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TOPOLOGY OPTIMIZATION BY MEANS OF FINITE ELEMENT METHOD

Abstract: This paper presents on the basis of a practical example a computer aide method of optimization of the machine elements topology which is based on the Finite Element Method.

1. Introduction

The competitiveness of the market which is changing very dynamically, can be preserved only by responding to the needs of our customers. Rapid technological development faces the designers and constructors with a very difficult task. They need to develop a system and design according to the expectations of the client, while on the other hand maintaining the criteria arising from the technical purposefulness and economic or productive capacity [1-3]. The solution allowing to meet such wide range of needs, and to prevent excessive increase in the cost of production is the use of typology optimization in the design process.

2. Presentation of the typology optimization method

Topology optimization determines the placement of the material in a defined area of the project so that, by the assumed boundary conditions and the loads, the shape of the structure was optimized taking into account the specific objective function [5,6]. Most frequently the objective function in the optimization of machine elements is the minimum weight, and the boundary conditions are [2,4]:

- not exceeding the allowable stresses,
- not exceededing the given strains,
- as well as the criteria resulting from the application of a specific manufacturing process.

Optimization is carried out in an area which is fixed in the process, during which subareas without material as well as subareas filled with material are formed. The optimization process is carried out in an iterative way. The pliancy minimum is sought for each step. The final result of the optimization is the optimal distribution of material within a given design area that meets established criteria. Fig. 1 shows the results of optimizing the topology of the fragment of a yoke. The topology optimization and strength analyzes described in this paper were carried out by means of the Finite Element Method in NX8.5 and TOSCA STRUCTURE 7.3 software.

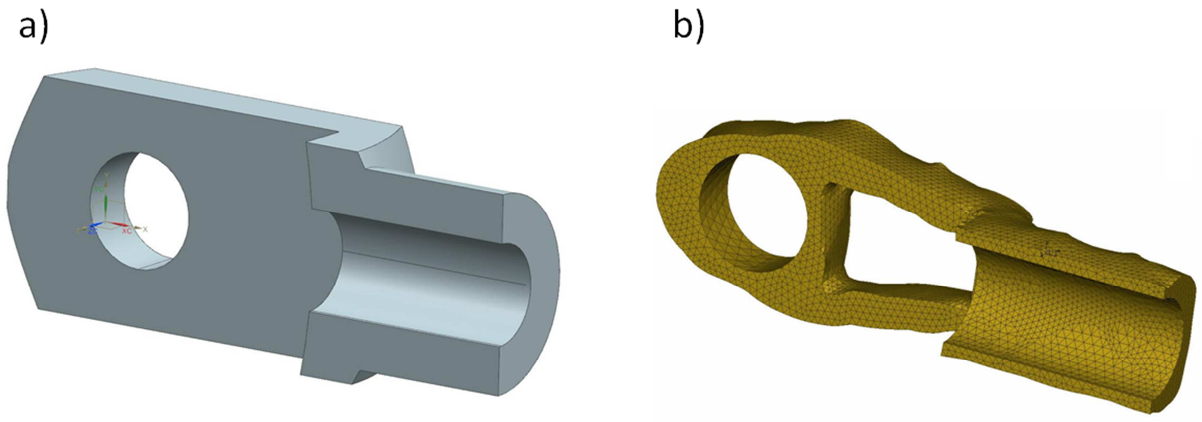

Fig.1. Results of the optimization of a yoke fragment: a) initial model, b) optimal topology

The obtained design form usually requires some additional adjustment of the shape to the criteria of the given technological process and the conditions which result form the performance, assembly, esthetic and ergonomic criteria [7,8]. The operations focus on adapting the optimal model to the mentioned criteria by smoothing and simplifying the shapes of the model, as well as removing the mass from certain regions and adding it in others. Fig. 2 shows a comparison of model the yoke before and after the optimization process.

