Numerical examination of like-honeycomb structures

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Abstract

In the paper based on the analogy with the biological tissue of bones, it was decided to examine more homogenous structure and also a heterogeneous structure too. Here, a new approach is proposed based on results from literature obtained using topology optimization 2D and 3D structures like beam, girder and cantilever. Proposed model of structure is similar to spatial trusses with honeycomb-shape porous. Parameters varied not only uniformly throughout the volume of the sample, but also be modified depending on various factors. They underwent a change in cell dimensions, among other things, the thickness of the wall. The obtained results were compared with those obtained previously for homogeneous samples.

Keywords: honeycomb structures, numerical simulation, FEM, parametric model

1. Introduction

Additive technologies are widely used for the presentation of the newly developed elements and geometric verification increasing use of elements produced in these technologies as a target produced small series structure poses new challenges as to their form and internal design features. Significant become their strength characteristics and durability. Existing systems for shaping the internal structure based primarily on land use geometric shape of the internal space realizing only a supportive function for external shapes based on the criterion of fill material, allowing you to reduce the amount of material used. For structural applications, it is necessary to adopt other criteria shaping the structure like the strength criterion. This places entirely new demands on the approach to the development of the internal form of the element made in additive technology.

Homogenic structure based on honeycomb pattern which is used while shaping the inside of the elements made in additive technologies, can be replaced by heterogenic structure which ultimately will assure the better strength and mass properties. The research has been carried in a few stages.

At the first stage it has been decided to test the structures which are similar to those which we can see in bones as a pattern of final structure. These types of structures have been tested in this stage as well as the choice of optimal calculation parameters which are used in these cases has been made.

Comparative studies of analytical and experimental research results have been carried at the next stage. Comparative studies covered samples prepared from cortical bone tissue.

The third stage covered elaboration and testing of numerical samples of the same shape but with the use of filling in a form of a honeycomb of different sizes allowing to create heterogeneous structures similar to the bones structure.

At the next stage the structure of samples has been elaborated which was of completely new inner form shaped as superposition of previously developed structures together with newly elaborated heterogeneous structure of changeable size of honeycomb cells. The orthogonal sample created in this way for bending tests has been subjected to numerical tests. The test results have been compared with initial structures of orthogonal samples based on the filling of typical, non-modified honeycomb.

The work focused mainly on the presentation of tasks and results from the third and fourth steps.

2. Modeling of honeycomb structures

Inspired by the existing solutions we adapted them to the relevant issues. In the literature we can find many papers concern topology optimization problem for 2D and 3D structures like beam, girder, cantilever or other massive support structures [1,2,7]. Some of them also based on the similarity of biomechanical structures [5,6]. Although the initial shape (volume) is full and continuous, however, final design is very similar to the truss, according to the considered issues of flat or spatial. The results obtained in the topology optimization allow us to propose a structure which is a spatial truss in which the elements have different cross sections, different lengths and different arrangement.

Based on the literature review the changes to the cells overlap with the contour of the truss were proposed. In the place where the space should be filled with cells, it has a thicker wall. Due to the limitations imposed by the additive technology model can consist of a relatively large empty space. It is therefore proposed to fill in these cells hexagonal. They have thinner wall. Results obtained in previous investigation were taken into account too [3,4].

Here proposed that the parameters which are prone to change they are wall thickness and cell size. In the case of wall thickness variations in the contour of the grid cell will have a thicker wall than the other. When the cell size will be changed in place of stroke it occurs density smaller cells. In the areas of "empty" cells it will be less, as will be higher. In the first stage it was decided to examine the effect of wall thickness on the obtained results. The dimensions of the model, the approximate dimensions of the tested bone samples were 4x4x40mm. We

*The research is partially financed by research project no. BKM-514/RMT-6/2016 (10/060/BKM_16/0039).

adopted this assumption in order to facilitate comparison of the obtained results. Away from the base to the opposite side of the cube was 1 mm. This is an external dimension of a cell. At this stage, we adapted it to the outer dimensions of the model. Changes in internal dimensions - wall thickness - result in a decrease or increase the free space inside the cell. All it correlated to the value of 1mm.

