Thermally Insulating Insoles Footwear Concept

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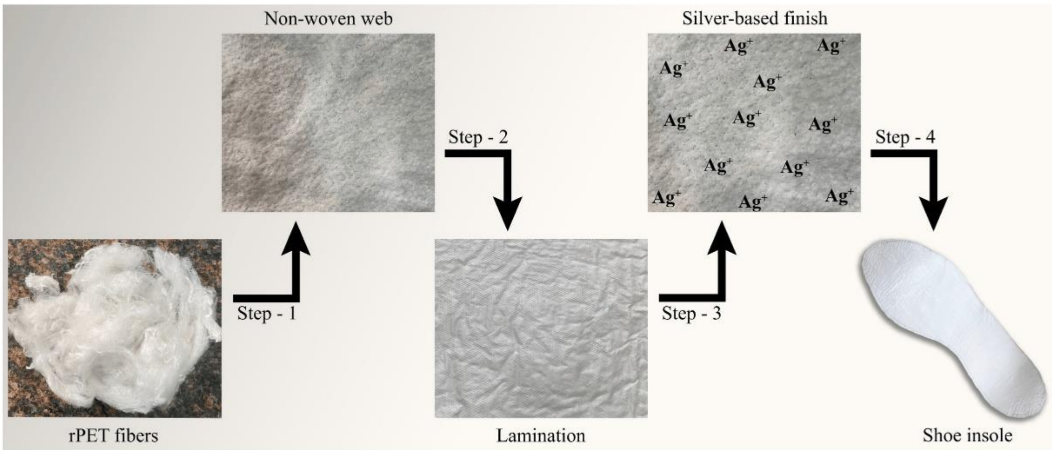
Abstract

The concept of thermally insulating footwear involves using a material to restrict the transfer of heat and maintain the wearer's body temperature. Added value in terms of sustainability can be gained by using standard manufacturing technologies frequently found in the textile industry to produce new products beyond present paradigms. Specifically we develop knitting techniques on a circular knitting machine to enable production of a thermally insulating textile composite for a multi- component footwear system. Four cornerstones defined the project; *sustainability, availability, comfort* and *flexibility*. The first two relate here to the production, while the last two are coupled to the wearer's experience of the product. Using an elaborated functional design tool the footwear system was theoretically divided into functional layers; inner, middle and outer, combined with an inner and outer sole. These detachable layers together create a flexible footwear system. A ready-made product, the middle layer with thermal insulating properties, was practically developed, taking use of a heat and water soaking protocol for inducing relaxation in the material and by this air encapsulation. Thermal insulation in insulated footwear works by trapping a layer of air that retains heat generated by the body while preventing cold air from entering. Materials like fleece are specifically engineered to provide this insulation.

Keywords: footwear, knitting, three-layer principle, comfort, thermal insulation, body protection.

Introduction

Experiments aimed at developing a structure that would have thermally insulating properties and be possible to produce on the circular knitting machine. Experiments involved machine adjustments needed to enable the machine to knit the composite, the pattern of interconnecting knitting loops, material and after- treatment, cutting and assembling. Before this an elaborate design process was performed, first described.



The Basis for the Product Development

Product development should lead to the realization of the demands and requirements which define the product and the production there for here we work according to the idea of Function analysis as a means to learn how to think and express the product in functions rather than in ready solutions and physical objects. By Functional analysis, function and the very physical
realisation in a certain object are disentangled, creating a freedom in mind. The process is inherently iterative; starting with a main function a decomposition into sub functions is performed. These are elaborated. Eventually the sub functions are associated with physical realisation.

The project is defined by the following four cornerstones:

- The **comfort** aspect includes creating, supporting and maintaining a comfortable microclimate under various kinds of external climate and levels of physical activity. Comfort embraces also other aspects – such as size fit, cushioning (Drez, 1980) etc. These will be of secondary focus here.

