First-Order Reliability Approach for Fatigue Resistant Topology Optimization of Elastoplastic Structures

P. Tauzowski[1] | B. Błachowski[1]| J. Logo[2]

[1] Institute of Fundamental Technological Research, Warsaw, Poland
[2] Budapest University of Technology and Economics, Hungary

Presenting author: Piotr Tauzowski

Deterministic approach for topology optimization consists in reducing the redundant material of the structure in such a way that its mechanical properties remain unaltered. However, from the engineering practice we know that such a optimization process can also increases the probability of failure. Therefore, it is important to represent and verify constraints such as compliance, stresses, displacements or material fatigue in a probabilistic way. Such a probabilistic approach allows to maintain a certain resistance of the structure to the variability of structural parameters, while in the deterministic approach, the optimal structure may not be reliable or its resistance to variability of structural parameters can be very small. The methodology proposed in the work allows the designer to control the level of structural reliability by introducing probabilistic constraints.

This work presents a recently developed reliability-based topology optimization of elastoplastic structures [1] extended with fatigue constraint. To tackle this problem a First Order Reliability Method (FORM) is applied, similarly as it was done by Honarmandi et al. [2] in the case of fatigue-constrained design optimization of cantilever beams. There are several kinds of procedures within the first order approach, among them: Reliability Index Approach (RIA). The present study recalls fundamental concepts from reliability analysis and introduces an algorithm for topology optimization of elastoplastic structures . In presented approach, the failure probability is understood as the probability of not exceeding a certain limit number of low-cycle fatigue cycles, based on the accumulation of plastic failure during cyclic loading. The multi-level load is taken into account

The presented numerical examples show dependence of fatigue resistance on the assumed volume fraction. All aspects of numerical analysis, including finite element formulation, algorithm for fatigue-constrained topology optimization as well as reliability analysis are investigated in our own software implemented in MATLAB with the aid of object-oriented programming. Currently, the system includes plane and solid elements for elastic and elastioplastic analysis. The object-oriented architecture provides a comprehensive basis for further system extensions.

[1] Tauzowski P., Blachowski B. and Lógó J., (2021) *Topology optimization of elasto-plastic structures under reliability constraints: a first order approach*,

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[2] Honarmandi P., Zu J.W., and Behdinan K. (2007) Reliability-Based Design Optimization of Cantilever Beams Under Fatigue Constraint, AIAA Journal 45:11, 2737-2746, doi: 10.2514/1.24807