TECHNOLOGY OF ILLUMINATIVE FABRICS

N. GOKARNESHAN and P. DHANAPAL
TIFAC-CORE in Textile Technology and Machinery
Kumaraguru College of Technology, Coimbatore - 641 006.

The refractive index of any material is related to the total reflection on the inter-phase of two optic materials. When the angle of reflection is less than the critical angle, the light returns to the same phase from which it is coming from, at an inverse angle. In the case of woven structures, the optical leakage will take place in weft depending on the reflection law and system geometry. In the case of bent fabric the weft bend angle will change in many complex ways and this accordingly changes the light emission. The light emission improves with structures having floating weaves.

Key words: *Cladding, Illumination, Light emission, Optical fibre, Optic leakage, Reflection*

INTRODUCTION

In the recent years, Intelligent systems have been integrated in textile applications and this has led to considerable improvement in comfort and performance characteristics of the textile materials, particularly fabrics. Evidently optics should be included among the possibilities.

Flexible display units open room for innovative design in architectural and industrial art applications for public premises, vehicles, and other related upholstery. The woven optical fibre constructions are not suitable for clothing purposes as they are too rigid and tough. Hence these are more suitable for novel development of flexible displays based on polymeric light emitting technology.

Illuminative optical fibre

Plastic optic fibre is used for illumination. The main source of the illumination is the core of the fibre that is constructed with cladding, which is nothing but step indexed fibre manufactured in the co-extrusion process. The manufacture of this fibre involves two stages. In the first stage fibres of 2 to 5 mm diameter are produced and in the second stage, it is melted. Polymeric optical fibre is generally made of polycarbonate, polymethyl methacrylate or polystyrene. These materials can be considered as substitutes in special applications such as illumination. Impurities limit the usage of materials other than those mentioned in data and telecom applications.

Polymethyl methacrylate has the best transmission (98% over 3mm) and has a refractive index of 1.492. It is used in conjunction with low molecular weight dopants and is stable when used upto 85°C in dry air. The polymer gets rapidly degraded at higher temperatures with humid conditions. The service age is also reduced to a few thousand hours. A service life of about 30 years can be expected when copolymers are used in ambient conditions of normal premises. Polycarbonate can be utilised at comparatively higher temperatures, and they are less sensitive to moisture. The requisite structure and properties for various applications are given in Table 1.

Optic fibre in woven structure

The refractive index of any material is related to the total reflection on the inter-phase of two optic materials. When the angle of reflection is less than the critical angle, the light returns to the same phase from which it is coming from, at an inverse angle. This is known as reflection. But when the angle of reflection is greater than the critical angle, an optic leakage will take place.

In the case of woven structures, the optical leakage will take place

Table - 1 : Important values of structure and properties of various applications.

S.No	Required dimensions and properties	Illumination application	Commercial Application	Communication Application
1	Diameter, m	100-5000	250-2000	500-1000
2	Diameter tolerance	25%	<10%	<10%
3	Cladding	Not important	Important	Very important
4	NA	Not important	0.3-0.65	0.5
5	Attenuation	3-5dB/m	0.5dB/m	0.25dB/m
6	Heat resistance	60°C	70°C	85°C

in weft depending on the reflection law and system geometry. In the case of bent fabric the weft bend angle will change in many complex ways and this accordingly changes the light emission. The light emission improves with structures having floating weaves. Plain weaves give the least emission due to many interlacing points. As the warp yarns in a woven fabric are comparatively less bent than the weft yarns, they can conduct light for longer distances in a given construction. Under lateral compression caused by weft tension forces, linear birefringence will be induced. The fibre sensitivity to torsion is small, although polarization response to torsion is significant. The torsion induces shearing stress in the cross section of the fibre, ultimately causing light wave plates to rotate, and the azimuth to be changed. Tension response to linear and circular birefringence is close to zero deformation.

Principle of light emission

It is preferable to use an optic fibre with light emitting cladding as warp, rather than weft, as this gives better control of the light emission. The options for this would be to either scratch the surface or to include fluorescent material on the cladding.

