FEM-AIDED MATERIALS SELECTION USING TOPOLOGY OPTIMIZATION

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Abstract
This paper presents a method that combines material selection procedure with topology optimization using ANSYS. The method is applied on a suspension of a handbike.

Key words: *handbike; ANSYS; material indices, DOE.*

INTRODUCTION

Material selection and engineering design are usually performed sequentially, which means that firstly a candidate material can be selected and consequently product dimensions are calculated to meet for example stress criteria. However, with use of topology optimization and design-of-experiment methods both can be done simultaneously.

MATERIALS AND METHODS

The method of materials selection based on material indices described in (Ashby, 2003) is derived for simple textbook cases like strut subjected to tension and a cantilever beam loaded in bending. However, the real world problems are more complicated with combinations of loading and complicated shape of components. In our earlier work we developed a material index for buckling of a cylinder. This task was still limited with the shape of the part. In case that the shape of the part is arbitrary with certain constraints a more sophisticated tools such as topology optimization can be applied. The algorithm for material selection using topology optimization is developed as follows. Firstly design space is creating taking into account maximum dimensions, constraints and variable parameters. Then the topology optimization itself is performed for a number of design points. Consequently the geometry is validated and material index is derived using curve fitting. The overall workflow with its relation to standard material selection procedure is shown in Fig. 1.

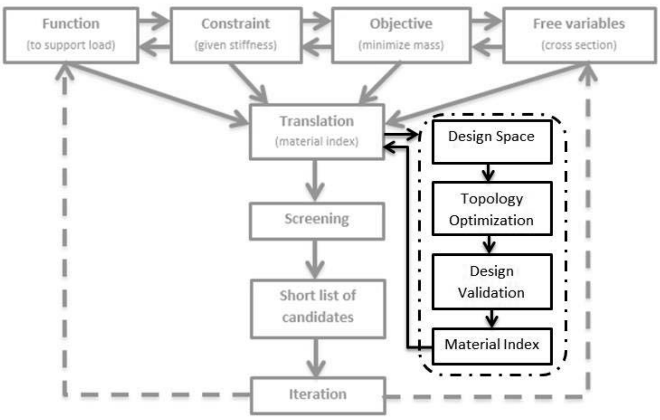

Fig. 1 FEM-aided Material Selection Algorithm

Topological optimalization

Topology optimization is a part of discipline called Structural Design Optimization. The goal of Structural Design Optimization is to find an optimal lay-out of material of a component. There are three different types of structural design optimization: size optimization, shape optimization and topology optimization. The size optimization determines optimal thickness of a part of a machine component. Structural optimization determines optimal profile or contour of a structure. Its goal is to find an opti-

mal shape of any element of machine component (circular or elliptical hole e.g.). Topology optimization is the most general and complex method. Topology deals with fundamental elements of geometry – number of holes or connections of a geometry of a component. Topology optimization works with topology, shape and size together. Can be used with isotropic, anisotropic or composite material, even fluids or gases. Topology optimization can solve structural, eigenvalue, thermal or fluid dynamics problems. (Bendsøe,& Sigmund, 2003)
Using one of mentioned method, a most of structural problems can be transformed to usual mathematic optimization scheme (to minimize an objective function) and solved using numerical method.
The characteristic input information for topology optimization is a design space (domain). The design space is a given volume of space, which is optimized (where optimized geometry is created) or initial design. The design space is divided to a subdomains due to discretization. Discretization is necessary for purpose of numerical solution. Another given information are applied forces, supports and material parameters of volume.
The next step is to create mathematical model of optimization. The objective function must indicate compliance of derived geometry. The goal is to minimize the objective function. The result must satisfy given constrains (maximal mass or stress).
The solution is an iterative process, consist of finite element analysis, sensitivity analysis, filtering and updating the design of structure in every step. Topology optimization can leads to very effective design, but a result strongly depends on proper settings of solver parameters. Theoretically is there many solutions can fulfill given mathematical requirements, but most of they isn't acceptable in technical scope.
Result is determined by size of elements, post processing (filtering, sensitivity), number of steps and solution options (penalty, gradient). To get smooth geometry, lowering size of element probably increases a number of connections. Another problem is creating complicated geometry with insufficient stiffness. Good post processing creates smooth geometry with required number of holes. The shape can be driven by method of filtering. A flowchart of topology optimization procedure is shown in Fig. 2.