- **Flexibility** refers to the footwear system's ability to be convertible in order to suit shifting conditions. For example adapting to changes in level of activity, changing weather condition, from outdoor to indoor, from wet to dry or from dirty to clean.

- **Sustainability** focuses on resource efficiency from the perspective of the company. Striving towards optimizing production processes through minimizing the use of energy and chemicals, as well as reducing the amount of waste produced. Packing material, stock and transport should also be rationalised in order to minimize storage, space, weight and so on.

- **Availability** focuses on innovative use of existing, accessible and widely distributed production equipment, as well as developing new techniques and applications for these machines. Availability focuses on the development of new knitting techniques on existing equipment rather than development of new machines. This enables production of rare textile structures by applying and combining techniques that are not commonly used.

The first two cornerstones relate to the wearer's experience of how the product meets its aim, and the last two relate to the production of the product.

Principles for a New Footwear Design and Production

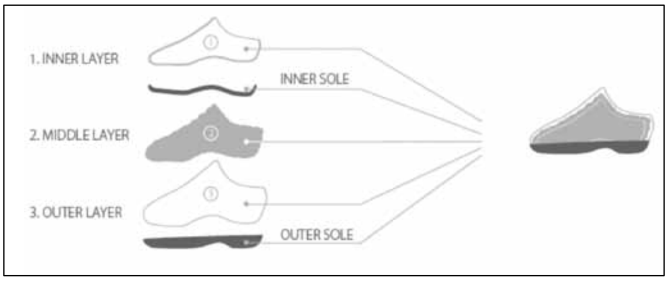
To start with, the footwear system was theoretically subdivided into functional layers: inner, middle and outer layer, together with an inner and an outer sole. All the detachable layers together form a flexible footwear system, fig 1. Shape and size of one of the author's (ACJ) feet were used for modelling the footwear layers.

Distributing Functions in Separate Layers

To enable comfort during shifting levels of activity, the footwear must be changeable. This can be done by the wearer, by adding or excluding units. This way of regulating the microclimate can be achieved only if the footwear is subdivided into detachable layers, where each layer of the footwear incorporates a function.

The project illustrates how the choices made during product development influence a wide range of aspects; individually for the user and in a wider perspective the production, its availability and environmental issues. Eventually all these aspects can be summarized in the four cornerstones that were chosen to frame this project; comfort, flexibility, sustainability and availability.

Fig 1: Detachable layers that together forms the footwear system.



The outer layer main function is to enable protection against penetration of wetness and wind, while still being breathable. The outer layer could for example be constructed of a plain- woven polyester which is laminated to a micro porous film. The seams of the outer layer must be taped. *The middle layer* main function is to offer thermal insulation. In order to achieve this, the material of the middle layer can be designed to enclose large volumes of air, which can work as a buffer to temperature shifts.

The inner layer function is to transport moisture away from the body to reach thermo physiological and sensorial comfort. To achieve these properties a fibre with low moisture absorption could be used combined with a suitable knitting structure. If the inner layer is knitted as a bilateral structure, which is connected with distributed knitting loops, the inner layer will acts as two socks, hindering the development of blisters as well as more easily transporting moisture away from the foot.

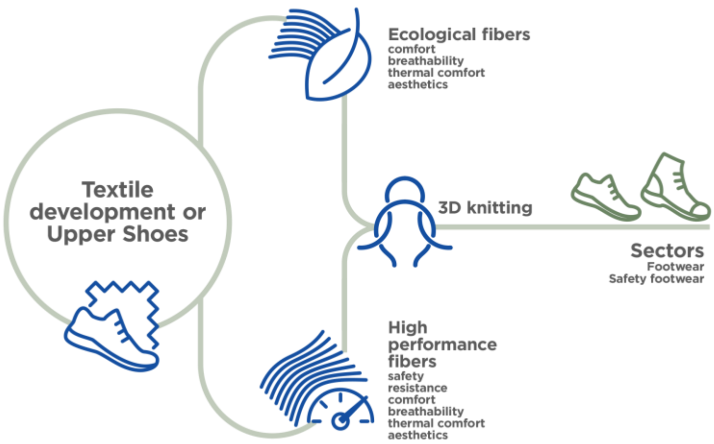
The sole of the footwear is divided into two parts. The inner sole or the foot bed, which is located close to the foot, compensates for the differences of the feet, and helps the body into a healthy posture as well as absorbing shock while walking. The outer sole enables protection against mechanical strain and wetness as well as absorbing shock while walking. The outer sole is moderately stretchable, which makes it easy to slip into by pulling the rear end of the sole over the heal and fixate it onto the outer layer of the footwear system. In the present study the middle layer is in focus and the following refers to the design and production of that.

