IGF Research Project 17868 N

Safer High Heels

Survival of companies in the fashion and seasonally dependent sectors such as the footwear industry depends upon their ability to implement the latest trends. Shoe bottoms and heels are particularly important design elements. And yet fashionable ladies' shoes, above all those with high heels, clearly also have to assure the safety of their wearers. In fact, some of the designs considered are rejected as unrealisable during the creation of practically every collection.

Goal of the Project

The goal of the PFI research project presented here, which was funded through the organisation for promotion of Industrial Community Research and Development IGF and undertaken together with another research establishment, the Research Institute for Leather and Plastic Sheeting (Forschungsinstitut für Leder und Kunststoffbahnen gGmbH, FILK), was to improve the technical realisability of fashionable heel designs in ladies' shoes. Insoles, heels, and methods of heel attachment were therefore analysed. Discussions with ladies' shoe manufacturers revealed that in particular very high and slender heels, such as that depicted in Fig. 1, cause problems. It can be assumed that a practicable solution for the attachment of such heels could be applied in principle to the attachment of all other heels.

Fig. 1: Problem heel

The forces and moments acting on different types of heels were determined with the aid of various measuring systems (Fig. 2). A sensor sole in a shoe was used to measure the plantar pressure distribution. Strain gauges were attached to the exterior of the heel, to the heel line, and to the exposed shank piece of the insole. The test persons also walked over a force-measuring platform.

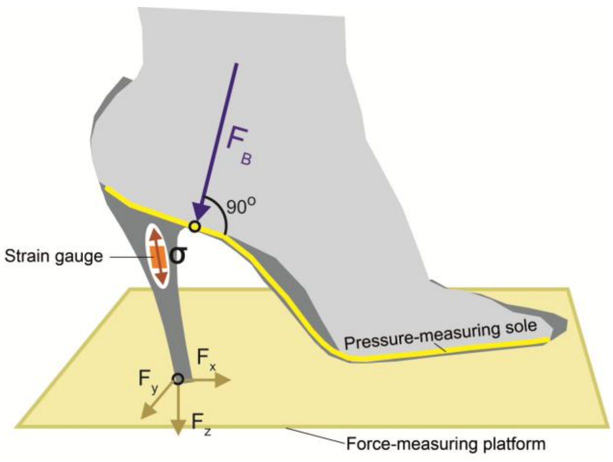


Fig. 2: Measuring systems used

The tests were undertaken with experienced wearers of high heels. The test shoes used are shown in Fig. 3.

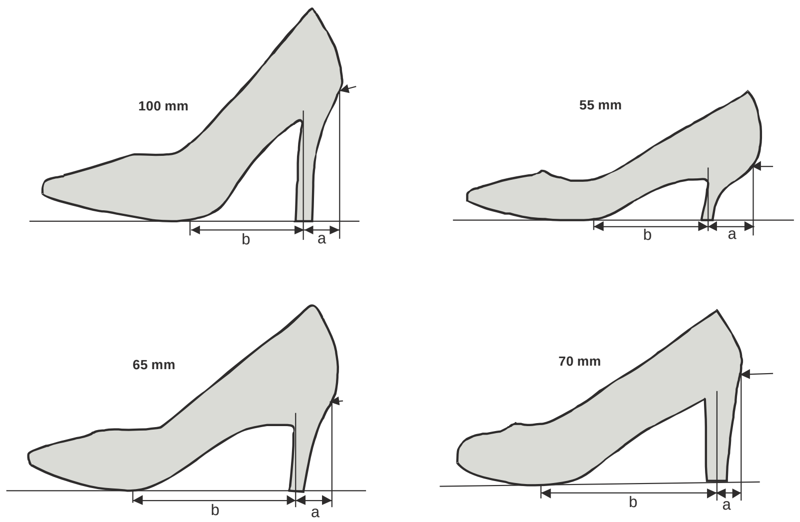
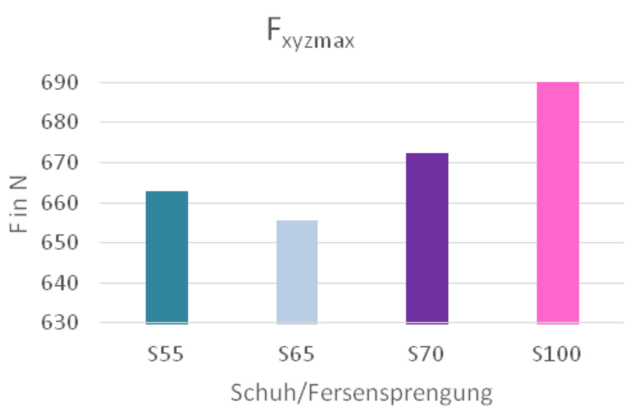


