineers, requiring development of complex computational models to assess the stability hazards and risk levels. These computational models involve combination of analysis tools and integrated optimization solutions, which generally induce intense engineering calculations with upscale time complexity. In order to create reliable engineering solutions within a reasonable amount of time, a robust optimization algorithm is necessary, leading to an efficient stability analysis framework. Within this context, various optimization techniques involving deterministic and metaheuristic approaches were proposed in the past decades. The proposed methods for this purpose often suffer from convergence issues when they involve deterministic paradigms or may be time deficient when stochastic concepts appear. Therefore, development and integration of an effective optimization algorithm is vital. In this study, a modified version of Differential Evolution (DE) algorithm named Elitist Differential Evolution (EDE) is introduced and proposed to solve slope stability analysis problems more effectively. To develop the complete analysis framework, the algorithm is integrated with a non-circular slip surface generation method and limit equilibrium based stability analysis techniques. Then, the performance of EDE is compared with the other optimization algorithms such as conventional Differential Evolution, Particle Swarm Optimization and Grey Wolf Optimization using the benchmark problems reported in the literature. The outcomes indicate that the statistical performance of EDE surpasses other methods, validating the applicability of the algorithm to slope stability analysis problems. Furthermore, convergence rate of EDE has become prominent in the numerical experiments, which further emphasizes the capability of the algorithm.

Abstract ID 1301

APPLICATION OF MULTIOBJECTIVE OPTIMIZATION BASED ON DIFFERENCES OF MODAL DISPLACEMENTS AND MODAL ROTATIONS FOR DAMAGE QUANTIFICATION IN BEAMS

Jose Araujo dos Santos[(1)], Jose Aguilar Madeira[(2)], Hernani Lopes[(3)], Pablo Moreno-Garcia[(4)]

[(1)]IDMEC/IST, Portugal
viriato@ist.utl.pt

[(2)]IDMEC/IST and ISEL/IPL, Portugal
aguilarmadeira@dem.ist.utl.pt

[(3)]ISEP/IPP, Portugal
hml@isep.ipp.pt

[(4)]Universidad de Cadiz, Spain
pablo.morenogarcia@uca.es

Keywords: damage quantification, Euler-Bernoulli beam, modal displacement, modal rotation, multiobjective optimization, direct search method

Abstract: This paper presents an application of multiobjective optimization for the damage quantification in beams. The simulation of damage relies on the finite element analysis of Euler-Bernoulli beams and is carried out by considering a reduction in the Young's modulus of specific elements. The damage is quantified by minimizing two objective functions. These two functions are based on the difference in the Frobenius norm of matrices containing the modal displacements and the modal rotations of a beam in the undamaged and damaged states. The solution of the optimization problem thus defined is solved by a direct multisearch algorithm, which is an extension of the direct search algorithm to multiobjective optimization. This algorithm does not need any derivatives information about the objective functions. The validity, robustness and efficiency of the present application is tested for different boundary conditions of the damaged beam and high levels of noise in the simulated measured data.

Abstract ID 1303

COMPLEX SYSTEM OF IDENTIFICATION OF MATERIAL PROPERTIES OF MICROSTRUCTURE USING BIOINSPIRED METHOD

Arkadiusz Poteralski

Silesian University of Technology, Institute of Computational Mechanics and Engineering, Poland
arkadiusz.poteralski@polsl.pl

Keywords: microstructure,RVE,artificial immune system,identification

Abstract: The paper is devoted to identification of a microstructure distribution of materials using artificial immune system (AIS). The identification is performed on the basis of homogenized material properties. The coefficients of homogenized elastic matrix are used in the objective function. The goal of the identification is to obtain the material distribution in the microstructure which gives the same homogenized elastic material coefficients as the reference material. The objective function value in the identification process is evaluated with use of the FEM. Due to symmetry of the stiffness and compliance matrices, the 9 variables are independent in the fully orthotropic elastic material. The material coefficients in the case of linear problems can be obtained once for each microstructure. The six analyses should be performed for each microstructure to obtain the 9 independent orthotropic material coefficients. The distribution of the materials depends on the function depending on vector of design variables playing role of control points and coordinates. The level set of the function determines the topology of the structure. The material properties for each element of the RVE mesh depend on belonging to the sub or superlevel set of function. The artificial immune system is a computational adaptive system inspired by the principles, processes and mechanisms of biological immune systems. The algorithms typically use the characteristics of the immune systems like learning and memory to simulate and solve a problem in a computational manner. In this algorithm clonal selection mechanism was used. In the first stage of artificial immune algorithm the memory cells are created randomly. Next cells are proliferated and mutated creating new cells. The number of clones created by each memory cell is determined by the memory cells objective function value. The objective functions for each cell is evaluated. The selection process exchanges some memory cells for better cells. The selection is performed on the basis of the geometrical distance between each memory cell and its mutated cells (measured by using design variables). The crowding mechanism removes similar memory cells. The similarity is also determined as the geometrical distance between memory cells. The process is iteratively repeated until the stop condition is fulfilled. The stop condition can be expressed as the maximum number of iterations. Acknowledgment. The scientific research was partially funded by National Science Centre, Poland, grant no.2015/19/B/ST8/02629 and from the statute subvention of Silesian University of Technology, Faculty of Mechanical Engineering.

