Development of Yarns used for Medical Applications

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Nowadays more and more people have or get sick of venous diseases such as venous insufficiency, low foot blood pressure or even the phenomenon of swelling for diabetic people or for the post-birth period. Medical stockings provide a method to fight against these problems since ancient times but the results after every use was in compliance with the level of technology used to produce the stocking. This situation creates a challenge for the stocking manufacturers with developing new technologies and technical materials that give the best results and maximize the effects of compression stockings on the people that wear them. This paper is integrating the total design of a product, regarding the cycle of the product, profitability and satisfaction of the client problems, proposing new ideas of client approach using new technologies like mass customization through computer integrated manufacturing systems including 3 - dimensional body scanning and individual approaches to the client; and using this knowledge develops a kind of compression stockings that are fit-to-wear and satisfy the requirements of the clients concerning the efficiency of the product, comfort properties and durability.

Keywords: compression stocking, yarns, total product design, mass customization, apparel for technical applications, 3-D body scanning, computer integrated manufacturing

Medical elastic compression stockings *(MECS)* are widely used in venous diseases. Their effects on the venous system have been shown in the past and are being improving lately by using new technologies of producing them, usage of special yarns or knitted structures. Conventionally compression stockings are knitted on circular machines, but most recently new technologies of knitting are developing on flat bed knitting machines but also new circular machines like the machine that Lonati Group has developed, the Pendolina-Super, special designed to knit medical hosiery from microfiber yarns.

In the present work the stockings are knitted on a manual flat V-bed knitting machine using cotton yarns and cotton in combination with elastic yarns using two different methods of obtaining the shape of the stocking: the transfer of stitches and changing the denseness of the stitches to achieve the forecasted dimensions and level of compression.

Total product design of apparel for technical applications

The total product design settles a cross between the mechanical engineering and the actual artist design work. This concept studies both function of a product and its form, and the connection between the product and the final user (customer). It is not to design the gears or motors that make machines move, or the circuits that control the movement; usually, it brings together engineers and marketers, to identify and fulfill needs, desires and expectations of the customers and works to satisfy customers needs being in the same time competitive.

The structure of a product (medical compression stocking)

In present time a product is defined by three layers:

a) core product -focus on the benefit, core advantage which determines our decision;

b)actual product- emphasis on 5 physical characteristics of a product: quality, brand name, features, style and design, packaging;

c) augmented product - post-purchasing services and additional services provided by the company.

Example: medical compression stockings
The core product: solve legs circulatory problems
The actual product:
- brand name - the name of the brand whether or not is popular;
- quality - is it good or bad, won awards etc. (usually based on the brand);
- features - such as looks and special features (the functions of the product);
- style - color of the stocking, the structure;
- packaging - (when a customer purchases it) Is it in a box, wrapped in special wrap etc.

The augmented product: medically tested.

Mass customization in apparel manufacture

Mass customization and the manufacturing process in the apparel industry

In the apparel industry, there are many cost and time consuming processes that take place, from which raw materials and initial ideas transform to end product.Generally they consist of the following steps:
- identifying target market
- designing
- allocating jobs (i.e. especially if work is done overseas)
- sourcing fabrics, trimmings etc
- pattern making
- toil making
- adjustments
- process and operation planning
- laying of fabric and cutting
- sewing garments, plus any accessories (i.e. buttons, zippers)
- finishing - ironing
- putting labels
- packaging finished garments
- distribution - shipping

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However, the above process is eliminated by the use of mass customisation. Once the customer has selected the desired order, the design data is fed into the CAM process via local area network (LAN). Patterns and grading can take place immediately, digitally. Technical drawings and patterns are sent via telephone lines to either domestic plans or via satellite overseas, where garments are cut, sewed and distributed.

With software design packages, the process for apparel becomes digital. Assyst, Gerber Garment Technology (GGT) and Lectra Systems are companies that have developed such software packages. Designs are transferred to the pattern making process and then to numeric controlled (NC) cutting machines. These make processes shorter, faster and less labour intensive, as patterns and grading are automatically performed.

For Levi-Strauss all measurements are sent via modem to the Levi's factory in Belgium, where each personalized pair is cut out separately (single-ply cutting) and given a unique bar code. After completion the jeans will be retrieved from the production line, identified by their bar code and shipped within three weeks. The price premium is an extra Ł19 on jeans costing Ł46, and shoppers who are the prime targets for information on the new products, will be able to re-order garments using the bar-code label (Summers, 1996).

