Optical **F**ibre **S**ensors **E**mbedded into technical **T**extile for **H**ealthcare

Proposal/Contract no.:**FP6 - 027 869**

D1.3 –Annex1 : General information about textiles

1.- Process: Textile fibres and filaments

Textile fibres are classified in two main categories: **natural** fibres and **man-made** fibres.

Man-made fibres can either be **natural polymer fibres** (in which the fibre forming material is of natural origin) or **synthetic fibres**(in which the fibre-forming material is made from synthetic polymers). Both types can be made in form of either cut fibres (from a few millimetres to a few centimetres) or in form of continuous filaments (from a few hundred metres up to several dozens of kilometres).

Natural fibres themselves are made from animal (wool, silk, cashmere, angora…), vegetable (cotton, linen, jute…) or mineral raw materials (asbestos). The length of the fibres may vary greatly: from a few millimetres to several centimetres, and even to several hundreds of metres as is the case of silk. Because of this large variety in length distribution, there are several processes to produce yarns from fibres.

a) Natural fibres from animal origins

Natural fibres from animal origin all derive from animal hair. Only silk is obtained from the silkworm. Wool is doubtlessly the best-known natural fibre from animal origin in the world. It comes from sheepskin. Depending on the sheep's origin (Europe, Australia, New-Zealand, South-America, South-Africa) the quality may differ enormously and hence the final application of the wool. The finer the fibres, the more its softness is assured.

Other animal fibres on the market are :
- Silk fibres are longer than any other natural fibre since the length of a filament may vary between 900 and 1200 metres. Although silk is highly resistance, this property falls back very rapidly when wet.
- Cashmere fibres are derived from a goat.
- Camels, yaks, mohair, angora (goat or rabbit)… also produce fibres that are used in textiles.

b) Natural fibres from vegetable origins

Cotton is without any doubt the best-known fibre from vegetable origin. Cotton fibres have a light colour varying from crème to yellowish. The cotton fibre is relatively short. Depending on its degree of maturity, cotton fibres display a very different sectional shape. Most often, they are 'bean' shaped.

Next to cotton, there are other fibres such as :

- Linen: these fibres are obtained form the stem of the flax plant. They are very resistant, but more breakable and less flexible than cotton fibres. This lack of flexibility provokes problems in the field of creasing.
- Jute, hemp, sisal, kapok….

c) Natural fibres form mineral origins

The only fibre in this group is asbestos, which is now known because of its toxicity.

In contrast to the natural fibres, artificial and synthetic fibres are produced chemically.

Artificial fibres are made from materials that exist already of an animal, vegetable or mineral (inorganic) origin.

d) Artificial fibres from animal or vegetable origins

These fibres are produced by different chemical processes that process products from animal or vegetable origins.
In this category one finds :
- viscose or rayon (regenerated celluloses) from wood fibres
- chitin: produced from shellfish shells
- cellulose acetate or triacetate
- Polylactide (PLA)polymer produced from corn

e) Artificial fibres from mineral origins

These fibres are produced by different chemical processes that process natural products from mineral origins.
In this category one finds :
- glass fibres: depending on their composition SiO_2, CaO, MgO, Al_2O_3 et B_2O_3, glass fibres display different properties
- ceramic fibres: the content of Al_2O_3 , SiO_2 et B_2O_3 also determines the properties of ceramic
- silicon fibres : content of 99.9 % of SiO_2
- boron fibres are obtained by the depot of boron on the tungsten or carbon stem
- silicon carbon fibres
- carbon fibres : obtained by pyrolysis on either an acrylic or petroleum pitch (residue of thermal processing and distillation of petroleum fractions)
- metallic fibres: depending on the used compound, the metallic fibres obtain different properties.

f) Synthetic fibres

Synthetic fibres are produced by means of synthetic macromolecules obtained by chemical synthesis. The variation in the selection of polymers, chemical structure and macro-molecular structure imparts different properties to the fibres.
In this fibre category we find :
- Polyamide
- Polyester
- Polypropylene
- Polyethylene
- Aramid
- Polyurethane
- Polyvinyl chloride
- ….