Abstract ID 1304

HPC IMPLEMENTATION OF THE MULTIPOINT APPROXIMATION METHOD FOR LARGE SCALE DESIGN OPTIMIZATION PROBLEMS UNDER UNCERTAINTY

Vassili Toropov[(1)], Yury Korolev[(2)], Konstantin Barkalov[(3)], Victor Gergel[(3)]

[(1)]Queen Mary University of London, United Kingdom
v.v.toropov@qmul.ac.uk

[(2)]University of Cambridge, United Kingdom
korolev.msu@gmail.com

[(3)]Lobachevsky University of Nizhny Novgorod, Russian Federation
barkalov@vmk.unn.ru, gergel@unn.ru

Keywords: Multipoint approximation,metamodel,trust region,risk measure,superquantile,HPC

Abstract: This paper presents a new development in the Multipoint Approximation Method that makes it capable of handling large (1000 design variables) optimization problems with uncertainty in design variables as well as in additional 'environmental' variables. The approach relies on approximations built in the combined space of design variables and environmental variables, and subsequent application of a risk measure and optimization with respect to the deterministic design variables, all within the iterative trust-region-based framework of MAM implemented in a high performance computing (HPC) environment. Several risk measures are considered and compared including mean plus N*sigma and superquantile. The performance of the proposed techniques is demonstrated by examples of large-scale problems.

Abstract ID 1309

TOPOLOGY OPTIMIZATION FOR DYNAMIC SCALING APPLICATION USING A GRADIENT-BASED OPTIMIZATION APPROACH

Éder Oliveira[1], Frederico Afonso[1], Abdolrasoul Sohouli[1], ROBERTO Gil Annes SILVA[2], Afzal Suleman[3]

[1]Instituto Superior Técnico, Portugal
eder.oliveira@tecnico.ulisboa.pt, frederico.afonso@tecnico.ulisboa.pt, rasoul.sohouli@gmail.com

[2]Instituto Tecnológico de Aeronáutica, Brazil
gil@ita.br

[3]IDMEC and University of Victoria, Portugal
suleman@tecnico.ulisboa.pt

Keywords: Topology Optimization, Dynamic Scaling, 3D Printing

Abstract: A methodology was developed to prepare a dynamically scaled model of a lifting surface based on 3D printing potentialities. The dynamic scaling approach is a process to achieve a scaled model (scaled down, e.g., 1/10) able to reproduce the same equivalent dynamic behavior of the full scale model. The objective function was to find the same scaled eigenvalues and eigenvectors as the full scale. The design variables are the material density in the design domain. The matching of the modal parameters between the full scale model and the scaled model was achieved through topology optimization based on a gradient-based optimization. The optimization process is written in Matlab® and the finite element model was solved in Abaqus®. The developed optimization framework was tested with some case studies. The approach can be used to design a scaled model with different material compared to the full scale model.

Abstract ID 1311

WORST GEOMETRIC IMPERFECTIONS OF RODS AND SHELLS

Piotr Alawdin

University of Zielona Góra, Poland
p.aliawdin@ib.uz.zgora.pl

Keywords: rods, shells, worst geometric imperfections, optimal control

Abstract: Various forms of geometric imperfections of compressed rods which are subjected to loss of stability have been considered in the normative literature. Similar investigations are also intensively carried out for the shells with imperfections, taking into account sub- and post-critical behavior of the systems, as well as an inelastic deformation of materials. However, there are no recommendations regarding the choice of the worst forms of such imperfections. The existing intuitive hypothesis regarding the choice of a shape with which the rods lose their stability can only be considered as a prerequisite for a proof or disproof of this hypothesis. Besides, references to extensive engineering experience are not sufficient; furthermore, already known various counterexamples contradict this hypothesis. In this paper, we formulate a general optimization mathematical model for selecting worst geometric imperfections for rods and shells as a problem of optimum control. Analytical solution of this model has been obtained for subcritical behavior of elastic rods with different boundary conditions. It is shown that the optimal solutions for worst geometric imperfections do not belong to smooth functions, but to the discontinuous piecewise smooth functions. Differences between behavior of simply supported rods with the obtained anti-optimal (worst) geometric outlines and that of those with the currently used imperfect functions reach 19.2%. The presented formulation makes it also possible to evaluate and obtain more precise recommendations for the shells with imperfections.

