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OPTIMIZATION METHODS APPLIED IN CAD BASED FURNITURE DESIGN

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Abstract: *Nowadays, the weight reduction of furniture structures is an important issue, having a direct impact on the economic growth of a specialized company. In order to reduce the mass and to obtain an optimal material distribution in a given volume of the furniture parts, the most widely used methods are given by optimization techniques that are deployed via CAD programs. This paper presents two possible structure optimization methods that can be applied in the furniture industry. Both topology and topography optimization methods are employed: the topology optimization of a wall bracket and the topography optimization of a sheet metal bracket using dedicated software. Based on the conclusions of this study, useful insights can be gained by a company starting up furniture production.*

Key words: *topology optimization, topography optimization*

1. INTRODUCTION

Recent studies related to the modeling and the analysis of furniture design are focused on using a process of parametric CAD modelling and finite element analysis for achieving furniture pieces [1].

Conventional methods used in practical engineering optimizations have some limitations and finite element analysis is more useful in furniture design [2]. An example of applying some structural optimization techniques, with the ANSYS software, was realized on a laminated bamboo chair [3].

Another application is using a static and dynamic analysis with finite element analysis, in order to determine the maximum displacements and stress [4].

The optimization of the furniture parts can be achieved using Optistruct solver, integrated in Altair Hyper works. Among the different types of optimizations that can be completed in this software are the topology, topography and free-size optimizations [5].

In this paper some engineering optimization methods are studied, which can be applied to generate the optimal design of furniture pieces based on existing requirements.

Among the methods which are better suited for determining the optimal shape of the furniture pieces, here, are the topological and topographical optimizations. These methods allow the possibility to make changes to the proposed design, volume and shape.

In this study, a finite element model of a two piece structure was developed for undergoing the optimization process. The design variables and the restrictions were defined for the model.

The process should determine the minimum value of a dependent function based on the design variables. A mathematical algorithm is used to find the best solutions. Because optimization is an iterative process software programs have been developed that solve these problems numerically, which is more suitable in an industrial environment, as we shall present below.

2. THE CAD MODEL

The import of the CAD geometry of the model is the first step of the software optimization process. A furniture wall bracket base model has been considered, with the characteristics indicated in figure 1.

The CAD model is first generated using SolidWorks software. The dimensional parameters of the model are defined based on the conceptual design that responds to the customer requirements and the envisioned function.

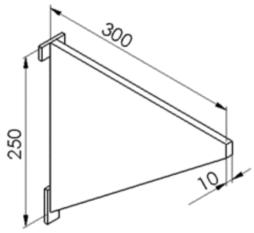


Fig. 1. The base model

The generated model is then exported in IGES format and it is imported in Hyper Mesh with Optistruct optimization solver.

3. TOPOLOGICAL OPTIMIZATION

In this section, the topology optimization technique is presented using the Optistruct software. Topological optimization problems are solved in Optistruct solver using either the density or homogenization methods.

In the first case, the density of the elements represents the design variable of the process. The continuous variation of it can go from void (0) to solid (1). Also, the material stiffness and its density are assumed to be in a linear relationship [5].

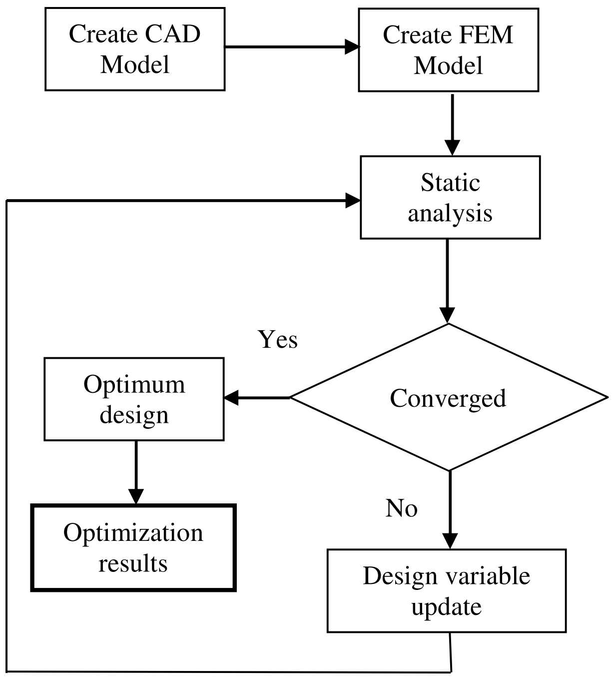


Fig. 2. Flowchart of the optimization process.

