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FATIGUE AND STRESS CONSTRAINED TOPOLOGY OPTIMIZATION OF 3D STRUCTURES SUBJECTED TO MULTIPLE LOAD CASES

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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.