Abstract ID 1316

A NEW ENGINEERING ENVIRONMENT ADAPTED TO PRELIMINARY DESIGN ININDUSTRY

Jean BIGEON[(1)], Emmanuel Bigeon[(2)]

[(1)]G-SCOP/CNRS, France
jean.bigeon@grenoble-inp.fr

[(2)]ETS, Canada
emmanuel.bigeon.1@ens.etsmtl.ca

Keywords: software engineering, optimisation, analytical modelling

Abstract: We present a new platform dedicated to preliminary design. This platform allows to size manufacturing products. This environment is based on a separation of concern between the physical model development, the industrial and manufacturing constraints and objectives choices and the algorithmic resolution methods. These three concerns reveal three type of users. The first user, the research engineer, is in charge of developing, testing and validating physico-economical models in form of set of mathematical equations. In our platform, this does not require any programming skills. The transformation of the mathematical model into a code usable by the platform is done using grammars and code compilation concepts. Nonetheless advanced mathematical concepts such as complex numbers, integration, derivation, differential system resolution, implicit systems and even regression are supported by the environment. The role of the second user, the designer, is to define the constraints on the model. This role is the one that requires the less expertise as it usually consists in adapting external specifications. The software presents the designer with a view of the model's parameters (without the underlying equations) for him to choose optimization variables, constants and constraints in addition to the objective function. The platform provides information on the optimization process that can be helpful in case it fails, to adjust specifications accordingly. The third user, the numerician, defines if needed optimization methods. The platform allows, through the use of a public API, the integration of implementations of (possibly new) optimization methods that will then be available transparently in the platform. The optimisation problem created by the environment provides an exact gradient that is analytically computed, allowing the efficient use of derivation based algorithms. The software provides additional functionalities commonly required in the industry: interoperability with already existing environments such as Matlab/SciLab, Excel. We also provide the access to models through black-boxes as well as the use of black-boxes inside a model. An actual electrical engineering product's design with our software will be developed extensively in the full paper.

Abstract ID 1317

BAYESIAN METHOD FOR THE SOLUTION OF AN ENGINEERING DESIGN INVERSE PROBLEM

Iwona Nowak

Institute of Mathematics, Silesian University of Technology, Gliwice, Poland, Poland
iwona.nowak@polsl.pl

Keywords: the Bayesian approach,inverse problem,multicriteria optimization problem,thermoacoustic engine optimization,numerical modelling

Abstract: In this article, numerical methods for solving engineering problems defined as multicriteria optimization and inverse problem are presented. It deals with the optimization of the design of thermoacoustic engine in the frame of which both types of tasks are solved. The first heuristic serves to find many p-optimal solutions simultaneously, which represents a compromise between usually mutually contradictory goals at work. Based on them, the full Pareto front is approximated. The inverse problem solution reproduces parameters for solutions located on a designated front but those that are not found in multicriteria optimization. In this article, it is proposed to use the RACO heuristics for determining p-optimal solutions and the Bayesian approach as a method for solving ill-conditioned inverse problems. Optimization of the construction of the thermoacoustic engine is aimed at verifying proposed methodology and present the possibility of using both methods in engineering problems. The problem discussed in this article has been formulated and the numerical methods used in the solution have been presented in details.

Abstract ID 1319

APPLICABILITY OF SIMPLIFIED MODELS OF RAILWAYS TRACKS OBTAINED BY OPTIMIZATION AND FITTING TECHNIQUES

Zuzana Dimitrovová[(1)], André Rodrigues[(2)]

[(1)]DEC/FCT/UNL and IDMEC/IST/UL, Portugal
zdim@fct.unl.pt

[(2)]Banedanmark, Portugal
andre.rodrigues.fct@gmail.com

Keywords: high speed rail; structural vibrations; finite element method; discrete supports model; optimization; numerical calibration

Abstract: In this paper, the range of applicability of the discrete supports model (DSM) of ballasted railway tracks is delimited and general formulas for identifying its properties are proposed and validated. To calibrate the DSM, a 3D finite element model (FEM) is implemented and validated by comparison with published experimental measurements. The equivalence between the DSM and 3D FEM is measured using the vertical displacement of the rail, which is a common element to both models and the interface between the load and the track. Following a review of the existing literature, formulas for identifying the properties of the DSM are proposed. These formulas are validated by fitting the results of the DSM to the 3D FEM using optimization techniques, covering a large range of typical properties of the track. As a result, the range of applicability of the DSM and the proposed formulas is also established. A good approximation to the 3D FEM is achieved, particularly when the load moves slower than the velocity of propagation of elastic waves in the soil. For high velocities and/or soft soils, the wave propagation becomes more relevant to the dynamics of the track, and the DSM is less reliable.

