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Modelowanie, symulacje numeryczne i badania doświadczalne struktury elementów egzoszkieletu

Rozprawa doktorska

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SUMMARY

As part of this PhD. dissertation, research on the support structure was carried out in the aspect of use in lightweight structures. As a specific example, elements of exoskeletal or orthosis for children were selected. The research was focused on the use of incremental technique (3D printing) in the process of manufacturing specific elements. An important feature was the ability to control the strength and stiffness of the proposed structure. A detailed description of the purpose and scope of research and a thesis are presented in Chapter 1. Basic information on exoskeletons is contained in Chapter 2.1, which describes the various uses (fields of application) and existing solutions. In turn, chapter 2.2 contains information on techniques of rapid prototyping, the most attention was devoted to the technique used in research - FFF.

In the subsequent stages of the work, research on structures that promised hopes for practical application was addressed. In general, it was decided to base on biological analogies. In this aspect, Chapter 3 describes a structure based on human bone. Theoretical foundations are described in section 3.1, they concerned the construction and properties of bones. Subsequently, in subsection 3.2, numerical studies of the structures of the bone tissue model were described, and Chapter 3.3 presents experimental studies carried out on bone samples taken from human corpses. This was an inspiration for further research, which became the main part of the doctoral thesis. The structure examined as foamed metals was studied the first. Literature studies have been carried out, which are described in Chapter 4.1. In the next stage of work, the issue of homogenization of the numerical structure was addressed, as described in chapter 4.2. Using earlier results, it was attempted to determine substitute material constants using numerical homogenization, then, based on the obtained results, to deal with numerical research of structures with different distribution of voids inside the RVE element. Structures with closed and open voids with regular and irregular voids were investigated. The results were satisfactory, however, due to the limitations of the rapid prototyping technique, it was necessary to propose another different structure.

In the next stage, a honeycomb structure was proposed. The research began with a literature review concerning both the structure itself and its production. Then, numerical research of the structure was carried out, in which various modifications were introduced in subsequent stages. Again, due to the limitations of the technology in which the samples were planned to be made, a different solution had to be proposed. The new structure was also based on the honeycomb structure, but in this case the empty spaces were modeled, not the cell walls. For the needs of work, it was called the reverse (inverse) honeycomb structure. This time, while working on the structure, the restrictions imposed by the 3D FFF printing technique were taken into account. For numerically modeled samples, three-point bending test was simulated. Based on the obtained results, several models were selected and then produced on the Original Prusa i3 MK2.5S equipment owned by the Institute. On the obtained samples an experimental three-point bending test was carried out. The obtained results were analyzed and compared with the results of numerical calculations.

At the final stage of the work, exemplary solutions of the exoskeleton element for the child's forearm with the proposed structure were designed, modeled and numerically tested. The two proposed solutions differed in the way they were combined with other elements of the device. They were tested numerically and then produced on an Original Prusa i3 MK3S printer.

An important effect of the conducted research is to propose a structure that can be produced using the 3D printing technique on the available equipment and at the same time you can control the mechanical parameters (strength and stiffness) based on the results of numerical calculations verified by experimental research.