Fig. 3: Side views of the test shoes

a – Distance between the mid-tread point of the heel tip and the heel height measuring point projected onto the walking surface
b – Distance between the mid-tread point of the heel tip and the ball tread point

The shoes are designated as follows:
S55 – Shoe with 55 mm heel lift
S65 – Shoe with 65 mm heel lift
S70 – Shoe with 70 mm heel lift
S100 – Shoe with 100 mm heel lift

Results



Forces acting on the heels perpendicular to the walking surface can exceed the body weight force by up to 15 %. The magnitude of the maximum forces depends upon the design of the heel. Higher heels give rise to higher maximum forces (Fig. 4); however, this dependence is also subject to the influence of other factors such as heel shape and positioning.

Fig. 4: Comparison of the magnitudes of the resultant force F_{xyzmax} for the four heel variants

As seen in Fig. 5, the times at which the maximum tensile and compressive stresses are recorded by the strain gauges on the heel and on the shank spring do not coincide with the times of occurrence of the maximum force F_{zmax} on the force-measuring platform. It therefore follows that the forces responsible for extreme stresses on the heel and the shank are smaller than F_{zmax}.

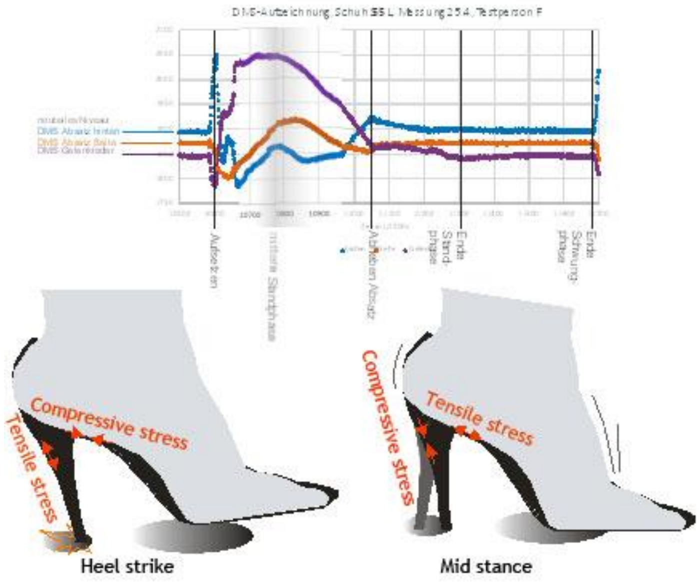


Fig. 5: Characteristic features of the stress curves

The stress profiles determined with the aid of the strain gauges attached to the back of the heel and to the shank reveal both similarities and differences between the heel variants. In particular, S70 showed a number of distinctive features attributable to the particular shape and positioning of the heel.

The pronounced individual influence of the test person in searching for temporary equilibrium on the small area of contact of the heel is evident from the stress profiles recorded by the strain gauges placed on the side of the heel.

