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SOME EXPERIENCES IN STRUCTURAL TOPOLOGY OPTIMIZATION

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Abstract

An algorithm for topological structural optimization using homogenization theory and optimality criteria methods is presented. Material models and homogenization theory are briefly introduced. Some examples of plane problems are presented, mainly to demonstrate the effect of material models and types of element on the optimum layout.

1 Introduction

1.1 Types of Structural Optimization

In parallel with advances in computer technology, considerable progress has been achieved in the field of numerical methods for structural analysis and this has made it possible to address the problem of structural optimization. The early research focused on *sizing optimization* problems which involved, for example: finding the optimum cross sectional properties of members of a truss or frame structure or the thickness optimization of a plate structure. In these problems the domain is fixed and does not change during the optimization process.

As a further development the problem of finding optimal boundaries of a structure was considered. Examples of this type of problems include: finding the boundaries of a plane stress problem or the location of joints of a skeletal structure or finding the optimal values for parameters which define the middle surface of a shell structure. In the literature this class of structural optimization problems is referred to as *shape optimization.* In these problems the domain is not fixed but the topology is.

The size and shape optimization methods may lead to sub-optimal results as they suffer from not necessarily having an optimum starting topology. To overcome this deficiency *topology optimization* needed to be considered. Typically in topology optimization of 2D and 3D continua the aim is to determine features such as the number of holes and their location. Finding the optimum configuration and spatial sequence of members and joints of a skeletal structure also lies in this category. The ideal is to find a method to simultaneously optimize the geometry (i.e. size and shape) and topology of structure. This is sometimes called *layout optimization* [l].

1.2 Aspects of Topology Optimization

Topological structural optimization has the complex features of both size and shape optimization problems. Conventional shape optimization by the boundary variation method normally requires several re-meshings in the optimization process and results in final designs that are topologically equivalent to the initial design. Trying to change the topology as well as the shape during the scheme will increase the complexity of the problem and will make it a very difficult task. Because of these complexities this class of problems is regarded as one of the most challenging ones in structural mechanics [2].

Methods for obtaining optimal topologies vary from rigorous mathematically based methods (e.g. the homogenization method) to more engineering-intuitive methods (e.g. hard kill/soft kill method). In this paper we will focus on the former approaches.

Usually the result of structural topology optimization for 2D and 3D continua is a contour plot of material density for which an optimal topology must be discerned eith;r automatically using some kind of image processim; or intuitively using engineering judgement or by a combination of both.

In an attempt to solve the topology optimization problem Bendsoe and Kikuchi [:l] suggested the *homogenization method* which has since attracted the attention of many researchers. In this method the optimal topology is accompanied by a rough optimal shape and size and consequently, it is sometimes called *generalized shape optimization.*

Consideration of the following factors provided the inspiration for the homogenization method:

Generalized shape optimization is inherently a point wise “material/no material" problem.

Implementation of this ‘on-off’ approach to an optimization problem requires the use of discrete optimization algorithms and such an approach would be unstable.

- The experience of previous researchers has proved that in many cases the optimum result contains regions with infinitesimal cavities or ribs [4, 5].
- By introducing a microstructure to the material model, Kohn and Strang [6] could obtain a well-posed, relaxed formulation for the two dimensional heat conduction problem