Development of a diamond shaped light radiating textile – an experimental flat knitting process with optical fibres

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Figure 1. A diamond shaped light radiating textile lampshade viewed from below and in profile.  
Source: Elisabeth Jacobsen Heimdal and Linda Oscarsson.

ABSTRACT

This paper is about the experimental product development of a light radiating textile lamp in which optical fibres are used as the only illumination source. The assigning company is GloFab, a company located in Stockholm, which designs different kinds of light radiating textile products. The paper is based on the work of a research project which had an inductive approach; the project consisted of a literature survey and experimental work on a flat knitting machine located in the knitting laboratory at the Swedish School of Textiles, in Borås, Sweden.

The aim with the research project was to explore the possibilities to produce a knitted lampshade integrating optical fibres, shaped as a diamond with a hexagon basis (Figure 1).

This was done on an electronic flat knitting machine with special equipment suitable for the feeding of yarn with high stiffness. This is interesting for GloFab because it gives possibilities to industrialize the production process and by doing so reach a wider market. In a broader perspective it is relevant to study how new materials can be used in traditional textile processes. The product development consists of two parts: exploring the possibilities to knit the desired shape on one hand and experiments about knitting with optical fibres as a weft insertion on the other hand.

AUTHOR KEYWORDS

Optical fibres, flat knitting, knittability, light radiating textiles, technical textiles.
INTRODUCTION

GloFab is a young brand, its products are spectacular light radiating textiles and the idea is to create value for the customers by making their venues more attractive. It all started in 2003 when Torbjörn Lundell, the founder of GloFab, created a visionary image, picturing a man sitting in the dark surrounded by glowing textiles (Figure 2).

This vision resulted in several products, such as curtains or room dividers and a lamp shaped as a globe, made of big handmade laces in the technique macramé, created from optical fibres. All products function as either lamps or light sources (Figure 3) [7].

All of GloFab’s products are today handmade in Sweden and many are especially designed for each customer. This evidently leads to high production expenses and much time spent on project administration. In order to expand on the market it is necessary to fabricate products faster and in a less cost requiring way. It is nevertheless important to keep the innovative concept and keep the same unique experience as GloFab’s already existing products. A way to adapt the macramé concept into an industrial context is knitting on mechanical flat knitting machines. Yet another advantage with knitted fabrics is the possibility to create 3-dimensional shapes, compared to for example weaving which gives flat, inelastic fabrics.

Using optical fibres as an illumination source is an innovation of an already existing concept (a lamp); the innovation being that the light source is not located in the centre of the construction but in the 3-dimensional shape itself. Hence there is no longer need for a light bulb and this brings many exciting opportunities to create new decorative light designs.

In line with the GloFab concept it was interesting to explore the possibilities to knit the lampshade shaped as a diamond as this gives a luxurious feeling to the product. Furthermore, it makes it possible to industrially produce a GloFab product, while still keeping the unique feeling of the already existing handmade light radiating textiles. It was also in an early stage of the project considered achievable to knit a diamond shaped textile on a flat knitting machine and it was important from a design point of view to explore this further together with the possibilities of knitting with optical fibres.

RESEARCH QUESTIONS

The following research questions were formulated:

− How can a diamond shape be knitted on a flat knitting machine? How is such a product to be dimensioned and designed?
− How can an optical fibre of diameter 0.25 and 0.75 mm be integrated as weft insertion in a form knitted product?

KNITTABILITY OF BRITTLE FIBRES

The advantages with knitted products are their outstanding characteristics such as flexibility in production, knitting to shape, superior resistance to impact and finally their high ability to conform to complicated forms [4]. In order to integrate textiles and optical fibres for illumination, knitting is an interesting choice because of its positive characteristics mentioned above. The task includes the use of less common materials used in the knitting industry and therefore it is relevant to study knittability of brittle materials.

Products with high mechanical properties are generally produced from high-performance materials, for instance glass, aramide, carbon or even ceramics.
These materials are difficult to use in the knitting process due to their high stiffness and high coefficient of friction and some of them are brittle causing breakage in the loop formation process [4]. According to Savci et al [5] studies have shown that fabric dimensions and physical properties both depend on the loop length. The important factors for controlling loop length are the stitch cam settings, yarn input tension settings, fabric take-down tension and yarn-to-metal friction properties. In addition the loop length can also be affected by the knitting speed which influences the friction. Further more Savci et al means it is evident that the knittability of high performance yarns, such as glass fibres, depends on frictional properties, bending stiffness, and yarn strength. This special type of fibres requires low-tension settings, appropriate tension control of both yarn and fabric, and minimal metal surface contact during knitting [5].