A surface that can emit light in a controlled way should have reflective surfaces in a harmonic lattice with a dimension which fits together with the used wave length. The possibilities include very accurately manufactured dints, whose sizes and distances are in multiples of half the wavelength. Any notch or scratch may be too coarse and lose the whole light power at a single or a few points. Practically, the construction would be difficult to manufacture, and needs to be covered with mechanically protective cladding of a relatively low refractive index (refractive index of cladding should be less than that of core).

Thus light emitting materials are a practical alternative to cladding. In the cladding the light mode meets the active orbital, causing a state of excitation, which in time emits photon. Control of the emission is markedly better. The remaining questions are the correct layer thickness of the cladding in the magnitude of wavelength, and secondarily its wear resistance. The optic fibre material PMMA is UV radiation-sensitive, which favours photoluminescence instead of UV fluorescence.

Applications of back lighting

Woven back lighting elements have found limited end uses such as certain medical and electronic applications. It has been used in lighting for dental surgery. In electronic devices, fibre optic back lighting is used for high brightness and low power 30ft-l and 10-20mA, combined with long lifetime (upto 100 000 hours). Other technologies are related to highly conductive and light emitting polymers. Active research is being pursued in the area of polymer light emitting diodes. Flexible film substrate constructions have been introduced. An interesting aspect of the polymer light emitting diodes is the possibility of producing them with gravure printing, or ink jet technology.

Application of fibre material in mass illumination

The light power transmission or the amount of light power that could be transmitted through an individual optical fibre, depends on the optic opening, cross sectional area, and on the attenuation of the fibre. In the case of plastic optical fibre the acceptance angle is greater than 35°, and the core diameter is large ranging from 500-1800µm. The attenuation of this fibre is 10-50 times higher than silica glass. However, the flexibility of plastic is far superior in comparison to that of glass particularly at temperatures upto 80°C. PMMA, in particular, becomes brittle at sub zero temperatures.

The restriction of POF in mass illumination is the light power threshold value which limits polymer degradation. The fibre degrades rapidly with increase in constant light power ranging from 30-50mW/mm^2. The extensive use of UV component <400nm is particularly hazardous. Transmission of bulk light power is thus complicated. However, the development of a hollow fibre may improve the performance. Intensive light sources can be obtained only at the end of the fibre. Due to the aforementioned factors, POF illuminations are suitable for limited signal panels and sign elements.

Weaving with optical fibre yarns

Fabrics have been woven using different types of fibre materials. These include 400µm PC polycarbonate fibre, 1000 µm SI PMMA fibre and 400 µm PMMA fibres. These fibres had reasonable level of toughness. Initial trials with these materials were carried out in handloom. The result revealed that a higher tensile was required when POF was used as warp. The weaving speed had to be reduced, or the fibre had to be warmed during weaving, so as to attain the required toughness for the process. The POF tends to slip due to its monofilament structure.

A narrow width weaving machine has been used for prototyping. The warp and weft yarns were made of polycarbonate fibres. Though the strength of the polycarbonate was adequate, it posed certain problems. Due to the non-oriented structure of POF, the fibres got elongated under the required tension. Polycarbonate showed markedly reduced optic properties during testing. When POF was used as warp and weft, a positive shedding mechanism is required to control the harnesses. The positive rapier system of weft insertion has been found to be the only suitable system for weaving of POF yarns.

The use of polycarbonate POF yarns as weft presented no problems in jacquard weaving. It has been possible to produce a variety of fabrics.

All the fabrics produced were generally tough and had a considerably robust structure. This has been attributed to the size of POF monofilament. However, the minimum diameter of POF which remains useful in the application is 60 or 125µm, reducing the emitting light power per fibre to 5 to 20 per cent from the actual values.

Finishing treatments

Various methods of finishing treatments have been given to the woven fabrics so as to produce optically active surfaces. The structure of the woven fabric has been mechanically abraded manually with sand paper, causing extensive scratches on surfaces. The procedure has been controlled by using stoll abrasion testing equipment. Fabrics were attached in the tester for a short duration of about 20 rounds, and the surface of the fabrics were abraded on one side. Side notching has been done with a motion-limited press, equipped with a cutting knife of a particular shape. When closing the press, the knife cut the POF warp. The weft was not markedly destroyed while it had higher flexibility, and it was thus able to move under the knife, contrary to the tough POF monofilament. Chemical abrasion has not been tested as the chemicals could affect the weft fibre materials.

