

# APPLICATION OF 3D TECHNOLOGIES TO INCREASE THE EFFICIENCY OF ORTHOPEDIC FOOTWEAR PRODUCTION

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Today, the situation in Ukraine presents new challenges to producers and scientists in various spheres of the national economy. With the beginning of a full-scale war, the need for prostheses increased dramatically due to the large number of amputations, especially of the lower limbs of the Ukrainian military. On the other hand, progress in the medical field leads to a gradual decrease in the number of amputations, while the need for orthopedic shoes, made to individual order, taking into account the needs of the patient, is increasing. Such shoes belong to complex products that require a scientifically based approach to design processes, taking into account medical recommendations, followed by high-quality execution of all technological processes of shoe manufacturing on modern equipment.

The traditional approach to the manufacture of orthopedic shoes, which is still practiced in Ukraine, is associated with low-quality budget technologies, which aimed to provide a large number of patients with orthopedic shoes at minimal costs. This approach proved to be ineffective for most patients and tiring for manufacturing specialists. To date, most of the large state-owned enterprises that produced individual orthopedic shoes have stopped working and closed down, because the format of their work is not able to ensure an adequate level of work performance today.

On the other hand, in the developed countries of Western Europe, the production of orthopedic shoes is a powerful sector of the economy, which has deep traditions, a scientific approach and high-tech production methods. (1)

Currently, there is an urgent need in Ukraine to introduce a modern progressive approach to the development and manufacture of orthopedic footwear for various pathologies and for all vulnerable groups of the population, and first of all, for military personnel after combat wounds. In the absence of qualified specialists, a professional school for their training and effective production methods, the only way to improve the production of orthopedic shoes in Ukraine is the introduction of digital technologies at all stages of shoe development and production.

The peculiarity of orthopedic shoes in case of complex pathologies and deformations is the need for multiple adjustments of both the shoe last and the design of the shoe upper, since a number of factors affect the fit of the shoe in such cases. This leads to a significant increase in the price of shoes, while the state covers a small amount of the cost of shoes (2-2.5 thousand UAH). (2)

Therefore, a modern approach to the production of custom-made orthopedic shoes requires the implementation of an effective work algorithm involving 3D technologies, which will allow optimizing the technological process while minimizing repeated product adjustments.

3D scanning of the foot is the most effective way to obtain baseline information about the patient's foot (3). However, the use of 3D scanning does not exclude the use of plaster casts, since the production of plaster casts is indicated, for example, if it is necessary to correct the biomechanical position of the foot during the development of corrective shoes. The produced plaster cast is also scanned on a 3D scanner. The resulting file can be loaded into the environment of specialized or universal 3D CAD for design of an individual shoe last. Production of a last from a digital model can be carried out by an additive or subtractive method. The production of a shoe last by the additive method using a 3D printer is a more progressive and environmentally friendly method, which does not require additional premises and auxiliary operations in the case of using FDM printing technology.

Personalized 3d-shaped elements of orthopedic footwear, such as shoe lasts, orthoses and orthopedic insoles, can be effectively manufactured using 3d printing. The form of such spatial elements, modeled in the CAD environment, must be filled with the internal structure, which is created in special slicers, before the printing process. The parameters of the formation of the internal structure of the mold together with the properties of the selected 3D printing material determine the main characteristics of the future product. At the current level of development of additive technologies and materials used, it is possible to achieve the needed specified physical and mechanical properties of the elements of the shoe form (4)

However, the development of orthopedic shoes is associated with a number of challenges:

- 1) The difficulty of developing the correct parameters and shape of the shoe last, since one should take into account not only the anthropometric features of the foot, but also medical recommendations and the features of the functioning of the foot in specific conditions (with orthoses, insoles, etc.)
- 2) When applying additive technologies for the production of shoe lasts and orthotics, it is very important to choose the correct parameters of the internal structure of the product and the choice of material for 3D printing to achieve the needed functional properties.
- 3) the difficulty of achieving the aesthetic perfection of the shoe shape for the right and left foot with different foot parameters.
- 4) The difficulty of taking into account all objective and subjective factors affecting the perception of shoe fit, especially in cases of certain clinical conditions and medical diagnoses (increased or decreased sensitivity, tendency to swelling, spastic conditions, risk of ulcers, phantom pains in cases of partial amputations, etc.)

- 5) The need to use special frame elements that aim to keep the foot in the right position
- 6) Impossibility in most cases to use standard parts of the bottom, as orthopedic shoes impose strict requirements on the design of the insole and sole
- 7) The need for separate development of the right and left half-pairs of shoe last and shoe patterns, which dramatically increases the complexity of design and technological processes

These problems are aggravated by the fact that in Ukraine there is a lack of funding and qualified professionals for the development and production of such shoes.

In general, orthopedic shoes can be made on the following lasts:

- Standard last with overlays in certain areas (Fig.1 a)
- New last, developed in accordance with individual anthropometric features (Fig. 1 b)



Fig. 1 The ways of creating the personalized shoe last

Even the use of modern digital technology for shoe last development does not guarantee a perfect result on the first try. After trying on a trial pair of shoes, it is often necessary to adjust the shoe parameters

However, a pad made by 3D printing is practically not subject to re-adjustment when parameter discrepancies are detected. Therefore, errors in the shoe last design will lead to the need to re-manufacture a new last, which will dramatically increase the final price of the product.

Such problems can be minimized by implementing a reasonable and effective algorithm, when before the physical shoe last is manufactured, a test sample of the shoe is first produced, made by 3D printing with the use of flexible elastic filament. Trying on such a sample on the patient's foot will give an idea of the correctness of the shoe parameters and the need to make corrections. And only after that, we can proceed to the production of a shoe last, on which a bespoke leather shoe will be made.

The general process of developing custom-made orthopedic shoes is presented in the form of a diagram on Fig.2:



Fig.2

## Conclusions

The problem of finding effective approaches to the production of orthopedic shoes in Ukraine is very acute. Solutions can be found in the wide application of advanced digital technologies at the stage of design and modeling with a mandatory increase in the level of execution of technological production processes. An important advantage of digital technologies is the possibility of developing products even in the absence of the patient's physical presence in the workshop. The use of additive technologies makes it possible to achieve a high degree of customization and personalization of shoe forms, which is especially important in the case of individual orthopedic shoes.

## References:

- 1) Hartmut Seidich, Dustin Seidich, "Uppermaking for Bespoke and Orthopaedic Shoemakers" ISBN-13: 978-3946775-87-4. Germany 2024, 300 p.
- 2) Про організацію забезпечення окремих категорій населення технічними та іншими засобами реабілітації : Міністерство соціальної політики України, НАКАЗ N 1208 від 06.08.2019. Дата звернення 5.10.2024  
[https://ips.ligazakon.net/document/re33974?ed=2021\\_11\\_03](https://ips.ligazakon.net/document/re33974?ed=2021_11_03)
- 3) L. Chertenko et al., "Practical Aspects of 3D Scanning Results Application in Shoe Last Design", *Proc. of 3DBODY.TECH 2023 - 14th Int. Conf. and Exh. on 3D Body Scanning and Processing Technologies*, Lugano, Switzerland, 17-18 Oct. 2023, #28, <https://doi.org/10.15221/23.28>.
- 4) Iacob, M.C.; Popescu, D.; Petcu, D.; Marinescu, R. "Assessment of the Flexural Fatigue Performance of 3D-Printed Foot Orthoses Made from Different Thermoplastic Polyurethanes. " *Appl. Sci.* 2023, 13, 12149. <https://doi.org/10.3390/app132212149>