3D-Printed Polymeric heels for Orthopaedic Footwear: the Study of the Possibilities of Using Different Polymers and Methods

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Introduction

Problem. The current individual orthopedic is made by hand only, with the use of standard design solutions, so the traditional method of footwear production creates a number of limitations related to the combination of different parts of the footwear, material usage, and design.

The purpose - the aim of the study is to analyze the possibilities of quickly and accurately designing heels for orthopedic footwear according to individual dimensions, to search for the most suitable study of the possibilities of using different polymers and methods.

Methods and Materials

In this study were designed footwear heel of original design and height of 3 cm. Materials ABS, PLA, PA12, and 3D printing by fused deposit modeling (FDM) and selective laser sintering (SLS) technologies were selected for the research. In order to research qualitative parameters of footwear heels, for the testing, there was selected the finite element method (FEM) and software Solidworks. The evaluating results of the theoretical study, experimental compression tests were performed with a 3D printed plastic heel.

Research object

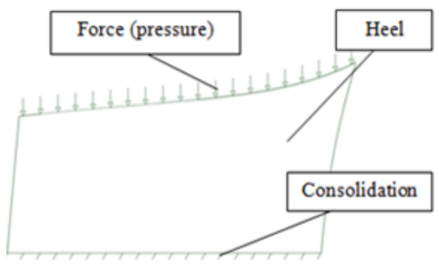
In this study were designed footwear heels of original design and height of 3cm using SolidWorks software that aids at the conduct of three-dimensional design solutions.

1 table. Properties of the materials

Characteristics	PA12	ABS	PLA	Sample
Module of elasticity	1650 MPa	1900 MPa	2300 MPA	
Poisson coefficient	0.35	0.39	0.35	
Density	930 kg/m3	1020 kg/m3	1300 kg/m3	
Ultimate strength	48 MPa	38 MPa	35.9 MPA	

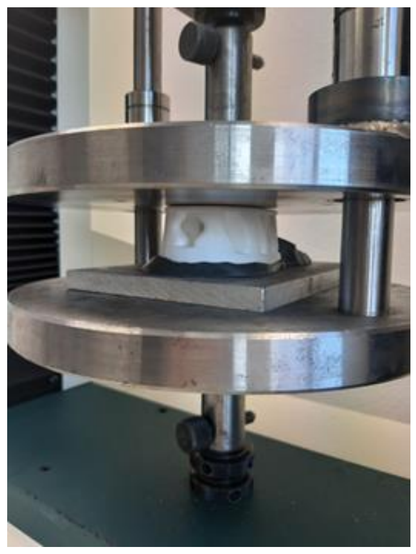
Virtual bearing/compression

The samples were put horizontally to the basis, imitating simple standing during the test (Fig.1). There was applied the force of 1000N.



Compression test

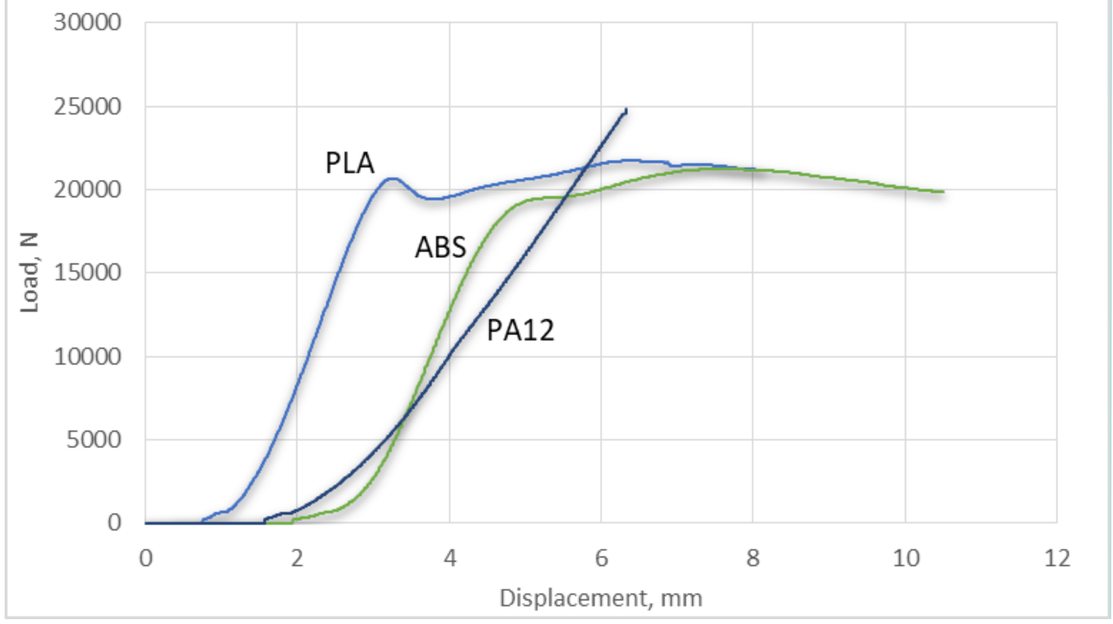
The experiment was done using the universal testing machine Tinius Olsen H25 KT with special compression unit. Figure shows a view of the heel fixation under compression test. For that reason metal plate which helps insert the heel was made. Test speed was 5 mm/min.



