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TOPOLOGY OPTIMIZATION OF THREE DIMENSIONAL STRUCTURES WITH CONTACT CONDITIONS

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ABSTRACT

Bendsøe and Kikuchi [1] proposed in 1988 a generalized shape optimization method, introducing a material distribution model based on a porous material. With this approach the topology optimization problem is formulated in the continuum mechanics framework and it led to an intense research work in this research field for the last two decades. In the early years several two-dimensional models considering different aspects of the problem were analyzed. Different types of microstructures were tested, topology design models for vibration and buckling loads control were developed and shell and plate structures considered. More recently, three-dimensional models have been proposed, extending the concepts developed for two-dimensional problems, and launching topology optimization as an important design tool (see Bendsøe and Sigmund [2]). Despite the high level of development of the field, models for topology optimization focusing particular aspects and problems still have a special interest. It is the case of the development proposed in this paper where it is presented a three-dimensional computational model for topology optimization of structures with contact conditions.

This work is based on the model presented in Fernandes *et al.* [3], where a material distribution approach is used to minimize the structural compliance under multiple loads, subjected to an isoperimetric constraint on volume. In the present work, due to the presence of contact conditions, the objective function is redefined and the equilibrium equation is expressed for contact problems. The necessary conditions for optimum are derived analytically based on the Augmented Lagrangian associated with the problem. The methodology is similar to the one proposed by Rodrigues [4] for shape optimization of mechanical components. The stationarity of the Lagrangian with respect to the design variable yields a linear elastic problem with additional displacement constraints on the contact boundary, obtained from the solution of the state problem. The model is approximated numerically through a suitable finite element discretization and solved by a first order optimization method. The computational model developed was tested in several numerical applications with successful results (see figure 1).

Besides the application on structural optimization, the model has a special interest for

biomechanics applications, particularly for orthopaedic implants. The structural optimization model is adapted to study the bone remodeling after a non cemented hip arthroplasty [5]. In this problem the interface bone/implant requires a contact approach and the contact model proposed in this work has a special interest in this field [6]. Numerical examples in this area are also presented.

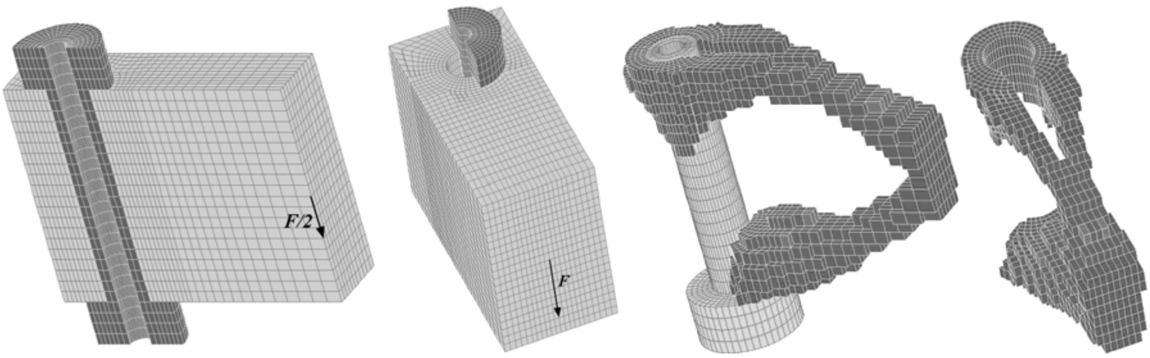

Figure 1 – Finite element model and final solution of a cylinder supported domain. Contact conditions are considered between the cylinder and the design domain for topology optimization. In the right (finite element model) the cylinder is represented in black and the design domain in light gray. In the left (final solution) the cylinder is represented in light gray, and the element densities of the domain of topology are represented in a gray scale where black represents the full material. Elements with density below 0.1 are not represented.

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