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TOPOLOGY OPTIMIZATION UNDER MULIPLE LOAD CASE USING A BIOMIMETIC APPROACH

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ABSTRACT

1. Introduction

Biomimetics is the concept of taking ideas from nature and implementing them in engineering design. One of the most important elements of the living entities are their mechanical structures, which enable others life functions. In many situations the problems concerning maintaining the mechanical structure of living entities are very similar to the problems found in mechanical engineering. The Wollf's law, which has been stated in the 19th century indicates that the bone is able to adapt to mechanical stimulation. The process of the trabecular bone adaptation can be treated as a special kind of topology optimization under multiple loads.

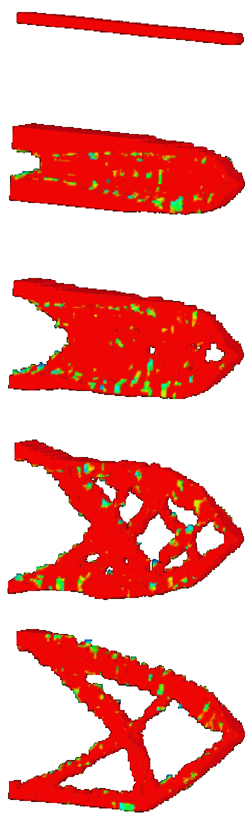

Figure 1: Optimization results of the cantilever beam – bounadry condition (left side) clamped wall, load (right side) vertical bending force

2. Trabecular bone remodeling phenomenon as a topology optimization process

The model of the bone remodeling process discussed in the paper is based on the regulatory model of Ruimerman and Huiskes [1]. It is assumed that structural surface evolution is a function of strain energy density (SED) with "lazy zone", a special range of SED allowed on the bone surface. If the SED value in the structure is higher than the upper "lazy zone" value the tissue material is added, if it is lower then the lowest "lazy zone" value the material is removed. If the SED value contains in the "lazy zone" no adaptation occurs. This mechanism is responsible for bone failure preventing. The trabecular structure is able to "remember" different loads from the history and keep this memory "hidden" in the structural configuration. Shape design with

Shape design with optimal stiffness investigations carried out by Wasiutynski [2], Dems and Mroz [3] and others lead to some theorems concerning the surface - design shape. The most important conclusion is that for the stiffest design the energy density along the boundary shape to be designed must be constant. By balancing the strain energy density value on the bone surface, the maximum stiffness of the entire structure is ensured.

3. Topology optimization under multiple load case

To compare the presented method with the topology optimization method, the standard topology optimization example was chosen. On Figure 1. the optimization results of the cantilever beam using of the presented method based on the trabecular bone surface adaptation is presented. The simulation results show the essence of the approach. The starting domain is as simple as possible; it is just the linear connection of the load (vertical bending force) and the clamped boundary area. The result is very similar to well known results obtained by standard topology optimization method [4].

The same starting configuration was studied under multiple load cases. Two different load cases was examined – first, identical with the study presented on Figure 1., and the second, with the same boundary condition definition and horizontal bending force. The results of the multiple load study are presented on Figure 2.

4. Conclusions

The presented method is able to produce results similar to the standard topology optimization and has some special features, such as domain independence and multiple load cases problem solution embedded in the optimization scenario which can be useful in mechanical design, especially in case when the functional structures are needed during the optimization process. The optimization procedure comprises the optimization of the size, shape and topology, related to the material properties, something that occurs naturally in biological structures.

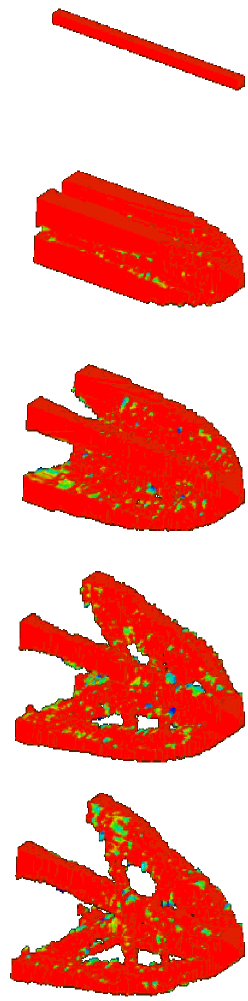

Figure 2: Multiple load optimization results of the cantilever beam – bounadry condition (left side) clamped wall, load (right side) vertical bending force and horizontal bending force

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