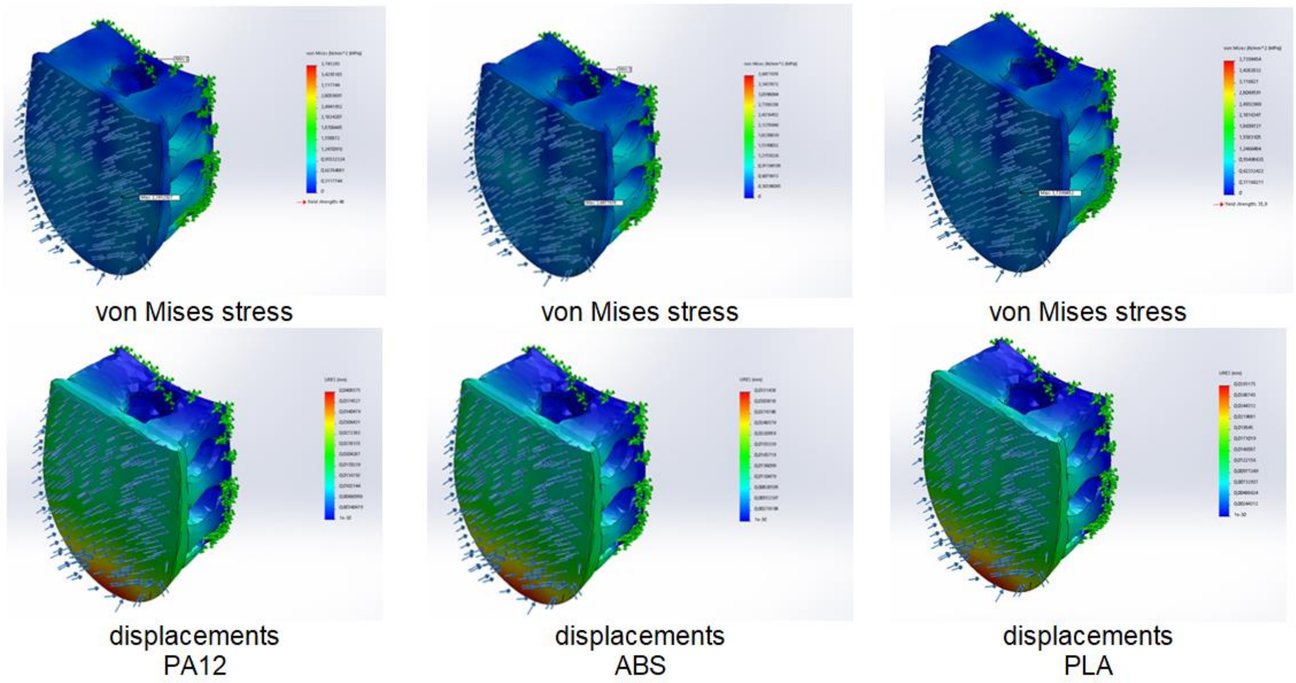
Results

Deformation of the heel wall after compression

Load-displacement curve of heel



A virtual compression simulation



As it can be seen from the presented figures, using a force of 1000N, the maximum stress (3.741 MPA) and the maximum displacement (0.040 mm) were formed in the sample of PA12 material (see Fig. PA12). It was estimated that the lowest stress and displacement are of heels, accordingly, from the ABS material (3.647 MPa) and PLA material (0.029 mm). In summary, it can be stated that von Mises stress is of almost the same values comparing all tested heels from thermoplastic materials. In the displacement case, the maximum and minimum values differ by 27.5%. It means that heel made from PLA material is more flexible and soft. Therefore the heel is made of PLA material can provide better cushioning effects, attenuate blow during walking, and decrease fatigue sensations of a foot.

From the curve given:

- ✓ After the compression test heels of materials PLA, ABS, PA12, the straight part of the curve up to 20000N shows no signs of sample damage.
- ✓ The tines heel wall of such a design is not weak and can be left to further design development.
- ✓ Compression test confirmed that PLA, ABS materials showed more ductile behavior than PA12.

Conclusions

- ✓ A mechanical deformation test was performed to confirm the simulation results, which It was found that the results of the deformation test are consistent with the simulation results. Therefore, a heel made using 3D fused deposit modeling (FDM) and selective laser sintering (SLS) technologies from plastics (PLA, ABS, PA12) with design elements would perform its function and could be used in footwear production.
- ✓ Performance evaluation by simulation and physical experiments showed that Poly lactic acid (PLA) plastic has the best mechanical properties that will provide satisfactory strength under different load conditions based on 3D modeling analysis printed models.
- ✓ The elastic behavior of 3D printed heels indicates that the heel made from the SLS technology of PA12 materials is more rigid than the FDM technology and PLA material is softer and flexible, therefore will provide better cushioning effects.
- ✓ Based on the presented research principles, it is possible to apply engineering design schemes with simulation to the creation of heels to predict the product's mechanical properties while maintaining the developed design model.