

## FLAT KNITTING OF OPTICAL FIBRES

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### ABSTRACT

This paper presents an experimental research in the areas of knitting technology and optical fibres. The aim is to explore the possibilities to knit stiff monofilament optical fibres in flat knitting machines. The yarns used were transparent monofilament of polyester and optical fibres of PMMA (Polymethyl Metacrylate). Result shows that a hexagon shaped flat knitted prototype can be produced but also difficulties to knit monofilament yarn with optical fibres. The optical fibres was put into the structure in straight angles as weft insertion, to avoid bending and breakage of the monofilaments. Another problem was the take down device on the knitting machine but a solution of this is presented in the paper.

**Key Words:** Optical fibres, flat knitting, knitting technology, technical textiles

### 1. INTRODUCTION

This paper is about an experimental research in the areas of knitting technology and optical fibres and the aim is to explore the possibilities to knit with stiff monofilament optical fibres. Fibres with high stiffness are known to have a limited knittability and difficult to process in knitting machines [1]. The machine used is an electronic flat knitting machine STOLL CMS 330 TC with special equipment suitable for the feeding of yarn with high stiffness. In order to facilitate the progression of the work, different yarns were used. It was expected to be a challenge to work with optical fibres, and therefore the choice was made to use other yarns with better knittability in a first phase. The optical fibres that were used in the structure was guided into the prototype as weft insertion and was made of PMMA (Polymethyl Metacrylate). A hexagon shaped textile can be knitted on a flat knitting machine by shaping six triangles one after each other [2]. This is done by decreasing and increasing the number of wales in the fabric. The difficulty of this process is the stress appearing on the inner side of the fabric, as a result of the high difference of number of courses knitted on the inner and outer side of the fabric. This stress causes either yarn breakage or entanglement. The advantage is that the desired shape is obtained, and that all the fibre ends can be gathered in the centre. Knitting a hexagon in one piece turned out to be possible using a monofilament of transparent polyester as base yarn. In rectangular pieces, integrating optical fibres as weft insertion was quite unproblematic, however in the integral knitted textile, the stress on the inner side of the fabric regularly caused fibre breakage. Problems also occurred when trying to integrate the optical fibre as a weft insertion. The stress on the fibre turned out to be too high, regularly causing yarn breakage. This shows that the idea to create this type of product is good but some modifications of the flat knitting machine must be done to succeed. The main task has been to knit the shape and to integrate optical fibres in to the structure and study yarn feeding and inlay of the optical fibres in the knitted structure.

This paper shows that a hexagon shaped flat knitted prototype can be produced but it shows also difficulties to use monofilament optical fibres. An individually controlled take-down system is one modification that could benefit knitting a structure of this kind. One result of this paper is some development suggestions of the knitting machine that can make it possible to use optical fibres more with better result in the future.

## 2. METHODOLOGY

The method used in this paper is an inductive approach; it is based on a literature survey and experimental work on a flat knitting machine in the knitting laboratory at The Swedish School of Textiles. The knitting technology and production issues together with information about optical fibres are taken into consideration and implemented in the development of a shaped textile product. The main task has been to knit the shape and to integrate optical fibres in to the structure and study yarn feeding and inlay of the optical fibres in the knitted structure.

## 3. KNITTING OF FIBRES WITH HIGH STIFFNESS

A lot of research has been done over the years about the influence of different parameters and factors between yarn and knitting elements during the knitting process [3]. Important factors in the knitting process in contact between yarn and knitting elements are friction, strength, flexural rigidity, elastic properties of the yarn, velocity of knitting elements and yarn in the knitting zone [1]. Under the dynamic conditions of loop formation in the knitting process according to Amoton's Law of Friction, the yarn tension increases on the yarn supply side of the knitting zone stitch cam and the lowest tension occurs on the yarn on the other side of the knitting cam.

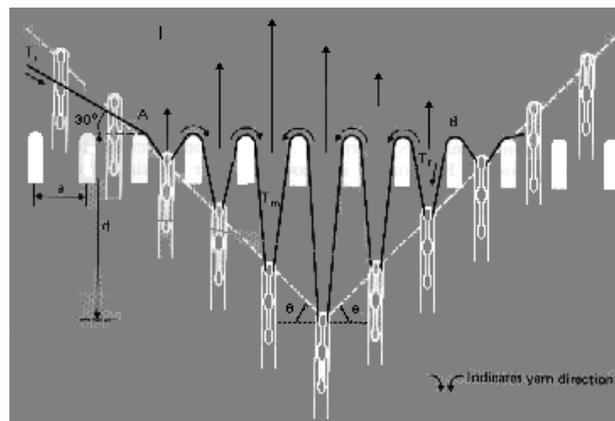
$$T_i = T_{\text{run-in}} \times e^{\mu\theta}$$

$T_i$  = Yarn tension at any point in the knitting zone

$T_{\text{run-in}}$  = yarn input tension.