The wall thickness was 0.4 mm maximum and a minimum of 0.05 mm. It decided to make changes in different ways. The basic wall thickness is assumed to be 0.25. The initial model was uniform and the wall thickness of each cell is the same. Initially, the increased wall thickness situated on the outline of the grid and at the same time reduces the thickness of the cell walls outside contour. In a next step it was decided that the difference between the thickness and a second cell is not too high. For example, when the contour of the cell wall in the grid has a wall thickness of 0.25 mm, a cell wall beyond the periphery is 0.2 mm (Fig.1).

In a further step it is proposed that underwent a change in cell dimensions and the wall thickness in each case was similar. The maximum distance between opposite walls was 2 mm, and 0.5 mm minimum. The wall thickness has been changing, but always all cells have the same dimension.

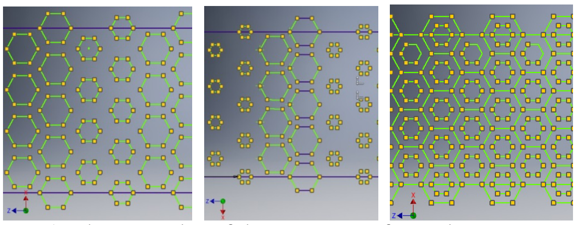

Figure 1: The examples of the geometry of samples

All numerically tested samples have the same dimensions as a previous tested samples prepared from cortical bone tissue. The sample with a length of 40 mm, a height of 4 mm and 4 mm wide was modelled for two layers structure and sample with a height of 2 mm for one layer structure. Boundary condition (support and load) assumed as typical during tree-point bending test. Acting force equals 5 N.

In two layers models different pattern was used in construction of bottom and upper layer of structure. Figure 2 shows bottom and upper view of structure in the same place, respectively. Changes in the structure of the layers resulted in a change of simulation results.

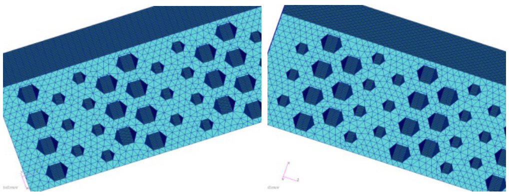

Figure 2: Enlarged view of bottom and upper surface (in the same place) of two layers structure

3. Result and conclusions

However, the displacement distribution for both, one layer and two layers model is typical as in bending nevertheless the distribution of von Mises reduced stresses and bending (normal) stresses are disrupted in sections where there are voids. One can observed that the larger the size of the void influence on the greater stress concentration.

Changes introducing in the sample structure effect on the decreasing of maximum value of displacement and stresses in two layers model and also in one layer model. In one layer model it can be observed that displacement equals 0.115 mm for initial configuration of the voids has decreased to 0.098 mm for the next configuration of the voids. The same trends were seen for two layers models. In that case displacement equals 0.011 mm for initial configuration of the voids has decreased to 0.0091 mm for the next configuration.

When the reduced von Mises stresses are taken into account it can be noticed decreasing initial maximum value (for initial configuration) from 166 MPa to 109 MPa for next configuration in one layer model. These same relationships exist for two layers models. Here, stresses has decreased from 21 MPa to 16,7 MPa. Bending stresses also changed and decreasing when the voids configuration is shaped in the right way.

We can also observed significant reduction the value of displacement and stresses when we move from a single layer structure to the two. It coming from, not only increasing the cross-section of the beam but mainly, from the changing in internal structure of a sample.

Along with the reduction of empty space an improvement of the results. The introduction of too much free space resulted in a significant deterioration of the results. In some cases, they proved to be critical. Not each inhomogeneous model was better than the homogeneous. In some cases, the obtained results were worse than the base case model. A similar phenomenon was observed when comparing the results between the models produced by changing the thickness of the walls, and where changes underwent cell dimensions base. It is impossible to say with certainty that some changes have a better impact on the obtained results, and other worse.

In further studies we propose to performed sensitivity analysis to indicae which factors (dimensions) are the most important. We also plan to use numerical homogenization in further numerical testing.

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