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Stronger insoles for high heels

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There are various concepts of fashionable designs for high-heeled shoes which, as yet, cannot be realised. It is also not fully known how suitable materials could be engineered as regards the economic and technical demands these shoes would impose. Tests to characterise the static and dynamic forces occurring when walking in high-heeled shoes are not always sufficient a basis for R&D into innovative new design concepts.

The key to economic success for manufacturers and distributors of high-heeled shoes is to broaden their current spectrum of inventive designs so as to strengthen the 'WOW' effect for their

customers. The application of new material and construction principles must therefore also be included in any R&D programme. Input from researchers, engineers, manufacturers and marketers has all to be considered in order to gain new concepts for shoe designs that will be successful.

The Pruef- und Forschungsinstitut Pirmasens (PFI) and the Forschungs-institut für Leder und Kunststoffbahnen (FILK), combined their expertise in shoe and material know-how to initiate a research project under IGF/AiF-grant no. 17868 N mainly aimed at small- and medium-sized enterprises (SMEs) which included the following research projects, the sub-

steps and current results of which are given in *Figure 1*.

1. Engineer new insole materials using an iterative prototyping development approach.
2. Test the improved materials and determine gait-physical characteristics of the insoles.
3. Prepare insole samples using standard shoe-technology within SME environments.
4. Incorporate the improved insoles in actual high-heel shoes.
5. Analyse the improvements using test participants in gait and shoe pressure tests.

TEST PROCEDURES

The connection of the pin used to secure the heel to the insole is inefficient due to inadequate strength in the construction of the insole itself. Any potential improvement in the holding strength of the insole would help make it possible to realise more advanced structures for high-heel designs. Standard cellulose board insole materials were combined with various others to produce trial laminates. These were then compressed and cut out in order to produce insoles for use in prototype shoes.

The approach taken was to use different textile reinforcement elements for improving the mechanical strength of the insole while, at the same time, maintaining the material flexibility properties needed for comfortable gait; for example, narrow-woven fabrics made using mono- and multi-filament glass, and polyester yarns. We compared the impact for improving the mechanical strength as well as the bending properties which are essential for walking comfort.

Due to the 4th paradox of composite materials (so-called Slayter-paradox) that dictates how adding extra fibres can add strength to a laminate, insoles produced as textile reinforced laminated composites do indeed improve the pin-holding strength. Materials and fabrics which are readily available such as acrylic, polyolefin, glass or polyester fibres have been used for these investigations. Aramid or carbon-fibre based solutions would not be a reliable choice for a consumer goods market. A typical insole



Figure 1 – Steps and results for engineering insoles for high-heeled shoes.

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sandwich-type composite is shown in Figure 2. Cellulose insole board was used for the basic insole on to which various textile reinforcement fabrics were applied using an industrial adhesive. Finally a cellulose-based board was used for the top side of the insole in the waist and heel area.

Due to the fact that the cellulose-based materials used show anisotropy (different properties in different directions) in their mechanical behaviour, we oriented the warp direction of the textile fabric parallel and perpendicular towards the fibre orientation in the cellulose-based layers. The bending modules of our developed insole laminates have been determined to be in the range from 290 MPa (megapascals) to 500 MPa (according to DIN EN ISO 178), which can be compared to commercial

materials for insoles, where it is normally in a range between 300 MPa and 800 MPa.

TEST RESULTS

Three types of woven fabrics and laid webs for reinforcing laminate structures were tried.

1. Narrow-woven polyester and glass mono- and multi-filaments and yarn.
2. A laid web of polyester filaments on a glass fibre non-woven underlay.
3. Reinforcement woven fabrics made of rubberised clinched glass fibre filaments.

The heel-pin holding strength of commercial insoles provided by SMEs and our developed laminate samples was analysed according to DIN EN 12745 and ISO 20867. Results are given in Figure 3. Values for various industrial reference materials normally fall within a range of 285 N up to 385 N. In comparison, our test results showed that by using different textile reinforcements, we were able to increase the heel-pin holding strength up to a range of 530 N to 875 N. The best results were obtained using narrow band woven fabrics made of polyester fibres and were up to 2.5 times higher than with standard material combinations.

The orientation of the woven insert in the insole laminate certainly influences the holding strength, whereas the warp or weft weave direction makes only a small contribution. In our samples, where the orientation of the woven