$\mu$  = Mean coefficient of friction between the knitting elements.

$\theta$  = The sum of the angles of wrap in radius between the yarn, needles and other elements in contact with the yarn.



**Figure 1.** Model of weft-knitted loop formation indicating the mechanism of Robbing-back and the build up in yarn tensions acting on the needles [4].

This is because of that it is easier to “rob back” yarn from the already formed loops than to pull new yarn from the yarn package due to the fact that the tension is higher on this side. The tension on the yarn during knitting is influenced by the number and the angles of yarn wrap between yarn and machine elements and the fact that robbing back can reduce tension in the yarn, figure 1. Robbing back is the term for the yarn that comes from the already formed

loops back into the knitting zone, because the yarn tension is lower on this side and higher on the yarn package side. Research done by Abou-iiana [5], shows that with an increase of input tension  $T_{run-in}$  the position of maximum knitting tension moves towards the yarn supply side and with lower input tension the point of maximum knitting tension lies closer to the knitting point. The tension on the yarn during knitting is influenced by the number and the angles of yarn wrap between yarn and machine elements and the fact that robbing back can reduce tension in the yarn, figure 1. Robbing back is the term for the yarn that comes from the already formed loops back into the knitting zone, because the yarn tension is lower on this side and higher on the yarn package side. Research done by Abou-iiana [5], shows that with an increase of input tension  $T_{run-in}$  the position of maximum knitting tension moves towards the yarn supply side and with lower input tension the point of maximum knitting tension lies closer to the knitting point.

These factors and the fact that many parameters cooperate and influence each other between yarn and machine elements make knitting a rather complex process. When it comes to producing knitted structures of yarns or monofilament fibres with high stiffness such as carbon, aramid or polyester monofilament, parameters such as friction and flexural rigidity of the yarn are of considerable importance for the knittability of the structure.

#### 4. KNITTING OF OPTICAL FIBRES FOR LIGHT RADIATION

##### 4.1 Flat knitting machine with special equipment for knitting with stiff yarns

The knitting was done on an electronic flat knitting machine, Stoll CMS 330 TC, gauge E12 and needle size 10. The machine is a v-bed flat knitting machine special equipped for the knitting of stiff fibres and yarns shown in figure 2. A significant problem with these type of material is that some of these stiff yarns are almost inextensible, which causes tension peaks with breakage of the yarn or single filament in the yarn bundle. It is an advantage to be able to adjust the yarn feeding into the machine according to the actual requirements of the structure. Often when knitting with stiff yarns, it is desirable to feed the yarn without any tension into the latch needles of the machine.



Figure 2. Flat knitting machine STOLL CMS 330 TC [2]

## 4.2 Knitting of a hexagon shaped product prototype

The knitting of a hexagon shaped textile can be knitted on a flat knitting machine by shaping six triangles one after each other [2]. This is done by decreasing and increasing the number of wales in the fabric. The concept of the prototype shape is shown in figure 3. The figure shows a cycle of knitting in the software program that controls the machine during the knitting process. The knitting cycle starts down to the left and knits row by row and between each row the width of the fabric is decreased in width. In the middle the fabric width starts to increase, and the knitting continues until the second triangle is formed. The final prototype consists of six triangles.