Development of Shape

Requirements related to the wearer's experience of comfort and aspects related to the sustainability and availability of the production process were equally important during the development of the footwear system. Several experiments were conducted using different materials and approaches. From this work a footwear shape, meeting the requirements of the cornerstones in varying degrees evolved.

Fig 2a: The origami inspired phase for minimizing material

Fig 2b: The three-dimensional shape of the footwear was received through folding a two-dimensional material



Experiments and Results

Circular Knitting Machinery

All experiments were conducted in-house with a double-bedded circular knitting machine OVJA 36 with 36 knitting systems, 20 needles per inch, npi, and electronic needle selection. It is equipped with 1872 needles in both the cylinder and dial. The machine speed is 18 rpm. It is imperative that the machine is double-bedded for it to be able to knit a two layer structure. The machine can be programmed either mechanically, or digitally by translating a drawn pattern of knitting loops into binary language (knit or do not knit). In most cases a combination of these two ways, mechanical and digital, is used. To enable the circular knitting machine to knit a double structure with a non-knitting filling material, several adjustments was made on the machine. The adjustments concerned increasing the distance between the two needle beds and lowering the knitting systems thread guides to allow the filling material to be lead into the textile structure without interfering with the needles. The loop size and the yarn speed were adjusted individually depending on the task of the knitting system.

Knitting the Composite

Three different patterns were created to experiment with the placement of the interconnecting knitting loops. The patterns were computer drawn. The machine relates to the pattern by reading one pixel as one needle movement.Depending on the dimension of the knitting loop the pattern has to be adjusted in order to have the right pattern dimensions of the knitted material. The loop measurements can not be foreseen exactly before the structure is knit, so measurements of the loop dimensions were made on the first finished textile (after heat-treatment). As seen on the picture (fig. 3) the patterns include areas where nearly every loop interconnects the textile layers, opposed to areas which do not include any interconnecting loops. Neither one of these scenarios was optimal. The areas that caused the least amount of problems while knitting were
areas where the courses either had or did not have interconnecting loops exceeding five to ten loops without interruption. This is due to the incorporation of the non-knitting filling yarn.

Depending on the number of needles that go up into knitting position, the filling yarn is left without guidance from the needle. If many needles in a row go up, or stay down, both scenarios influence the stability of the filling yarn, risking the filling yarn to intertangle with the needles. Ideally every other needle should go up into knitting position and thus keep the filling yarn on track. On the other hand, to have many binding points in a row on a wale creates no problem since the different binding points in a wale are created separately by different knitting systems.

This ended up in a final pattern with no more than five interconnecting loops or five loops not interconnecting in a row (course). The pattern of interconnecting loops is large on the upper side of the footwear layer to enable high insulating capacity. The pattern was scaled down on the sole of the footwear layer to achieve higher stability (fig. 3). The attempt to optimize processes and minimize misunderstandings between production stations lead to the idea of incorporating as much information into the pattern and the knitting process, as possible. Therefore the pattern was designed to have lines, visualised by interconnecting loops, as a guidance to the later process stage of cutting.