Abstract ID 1320

EFFICIENT MULTILEVEL SOLUTION OF TOPOLOGY OPTIMIZATION PROBLEMS WITH EIGENVALUES

Federico Ferrari, Ole Sigmund

Technical University of Denmark, Denmark
feferr@mek.dtu.dk, sigmund@mek.dtu.dk

Keywords: Eigenvalue optimization; Vibrations; Buckling; Large-scale problems; Multigrid

Abstract: Topology optimization involving eigenvalues is addressed and an efficient method for the solution of large scale problems is proposed. Eigenvalue problems are classically encountered in structural optimization, either as objectives or behavioral constraints, as vibration or stability requirements have to be introduced in the design. Despite the impressive development of topology optimization, both in methods and applications, the repeated solution of eigenvalue problems in a large scale optimization setting still presents severe challenges. We propose an alternative optimization problem, based on the minimization of a measure of the structural compliance and which can be effectively adopted as a surrogate method for optimizing the eigenvalue-related structural responses [P1]. Associated with such objective function is a linear state problem, essentially a frequency response problem, which can be solved extremely efficiently by using preconditioned iterative methods. For this we use a multilevel strategy both for computing the parameters defining the linear frequency response problem and for actually solving it [P2]. A full eigenvalue analysis is performed only on a coarse scale, and the modes are projected on the fine scale, where the optimization problem is set up and the frequency response is solved. The overall procedure leads to an optimal (linear) scaling of the computational cost, conceptually making eigenvalue topology optimization as cheap as a simple compliance-based one. The procedure also allows the computation of useful upper and lower bounds to the fine scale eigenvalues. Applications concerning topology optimization for free vibrations and buckling loads, for both 2D and 3D structures are presented. Besides discussing computational savings, the performance of the multilevel frequency response is examined for situations where eigenvalues coalescing occurs, evidently mesh dependent problems are studied, or spurious localized modes are prone to appear.

References

[P1]Andreassen E., Ferrari F., Sigmund O., Diaz A. - Frequency response as a surrogate eigenvalue problem in topology optimization, International Journal for Numerical Methods in Engineering, Vol. 113, Issue 8, pp. 1214—1229

[P2 Ferrari F., Lazarov B. S., Sigmund O - Eigenvalue topology optimization via efficient multilevel solution of the Frequency Response, Submitted

EngOpt2018 - 6th International Conference on Engineering Optimization
Instituto Superior Técnico, Lisbon Portugal • 17-19 September, 2018
Editors: H.C. Rodrigues, J. Herskovits, C.M. Mota Soares, et al.

Abstract ID 1321

STRUCTURAL ANALYSIS AND OPTIMIZATION OF A UAV WING

Virgínia Infante[(1)], João Ferreira[(1)], Diogo Vicente[(2)], Jose Madeira[(3)]

[(1)]Instituto Superior Técnico, Portugal
virginia.infante@tecnico.ulisboa.pt; joao.alves.ferreira@ist.utl.pt;

[(2)]UAVISION, Portugal
diogo.vicente@uavision.com

[(3)]IDMEC, Instituto Superior Técnico, Portugal
aguilarmadeira@tecnico.ulisboa.pt

Keywords: UAV,wing,structural analysis,topologic optimization

Abstract: The use of unmanned aerial vehicles, also known as UAV's, are extremely useful on environmental operations such as on the measure of the gases emitted by a boat. By being controlled from a distant point, having a reasonable autonomy and an amazing agility, this kind of vehicles came to add an efficiency on the results of those operations. It is also a safer procedure where there are no human lives in danger. In this context, it is always needed better characteristics concerning the structure of the vehicles, namely the wings, which have a key role during the flight. The present study was developed with "UAVision" company, doing the structural analysis and topological optimization of the wing of one of theirs UAV´s. With this work, the main goals were the minimization of the mass, as also as the minimization of the maximum bending of the wing, to improve the autonomy of the vehicle and its flight stability. For this purpose, a program was built from scratch, using the commercial software ANSYS Mechanical APDL 18.1. A "bottom-up" strategy was chosen, creating small subsystems to reach a complex and final system, resulting in the 3D modulation of the wing. The topological optimization process was solved by Direct MultiSearch (DMS). DMS is a solver for multiobjective optimization problems, derivative-free and does not aggregate any components of the objective function. DMS maintains a list of feasible non-dominated points. At each iteration, the new feasible evaluated points are added to this list and the dominated ones are removed. Successful iterations correspond then to an iterate list changes, meaning that a new feasible non-dominated point was found. Otherwise, the iteration is declared as unsuccessful. The optimized wing was then manufactured for validation by experimental tests. The optimization process contributed to improve the performance of the wing in more than 25% when compared to the non-optimized wing.