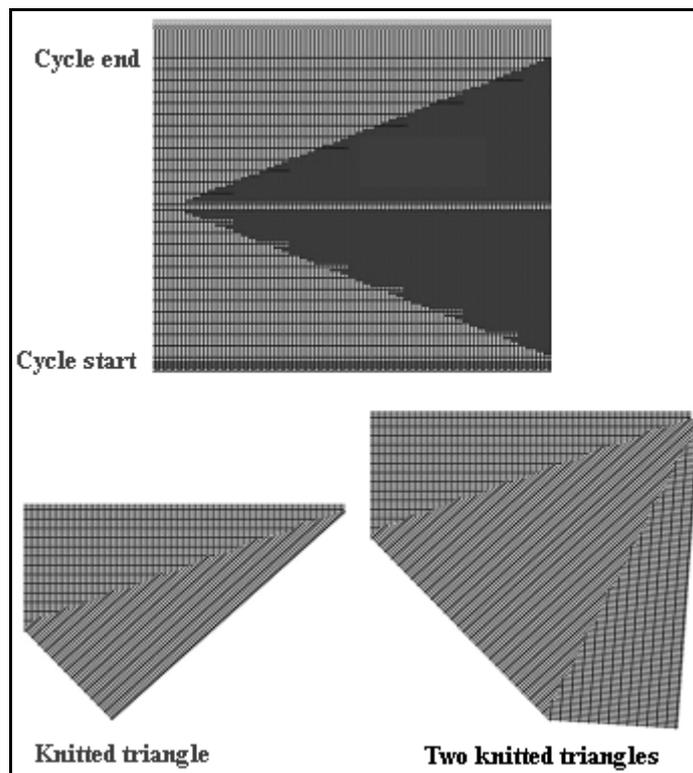


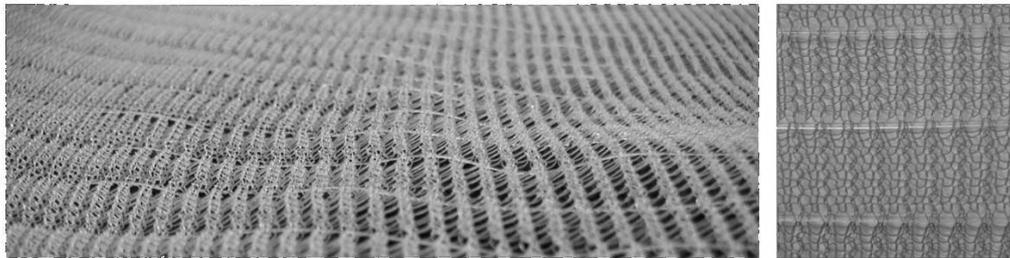
Figure 3. knitting of a hexagon shaped textile by shaping triangles [2]

The difficulty with this process is the stress appearing on the inner side of the fabric, as a result of the high difference of number of courses knitted on the inner and outer side of the fabric. When knitting this diamond shaped prototype one significant problem occurred. Due to narrowing of fabric width there are more wales knitted on the left side of the structure, then on the right side. This will cause an over production of fabric at the left side, and this is a problem for the takedown device of the machine. The takedown device is pulling down the fabric with the same tension along the width of the fabric with the result that the fabric is not pulled down enough to the left. This increases the risk of needle damage.

## 4.2 Knitting of optical fibres

It is not possible to knit with loops with the type of optical monofilament fibres used in this case. The optical fibre will break immediately when bent above the minimum bending radius, which would happen during loop formation. The optical fibres must be layed into the

structure by weft insertion as shown in figure 4. Even when the monofilaments are integrated into the fabric with weft insertion breakage of the fibres occurs.



**Figure 4.** Optical fibres integrated in the structure [2]

## 5. CONCLUSIONS

This paper shows that it is possible to knit a hexagon shaped fabric with inlay of optical monofilament yarns. However, two problems occurred. First problem: loop formation with the stiff mono filament was not possible, the optical fibre must be layed into the fabric as weft insertion with the optical fibres laying straight in the fabric. The second problem was the takedown device of the machine, it pulled the fabric down at the same rate over the whole width of the fabric. It would have been preferable if it's been a adjustable take down device. Shima Seiki, SWG-X is a flat knitting machine on the market with this type of adjustable takedown device [6]. This is made up of two devices, one front one back, each consisting of 44 paddles (each 1.5 inches wide) and each paddle has pins to hold onto the fabric, also each paddle is selectable, on, off, hold, strong, medium, weak. This means that it is possible to adjust the take down force along the the fabric width.

## 6. REFERENCES

1. Lau, K.W. and Dias, T., Knittability of High-modulus Yarns, *Journal of the Textile Institute*. 1994, Vol.85, No.2, 173-190.
2. Oscarsson, L., Heimdahl, E., Lundell, T. and Peterson, J., Development of a diamond shaped light radiating textile – an experimental flat knitting process with optical fibres, *Book of Proceedings, Ambience08, Borås, Sweden, 2008*, 115-121.
3. Knapton, J.J.F. and Munden, D.L., A study of the mechanism of loop formation on weft-knitting machinery, *Textile Research Journal*, 1966, Vol.36, No.12, 1072-1081.
4. Spencer, D.J., *Knitting Technology*, Pergamon Press: Second Edition. 257-259.
5. Abou-iiana, M., Fadenzugkrafte beim Stricken mit Relativbewegung, *Melliand Textilberichte/International Textile Reports*, 2000 Vol.81, No.9, 726-745.
6. Shima Seki MFG., LTD. 2009. *Shima Seiki SWG-X Wholegarment® Computerized Flat Knitting Machine*. Available at: [http://www.shimaseiki.co.jp/product\\_knite/swgxe.pdf](http://www.shimaseiki.co.jp/product_knite/swgxe.pdf) [Accessed 17 April 2009].