The degree of filament breakage also depends on the choice of structure as well as the filament diameter and yarn torsion. Yarn with a smaller filament diameter and a higher torsion has a lower degree of filament breakage with higher loop lengths [4]. When it comes to optical fibres the thickness has an influence on the light emitting properties. In fact, the thicker the fibre, the more light it can transport; but the more difficult it becomes to knit with [6].

Optical fibres are quite strong and are difficult to break, until they are bent above the minimum bending radius. This is the smallest possible value of the radius of the arc formed by the fibre as it is bent. If the fibre is bent over this radius it will break immediately. The optical fibre of 0.25 mm in diameter that was used in the project has a minimum bending radius of 1.5 mm. The fibre of 0.75 mm has a minimum bending radius of 7.5 mm [9,10].

When it is not possible to form loops with a fibre, it can nevertheless be integrated in the knitted fabric by weft insertion.

**OPTICAL FIBRES FOR LIGHT RADIATION**

Optical fibres are not in their natural state light emitting. In the most common optical fibres, the majority of the data travels inside the fibre and emerges at the end or is lost inside the fibre [3]. However, for illumination purposes, this loss of data or light is just what is wanted. There are several ways to make the fibre light emitting. One way is to add special, light-scattering materials to the core of the fibre, and then much of the light directed into the fibre is spread out along its sides, because the light becomes redirected when it hits the scattering material [3]. Light scattering can also be made mechanically, by scratching the surface of the fibre, creating small dints on its surface. These dints will also cause the light to emit, due to the special properties of optical fibres [2]. Yet another option is to bend the fibre continuously, then light leaks out of the fibre when it is bent within a certain rate, and if this happens regularly along the fibre the whole fibre will appear as light emitting [6]. The bending can be done by using the fibre in a textile construction, which was done in the research project.

**METHODS AND MATERIALS**

The knitting technology and production issues together with information about optical fibres and design requirements were taken into consideration and implemented in the development of the diamond shaped light radiating textile. The main task for the research project was to knit the diamond shaped lampshade; being able to obtain the right shape and to integrate the optical fibres into the structure. Finally it was intended to construct a prototype.
The knitting was done on an electronic flat knitting machine, Stoll CMS 330 TC (Figure 5), gauge 12 and needle size 10.

In order to facilitate the progression of the work, different yarns were used. In fact, it was expected to be a challenge to work with the optical fibre, and therefore the choice was made to use yarns with better knittability in a first stage.

The materials used as base yarn were three-thread texturised monofilament of polyester, which was later changed to transparent monofilament of polyester with the diameter of 0,12 mm, and at the final stage 0,15 mm. For the weft insertion two-thread spun acrylic yarn was used to begin with, and later changed to green monofilament of polyester with the diameter of 0,17 mm. When experiments started with the optical fibres as weft insertion it was fibres of PMMA (Polymethyl Metacrylate) with the diameter of 0,25 mm and 0,75 mm. In the final prototype the yarns were transparent monofilament of polyester, transparent for the base yarn with the diameter of 0,15 mm and coloured polyester monofilament with a diameter of 0,17 mm. The transparent yarn used as base yarn reflects light, which gives an aesthetic quality to the product with a lustre effect. The prototype is shown in Figure 6.

Just like the rest of GloFab’s products the lampshade was desired to be developed as a large product. Its dimensions were defined by the length of a loading pallet, which by European standard has a length of 1 200 mm. In an upstanding position many lampshades can then be loaded onto a pallet and shipped off. Looking at Figure 1 the distance from the roof to the bottom point of the lamp is approximately 300 mm. The hole in the middle is approximately 100 mm.
EXPERIMENTAL RESULTS

A diamond shaped textile can be knitted on a flat knitting machine by form knitting six triangles one after each other by decreasing and increasing the number of wales in the fabric (Figure 7). The challenge of this process is the stress appearing on the inner side of the fabric, as a result of the high difference of number of wales knitted on the inner and outer side of the fabric (Figure 8).

This stress causes either yarn breakage where fewer wales are knitted or entanglement at the other side. Though the shape could have been knitted in another way, it was necessary to do it in this way as the fibre ends will later be gathered in bunch in the centre of the diamond and connected to the light supply equipment.

As previously mentioned, optical fibres break immediately when bent above the minimum bending radius, which would happen during loop formation. Therefore it became clear that it would not be possible to knit with the optical fibres, so they had to be integrated in the fabric by weft insertion. To do this, in rectangular pieces was quite unproblematic (Figure 9), much thanks to the special yarn feeding device attached to the machine.

However when trying to integrate the optical fibres in the form knitted textile, the stress on the inner side of the fabric regularly caused fibre breakage. As the results show that it was possible to integrate optical fibres with diameters of 0.25 and 0.75 mm in rectangular shaped fabrics it became clear that the prospect to create the desired product is good, with some modifications of the flat knitting machine.