Abstract ID 1329

INVERSE DYNAMICS OPTIMIZATION INCLUDING MUSCLE DYNAMICS – INFLUENCE ON THE MUSCLE FORCE SHARING PROBLEM OF THE SHOULDER

Carlos Quental, Margarida Azevedo, Jorge Ambrósio, Sérgio Gonçalves, Joao Folgado

[(1)]IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Portugal
carlos.quental@tecnico.ulisboa.pt; jorge.ambrosio@tecnico.ulisboa.pt: *jfolgado@tecnico.ulisboa.pt;*
margarida.azevedo@tecnico.ulisboa.pt, sergio.goncalves@tecnico.ulisboa.pt

Keywords: Multibody dynamics,inverse dynamics optimization,muscle force sharing problem,muscle dynamics

Abstract: The muscle dynamics, i.e., activation dynamics and muscle-tendon contraction dynamics, are rarely considered in inverse dynamic simulations due to the limitations of the optimization methods commonly applied. The static optimization cannot handle time-dependent objective functions or constraints because it solves each instant of time independently, whereas the global optimization and extended inverse dynamics methods are limited by the number of muscles and instants of time that can be considered as the size of the optimization problem rapidly becomes too large to be solved. A novel method, named window moving inverse dynamics optimization (WMIDO), was recently proposed to overcome these limitations and allow the analysis of time-dependent objective functions and constraints. Considering that the influence of the muscle dynamics on inverse dynamic simulations is still an open issue, the aim of this study was to compare, using WMIDO, the biological performance of four musculotendon models differing in the simulation of the muscle activation and contraction dynamics. The muscle force sharing problem was solved for abduction and flexion motions of the shoulder using a musculoskeletal model of the upper limb. The musculoskeletal model applied is composed of 7 rigid bodies, constrained by 6 anatomical joints, and acted upon by 22 muscles, represented by 74 muscle bundles. A three-element Hill-type muscle model is used to describe the muscle behavior. Four musculotendon models were considered: (1) rigid tendon model without activation dynamics,[(2)]rigid tendon model with activation dynamics,[(3)]elastic tendon model without activation dynamics, and (4) elastic tendon model with activation dynamics. Considering the Lagrange multipliers associated with the kinematic constraints and the muscle forces as design variables, the muscle force sharing problem was formulated as the minimization of the muscle energy consumption subjected to the fulfillment of the equations of motion, the boundary constraints of the muscle activations, and the stability constraints of the shoulder and scapulothoracic joints. The simulations including activation dynamics had also to ensure the boundary constraints of the muscle excitations. The inverse dynamics optimization was solved in Matlab using WMIDO with a window size of 10 instants of time and a marching step of 4 instants of time. The muscle and joint reaction forces were similar for all musculotendon models considered, which suggests that for slow-speed, standard movements of the upper limb, the activation and muscle-tendon contraction dynamics can be neglected without compromising the solution of the muscle force sharing problem.

Abstract ID 1331

OPTIMAL SPECTRAL MATCHING OF STRONG GROUND MOTION BY OPPOSITION-SWITCHING SEARCH

Mohsen Shahrouzi

Kharazmi University, Iran
mesha140@yahoo.com

Keywords: Opposition-based meta-heuristic,Novel Optimization Algorithm,Ground Motion Scaling.

Abstract: Earthquakes are sources of seismic loading on structures with probabilistic nature of their records. As a result, no single earthquake is reliable for decision making in consequent structural design. A common solution to reduce such probabilistic effects is spectral matching of earthquake records with a target design spectrum within a prescribed period interval. Selection of the corresponding scale factors in such a process is formulated here as an optimization problem while the objective is to achieve the best compatibility of the mean spectrum with the target. A new algorithm is proposed here in after to solve this problem. It utilizes switching between movement of a candidate design vector and its bound-based opposite toward the current best solution. The algorithm is design for simplicity and efficiency for such a practical engineering task. Numerical tests exhibit considerable reduction of spectral matching error with respect to common practice in application of uniform scale factors.

Abstract ID 1332

TOPOLOGY OPTIMIZATION OF A STEEL JOINT FOR TEMPORARY SPACE FRAMES

Daan Van Cauteren(1), Jeroen Pellens(2), Mathias Van de Winkel(3), Mattias Schevenels(2)

(1)KULEUVEN, Belgium
daan.vancauteren@student.kuleuven.be

(2)KU Leuven, Belgium
jeroen.pellens@kuleuven.be, mattias.schevenels@kuleuven.be

(3)VAKWERK, Netherlands
ar.mathias.vandewinkel@gmail.com

Keywords: topology optimization,industrial application,space frames,temporary structures,modular building system