INDUSTRIAL PRODUCTION TECHNIQUES FOR MAN-MADE FIBRES

- Melt spinning technique (Polyester, Nylon 66, Nylon 6, Polypropylene, PE)
- Wet spinning technique (Viscose rayon, Acrylic, Spandex, PVC, PVA, Aramids)
- Dry spinning technique (Cellulose Acetate, Triacetate, Acrylics, Spandex (Lycra), PVC)
- Gel-spinning technique (High performance PE (Dyneema, Spectra)
- Conjugate spinning technique (Micro-fibres, Bicomponent fibres)
- Electrospinning technique (Nano-fibres)

SOME PHYSICAL PROPERTY DATA OF SELECTED FIBRES

	Cotton	*Linen*	*Wool*	*Viscose*	*Polyester*	*Nylon*	*Acrylic*	*PP*
Tenacity g/den dry	**3-5**	**5.5-6.5**	**1-2**	**Reg.2**	**4.5-5**	**4.6-5.8**	**2.5**	**3.5-8**
Breaking elongation	**4-7%**	**2.7-3.3**	**35%**	**Reg. 20% HWM 12%**	**20-30%**	**30%**	**20-55%**	**40%**
Elastic recovery (from 2% elong.)	**70%**	**65%**	**100%**	**R 80%**	**97%**	**100%**	**95%**	**100%**
Resilience	**low**	**poor**	**excel.**	**low**	**excel.**	**excel.**	**good**	**good to Excel.**
Moisture regain at 65%RH	**8.5%**	**10%**	**15%**	**12-13%**	**0.4%**	**4.2-5%**	**1.5-3.0%**	**0.1%**
Density	**1.54**	**1.50**	**1.32**	**1.52**	**1.38**	**1.14**	**1.14-1.19**	**0.91**

2.- Process: Yarn production

It is relatively easy to obtain yarns from natural fibres. Indeed, the fibres are either harvested in nature or in the fields, or they are obtained after shearing animals. In general, the materials are cleaned and sometimes chemically processed before their transformation into fibre filaments during spinning operations.

In the case of artificial or synthetic fibres, there are two sorts of yarns:
- yarns produced from short and discontinuous fibres
- filament yarns produced from synthetic filaments

CONVERSION OF FIBRES TO YARNS

An understanding of yarn performance begins with classification:

- *SPUN YARNS* are those made by twisting together staple-length fibres into a strand.

- *MULTIFILAMENT AND MONOFILAMENT YARNS* are made directly from filament fibres usually without twist.
- *SINGLES YARNS* consist of just one strand of fibres.
- *DOUBLED OR PLIED YARNS* are formed by twisting together two or more singles. Cords are formed by twisting plied yarns together.
- Cables are made by plying cords and ropes by plying cables
- *SIMPLE YARNS* are smooth, even and homogeneous
- *FANCY OR NOVELTY YARNS* are wrapped, looped, or twisted about each other to achieve various aesthetic effects.

3.- Process: Production of woven fabrics

CONVERSION OF YARNS INTO FABRICS

When the yarns have been manufactured from textile fibres by the methods described earlier, they are used for the production of fabrics by weaving or knitting.

Weaving

All woven fabrics are made up of two sets of threads , the *warp* and the *weft,* which are interlaced by different techniques.

The threads which extend throughout the length of the fabric are termed *warp* threads, while those which go across are termed as *weft* threads. More technical names for these same threads are *ends* and *picks,* respectively.

Since it is generally necessary for the warp threads to be strong in order to withstand the considerable strains to which they are subjected to in weaving, they are the more important and the inferior weft threads are frequently referred to as "filling"

In order that the fabric may have strength and compactness combined with a fair degree of elasticity, it is necessary that the warp and weft threads pass alternately under and over the warp threads, then the fabric will be a *plain weave* and will represent the simplest type of weave.

These weft threads may also pass under two, then over one, then under two and over one, and so on. A *twill fabric* is built in this way. A *sateen fabric* is made with the weft threads passing over and under different number of warp threads so as to avoid producing any pronounced patterned effect.

If either the warp or the weft thread are considerably thicker, then a *rib type* fabric will be produced.

