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A NEW APPROACH FOR STRESS-BASED TOPOLOGY OPTIMIZATION: INTERNAL STRESS PENALIZATION

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Abstract
The design problem for industrial applications is in many cases weight optimization subjected to material failure criteria (e.g. an admissible stress limit). Ideally, one would like to take these material failure criteria into account from the beginning of the topology optimization process. However, several difficulties arise when including a stress criterion in topology optimization [1]: 1) the non-linear nature of the stress response makes the problem prone to convergence to local optima, 2) the occurrence of singular optima and 3) the high number of local stress states to be considered results in a prohibitive number of constraints and, thus, very costly sensitivity analysis. Several techniques have been proposed to overcome these difficulties, including: constraint relaxation to circumvent the singularity problem and constraint aggregation techniques to replace the large number of local constraints by a global constraint to reduce computational costs. However, new difficulties arise such as dependency of the topology optimization process on the parameters introduced by these measures.

In this paper, we study a new approach for handling an admissible stress limit in density-based topology optimization. The main idea is to perform compliance-based topology optimization and concurrently penalize overstressed material by considering it as 'damaged'. Damaged material can carry less load than undamaged material. Consequently, overstressed material will contribute less in the overall stiffness, which motivates the optimization process to avoid these regions in the final solution. This idea is implemented by introducing a damaged model next to the original SIMP model. Material, which is overstressed in the SIMP model, is considered as 'damaged' in the damaged model. Here, damage is represented by degrading the Young's modulus depending on the degree the stress exceeds the admissible stress limit. Therefore, the compliance response of the damaged model depends implicitly on the stress state of the original SIMP model. Compliance-based topology optimization is then performed considering the compliance of the damaged model. In this way, high stresses are discouraged through this fully consistent 'internal penalization' approach, motivated by physical phenomena. In our implementation choices, numerical convenience and economy takes priority over precise structural damage modeling. In this approach only a single objective and a single constraint are considered; volume minimization subjected to a compliance constraint or *vice versa*. Consequently, there is no need for applying constraint aggregation techniques to reduce computational costs. A disadvantage of penalization-based techniques is that the admissible stress criterion is never exactly satisfied, but this also holds for constraint aggregation techniques used in the conventional approach.

At the time of writing this abstract, the method has been implemented and tested on elementary examples. Results were obtained where the stress is around the admissible stress limit and/or remarkably lower than for the same problem where only compliance is considered. For the final contribution, we will test the method on more elaborate problems and report on how this method compares to existing stress-based topology optimization techniques.

[1] C. Le, J. Narota, T. Bruns, C. Ha, D. Tortorelli, "Stress-based Topology Optimization for Continua", *Struct. Multidisc. Opt*., Vol. 41, pp. 605-620 (2010).