Topology optimization of mechanical and aerospace components subject to fatigue stress constraints

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Abstract

While topology optimization has been based mostly on compliance type formulations, industrial applications call for more elaborated formulations including several restrictions on the local displacements and the stress constraints in some critical zones. Topology optimization with stress constraints was initially considered in Ref. [1]. Later the stress constraint formulation was further extended to consider non equal stress constraints limits [2] and to improve the solution efficiency using different strategies such as global stress constraint formulations [3-4]. In the present work, the authors are investigating the formulations of stress constraint topology optimization to support the redesign of structural components that have to be fabricated using additive manufacturing. In this perspective, design problem requirements include tackling fatigue constraints during stress constrained topology optimization.

The work investigates different formulations of fatigue resistance which could be appropriate in a topology approach. At first the classical approach of mechanical engineering based on SN curves and Goodman or Soderberg lines. The treatment of these fatigue restrictions can take advantage of former work developed for unequal stress constraints by considering mean and alternating components of the stress state. In a second step our research is now focussing on more complex situations (3D stress states) which require resorting to more advanced criteria. Dang Van fatigue theory [5] has been selected but calls for a more elaborated procedure that is currently validated. Topology optimized structural layouts predicted using classical stress criteria, Goodman and Dang Van theories are compared.

References
[1] P. Duysinx and M.P. Bendsøe. Topology optimization of continuum structures with local stress constraints. Int. J. Num. Meth. Engng., 43, 1453-1478, 1998.
[2] M. Bruggi and P. Duysinx. Topology optimization for minimum weight with compliance and stress constraints. Struct. Multidisc. Optim. 46, 369–384, 2012.
[3] P. Duysinx and O. Sigmund. New Developments in Handling Stress Constraints in Optimal Material Distributions", 7th AIAA/USAF/NASA/ISSMO Symposium on Multidisciplinary Design Optimization, Saint Louis, Missouri, USA, 2-4 Sept. 1998.
[4] C. Le , Norato J., Bruns T., Ha C. and Tortorelli D. Stress-based topology optimization for continua. Struct. Multidisc. Optim. 41: 605-620, 2010.
[5] K. Dang Van, B. Griveau, and O. Message. On a new multiaxial fatigue limit criterion: Theory and Application. Biaxial and Multi axial Fatigue, EGF3 (ed. M.W. Brown and K.J.Miller). pp 479-496. Mechanical Engineering Publication. London 1989.