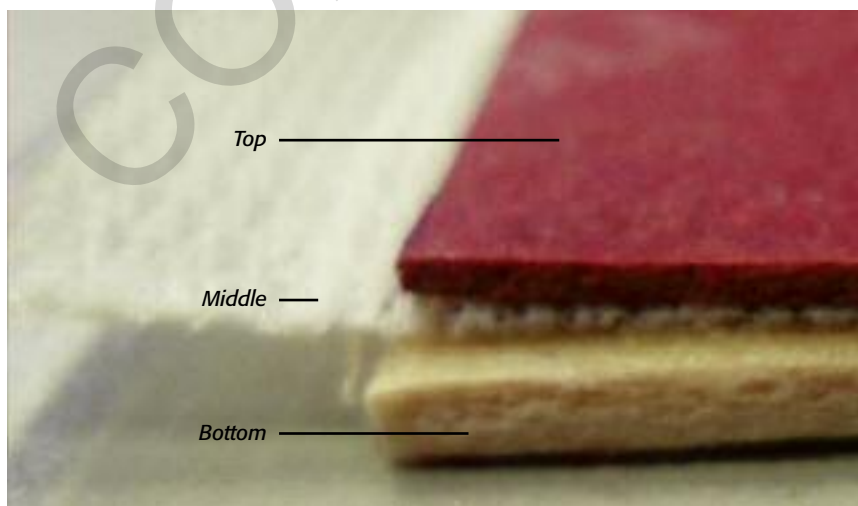


Figure 2 – Structure of the laminated insole. Top: cellulose-based top layer. Middle: textile reinforcement. Bottom: cellulose board basic insole. CREDIT: PFI

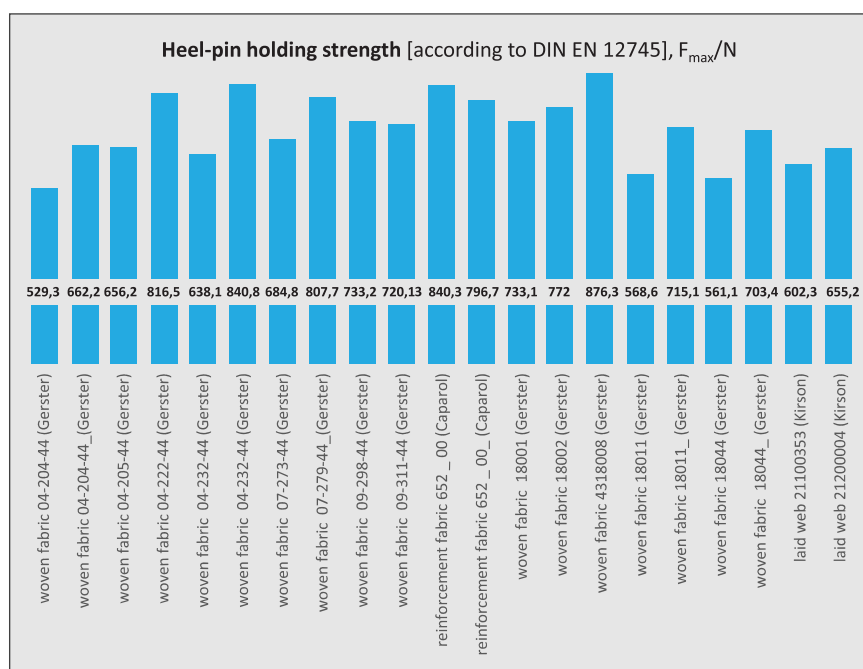


Figure 3 – Heel-pin holding strength is up to 2.5 times higher than on current commercially available insoles. CREDIT: PFI

HIGH HEELS - ALWAYS A PROBLEM

Throughout history, most women have always liked high heels. This has partly been due to the fact that they made the wearer appear taller and, when skirt lengths became shorter, to flatter their legs by tightening the calf muscles and making them look slimmer and more elegant. Needless to say, there have also been women who were prepared to take fashion to the extreme as witnessed by this example from the end of the 19th century which at 17cm must have created quite a problem for walking.

It would also have created problems for the shoemaker except for two things. The first is that the shoes would probably have only been worn briefly on special occasions. The second is that the actual area of attachment is large which allowed the stress loads to be spread over a wider area and a large number of attaching pins.

Modern extreme heels such as those shown in the title image for this article are small in area and so rely on a single large serrated central nail. The heels will be made from ABS which is extremely strong and with exceptionally good nail holding properties. This means that all the stress is concentrated on the small area of the insole directly around this central nail.

Clearly, the larger the head on the nail, the less the strain on the insole material. However, there are limits on the size of head that heel nailing machines are able to accommodate unless made specially for this application which would not be economically viable. The problem therefore can only be resolved by increasing the insole's capacity to absorb these extreme stresses without breaking or tearing.



reinforcement element is in a cross direction to the insole material, the heel-pin holding strength has proved higher in comparison to a lengthwise one. Nevertheless, they all show a higher heel-pin holding strength in the range of 18–26% regardless of the actual orientation of the woven insert in the laminate structure.

The excellent static and dynamic mechanical properties of fibre reinforced insole laminates definitely increase the stability of high-heeled shoes. We fully expect to be able to fulfil the demands of the shoe industry in respect of substituting current insole materials by textile reinforced insole laminates on the one hand and achieving flexibility and wear comfort for customers on the other. In the next stage of our insole R&D programme, we will use our promising improved sample insoles to produce prototype shoes. Where standard material-locking joints such as lockbolt systems are used, we will engineer a suitable sleeve to connect the high-heel pin with the insole laminate.

Finally these systems will be used for gait analyses and pressure testing during walking. Unfortunately, the fitting of the lockbolt to the insole may lead to undesirable delamination and fibre disruption because the insertion of a steel sleeve leads to a critical radial shear stress expansion. In any case, the increased complexity of the whole screwed and riveted joint structure calls for additional testing in order to design perfect material combinations to improve joint strength. Results of these further investigations will be described in the second part of this article. 🔗

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