There are a very large number of variations of the methods for interlacing the warp and weft threads and so it becomes possible to weave a wide variety of fabrics all of which have special properties and uses.

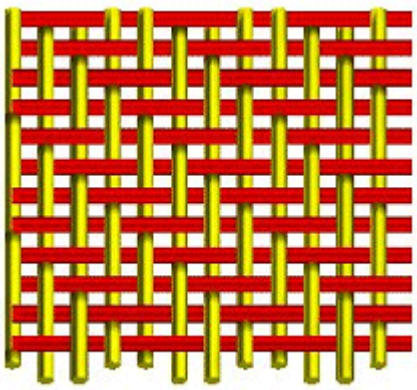
A woven fabric corresponds to the orthogonal interlacement of two series of yarns.

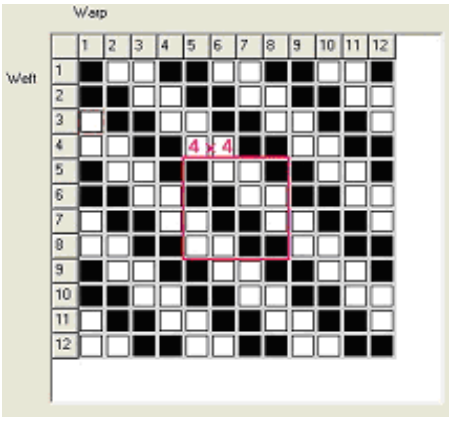
The production of a woven fabric is divided into three major steps, i.e:

- conception
- preparation
- weaving

a) Conception

This step represents a first phase in the creation of a fabric. Indeed, during the conception, the weaver or designer will define the sequence of the warp and weft yarns to be installed onto the machine as well as on the weave (interlacement of warp and weft yarns) in order to obtain the desired design.





The *weaves* that constitute the basis to form other weaves are the following:
- *Plain* weave is the simples weave. Each yarn constantly switches place, resulting in a very intertwined, symmetric fabric where direction and face are neutral.
- *Twill* weave allows obtaining diagonal stripes on the fabric's surface.
- *Satin* weave presents even and dense surfaces, and is used when one desires to obtain two different kinds of lustre on both sides of the fabric.

b) Preparation

Before proceeding to weaving, the warp yarns have to be winded onto beams. This step is called **WARPING** and consists in winding the yarns one by one in a parallel way onto a metal cylinder that is closed on each side by lateral discs. The transfer operation from the cylinder onto the weaving beam is called **BEAMING**.

For a certain number of weaving processes, the yarns undergo a complementary treatment: **SIZING**. The aim of this treatment is to obtain a warp that will produce a quality fabric by lubricating the yarns.

DRAWING-IN, an operation after warping/beaming consists in bringing all warp yarns into the comb of the loom as well as in the heddles of the different blades according to a well-defined order.

c) Weaving

Weaving is the rectilinear or circular interlacement of warp and weft yarns in the aim of producing a fabric.

The woven fabric is formed by two yarn series that intersect perpendicularly.

The yarns that are deposited in the sense of the machine are called **warp** yarns.

The yarns deposited in the perpendicular sense of the machine are called **weft** yarns.

d) 'woven narrow fabric'

In narrow fabric weaving, the weft yarn is formed by one yarn in one needle making a knot at the borders of the fabric.

Thus the yarn border is finished and does not need any treatment

4. Process: the manufacturing of Knitted fabric

Knitting is a method of converting yarn into fabric by intermeshing loops, which are formed with the help of needles. There are two basic forms of knitting technology, weft and warp knitting. Hand knitting process is weft knitting, which can also be done by machine. In this process, work progresses width-wise, in either a back and forth cycle or a circular cycle. In each cycle, known as a course, a new row of stitches is formed. In each row there may be number of stitches depending upon the width of the fabric to be knitted. Each stitch of the row gets build-up intermeshing with the previously held stitches of the preceding row. The vertical row of stitches or chain of loops hanging vertically from the needles is called a wale.

