INNER SHAPE FOOTWEAR DESIGN OF THE PATIENS WITH DIABETES

Nicolae ISCHIMJI[1,2], Stan MITU [2] and Liviu MĂRCUŞ [2]
[1] Technical University of Moldova , Chisinau, Republic of Moldova
[2] Technical University "Gh Asachi " Iasi, Romani

Abstract: *This paper presents new principle of design and validates inner shape footwear designed specifically for people with diabetes. The shoe inner dimension provides the relevant inner dimensions for a particular shoe such as length, joint girth, instep girth, and any other dimension upon request. Is used by manufactures because it improves the design of shoe lasts, improves the accuracy of shoe production and the uniformity of the inner dimensions of shoes, and detects and analyzes undesired differences. However, tools for designing shoes for people with diabetes do not currently have the capacity to modify the last in order to reduce the risk of foot ulceration, whilst at the same time preserving the style of the shoe. The paper describes the procedures and the geometrical algorithms to handle the last geometry. Finally a case study is reported to show the advantages provided by the proposed approach in terms of achieved quality of the design process and expected footwear performance.*

Keywords: *inner shape footwear, design, last, diabetes.*

INTRODUCTION

In the present orthopedic trade, the last-maker starts from a basis last which may be well-removed from the final shape which he requires, and then proceeds to adjust the shape with reference only to the limited measures of the foot. This requires a great deal of skill to maintain acceptable last characteristics. Additionally, the last is not made as an exact match to the foot measures, but a system of “last allowances” (ie. differences between specified foot and last measures) is employed. Suggested last allowances are not available in published literature, and initial discussions suggest that they vary from company to company, are not used consistently, and are adapted for individual orthotics to compensate for tendencies to measure loose or tightly). The target areas in last design should therefore include a study of the influence of basis last choice on the final design, formalization of last allowances, and development of a system of last assessment.

Diabetic foot is a common complication of diabetes. Diabetic foot care is very important because any injury, even a minor one can lead to serious complications. Due to peripheral nerve lesions (diabetic neuropathy) and blood vessel injuries, small injuries occurring at this level can be easily overlooked and can get over infected. The patient does not feel pain caused by various injuries, in some cases even the discomfort caused by inappropriate footwear. These injuries can cause the foot deformation [3].

It is common practice to prescribe customized footwear to people with diabetes to reduce the risk of foot ulceration. Although shoe customizing systems have been proposed, effective tools for designing shoe lasts for diabetic patients are lacking. The shape of the lasts must meet certain biomechanical objectives, while maintaining the style of the shoe. The main contributions of this work are as follows: the creation of an artificial-neural-network-based framework to correlate foot measurements and medical data to required footwear features; the definition of repeatable geometrical procedures to measure foot and last; and the definition of geometrical operators to modify the last shape according to its original aesthetic and specific footwear parameters. These parameters are by a knowledge-based system on the basis of the patient's pathology and best practices of experienced technicians. Dedicated systems integrated in a common platform are implemented to support the last design process. Test case studies and a survey show the advantages provided by the proposed approach in terms of achieved quality and shoe developing time. A design framework with dedicated tools is proposed for the customization of shoe lasts for diabetic patients. Further research should be focused on tools to design the insole, outsole and other shoe components.

The shoe last is the ultimate determinant of fit of a shoe, since it determines the space within the shoe. The characteristic features of lasts have been developed over centuries for the volume trade, and last design and making is an established and documented skill in that trade.

METHODS AND TOOLS

Research has shown that specific parts of the upper shoe, and as a consequence also the shoe last, affect the shoe fit [1-4]. However, in its shape, the last reflects the characteristic of the outsole and insole of the diabetic shoe. In particular, the following four areas of the foot appear to be critical:

Counter : the part of the shoe extending around the heel;
Toe box : the part that covers the toe area;
Vamp: the part that covers the instep;
Throat: the part at the bottom of the laces.

The method to design bespoke diabetic footwear is based on the definitions of the biomechanical variables relevant to footwear design. These variables effectively characterize the intrinsic properties of the foot, therefore they will subsequently be referred to as foot is the high pressures under the 1st MTP (metatarsophalangeal) joint. For every possible shoe design, the term footwear design features is used to refer to the individual characteristic, such as geometry, dimension and material, which are used to specify the design. For instance, the most important features of a rocker sole are: the rocker angle, the sole stiffness, the apex position and the apex angle. The design of diabetic footwear must be based on a in-depth understanding of the interaction between the footwear design features and the biomechanical characteristics of the foot. In order to draw these relationships, analyses have been accomplished on patients with diabetes measuring and monitoring a wide range of the biomechanical parameters [3].