Abstract: This contribution focuses on a recently developed modular building system for temporary space frames [1]. The building system is based on standard scaffolding bars, which are connected to a custom-designed steel joint by means of a pin-lock system. The system has already been used to build various types of pavilions for festivals and other temporary events. While the boltless connection system allows for fast erection and dismantling, the custom-designed joint is relatively heavy and, as a consequence, difficult to handle. In order to reduce the weight of the joint, a new design is proposed based on topology optimization, which is presented in this contribution. The joint consists of 3 intersecting square plates that are mutually perpendicular. A maximum of 12 bars can be connected to the joint – one bar at each corner of each plate. The design load of the joint is equal to the axial load resistance of the bars, which is 30 kN. The weight of the joint is reduced by removing obsolete material from the plates by means of water jet cutting. The perforation pattern is determined by topology optimization. The optimization problem is formulated for a single plate as a 2D minimum compliance problem with a volume constraint and with multiple load cases. The load cases reflect all possible combinations of maximum tension (30 kN), zero force, and maximum compression (-30 kN) at each of the 4 corners of the plate. After the optimization, a 3D joint is assembled as the intersection of three identical perforated plates, and the Von Mises stresses for all possible load combinations are computed. Next, the volume constraint is adjusted to ensure that the Von Mises stress does not exceed the yield stress, and the 2D optimization problem is solved again. This procedure is repeated until convergence is reached in terms of the volume constraint. The geometry of the optimized joint is significanlty different from the original geometry, and the weight is about 50 % of the original weight. In the coming weeks, a prototype of the optimized joint will be produced by means of water jet cutting. The strength and stiffness of the prototype will be determined by means of tension and compression tests, and compared with the values predicted by the numerical model used for the optimization. [1] M. Van de Winkel. VakWerk. www.vakwerk.net, April 2018.

Abstract ID 1334

CONCURRENT TOPOLOGICAL OPTIMISATION: OPTIMISATION OF TWO COMPONENTS SHARING THE DESIGN SPACE

Massimiliano Gobbi, Federico Ballo, Giorgio Previati

Politecnico di Milano, Italy
massimiliano.gobbi@polimi.it, federicomaria.ballo@polimi.it, giorgio.previati@polimi.it

Keywords: Structural optimisation; Topology optimisation; multi-component system optimisation; SIMP;

Abstract: Topology optimization is a widely used technique for deriving efficient shapes for components in many engineering fields. In this work, a novel topology optimization problem formulation is proposed. The case of the concurrent topological optimization of two different components sharing a portion of the design space is considered. The design problem represents the relevant design situation in which more than one component has to be fitted in an enclosed space and each component has its own load carrying function. The proposed algorithm assigns the shared space to one or the other body depending on the relative sensitivity to each element to the total compliance of the system. After each element has been assigned to one of the two design domains, the connectedness of the two domains is checked. In case some unconnected regions are present, the assignment of these regions is reversed and the connectedness of the two design domains is enforced. The volume fraction is enforced at system level, i.e. the volume fractions of the two domains can be different, but the total volume fraction complies with the set value. In this way, the available mass can be allocated in the most convenient way among the two bodies. Some examples are presented to show the performance of the proposed algorithm. In one example, two structures for which the optimal solutions are known from the literature have been considered. The two design domains are overlapped as to allow the two optimal solutions to be found. The two optimal solutions are obtained by the concurrent topological optimization algorithm. Moreover, by imposing some reasonable, but not optimal, divisions of the design domain, structures with higher compliances have been obtained.

Abstract ID 1337

DESIGN OF CELLULAR COMPOSITES WITH METAMATERIAL MICROSTRUCTURES BY TOPOLOGY OPTIMIZATION OF LEVEL SETS

Zhen Luo[(1)], Tao Wu[(2)]

[(1)]University of Technology, Sydney, Australia
zhen.luo@uts.edu.au

[(2)]Huazhong Univesity of Science and Technology, China
wutao1972@hust.edu.cn

Keywords: Topology Optimization,Level Sets,Multiscale Design,Cellular Composites,Metamaterials Microstructures.

Abstract: This paper is about topology optimization for an integrated multiscale design of cellular composites that consists of multiple regions of elastic metamaterial microstructures. The multiscale design mainly involves two optimization stages: the free material distribution optimization and the concurrent topological shape optimization. The macro structure is overall configured with multi-regional patches of different types of microstructures, while each patch is featured with identical material microstructures. At macro scale, a free material distribution method with a regularization mechanism is used to find a reference layout for global material distribution of different element densities. At micro scale, each macro element is treated as an individual microstructure corresponding to a discrete density. Hence, all the macro elements located within the same region can be represented only by one representative microstructure, due to the same discrete densities or volume fractions. Any of the representative microstructures can then be topologically optimized by a powerful level set method associated with the numerical homogenization method. The multiscale design is concurrently positioned into a unified process of design optimization, so both topology of the macrostructure, and the topologies and locations of the representative microstructures in the design space are optimized. Numerical examples show that the proposed method is able to improve the concerned structural performance under an affordable computation and manufacturing cost.