Weft knitted fabrics can be produced in either flat or tubular form. Weft knitted fabric is generally highly elastic and highly drape-able, two attributes, which make it suitable for a wide range of apparel applications. Weft knitted fabric is porous and comfortable both for outer garments and undergarments.

In contrast, in warp knitting, which is done by machine, the work progresses length-wise, through the intermeshing of loops in the direction of wale. In this process all the loops on the knitting needles in the row remain in the knitting mode. The main advantage of warp knitted cloth is that, unlike weft knitted fabric, it is not easy to unravel. However, these fabrics are not as elastic as weft knitted fabrics.

a) Weft knit fabrics.

This type of knitted fabrics may be produced either on rectilinear knitting machines or on circular knitting machines. In both cases, they may be produced on a single needle bed or on a double needle bed.

Weft knit fabrics are obtained by a single interlacing yarn.

The stitches are obtained by the alternate movement of the needles forming a loop by letting the yarn pass through the previous stitch. The yarn is fed according to the successive stitch formation .

Principle of weft knit fabrics

The needles are mounted or suspended one by one by means of cams. When the needle rises, the yarn that has been clasped during a previous passage descends while opening a valve and will position itself underneath it. A loop is formed around the needle. At that precise moment, the needle has reached its highest point. It starts to descend while clasping the yarn once again. The loop that is formed closes the valve on the yarn that is just being seized by the needle. Thanks to the descent of the needle in the needle bed (knocking over), the loop forms a new stitch when it drops from the needle.

Three sorts of stitches may be realised according to the movement imposed by the cams :
- the '*simple*' stitch is formed when the needle rises, clasps the new yarn and pulls it through the previous stitch.
- '*Tuck* ' stitch is formed when the needle does not reach its maximum height. It clasps the new yarn but the previous loop cannot descend underneath the valve. The loop remains in the crochet hook of the needle. The former loop and the new yarn are in the needle's crochet at the same time. Both are torn off during the next descent when the needle rises to its point of release. Tuck stitch allows obtaining a wider, thicker but less elastic knitted fabric.
- '*Floating*' stitch is formed when the needle remain in its original position, i.e. when it does not rise to take a new yarn. The new yarn floats through one or more wales of the knitted fabric, which is therefore tighter, narrower and less elastic.

Basic knitted fabric

'**Jersey**' is the simplest structure. It possesses two distinct faces and is produced on a knitting machine with a single needle bed. Widthwise, it may be stretched to double its size. It has a tendency to curl up at the rims and is easily laddered.

'**Double jersey**' shows stitch wales on the knit side and stitch wales on the purl side that are juxtaposed. Double jersey is produced on knitting machines with a double needle bed. The ribs may be symmetric of asymmetric. This knitted fabric is very elastic widthwise.

It is also possible to modify the presentation and characteristics of a knitted fabric by playing on the stitch through:
- tightness: the length of the yarn pulled by the needle determines the size of the stitch
- yarn : every yarn characteristic (fineness, twist, colour…) may modify the knitted fabric's aspect
- needle : needle type and sequencing

Furthermore, it is possible to work with patterning,….

b) "warp" knitting.

To produce a warp knitted fabric, a.k.a. run proof, one needs at least as many yarns as there are needles on the machine. This implies working with a beam to guarantee a tension that is equal for each yarn.

The pattern rods contain yarn winders (one for each needle) to feed yarn to the needles. The number of pattern rods may vary form 2 to 7 according to the type of machine. Machines are equally making use of plates to form the stitch and to support the knitted fabric. The rods have a lateral movement to convey the yarns from one needle to another. Each yarn will be connected to the previous stitch by means of the same needle or neighbouring needle. In this case, all needles receive the yarn at the same time to form a stitch course together.

Depending on the way the yarns are distributed on the needles, one gets an open, dense or tramée stitch.

The warp stitch has three parts: the loop, the underlap and overlap. The loop is formed by the needle whereas the underlap is obtained by the movement of the pattern rod towards another needle. The overlap corresponds to a lateral movement of the rod in order to wind the yarn around the needle .

Warp knitting can produce either single or double fabrics, depending on whether a machine with one or two needlebeds is used (see below).

c) Knitting machines.