Table 1: Relationships among footwear design features, biomechanical objectives and last parameters to be modified.

Footwear design feature	Biomechanical objective	Last parameters to be modified
Width of metatarsal heads, ball girth, instep girth, heel girth	Accommodate insole to realise plantar pressure Minimise changes in foot shape during walking	Ball circumference Ball width Instep circumference Heel circumference
Total foot length, metatarsal width and navicular drop	Minimise changes in foot shape during walking Minimise shear load on the forefoot	Last length Ball circumference Ball width
Toe box height, toe girth	Minimise pressure on dorsal aspect of the forefoot and toes Minimise pressure on the 5th metatarsal base	Toe circumference
Rocker sole: rocker angle, apex position, apex angle	Minimise pressure under 1st MTP joint and toe Minimise pressure under 2^{nd}-5^{th} metatarsal heads Minimise vertical shear loading at the posterior aspect Minimise pressure under the mid foot	Heel height Ball width
Toe spring	Minimise pressure under 1st MTP joint and toe Minimise pressure under 2^{nd}-5^{th} metatarsal heads Minimise vertical shear loading at the posterior aspect Minimise pressure under the mid foot	Toe spring height
Hell height	Minimise over pull on the Tendon Achilles and the pressure under the forefoot	Hell height
Size of shoe entry	Minimise pressure on dorsal aspect of the forefoot and toes Minimise vertical shear loading at the posterior aspect Minimise pressure on the 5th metatarsal base	Ankle circumference Heel circumference

An outlook on the obtained results is provided by the table1. In particular, a selection of the footwear design features which have a direct influence on the last definitions process is reported. The third column shows the last geometrical parameters which have result to influence the preventive function of the footwear. However, from the analyses of the gathered data, the following consideration can be drawn:

- The hell height represents the height of the back of the sole. The correct last hell height is combining the apex position, the rocker angle and intrinsic parameters of the chosen last.
- The apex angle determines a release of the foot pressure on the sole while walking. Such an effect must be facilitated providing a customized last shape in the metatarsal zone.
- A shoe that has a high and rounded toe box provides the best fit allowing the toes to fit and move comfortably inside the shoe.
- Finally, ankle circumference and heel circumference determine the size of the shoe entry and must be balanced with the pressure at the foot to hold the foot within the shoe during the gait.

The experimentation has allowed the list of the footwear features to be drawn and the range of variability of the parameters to be determined.

CASE STUDY

The approach described in the previous sections has been developed of the Research Project 07. 420.16. INDA have been conducted in the Republican Center Experimental Prosthesis, Orthopedics and Rehabilitation (CREPOR), Republic of Moldova [5] . The evaluation of the case study has been only patient with diabetes (men, 58 years). In the experimentation phase, the last design process has been obtained foot casts by weight bearing, used plaster of Paris splint and next section in plane longitudinal and transversal. They are based where construction last section is used to refer to the individual characteristic and the biomechanical characteristics of the foot (fig.1-2).