In the case of the homogenization method, the internal structure of the chosen material is presumed to be a porous continuum [5].

The flowchart of the necessary steps in order to achieve the proposed process is presented in figure 2.

The results of finite element analysis will be used in order to generate the optimal model. For this type of optimization the objective function is represented by the minimization of the material volume required for the final product design. In case of production, this achieves savings in terms of costs (less material, less machining, less energy consumed) and it is environmentally friendly (less waste, easier recycling at the end of product life). The difference between the final form and the initial design can decisively impact the company's competitiveness.

In the following, the topological optimization of the wall bracket is presented. After the geometry generation, the next step is the volume discretization of the model. The material assignation, in this case aluminum, the load case designation and the parameter setup are performed. The finite element analysis is completed using the Altair HyperMesh software, and for optimization the Optistruct solver is used, which is integrated in this software. The model is meshed in prisms and hexahedrons solid elements. The base model is rigidly connected, as shown in figure 3. The applied force has a value of 200 N.

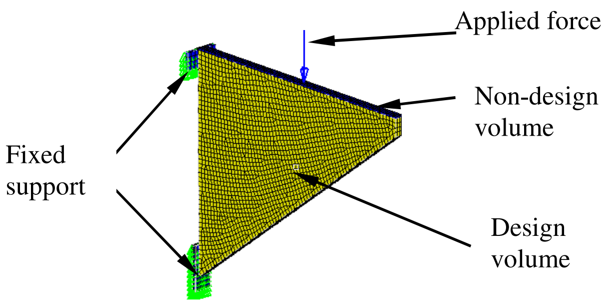


Fig. 3. The base FEM model

In order to optimize the distributions of the material in the design volume, the objective function provides the use of 25% of this volume. The initial mass of the design volume is 1.093 kg. After solving the finite element load case, the results of the method are presented in figure 3.

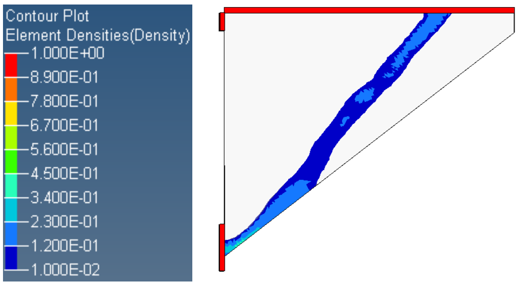


Fig. 3. Distribution of the material in design volume

The end point of the optimization process is given by the reconstruction of the optimized shape. The final mass of the wall bracket after redesign is approximately 0.379 kg.

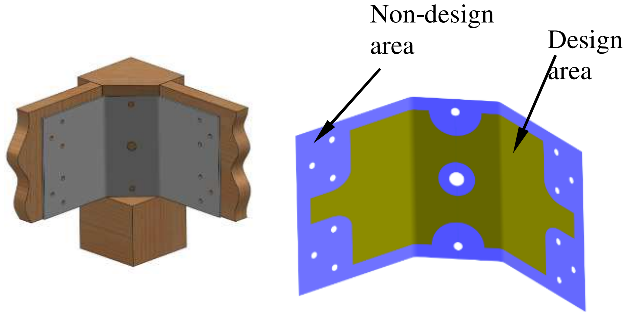
In the following figure the redesigned shape of the wall bracket model is presented, generated using the SolidWorks software. To strengthen the bracket an additional reinforcement part was added.

Fig. 4. The shape of redesigned model

4. TOPOGRAPHICAL OPTIMIZATION

The topographical method is an advanced type of shape optimization. The design area will be provided with a reinforcement pattern, this shape depending on the design variables. This approach could be used in the furniture industry for determining the optimal geometry of the connector parts, such as the hinge mechanisms, or other metal furniture frames.