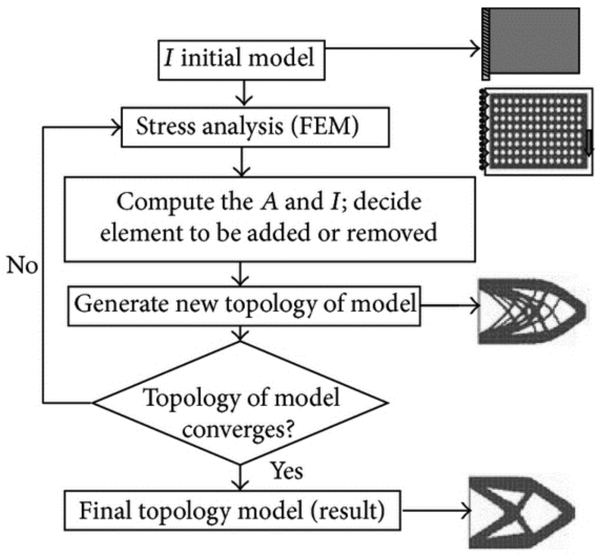

Fig. 2 FEM-aided Material Selection Algorithm (Rahman et. All, 2014)

Handbike

Handbike (also known as a handcycle) is a device enable cycling tourist for people with physical disabilities. Physical disability refers to the lower part body (amputation of the leg, spinal cord break). Because users cannot use their legs, they have to use for propulsion their hands.

Beside a classic bicycle is the handbike composed from frame with minimum 3 wheels (due to stability) and handlebars, where are placed all controls including propulsion. Because design of the handbike will be always more complex than a classic bicycle and users need to use their hands for propulsion, is very important to make the whole device as light as possible, because every extra gram unnecessarily exhausts the user.
In this case was selected a variant of the handbike with two front wheels with suspension. One of these parts is the front suspension fork which has been subjected to topological optimization.

RESULTS AND DISCUSSION

The described method was applied on suspension of a handbike in order to determine the relation between Young's modulus and density of an optimal material for given problem. In Fig. 2 the design space for topology optimization and resulting optimized shape is shown.

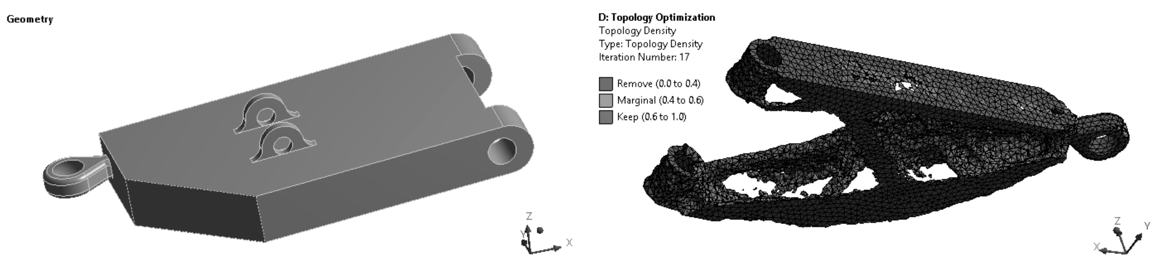

Fig. 3 Design Space for Topology Optimization and Optimized Shape

Preliminary results showing relation between Young's modulus and density for best performance of handbike suspension can be seen in Fig. 4. The output file resulting from topology optimization in ANSYS that contains the optimized shape results comes in .stl file format. This particular file format is used e.g. for 3D printing and the procedures of converting other CAD geometry file formats into .stl are well developed. However, in this case in order to perform design validation properly the .stl file needs to be converted back into solid geometry file format such as .stp. The back conversion is a rather complicated task and not all CAD systems are capable of such request. The processing time strongly depends on complexity of the input .stl file and therefore it conflicts with the requirements on mesh density. Therefore only preliminary results are given.

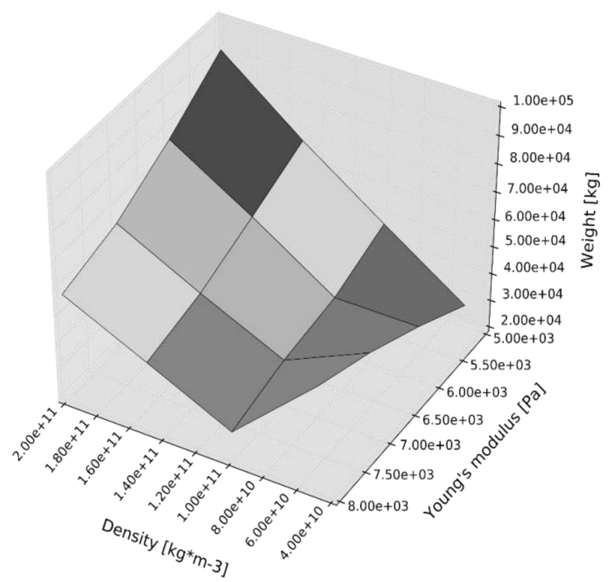

Fig. 4 Design Space for Topology Optimization and Optimized Shape

CONCLUSIONS

In this paper a method for material selection using topology optimization is described. The method can be utilized for material selection when the designed product is subjected to various sources of loading and the resulting shape is arbitrary with some constraints for neighboring parts in an assembly.

ACKNOWLEDGMENT

This study was supported by the internal project of University of West Bohemia SGS-2016-012.

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