Manufacturing of stockings for medical applications

The Manufacturing of Medical Compression Stockings

Compression hosiery is produced usually on wrap knitting machines with the disadvantage of using the same number of needles and having the problems of obtaining the compression profile as in the standard. The structure of the garment is decisive in obtaining the right compression value and even durability of the stocking. Flat bed knitting machines are provided in tubular knitting with the advantage that the number of needles used can be changed, needles can be introduced, extracted ,giving the possibility to obtain the right girth of the garment without having to change the loop length of the structure stitches.

MECS should be produced with either of the following knit types.

A. Flat-knitted MECS (with seam) have inlaid elastic threads or inlaid elastic and knitted elastic threads. The inlaid thread should occur in at least every second course. When MECS are knitted without inlaid threads a minimum linear den-sity of 156 dt_{ex} in at least every other course should be used. The shape of the MECS should be achieved by changing the number of needles.

B. Round- knitted MECS (seamless) have elastic threads or inlaid threads and knitted elastic threads. The inlaid thread should occur in at least every second course. When compression stockings are knitted without inlaid threads a minimum linear density of 156 dt_{ex} in at least every course should be used. The shape of the stockings can be determined by varying the tightness of the courses and the tension of the knitted threads. MECS should have closed and knitted heels with the appropriate anatomical form and stretch qualities.

The perfect fit is a must for such a type of stocking to make sure, that the right compression is provided. The measurements are taken by the doctor and made available to the stocking manufacturer. They use their own calculation programs to determine the correct fitting of the stocking by considering an adapted size for generating the pressure which has to be achieved. The calculated forms are used by the pattern preparation system (Stoll - SIRIX 110) and converted into a Jacquard and command program which can be interpreted by the machine control.

If the set up is existing in the production plant, the Jacquard and machine parameters can be transmitted automatically to the flat knitting machine via an online connection between the knitting machine and the pattern preparation system. The Stoll software allows an active communication between the machine and the SIRIX design system and thus enables an automatic production control. Such a procedure is important for the manufacturing of custom - made stockings as the organization of the production represents the processing of a series of single orders.

The processing of elasthan fibers demands special machine equipment to ensure a constant and even compression effect. Stoll developed a particular yarn feeding set up to realize a yarn processing of low and equalization. The yarn passes storage feeders to relax from tension variations-arising from the spinning process and the draw off during knitting. The next step is the active pull off support by pre -accelerating the yarn by applying a continuously running friction feed wheel before getting into the actual loop formation area. The yarn tensioning is implemented by a vacuum device which gently draws back the yarn at moments when the carriage changes its way or when the yarn is not processed.

In addition a special yarn feeder is in use for the weft insertion of the elasthan thread. This yarn feeder system works synchronously to the movement of the carriage and is able to block the yarn feeding at moments when the carriage returns or when the weft is not inserted. Thus yarn migration can be prevented and it helps to attain a constant tension within the fabric. The weft insertion feeder can be shifted up and down to prevent any collision and to contribute to a flat selvage formation, which helps at the subsequent sewing process. The inserted weft can generate a fairly high compression and in combination with the formed shape correctness these types of pressure garments are mostly applied, when scar is stable enough to stand a higher level of pressure.

Experimental part

Materials

The materials used to develop the project consist in an Omega Manual Flat V-bed Knitting Machine, 1.2 meters length, 12 gauge and 20 units of stitch density control. The machine has four yarn feeders and it is provided with two types of needles making possible the knitting of cardigan and other structures. The yarns used for this stocking are: one cotton yarn and one cotton yarn in combination with an elastomeric yarn fed on the same yarn conductor inserted at every 3 lines to ensure the elasticity of the knitted fabric and the compliance with the compression profile.

Methods used

The first principle used in stockings knitting is the tubular knitting technique which is created when the constituent thread or threads of the fabric knit spirally. This way there are produced tubes particularly used in this case for stockings in order to cover the legs and have the same shape as them avoiding in this way sewing or other finishing processes. In figure 1 there is presented the principle of tubular knitting, more specific the tubular jersey on all the needles. This structure is used because is has good parameters and it has a uniform distribution of the tension.