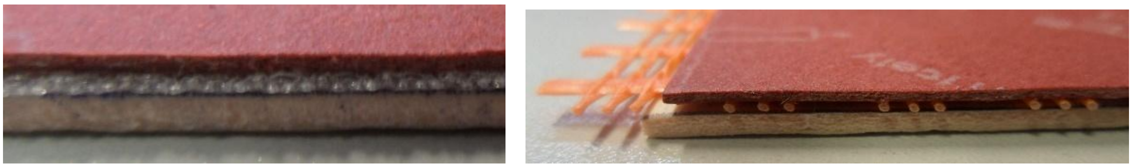
Development of Insole Materials

As part of the project, Freiberg-based FILK had the task of improving the properties of the insoles to permit more reliable attachment of heels by inside nailing. Thermoplastic elastomers were initially tested as insole materials. However, these materials proved unsuitable for the cold forming process used in insole production.

A second approach was to develop insole laminates as three-layer composites: Base layer, textile reinforcement, and top layer. Cellulose-based insole materials were used for the base and top layers. Narrow fabrics woven from mono- and multifilament yarns spun from glass and polyester fibres as well as bidirectional fabrics of various structures made up of the same kinds of fibres served as reinforcing textiles.

The tested composite materials showed values indicative of a significantly improved pin holding strength compared to reference materials without textile reinforcement (even without shank piece). The heel pin holding strength could also be increased 2.5-fold on use of lower priced polyester fibre based narrow fabrics. The orientation of the textile with the warp direction transverse to the cutting direction is advantageous because it gives an 18 to 26 % greater pin holding strength than that with the warp direction parallel to the cutting direction. Two insole laminates are shown in Fig. 6.

Subsequent wearer trials were conducted with insole laminates which were reinforced only in the heel region. The desired improvement of heel attachment could thus be achieved in a highly cost effective manner.



a) ***b)***

Fig. 6: Examples of insole laminates

- ***a) Duralite, Gerster fabric 04-204-44, Texon 480***
- ***b) Duralite, Caparol reinforcement textile, single layer, Texon 480***

Development of a New Method of Heel Attachment

PFI was searching above all for a new method of attaching the most problematic type of heel shown in Fig. 1. Tests were conducted with a screw-on metal rod which was attached to the insole, or more precisely to the shank piece, by means of a threaded union (Fig. 7). The strength of attachment via this threaded union was tested by the method of dynamic heel attachment testing developed by PFI (Fig. 8).

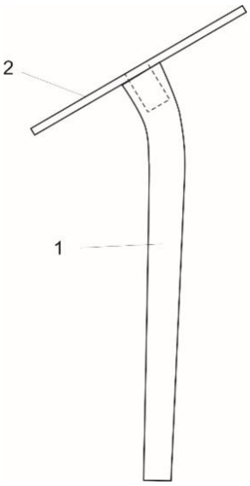


Fig. 7: Heel attachment variant
1 – Heel rod, 2 – Attachment of heel to insole

Fig. 8: Procedure for dynamic testing of heel attachment

Wearer Trials

Two options were selected for wearer trials. One pair of ladies' shoes was produced with insoles made of the laminated material which gave the best results in the pin holding test. For this pair inside heel nailing was used to attach a classical block heel (shoe with the white block heel in Fig. 9). The newly developed heel rod was used to produce the other pair (shoe in the foreground of Fig. 9).

Fig. 9: Test shoe with the newly developed heel attachment variant

Both variants were worn by a test person and rated as good with regard to comfort while walking and stability while standing. This is particularly important for the test shoe with the heel rod because the test person is standing on a very small area. This version offers a solution for particularly difficult types of heels.

IGF Project 17868 N of the Test and Research Institute Pirmasens e.V. – PFI, Marie-Curie-Str. 19, 66953 Pirmasens started in January, 2014, and was concluded in December, 2016. It was funded by the Federal German Ministry of Economics and Energy through the German Federation of Industrial Research Associations («Arbeitsgemeinschaft industrieller Forschungsvereinigungen» – AiF) within the IGF programme for promoting industrial cooperative research in accordance with a resolution adopted by the German Parliament. We wish to take this opportunity to express our gratitude for this funding.

The results are presented in detail in the concluding report of this project. A copy can be ordered from the contact below.

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