Abstract ID 1339

EXPERIMENTAL VERIFICATION OF NONLINEAR DAMPING INDUCED BY SLIPPING INTERFACES

Yifan YANG

LTDS Ecole Centrale de Lyon, France
yangyifan5558@gmail.com

Keywords: Nonlinear damping,friction contact,analytical model,experiment,verification

Abstract: Optimization of fatigue endurance is a common practice in vibratory system design, but it is always hard to meet the expected requirements due to the difficulty in damping estimation. Damping is essentially an external representation of energy dissipation, which takes mainly two forms: material damping and friction damping. In industrial assembled structures, where the majority of components are connected by rivet or bolt, the friction damping is normally 10-100 times higher than material damping. Therefore a reliable estimation of friction damping in the first place, as well as its optimization in the second place, is the basis for a correct fatigue endurance design. The current study can be divided into two parts: the first part presents an analytical model based on a clamped sandwich plate. The evolution of damping coefficient versus modal amplitude is chosen as the analyzed parameter. The frictional damping, in this case, is shown to be a function of modal amplitude and it can be influenced by contact properties like the clamping pressure, the coefficient of friction and the contact quality. The influence of geometric characteristics is then evaluated by finite element method in Abaqus. The numerical results point out that damping capacity is sensitive to macroscopic geometry such as curvature of the contact surface and the thickness ratio between the two plates. The boundary condition is also proven to be an influential factor for damping formation. The above studies provide the possibility for damping optimization in industrial application. The second part deals with the experimental verification of the analytical damping model. An experimental set-up was designed and the damping can be evaluated by a differential system with the help of an equivalent dynamic hysteresis model. The damping evolution is traced in terms of clamping pressure and vibration amplitude. The experiment results show the same damping evolution as the analytical model. Damping induced by the frictional interface is thus proven to be nonlinear and its optimization is verified to be feasible.

Abstract ID 1341

TOPOLOGY OPTIMIZATION OF CONTINUUM STRUCTURES USING CONTINUOUS MATERIAL DISTRIBUTION AND MIXED FINITE ELEMENT MODELS

Haitao Ma

Guangzhou University, China
htma@gzhu.edu.cn

Keywords: Topology Optimization,SIMP Method,Mixed Finite Elements,Continuous Material Distribution

Abstract: This paper presents a study on some of the issues with the conventional SIMP (Solid Isotropic Material with Penalization) model in topology optimization of continuum structures. The approach based on continuous material distributions and mixed finite elements is presented and investigated. By introducing design variables at chosen locations in the design domain, a continuous material pseudo-density can be defined and a smooth boundary can be achieved for the optimized topology. Mixed finite elements are used for the analysis of structures with variable material constants over individual elements. The 2D continuum and plate bending problems are considered and solution algorithms are presented. It is shown that, without the use of any special techniques, the new approach does not suffer from any of the numerical problems with the conventional element design variable and the nodal design variables, such as the checkerboard patterns or islanding phenomenon. Numerical examples are presented to illustrate the advantages of the presented approach and effectiveness of the algorithms.

References

(1) Bendsoe M P, Sigmund O. Topology optimization: Theory, Methods and Application. New York: Springer, 2003
(2) Sigmund O, Petersson J. Numerical instabilities in topology optimization: a survey on procedures dealing with checkerboards, mesh-dependencies and local minima. Struct Optim, 1998, 16:68-75
(3) Rahmatalla S F, Swan C C. A Q4/Q4 continuum structural topology optimization implementation. Struct Multidisc Optim, 2004, 27:130-135
(4) Pian T H H, Sumihara K. Rational approach for assumed stress finite elements, Int. J. Numer. Methods Eng., 1984, 20(9): 1685-1695
(5) Gao X, Ma H. Topology optimization of continuum structures under buckling constraints, Computers and Structures 2015; 157:142–152.

Abstract ID 1342

OPTIMAL LOCATION OF PIEZOELECTRIC SENSORS AND ACTUATORS FOR NOISE REDUCTION IN SANDWICH PANELS

Aurelio Araujo[1], Jose Madeira[1], Filipa Moleiro[2]

[1]IDMEC, Instituto Superior Tecnico, Portugal
aurelio.araujo@tecnico.ulisboa.pt, aguilarmadeira@tecnico.ulisboa.pt

[2]LAETA, IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Portugal
filipa.moleiro@tecnico.ulisboa.pt

Keywords: Sandwich structures,Piezoelectricity,Co-located control,Multiobjective optimization

Abstract: Noise reduction is a fundamental issue for the competitiveness in the transportation industry. Structures should be optimized for cost, weight, vibration and noise attenuation, subject to technological, failure and stress constraints. The generalized introduction of lightweight composites in the automotive and aerospace industries, while leading to significant weight reductions and associated fuel savings, pose a serious problem of low acoustic performance of these lightweight composites when subjected to mechanical or acoustic excitations. Passive damping technologies are nowadays frequently used to control sound and vibration levels through the use of viscoelastic materials, while active devices such as surface bonded piezoelectric patches can also be effectively used to control these undesired sound and vibration levels in lightweight composite structures. Sandwich composite panels may represent an optimized solution for both sound radiation and structural vibration for most frequency ranges. Viscoelastic materials are an efficient way of reducing structural vibrations and providing noise attenuation, which allied to active elements may lead to broader control capabilities regarding acoustic emissions. This paper addresses the issue of noise reduction in laminated sandwich plates using both passive and active elements. A finite element implementation of a laminated sandwich plate element with viscoelastic core and surface bonded piezoelectric patches is used to obtain the frequency response of the panels. The sound transmission characteristics of the panels are evaluated by computing their radiated sound power and radiation efficiency, using the Rayleigh integral method. The optimal location of the surface co-located pairs of piezoelectric patches is then obtained to minimize both weight and noise radiation. A recent methodology of optimization, based on direct search techniques, was used: Direct MultiSearch (DMS) optimization. This methodology does not use derivatives and does not aggregate any of the problem objective functions. Trade-off Pareto optimal fronts and the respective optimal active patch configurations are obtained and the results will presented, analyzed and discussed.

