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OPTIMAL TOPOLOGIES WITH LOADING UNCERTAINTIES

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ABSTRACT

The aim of this paper is to introduce and investigate a new type of probabilistic optimal topology design method where the elements of the loading are given randomly and they can have linear relationship. This pre-design condition can be considered as a load combination. In the proposed probabilistic topology optimization method the minimum penalized weight design of the structure is subjected to compliance and side constraints, respectively. The calculation of compliance value is based on the assumption that the magnitude and/or the line of action of the loading elements have uncertainties where their joint normal distribution function, mean values and covariances are known. If the probability of the compliance constraint is given by the use of recommendation of Prekopa [1], this probabilistic expression can be substituted with an equivalent deterministic one and used as a deterministic constraint in the original problem. The object of the design (ground structure) is a rectangular disk in plane stress with given boundary conditions. The material is linearly elastic. The design variables are the thickness of the finite elements. By the use of the first order optimality conditions a redesign formula of the stochastically constrained topology optimization problem can be derived, which is an improved one of the previously [2, 3] presented iterative expressions. The new class of optimal topologies with their numerical confirmation are presented. Through the numerical examples the paper investigates optimal topologies obtained in case of uncertain situations. The effects of the covariances of the loads and the given probability are particularly investigated.

An example problem can be seen in Figure 1 where the structure is given by a rectangular domain (Fig.1.) with two simple supports and two point loads. The height/length ratio is 0.7 and the supports are located at the middle of the left and right corners, respectively. The mean values of the loading $\overline{\mathbf{F}}^T = \left[\overline{f}_1, \overline{f}_2 \right]$ are 50 units and located at a quarter way along of the middle line. The rectangular ground structure is

dimensionless 120x84 units. The Poisson's ratio is 0. For sake of simplicity the value of Young's modulus is assumed to be unity. The assumed probability is given by $q = 0.8$. The applied compliance limit is C=450000. The covariance values are given in the following order: $\kappa_{1,1} = 0.0$, $\kappa_{2,2} = 1.0$, $\kappa_{1,2} = 0.0$, $\kappa_{2,1} = 0.0$. The calculated optimal topology is given in Figure 2.

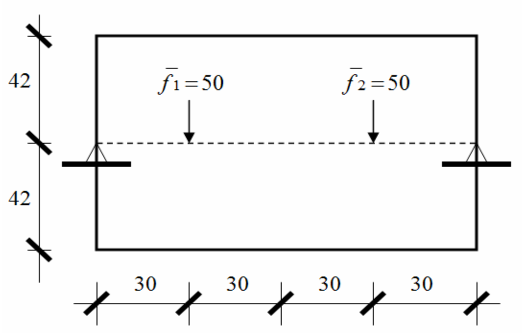

Figure 1: Design domain.

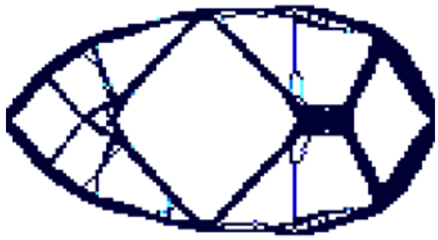

Figure 2: Optimal topology

The present stage of the research shows that to compute the stochastic topology needs the same computational time as it is in case of deterministic topology. The algorithm is rather stable and provides the convergence characteristics to reach the optimum. One can see that the covariance values and the expected probability values have significant effect for the optimal topology. The symmetricity of the design can be lost due to the effect of the covariance values. The applied method gives a wider possibility to the designer to take into consideration more realistic loading description than the deterministic topology design.

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