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MODELING AND ASSESMENT OF THE SPORTS EXOPROSTHESES L0AD-BEARING CAPACITY

Abstract. The purpose of the study is to analyze the structural strength of sports exoprostheses of the foot. The stress and strained state analysis of a prosthesis model made of different materials was carried out. The results can be used to improve the designs of sports exoprostheses and increase their strength and reliability.

Keywords: foot exoprosthesis, modeling, stress, stiffness, structural strength.

Introduction. Ensuring the strength and stiffness of special-purpose structures, including biotechnical and medical products, is one of the key problems of mechanical engineering. At the present stage, the problem of prosthetics, in particular sports prosthetics of the foot is becoming increasingly relevant. World statistics indicate an annual increase in the number of limb amputations [1].

The growth of demand for sports foot prostheses is associated with the desire of people with amputees to lead an active lifestyle and engage in sports. This is due to the constant improvement of prostheses, which are becoming more and more functional [2]. Optimization of sports prosthetic designs should improve the quality of life of patients with amputees [3]. The growing popularity of inclusive sports, the constant development of new technologies in the field of prosthetics, and the strengthening of state support for this area make research relevant.

This determines the importance of applied research for solving current problems of prosthetics [4].

Content and research results. The optimal solution that provides high accuracy, efficiency, and reliability of the results of assessing the structural strength of prosthetic foot is the finite element method, which allows creating prostheses of the highest quality standards. Autodesk Inventor software was used to create and analyze the 3D-model [5].

The prosthesis model is considered to be completely fixed at the point of attachment to the lower leg. The boundary conditions of the ground contact surface limit the movement and rotation of the model mesh nodes.

The stress-strain state analysis of the prosthesis was carried out for four prosthesis material options: titanium alloy Ti-6Al-4V, high- and medium-modulus carbon fiber, and high-strength composite with P-100 fiber and epoxy matrix. A wide range of external loads was considered: 500
÷3750 N.

The mechanical properties of the composites were calculated using a micromodel of unidirectional composite materials according to the rule of mixture [6].

The distribution of stresses and displacements for an external load of 3750 N in the model of high-strength carbon fiber prosthesis is shown in Fig. 1.

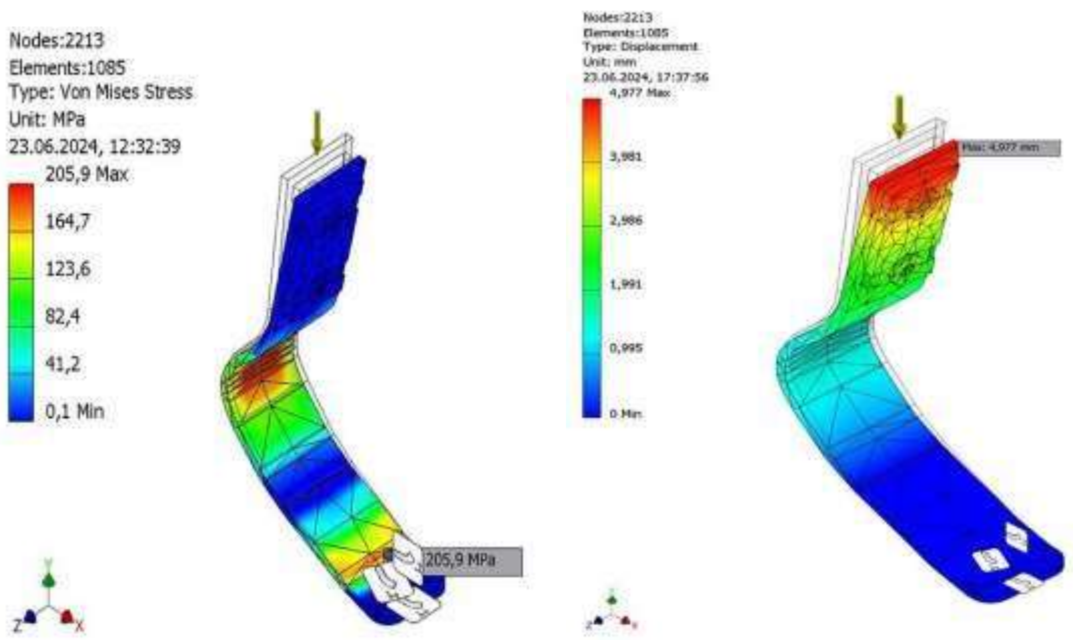

Figure 1 ‑ Stresses and displacements in a carbon fiber prosthesis model under a load of 3750 N (fiber – carbon IM7, matrix – epoxy resin)

Similar calculations were performed for models made of the materials mentioned above. In all cases, the maximum stresses are concentrated in the heel and the bending zone.

Analysis of the results obtained gives grounds to state the following:

- carbon fiber with IM7 fibers compared to the studied materials has the highest strength, which makes it an excellent choice for lightweight and high-strength prostheses; it has medium density and high wear resistance;

- prostheses with P-100 carbon fiber have the highest stiffness, but relatively high density, which increases their weight;
- prostheses made of titanium alloy Ti-6Al-4V have high strength and flexibility, but the highest density among the considered materials;
- models made of medium modulus composite have the lowest strength, which may be a limitation at high dynamic loads, moderate stiffness, while having low density and high fatigue resistance.

Conclusions.

1. IM7 carbon fiber models are the best choice for creating sports foot prostheses due to their high strength, stiffness and relatively low density. They are excellent for sports where speed, maneuverability and lightness are important, such as sprinting, jumping and cycling.
2. P-100 carbon fiber reinforced prostheses have the highest stiffness, which makes them ideal for sports where maximum stability and support are required, such as weightlifting or powerlifting. However, the relatively high density increases the weight of the prosthesis, which limits their application.
3. The polymer-carbon medium modulus composite provides a balance between stiffness and weight of the prosthesis. At the same time, its use is possible for people with relatively low weight and sports with moderate loads on the foot.
4. Models made of titanium alloy Ti-6Al-4V have high strength and flexibility, excellent corrosion resistance, which makes them ideal for use in conditions where the prosthesis is exposed to significant loads and high humidity, such as triathlon or swimming. However, their use is limited in some cases by their relatively high weight.

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