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MULTIMATERIAL TOPOLOGY OPTIMIZATION AS A GRADED MATERIAL DESIGN

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ABSTRACT

Topology optimization answers the question of how to distribute available *isotropic* material within a design domain and leads to an optimal design in which the new material forms an inhomogeneous isotropic composite [1]. In the present paper the objective function is the compliance of the body, equal to the strain energy. The objective function is minimized subject to a constraint on the mass of the body. The so called *artificial density approach* for updating the material properties is used. The stationarity condition implies a direct point-wise relation between the strain energy and the density of material, see [2]. One can say that the density distribution follows the effort of the body. For the numerical realization of the problem the FEM is used. Only this method assures a one to one correspondence between the design points and the Gauss points of the finite elements.

The inspiration of this paper is taken from human bone structures, where material properties are functionally changing. These changes follow usual structure effort, see [3]. Based on this, new material topology can be obtained with the properties satisfying the conditions required from a mechanical point of view.

In Fig. 1 the optimal topology and the normalized material density for the well known benchmark cantilever problem are shown using numbers (20x20 FE mesh). The results - the optimal solution - may be understood as graded material distribution of the mass density. The porosity of the optimal structure lies in the range from 0.53 to 1.00. The mass density is proportional to the Young's modulus of the material.

The constraints put on the mass of the structure are fulfilled in a specific manner. The number of *non-zero elements* is equal to 120 for the example discussed. The same holds for the discrete or 0/1 topology optimization process.

The variation of longitudinal stresses are shown in Fig.2. The cross-sections in Fig. 2 are marked just under the middle of each cross section elements from Fig. 1. The stresses are computed taking into consideration the distribution of the material shown in Fig. 1.

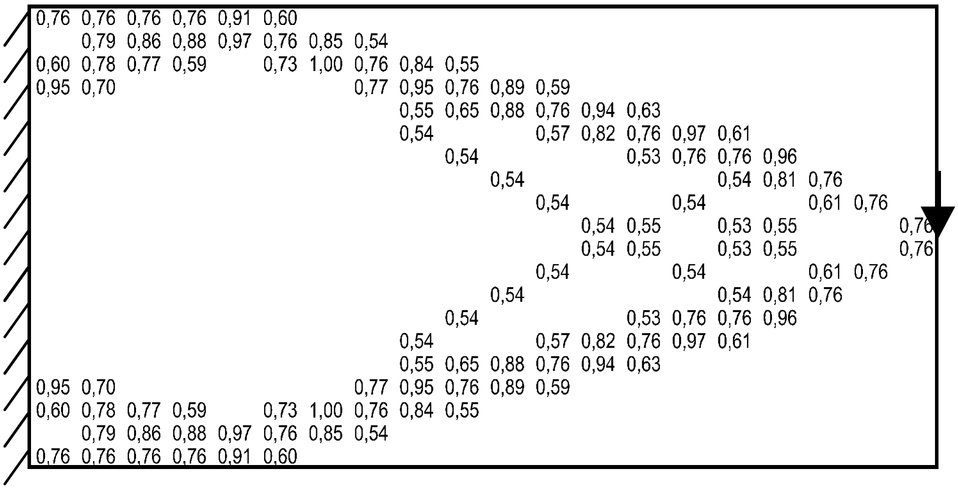

Fig. 1. Graded material optimal topology

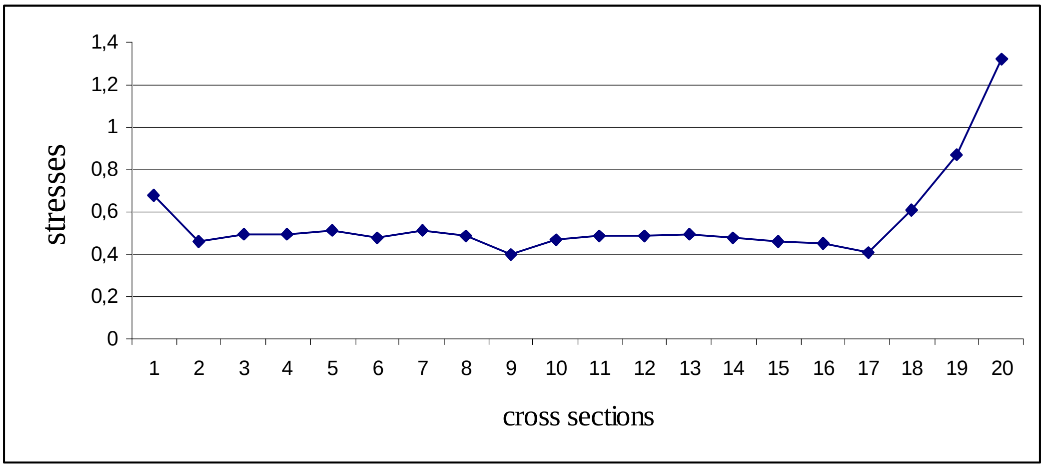

Fig. 2. Variation in longitudinal stresses for the above topology

As can be seen, the stress level is nearly constant, except the zones at the clamped edge and the cross sections near the application of the point load. It is worth emphasizing that the optimal solution found assures a uniform stress distribution, although this condition was not explicitly required in the initial optimal design formulation. Thus the topology optimization process results in the structure with a graded material, similar to that observed in human bones, cf. [3].

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