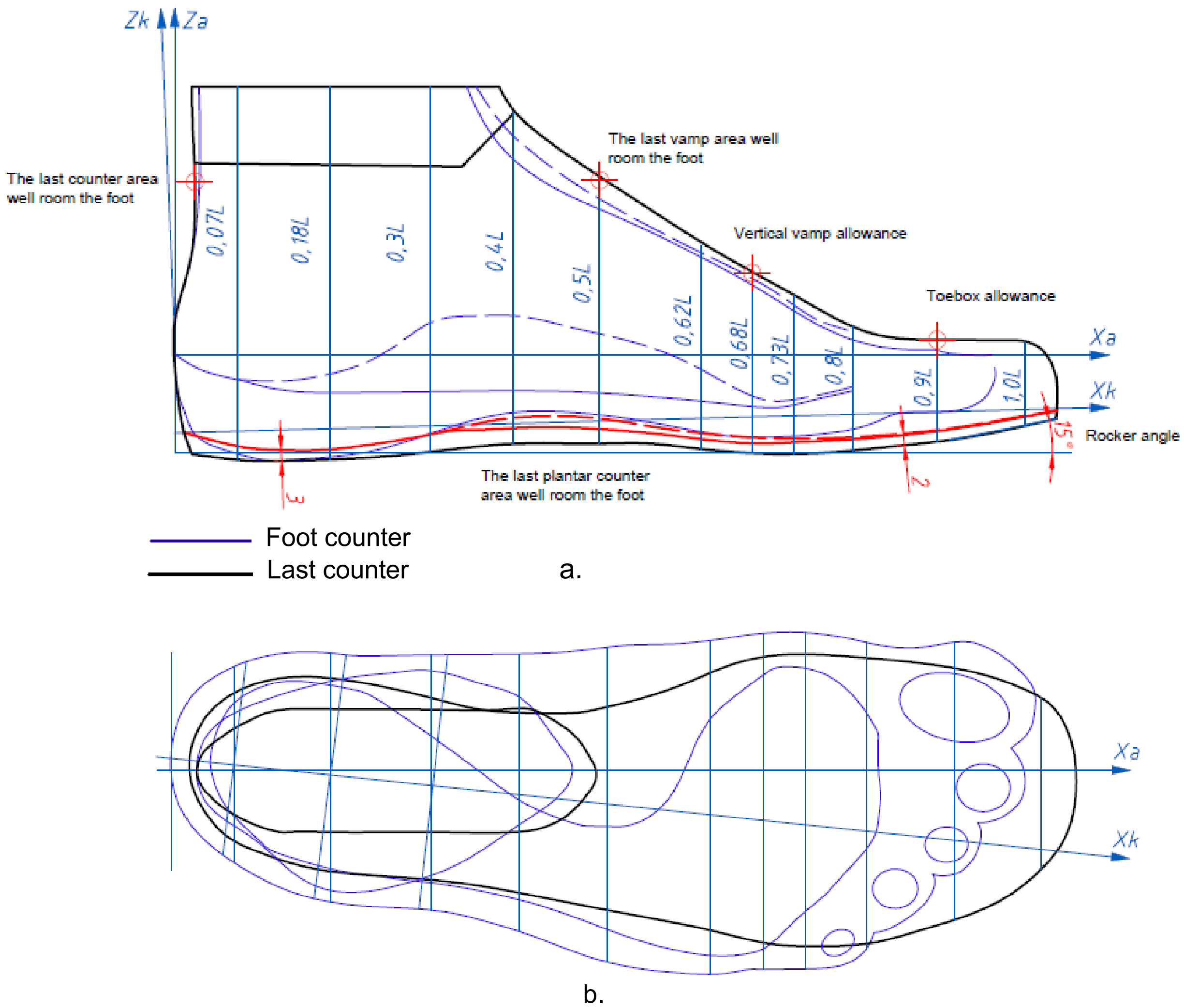

Figure1: Frontal (a) and horizontal (b) foot/last projection (patient (men) with diabetes, shoe size 43)