In figure 2 there is presenting the process of transferring the stitches from the extremity needles to the ones next to them. The first stage the figure presents the stitches that are going to be transferred and in the second stage the

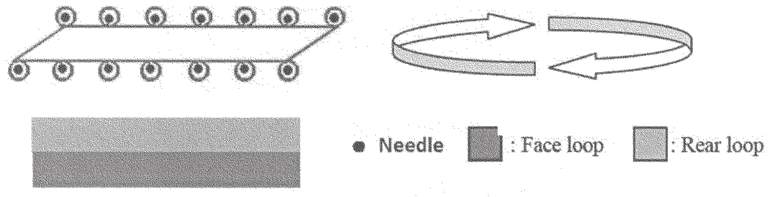

Fig .1. The tubular jersey

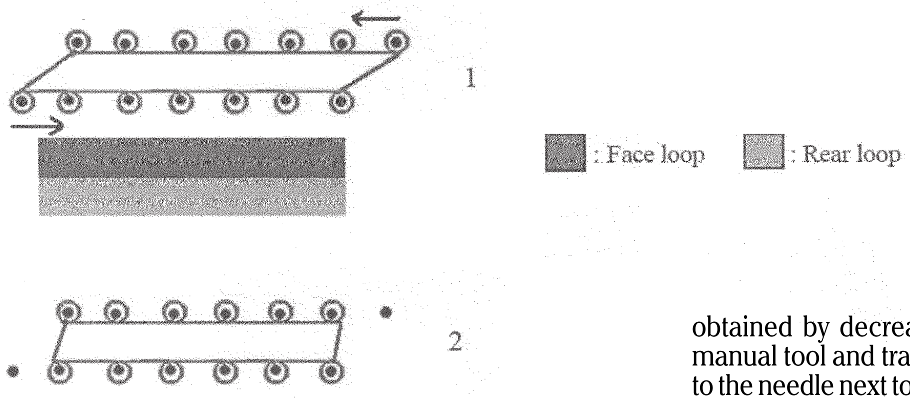

Fig. 2. The process of transferring the stitches

result of the stitch transfer, including the needles that are taken out of the process.

The guidelines to design the stockings are given by the British Standard and are presented in figure 3 with the following explanation: studying the shape if the leg researchers settled a set of values that are widely spread around the population and they help in obtaining the size of the stocking.

Considering the fact that the human leg is not a perfect cylinder the BS is establishing a distance of 10-15 cm from the ground up the height were the ankle girth should be measured 31 cm height the calf girth. The calf and ankle girths are general, and that is the reason why patients that intend to use these kind of stockings are recommended to consult a doctor to obtain the specific girth that they need. The ankle girth from the standard is 12-15 cm and the calf girth 18-25.

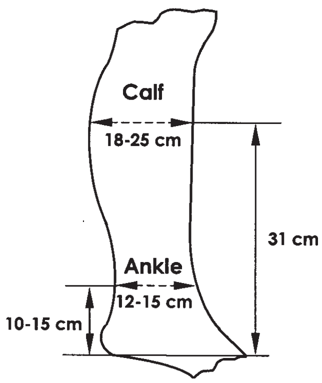

Fig. 3. The guidelines to design the stockings

The shape of the stocking is obtained by decreasing the number of needle, implicit, the number of stitches/cm obtaining this way the "cone " shape of the stocking necessary to respect the standard specifications, the value of compression around the ankle should be higher than at the calf to ensure the "pump" effect of the stocking. As it is presented in figure 4 the girth around the calf is bigger than at the ankle.

The way to obtain this shape depends of were the knitting starts. If the knitting starts at the calf then the "cone" is obtained by decreasing the number of stitches using a manual tool and transferring at the end of the row a stitch to the needle next to it in order. This operation can be made automatically on an electronic knitting machine. This method is widely used because it is very easy to follow the evolution of the compression, the loop remains the same, and if a number of stitches are generating a compression it is easy to calculate a function to comply with the compression profile.

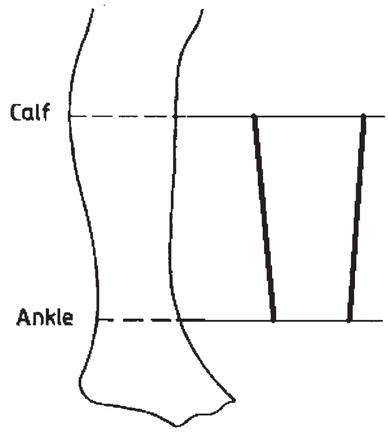

Fig. 4. The "pump" effect of the stocking

If the knitting starts with the hose then the process is reversed, the number of needles will increase but this technique has the disadvantage that at every needle introduced in the knitting process in the finished product appears a little hole generated by the loop that was formed on the needle right after it was introduced in the process.

Using the stitch transfer the elastic yarn feeding can remain the same, considering the fact that the shape of the stocking is already obtained and the pressure decreases up the leg, when knitting from hose to calf. As seen in figure 5, the efforts in an elastomeric textile shell it is demonstrated that "the compression is decreasing as the curvature of the stocking is growing" [1-4].

