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Stress-Based Topology Optimization of Continuum Structures under Uncertainties☆

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Abstract

This work addresses the use of the topology optimization approach to the design of continuum structures with failure constraints under the hypothesis of uncertainties in the spatial distribution of Young's modulus. To this end, the first order perturbation approach is used to model the response of the structure and the midpoint discretization technique is used to represent the random field. The objective is the minimization of the amount of material used in the design, subjected to local stress constraints under uncertainties. The probability of failure is bounded by the one-sided Chebychev inequality, since the exact probability distribution function of the stress constraints is not known in advance. The effective probability of failure of the obtained optimal designs are validated with the use of the Monte Carlo Simulation approach, indicating that the probability of failures of the topologies obtained with the stochastic approach are within the bounds provided by the one-sided Chebychev inequality. The optimization problem is solved by means of the augmented Lagrangian method, in order to address the large number of constraints associated to this kind of formulation. It is shown that the correlation length and the number of standard deviations considered in the formulation play an important role in both the obtained topology and effective probability of failure.

Keywords: Topology Optimization, Stess Constraint, Random Field, Uncertainties

1. Introduction

In order to address realistic designs in the realm of structural optimization, one has to incorporate stress constraints. Unfortunately, handling stress constraints in topology optimization of continuum structures is a challenging task. The main difficulties related to the material failure constraint are its local nature and the singularity phenomenon. As the stress criteria must be satisfied in every point of the domain, the theoretical number of constraints tends to infinity. Even when using numerical methods, like the finite element method, the number of constraints is usually large, due to the poor stress description associated to the compatible finite elements. Moreover, the classical optimization algorithms based on Karush-Kuhn-Tucker conditions are unable to reach a true optimal design due to the singularity phenomenon [1].

There are two main techniques often discussed in the literature that can be used to overcome the first difficulty, associated to the large number of constraints. The first one is to solve the optimization problem by using an active set strategy [1, 2] or by using an augmented Lagrangian algorithm [3, 4, 5]. The second technique consists in grouping all the stress constraints into

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