Findings of the studies conducted

Difficulties have been encountered in using POF as a light emitting weft in most of the cases, since the warp could not carry the necessary amount of tension for the creation of the required bend angle. When the required amount of warp tension was attained, the angle of warp bend was so high that it lost the light power in the fibre after the first 5-10 knots.

The abrasion results were not uniform. In order to control the process there is need to develop equipment suitable for the job. Side notching the POF weft made it possible to produce simple figures of light dots. Figures with fairly high light power could be produced by feeding the light from each side.

CONCLUSION

Illuminative fabrics have limited end use applications, such as dental surgery light sources, and in back lighting applications when high brightness and low power are combined with long lifetime. Fabrics having considerable light emission are tough and reasonably robust in structure.

The difficulty in control of the bend angle restricts the use of POF yarn. Light emitting weft is simpler. Simple patterns of light dots can be made by side notching the POF weft. The abraded monofilament distributes the light more evenly. The latter, together with fluorescent cladding, has to be abrasion protected for use. Other limitations derive from the limited mechanical properties at sub-zero temperatures, especially with the most common PMMA fibre.

Woven illumination systems are suitable for architechtural art applications for public premises, automobiles, and other related applications. Their advantage is that the light source and emitting surface can be separated. The best light power is achieved at the fibre end. Side-notched emission is also effective, but fluorescent warp is practical as well (side illumination). The light-emitting wovens are suitable for indoor use. Woven illumination is not recommended either for bulk light sources or flexible high definition displays.

REFERENCES

1. Ali Harlin, Mailis Makinen & Anne Vuorivirta, *Autex Research Journal,* (3), (2003).
2. US Patent 5,235,660, *Peachtree Fibre optics Inc,* (1996).
3. Hecht. E, *Optics, Addison-Wesley* (1998).
4. Paula saari, M.Sc Thesis 1987, Tampere University of Technology.
5. US Patent 4234907, (1980).
6. Pisukunov, N., Differential and structural calculation, MIR Publishers, Moscow (1974).
7. Xiaoming Tao, *Textile Asia,* (1), (2002).
8. www.lumitex.com
9. Grennendaal, L., Jonas F., Freitag D., Pielastzik H., Reynolds J.R., *Adv. Mater*, (12), 494, (2000).
10. Fibre systems Europe, Maxwell, I., (12), (2001). *Polymer materials*, promote microstructured optical fibre applications, Euro Photonics, (12-1), 24, (2002).
11. PCT/GB00/01406, (2000).
12. Weinert. A., Plastic Optical fibre, published MCD Verlag, (1999). ■

THE SOUTH INDIA TEXTILE RESEARCH ASSOCIATION

- **Coimbatore**

The inaugural function of SITRA's Golden Jubilee Celebrations was held on 24th February 2007. His Excellency Dr. A. P. J. Abdul Kalam, President of India was the Chief Guest of the function. Mr. E. V. K. S. Elangovan, Union Minister of State for Textiles, delivered the Keynote Address.

President Abdul Kalam at the Golden Jubilee function of SITRA.

President in his speech said, I am delighted to participate in the inauguration of Goldern Jubilee of the South India Textile Research Association popularly known as SITRA. During the last five decades the membership of SITRA has increased membership including textile institutions of foreign countries such as Sri Lanka, Malaysia, Nigeria, Indonesia, Bangladesh, Thailand and Iran. I congratulate the SITRA community both present and past who have built a robust institutional framework for textile research during the last five decades. I have observed that Coimbatore with its core competence in textiles has always maintained the leadership in textile industry inspite of recession in the industry at times. Also Coimbatore is well known for textile machinery production and Tirupur has become world famous for apparel manufacture. Members of SITRA have definitely made important contribution in realizing this status. My greetings to all the members of SITRA community on this occasion of Golden Jubilee Celebra-tions,textile business leaders, textile teachnologies and distinguished guests participating in this function.

President Abdul Kalam being greeted by Dr. Arindam Basu, Director, SITRA.

Mr. E.V.K.S. Elangovan, Hon'ble Union Minister of State for textiles on the occasion of inauguration of the Golden Jubilee Celebrations of SITRA on Feburary 24 2007, delivered delighted speech. ■