NUMERICAL AND EXPERIMENTAL TESTS OF INVERSE HONEYCOMB STRUCTURE USED IN THE EXOSKELETON FOR A CHILD

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1. Introduction

Very often when designing some devices, the important factors are the weight of the whole structures and the level of stiffening of its individual elements. It seems to us that one of such devices is an exoskeleton designed for children. We do not have such rigorous lifting requirements as in the case of exoskeletons for firefighters or army. In the case of an exoskeleton for a child, it is important that the whole structure does not weigh too much for a small patient. Sometimes the main task of the device is to correct movements made by the child. The exoskeleton forces natural, proper movement of the limbs, in order to eliminate pathological behaviors. The structure proposed by us is manufactured using a 3D printer. This facilitates the personalization of external coatings in a significant way. The structure will remain the same, its properties will not change, and a pattern will be applied to the outer coat that can make the treatment process more pleasant for the little patient. This is also a very important aspect, because in the case of rehabilitation, treatment is also important for the patient's attitude. Children are quickly discouraged. When we give them a device with which they could contribute, we will influence their psychological comfort.

2. The models preparation

Initially, the model adopted the classic honeycomb structure. Along with the subsequent numerical tests, based on the obtained results, some changes were introduced in the structure. Among other things, the thickness of the cell walls, the dimensions of the basic cell, and the building material of the structure were modified [1, 2]. Based on literature research and the obtained results of simulation of the numerical three-point bending test, changes in the geometry of the sample, and more specifically the empty spaces, were proposed. In the place of a rapid transition between the larger and smaller cells there were stress accumulation, as well as the direction of the crack propagation. They accumulated on combining two layers of cells. Combining it was also another layer of melted ABS material in the FDM 3D printing method. This change consisted of adding a transitional layer between the void layers.

The basic model with empty spaces was modeled so that changes in cell size introduced in one cell would automatically take place in the other cells. This significantly facilitated the introduction of changes and significantly reduced the time of modeling subsequent models. Therefore, modeling in the array was used. Due to the specificity of the base structure - honeycomb type - and bandwidth reshaping, it was impossible to model all cells with one pattern. In the final version there are two rectangular constructions in one larger formation. The same principle was adopted for models with a transition.

3. The experimental research

The experimental study was carried out on a MTS Insight 10 testing machine specially prepared for this study. The stand had to be adapted to the tested samples of small dimensions and forces used. The tests were carried out on samples made with the FDM rapid prototyping technique.. Due to limitations imposed by the manufacturing technique, the samples had to be scaled. They were enlarged three times, which gave analogously 12x12x120mm values. The head from standard to smaller has also been changed. Thanks to this change it was possible to create modeled samples on an available 3D printer - Prusa i3 MK2. The changes introduced in the numerical model, and due to the phenomenon of notch, were also beneficial from the technological point of view. The printer has managed to produce earlier samples. However, we were not able to check the print quality at critical locations because they were inside the sample. Knowing the capabilities of a printer, we are able to say that it coped better with creating samples with a "transition". Six series of trials were carried out with five samples in each. They differed in the dimensions of smaller and larger cells. As a result, they had different volume and mass. Depending on the type of the sample, there was another crack propagation (Figures 1, 2). As a result of the tests carried out on the strength machine, the following average values presented in Table 1 were obtained for subsequent samples. Most of the samples did not break. Only in the case of 23a sample series each was broken. In the case of these samples, the greatest force was observed, the mean displacement being the highest.

Model	Peak Load [N]	Deflection [mm]
10a	248,575	4,92
16a	151,257	3,58
17a	155,093	3,78
18a	155,735	4,46
22a	288,895	4,16
23a	312,047	5,04

Table 1. The average values of load and deflection in experiment

Figure 1. The crack propagation in sample 16a

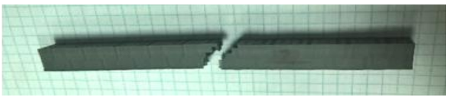

Figure 2. The crack propagation in sample 23a

4. Numerical simulation

In the next step numerical simulation of three-point bending test was performed. All numerically tested samples have the same dimensions as a previous tested samples prepared from ABS. The samples with a length of 120 mm, a height of 12 mm and 12 mm wide were modeled for each experimentally tested models. The models prepared in CAD system were imported to MSC.Software and before meshing material parameters were assumed. For ABS assumed Young modulus equals 1600MPa and Poisson's ratio 0.38. Boundary condition (support and load) assumed as typical during tree-point bending test. The spacing of supports is 100mm (due to experiment). The acting force assumed as maximal force for each test respectively (Table 1). Discretization of the models was carried out with tetrahedral elements of the Tet4 type with a linear shape function. The average distance between nodes was taken equal to 1mm. The developed models are composed of approximately 400,000 elements and have approximately 120,000 degrees of freedom. Vertical displacements (Y), reduced stresses (von Mises) and normal stresses along the longitudinal axis of the sample (Z) were selected as the representative results.

5. Conclusions

The research carried out was aimed at developing a lightweight structure and at the same time durable. An additional important limitation is the possibility of creating a structure in incremental 3D printing technology. The results obtained from numerical simulation well illustrates the mechanism of fracturing the samples observed in the experiment. However obtained distributions and values of stresses confirm the results obtained in experimental studies the deflection obtained in the numerical tests are smaller than in the experiment. It is observed that during manufacturing process the material properties change and may differ from those given for filament. This requires further research and "tuning" of the model. Also nonlinear analysis should be performed.

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References

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