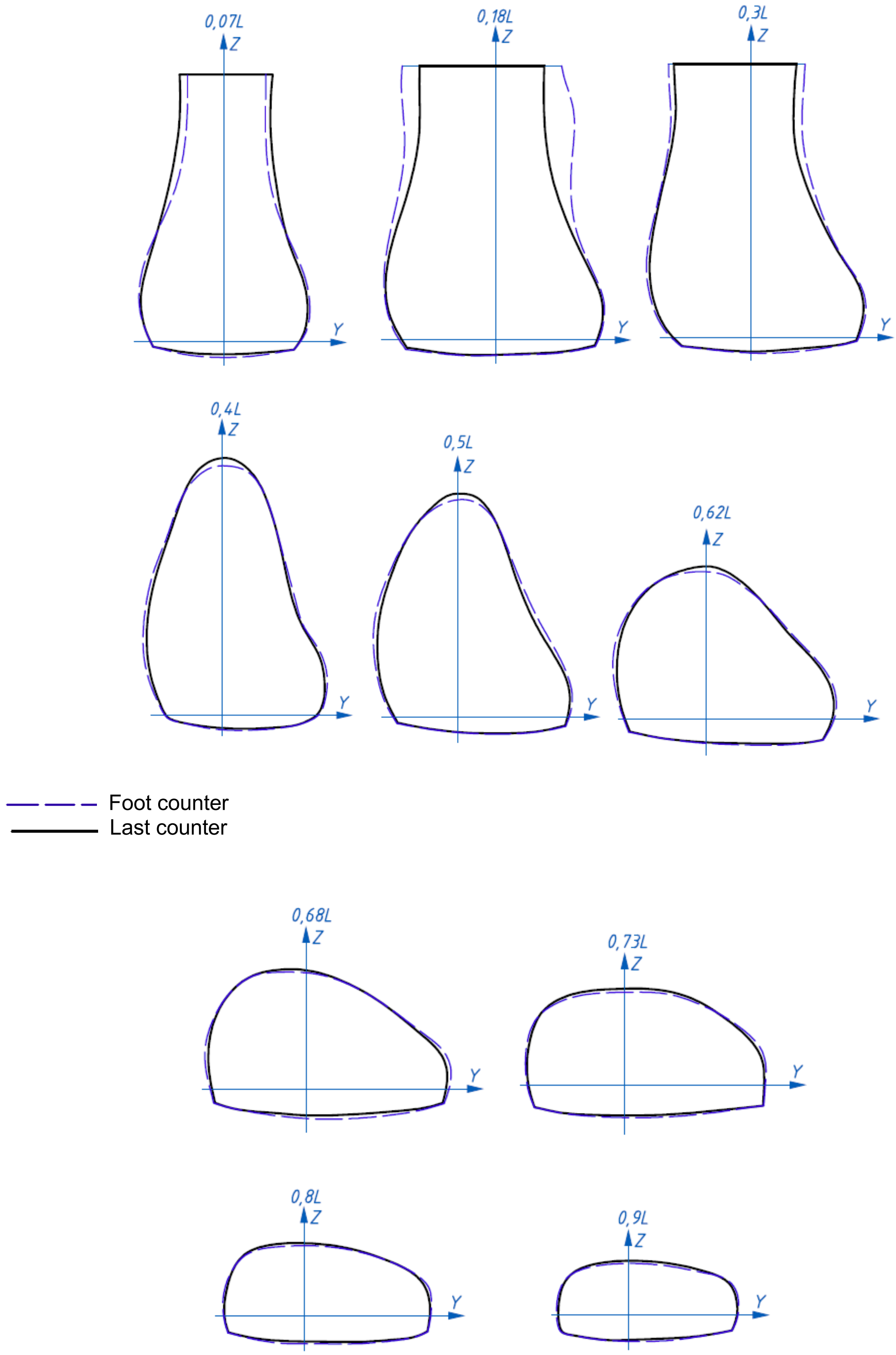

Figure 2: Design counter transversal-vertical foot/last section (patient (men) with diabetes, shoe size 43)

CONCLUSION

The paper proposed a new approach which is based around the idea that inner shoes for patient with diabetes should address the specific biomechanical objective of minimizing the pressure. The approach is implemented as a multi-phased approach. The major novelty introduced by the paper consists of a requirement to design shoes with the objective of minimizing the pressure under the foot. Such a method is specifically designed for individuals with diabetes and aims to reduce the rate of ulceration and subsequent complication. Benefits for shoe manufacturers:

Improve accuracy of shoe production by measuring the actual dimensions of the shoes coming off the production line Improve production uniformity of shoe inner dimensions

Compare the last to the shoe produced and analyze undesired differences

Improve the design of shoe lasts to improve shoe fit.

References:

[1] Mălureanu G., Mihai A., *Bazele proiectării încălţămintei*, Ed. Performantica, Iasi, 2003, p 356
[2] Fuchin V.A., *Teoreticeschie osnovâ proiectirovania vnutrenei formâ obuvi*. - M.: MGUDT, 2000, p 192.
[3] Mariana Păştină, Aura Mihai, *3D modelling of lasts used to obtain special footwear for patients with diabetes, Annals Of The University Of Oradea Fascicle Of Textiles- Leatherwork,* Volume I, 2010, No. 1, pp 188-191
[4] Luximon A., Luximon Y., *Shoe-last design innovation for better shoe fitting*, Journal Computers in Industry, nr. 8, vol. 60, 2009, pp. 621-628.
[5] Research Project 07. 420.16 . INDA *" Anthropometric studies on improving the technology of manufacturing therapeutic footwear "*

Corresponding address:
Nicolae ISCHIMJI
Faculty of Light Industry
Technical University of Moldova
Str. S. Radautan, 4
MD 2045, Chisinau
Republic of Moldova
e-mail: ischimjinicola@yahoo.com