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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

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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.