Abstract ID 1343

OPTIMIZED DESIGN OF LATTICE CORES WITH IMPROVED BUCKLING STRENGTH FOR ADDITIVE MANUFACTURING

Lei Zhang[1], Stefanie Feih[2], Stephen Daynes[2], Michael Wang[3], Jun Wei[2], Wen Lu[4]

[1]National University of Singapore, Afghanistan
leizhang@u.nus.edu

[2]Singapore Institute of Manufacturing Technology, Singapore
feihs@simtech.a-star.edu.sg, dayness@SIMTech.a-star.edu.sg, jwei@simtech.a-star.edu.sg

[3]Hong Kong University of Science and Technology, Hong Kong
mywang@ust.hk

[4]National University of Singapore, Singapore
mpelwf@nus.edu.sg

Keywords: Additive manufacturing,Buckling failure,Sandwich structure,Lattice core

Abstract: Sandwich structures with lattice cores are lightweight yet exhibit high specific stiffness, strength and energy absorption abilities. Traditional design of lattice cores are composed of straight and uniform truss members. However, the advances of additive manufacture free the design space and allow to design lattice cores with complex truss profiles for improved mechanical performance. In this paper, a shape design method is proposed for lattice truss members to improve their buckling loads, which dominate the compressive strength for low density lattice structures. Five types of lattice cores are studied, including three simple lattices (Kagome, bcc and fcc) and two hybrid lattices (bccz and fbcc). For the simple lattices whose trusses are considered identical, the proposed method is able to optimize the cross-sectional variations, while the truss diameters as well as cross-sectional variations of each type of truss are optimized for hybrid lattice cores. The sandwich plates with optimized lattice cores are fabricated via additive manufacturing and tested under compression loads. Experimental results show that the buckling strength of the optimized bccz and fcc lattice cores are improved by 91% and 22% compared to their original uniform counterparts of the same weight; meanwhile their stiffness is improved as well. Kagome and bccz lattice cores perform the superior specific stiffness and compressive strength among the five lattice configurations studied, showing their potentials for aerospace and automotive applications.

Abstract ID 1344

HOMOGENIZED CONVECTIVE HEAT TRANSFER: ANALYTICAL ANALYSIS AND INVERSE HOMOGENIZATION

Paulo Ricardo Valentim Francisco; Luis Manuel Varejão de Oliveira Faria

Leaders for Technical Industries, Engineering Design and Advanced Manufacturing,
MIT Portugal, Instituto Superior Técnico, University of Lisbon, Portugal
paulo.francisco@tecnico.ulisboa.pt; luis.faria@ tecnico.ulisboa.pt

Keywords: Convective Heat Transfer, Multi-Scale Homogenization, Topology Optimization, Inverse Homogenization

Abstract: The solution of the flow and heat transfer problem in a porous medium using traditional finite element methods requires considerable computational resources to both define the intricate fine scale geometry and to solve the large system of equations. In this work, we analyzed the heat transfer problem and argue that its physical and geometric nature makes it suitable for analysis through homogenization theory. We applied this mathematical method to the convection-conduction energy equation in a domain constituted by a periodic base cell. It provides an assessment that in a periodic medium, the solution of the convection-conduction energy equation is approximated by the solution of a heat equation. In this equation, a new term appears: a homogenized conductivity tensor that includes terms that account for convection. This equation can be used for the first time to: (i) study in great detail one single periodic cell of the microstructure and use its results to characterize the performance of the macroscale domain (ii) serve as a model for material engineering in heat transfer applications (iii) model problems in other fields that possess the same physical and geometric nature. Analytical examples are used to show that the homogenized conductivity tensor corresponds to a highly orthotropic material, with a great increase of homogenized thermal conductivity in the direction of the flow. A bidimensional inverse homogenization is used to determine the optimal topology of the periodic cell that maximizes the homogenized conductivity tensor. The numerical optimization was implemented using the method of moving asymptotes, and design sensitivities were obtained by means of the discrete adjoint method. Results converge to a waved walled structure, with a small obstacle in the center that separates and rejoins the flow.