In this case the density variables are used as process variables. The following part of the paper presents the example of a bracket.



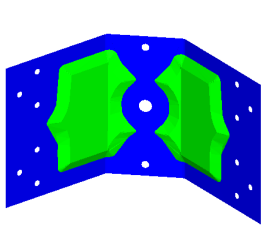
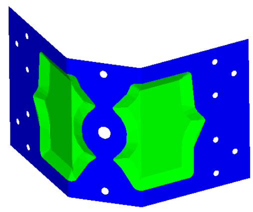
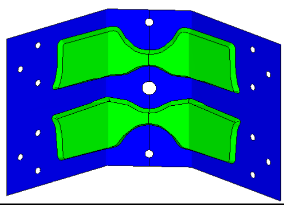
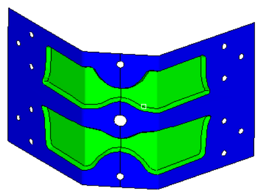
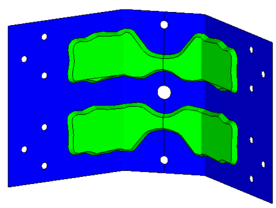
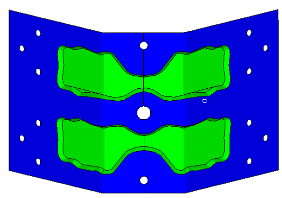
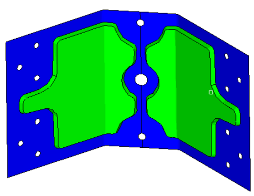
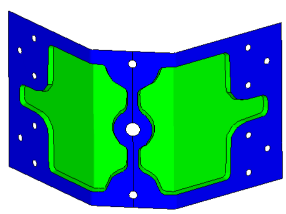
a) Base model b) Design/non-design space

Fig. 5. Furniture bracket

In figure 5a the base model of a furniture bracket is illustrated, which is used for connecting three wooden parts. Figure 5b presents the shape of the studied design and non-design areas.

The shape of the base model is meshed using finite shell elements, which is a characteristic of topography optimization. The design area of the model is meshed in 11174 shell elements, each with a length and thickness of 2 mm. The following table presents the variations of the optimal shape depending on the variation of the Optistruct settings. The resulting shape from the topographical optimization process depends on the chosen type and the grouping pattern.

Table 1. Possible variants for the final bracket

Front view	Rear view
	
Radial 2d pattern grouping	
	
Cilindric pattern grouping	
	
Circular pattern grouping	
	
Planar pattern grouping	

All the generated shapes, presented in the above table, can be used to achieve the primary function while allowing customized aesthetics and improved manufacturing costs.

5. CONCLUSIONS

Employing advanced software solutions, in this study two cases of structural enhancement of parts used in the furniture industry are presented. The topology optimization process applied in first part of this paper shows the optimal design of the model by reducing it to the minimum mass. The topography optimization method can be used for determining the optimal shape of a furniture connector, creating reinforcement patterns. This engineering enhancement process if used in furniture manufacturing can increase the product reliability and decrease production expenditures.

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7. ACKNOWLEDGEMENTS

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METODE DE OPTIMIZARE APLICATE ÎN PROIECTAREA CAD A MOBILIERULUI

Rezumat: În zilele noastre, reducerea masei structurilor de mobilier este o problemă importantă, având un impact semnificativ asupra creşterii economice a unei companii din acest domeniu. În vederea reducerii masei şi obţinerii unei distribuții optime a materialului componentelor de mobilier într-un volum dat, cele mai utilizate metode sunt date de tehnicile de optimizare. Această lucrare prezintă două metode de optimizare a structurilor ce pot fi aplicate în industria mobilei. În cadrul acestui studiu sunt descrise două metode de optimizare: optimizarea topologică a unui suport de perete şi optimizarea topografică a unui suport confecţionat din tablă folosind un program dedicat de optimizare a structurilor. Pe baza concluziilor acestui studiu, perspective utile pot fi obţinute pentru o companie care demarează producţia de mobilier.

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