Achieving the Air Encapsulation

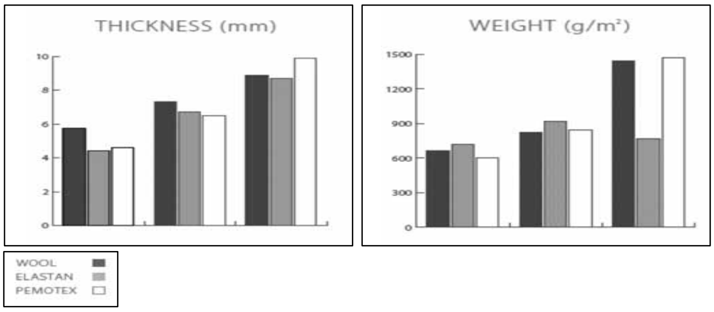
To enable the composite to contract in width and expand in height, a yarn with the ability to contract must be incorporated into the composite. The idea here is to take advantage of the shrinkage property, which most often is regarded as unwanted. Three materials were tested regarding their ability to contract the composite.

The materials were incorporated into the structure in the knitting process and constituted 50% of the back layer of the composite. The materials tested were Lycra/Elastan, wool (40/2) and Pemotex is a variant of Trevira flame-retardant textured filament polyester yarns. It is a bicomponent yarn with a low melt component that results in a stiffening of the textile surface at the finishing stage.

The aim of the experiment was to see which material that would add the most to the composite's thermal insulation and at the same time stabilise the composite. Lycra is knitted into the structure in an elongated state. When it relaxes from the tension, it pulls the surrounding structure together. The wool is knitted into the structure, and its corresponding composite is subjected to heat. When the wool shrinks, this will contract the composite. Pemotex is also knitted into the structure and since it is a heat sensitive bi-component yarn, it will shrink when the temperature reaches beyond the temperature at which it has been fixated (in the expanded state). Thereby it pulls together the rest of the structure in width, and since the composite has no physical restrictions in height, it will expand in that direction, resulting in a thickening of the composite.

After-treatment

Application of heat can be done in different ways, here we used two methods. Experiments were made to evaluate the difference between a) applying heat through puffing steam from an iron set at 200°, and b) with heat application by standardised house- hold washing, at 60° followed by hang drying. Washing thus includes both heat, water and mechanical processing.



Cutting and Assembling

The raw material from the knitting machine was cut along the pattern, which is formed by the interconnecting knitting loops. The tight position of the interconnecting knitting loops allowed for the material to be divided without exposing the filling material. Appropriate for this product would be to punch out the pattern parts with a continuous and heated punching-machine. Since all the fibres used in the footwear system are synthetic, the heat from the punch-machine would melt the edges, forming a closed textile edge. This would be desirable in the assembling process, avoiding the filling material from the composite to entangle and cause problems in the assembling process. Two methods of assembling the footwear were tested; before and after the heat treatment. Finally the former was chosen, since it resulted in a more satisfying shape. The product is shown in fig 7.

Fig : The final prototype of the thermally insulating layer included in the footwear concept.

Conclusions

The *tangible result* of the project is a three layered footwear concept, of which the thermally insulating middle layer was developed and produced on a circular knitting machine. The subdivision of the footwear into three separate and detachable functional layers enables it to meet the requirements of thermal *comfort*. To achieve and maintain thermo physiological comfort the footwear system needs to be convertible, to suit and shifting weather conditions and levels of activity. Adopting the idea of the three layer principle, the footwear concept uses the technique of adding and excluding functional units, and thereby fulfils the requirements of *flexibility*. In line with the *sustainability* requirement the footwear's 3D shape (pattern) is designed to utilize the material effectively in cutting, minimizing the amount of waste and optimizing the production process.

References

1. Holmér, R Afanasieva - International Journal of …, 1999 - Taylor & Francis
2. International Journal of Occupational Safety and …, 2004
3. B Talavera… - Textile Research …, 2013 - journals.sagepub.com
4. A Usupov - International Journal of Thermophysics, 2019 – Springer
5. MD Şuteu, R Pancu, SD Buhaş - Sustainability, 2022 - mdpi.com