There are various types of knitting machines to produce weft knit fabrics and warp knit fabrics.

The **FLAT** knitting machine, is as indicated by its name, a machine with straight needle beds. Its production capacity is lower than the one of circular knitting machines, but it possesses superior sampling possibilities.
It is almost exclusively destined to the production of fantasy garments, such as pullovers, women's and children clothing.

The **"large diameter" circular** knitting machines are destined to produce very long tubes. Their application field is the same as the one of rectilinear machines. Their output is superior, but some of their capacities are inferior to the ones of rectilinear knitting machines, taking into account that much time is needed to adjust and thread the machine. They are also used to produce sportswear, indoor clothing, pyjamas, children clothing, upholstery fabrics and textiles for the automobile industry. etc.

The **"small diameter" circular** knitting machines are specialised in the production of socks and stockings. Other application field: the production of orthopaedic articles such as knee caps, leg pads, neck protector, contention articles, etc. .

Body size machines are specialized in the production of body size garments, also referrec to as seamless garments. Such machines exist that are electronically controlled and have needle by needle selection and transfer jacks, allowing the knitting of single piece 3-dimensional garments including i.e. integrated waistband and knitted in patterns and text, needing only a minimum of finishing after knitting (i.e. sewing). A new generation of such machines, just released from Italian machine manufacturer Santoni, allows knitting of advanced garments as the cylinder is able to move in both directions and thereby knit real pouches, fabric strips etc, combined and interconnected with the body size garment.

Cotton knitting machines are designed specifically to produce knitted pads (sleeves, front, back) that have only be to confectioned. This type of clothing is known by the name of diminishing knitting or fully fashioned

The Karl Meyer single **Warp** knitting machines are principally destined for the production of high speed knitted fine fabrics with simple stitches. This type of machine uses almost exclusively yarns from synthetic fibres such as polyester, polyamide and elastomers. The knitted fabrics are used in the production of lingerie, corsetry, sportswear, bathing suits, lining, upholstery fabrics, etc...

The **Raschel** double needle bed knitting machines operate at a lower speed than the K. Meyer single warp knitting machines, but, contrary to the latter ones, they are able to produce more complex fabrics. The application field is very broad.

This type of machine allows the production of elastic knitted fabrics for corsetry such as lace and tulle, household linen such as blankets, bed spreads, curtains, upholstery fabrics, technical textiles including 3-dimensional medical textiles (i.e. continence mesh briefs, head bandage fixations, finger bandage fixations, urin bag fixations), etc

The crochet single needle bed knitting machines are mainly used in narrow fabric production. This type of machines allows to produce elastic and non-elastic fabrics for underwear, garment confection, medical textiles and technical textiles.

5. Process : textile finishing

Functional finishes are chemicals and mechanical processes which impart to fabrics specific performance properties they normally do not have. These finishes may, for example, make fabric water repellent, flame resistant, or resistant to bacteria and fungi. The functional finishes are usually more durable than the general finishes, since consumers expect the additional performance properties for which they have paid for to be retained by the textile material throughout its life.

Various types of these finishes are :

- Finishes that improve comfort
- Finishes that improve ease of maintenance
- Finishes that improve durability
- Finishes that provide environmental protection
- Finishes that provide biological resistance

These are the general procedures for the finishing processes at Tytex:

Warp knitted fully fashioned garments (continence pants, fixation devices etc):
Steaming (shrinking),
Cutting (separation).

In some cases (depending on product type): a small sewing operation after the cutting operation.
In some cases (depending on composition and hygiene requirements): washing and tumble drying after the cutting or sewing operation.

Weft knitted body size garments (continence pants, maternity underwear, hip protectors, hernia pants):

Washing and tumble drying (shrinking)
Cutting (crotch, other openings etc)
Sewing
In some cases (depending on end use and hygiene requirements): washing and tumble drying after the sewing operation.

Narrow fabrics (crochet, narrow weave, tubular fabrics for medical purposes):
Heatsetting
Rolling

6.- Process : Garment making

Different garment making methods and their impacts on the textile should be mentioned, i.e.
Cutting (methods)
Sewing
Welding