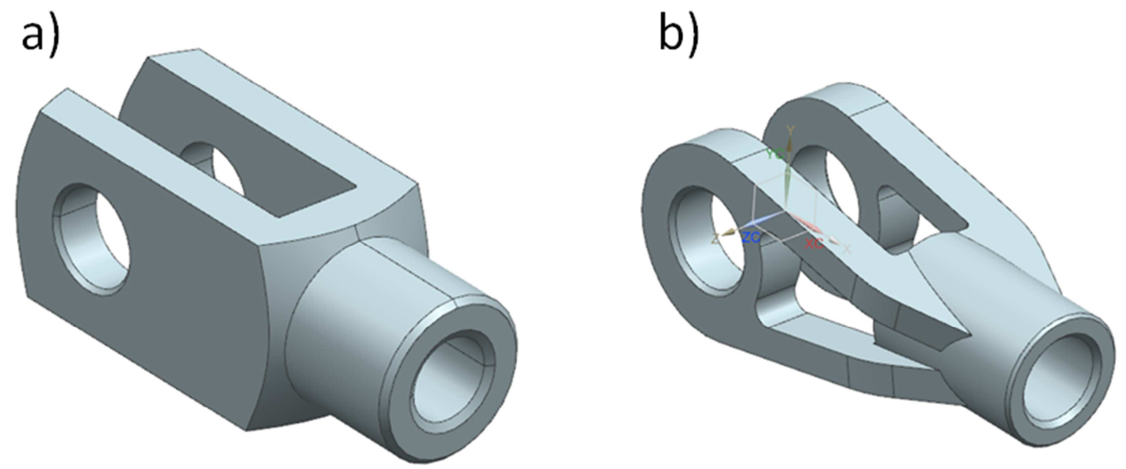

Fig.2. Comparison of the yoke models: a) model before optimization, b) model after adjusting the typology to the given criteria

The typology optimization has allowed to decrease the weight of the yoke 2,04g to 1,09kg, with the preservation of the same, both simple and stereo mechanical physical states, as in the initial model. Fig. 3 presents the results of the analysis of stresses In the fragments of the yoke before and after topology optimization.

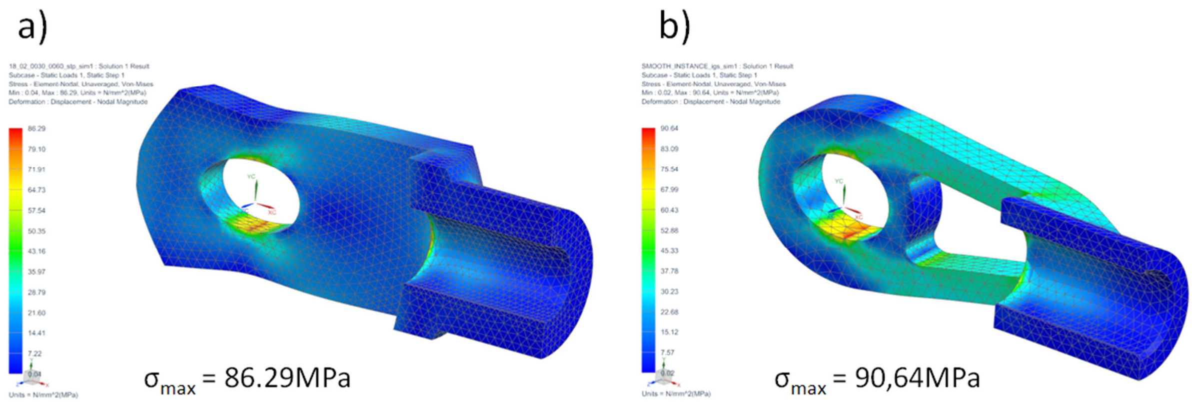

Fig.3. Results of stress analysis: a) model before optimization, b) adapted model

After the analysis of the results, it was concluded that the value of the maximum stress in the obtained model is similar to the stress appearing in the initial model. The stress distribution and increase in material effort in the specific areas of the model have changed, what is the effect of the changes in the distribution of material from the topology optimization.
Fig. 4 presents the stages of topology optimization using Finite Element Method.