In figure 6 is presented the experimental knitting on the manual machine along with the function used to obtain the shape and the planed compression.

As presented in figure 6 the knitting of the stocking begins at hose and as it goes up the leg there are a number of needles inserted in the knitting processes as explained in the figure.

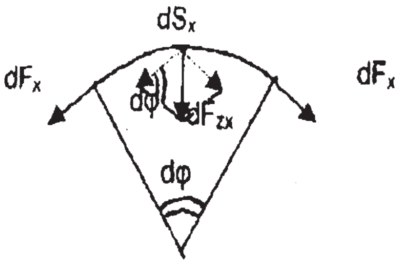

Fig. 5.The efforts in an elastomeric textile shell

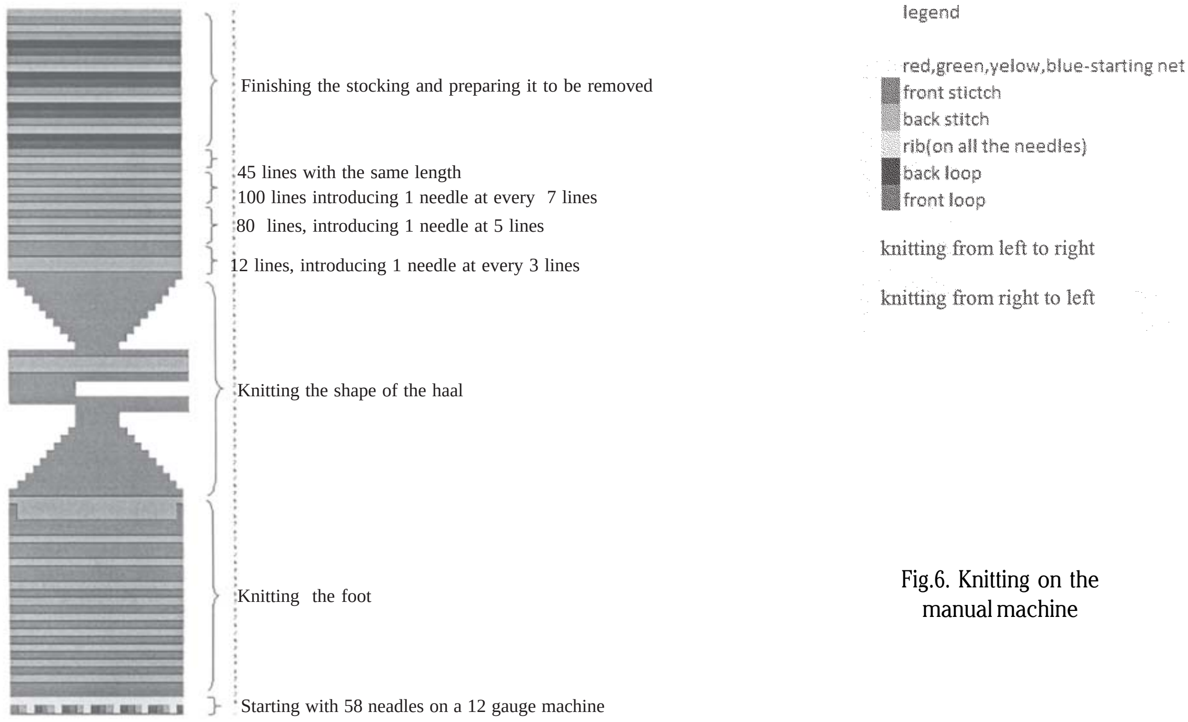

Fig.6. Knitting on the manual machine

Results and discussions

Using both techniques we succeeded in knitting two kinds of stocking using the loop transfer and the loop density and beside the fact that the stocking knitted using the density has a uniform aspect and no holes or other defects occur, the method using the loop transfer despite the fact that on the sides of the stockings defects appear as a side effect of the loop transfer, the second method is the most likely recommended because of the parameters stability and as the stockings compression has a closer value as designed.

Conclusions

Customization is a widely studied subject. However, there has a notable lack of almost any linking of customization to broader issues of manufacturing, marketing and research and design. Moreover, it can be said that customization is not a homogenous phenomenon that can be addressed as a whole.

Total product design is a process used by every firm that develops a new product because nowadays they are orientated to customers needs. The customer's opinion about a product is the most important one because the products are made for satisfying him.

The production of medical elastic compression stockings follows the principles provided by the concept of total product design and in the same time is approaching more and more to the customer needs using the computer integrated manufacturing systems provided by the mass customization concept.

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