FURTHER DEVELOPMENTS

Based on the experiments, as well as discussions with teachers and technicians at The Swedish School of Textiles, further development possibilities concerning the polymer choice, the flat knitting machine and new design possibilities have been outlined.
Choice of polymer

The optical fibre used in the experiments is made of PMMA (PolymethylMethacrylate), a purely amorphous polymer [1]. This clearly is an inconvenient when it is used in fibres that have to be employed in textile applications, as it makes the fibre fragile, and increases the risk for fibre breakage. PMMA has however, good optical properties. [Hans Bertilsson, personal communication, 10-05-2007]

There are other polymers with good optical and textile properties that are better suited for the knitting machine. Today, these do not exist as fibres, but a development has been started. Two of these are polyethersulfone (PES) and poly-4-methylpentene-1 (PMP), which has been commercialized as PTX by ICI. Polyethersulfone is amorphous, just like PMMA, but has however better mechanical properties. [Hans Bertilsson, personal communication, 10-05-2007] Poly-4-methylpentene-1 is semi-crystalline, but still has good optical properties as well as mechanical [8]. As the focus on textile products integrating optical fibres increases, the demand of fibres that have properties suited for textiles will probably increase, and then such fibres will be developed and commercialized. Unfortunately, both PES and PMP are much more expensive than PMMA. [Hans Bertilsson, personal communication, 14-05-2007] The choice of polymer is critical for the success of the experiment, and it is clear that the novelty of textile application for optical fibres explains a present lack of suitability of the optical fibres for textile applications.

Machine limitations

Another technical challenge in the experiment is the limitations of the machine. These limitations should be communicated to the machine producer, German Stoll, so that future machines better can satisfy the requirements set by new design ideas in the areas of smart and functional textiles. Four possible improvements on the machine are:

- Individually steered take-down rollers,
- Lower machine gauge,
- Holding down sinkers helping to hold down the optical fibre when it is bent in the transition from one wale to the other, and
- Bigger scissors, to cut thicker optical fibres.

It is important that educational institutions, such as The Swedish School of Textiles, as well as designers, product developers and companies working in the area of smart textiles communicate their needs to machine producers, so that the machines do not become an unnecessary barrier to the realization of their ideas, but rather support the development of new designs. In this experiment, the technical machine improvements are quite simple to realize, and this is probably often the case. As an example, the special yarn feeding-device eased the use of stiff material.

New design possibilities

Shape knitting with optical fibres revealed to be a true challenge, and opened our eyes for some new design possibilities. Integrating optical fibres as weft insertion in rectangular pieces was quite unproblematic, even with an optical fibre of 0.75 mm in diameter, see figure 10. These rectangular pieces could be shaped after they have been knitted.

Compared to weaving, knitting offers a more flexible, formable result, but is also seems that the knitting process is harder to match with optical fibres. Different kinds of lamps could in the future be knitted with optical fibres. Just by changing the shape of the product mentioned above and knit rectangular pieces the knitting process would be crucially facilitated. This could give flat lamps, hanging directly on the wall, or big tubes, similar to the popular rice lamps we see on the market today, but with this new technique. It is important to remember that optical fibres, just like LED do not emit any heat what so ever, and this absence of heat emission means the products can be placed in places where normal lamps can not. E.g. they can be positioned on textiles or other materials sensitive to heat. The optical fibres still must be connected to light supply equipment and this is still quite heavy and big, a bit noisy and emitting heat, but it can be hidden above the roof for example, and most likely it will be further developed in the future, along with the development of light radiating textiles!

CONCLUSION

The experiments show that it is possible to knit the diamond in one piece with transparent monofilament polyester yarn, which was desired to add value to the product. The project furthermore shows that a diamond shaped, flat knitted, light radiating textile can be produced but it shows also difficulties to replace the inlay polyester monofilament yarn with optical fibres. Nevertheless it resulted in a number of development suggestions that can make it possible to replace the monofilament with optical fibres in the future. These suggestions are based upon observations during the
knitting process. The diamond shape was obtained by knitting six triangles but by increasing the number of triangles, the stress would decrease, which would also be affected by changing the base yarn to a more elastic yarn. A bigger hole in the centre would again reduce the stress. Thicker scissors together with lower gauge of the machine would allow thicker fibres to be used. Lower gauge would also give a thicker base fabric which might be positive for this product.

This work shows there is a true chance that in the future, light radiating textiles can be knitted on a flat knitting machine.

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FURTHER READING

The complete research project report can be reached by contacting the authors, and is also available at the University College of Borås’ library.

REFERENCES

Printed documents


Digital documents