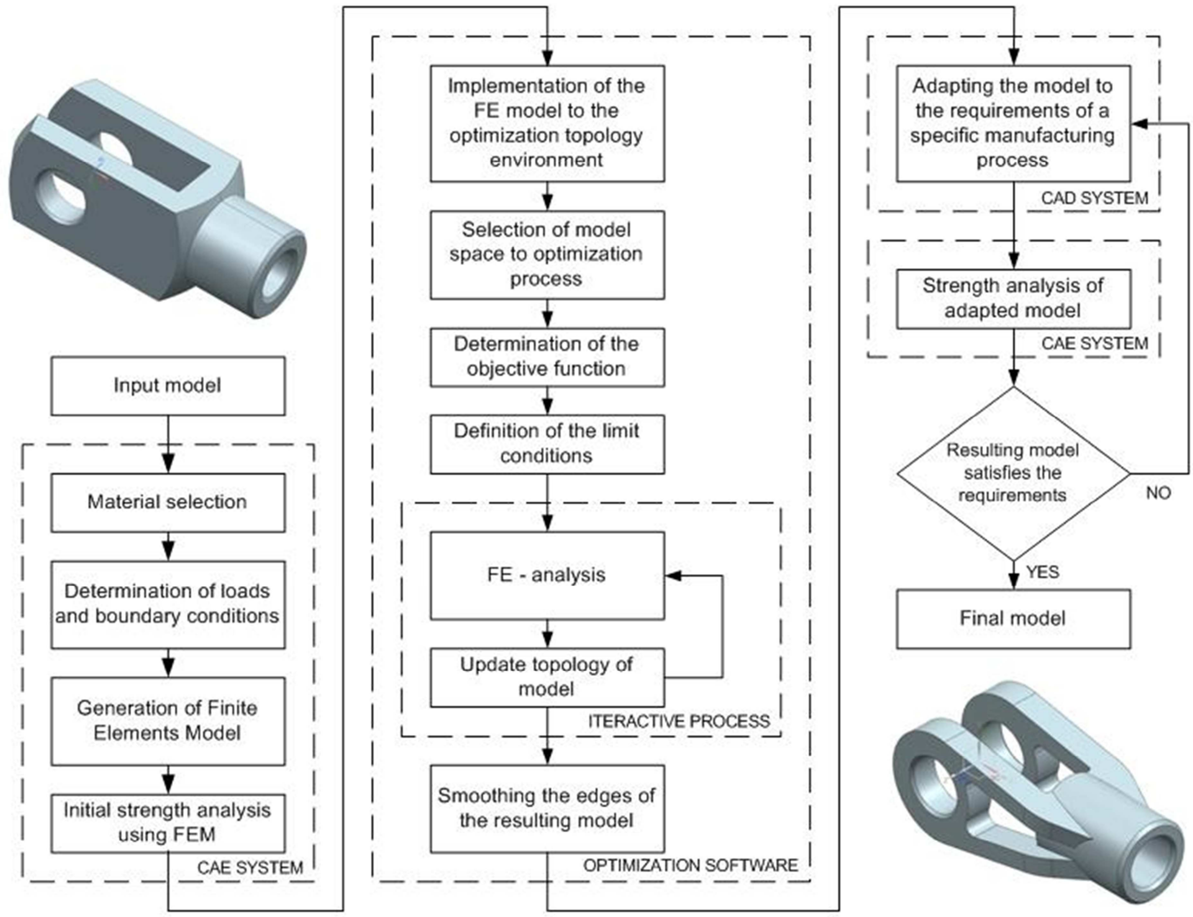

Fig.4. Stages of topology optimization using FEM

Presented algorithm allows to determine the optimal topology of machines elements accordance to the strength, manufacturing and economic criteria.

3. Conclusion

In the presented example of topology optimization of a yoke, the minimal weight and the following boundary conditions were determined as the main optimization criteria:

- stresses in the final model on the same level as in the initial model ($\sigma_{max} \leq$ 90MPa),
- displacement of any of the points of the yoke smaller than 0,1mm.

As a result of the optimization and the process of adapting the topology to the production criteria a model of a yoke was obtained which mass is less than about 47% smaller than the mass of the model before optimization, and the stress does not exceed the limit.
The next stage of the research should include the production of a prototype yoke and subjecting it to endurance tests in order to verify the convergence of the conducted computer stress analysis with the actual results.

Topology optimization obtained by means of the Finite Element Method is a relatively new field of knowledge ,which has nevertheless developed very rapidly in the last decade . It is a widely used practice in the machine building industry, and its development derives from the needs of some of the modern industries such as aerospace, automotive, and military technology. The use of the topology optimization of the design process - not only facilitates the process, but also leads to the reduction regarding the manufacturing time and the experimental verification of the product itself, what eventually leads to more rapid introduction of the new product to the market. By applying modern methods of optimization the company is able to build elements of higher rigidity, durability and safety , while reducing weight and cost. The described operations allow significant savings (in both material and time), increase in the effectiveness and efficiency of the design departments, and thus - the increase in market competitiveness.

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