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How to develop converted parts out of technical fabrics for medical applications | From yarn over weaving to converted items

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Abstract

Technical fabric can be used for a wide range of applications in the medical sector. The development of a medical fabric starts with the selection of the yarn: mainly synthetic yarns made of polyamide and polyester. The weaving process allows for great variability in the properties of the fabric. The main feature in finishing is the washing and drying process, but depending on the application, other finishing processes are used. Parts are cut from the fabric using different methods. In the medical sector, biocompatibility is of great importance and must be guaranteed depending on the application.

Read on to find out how yarn is used to develop highly complex medical components made of technical fabrics, for use in procedures such as heart surgery.

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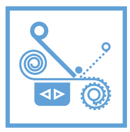
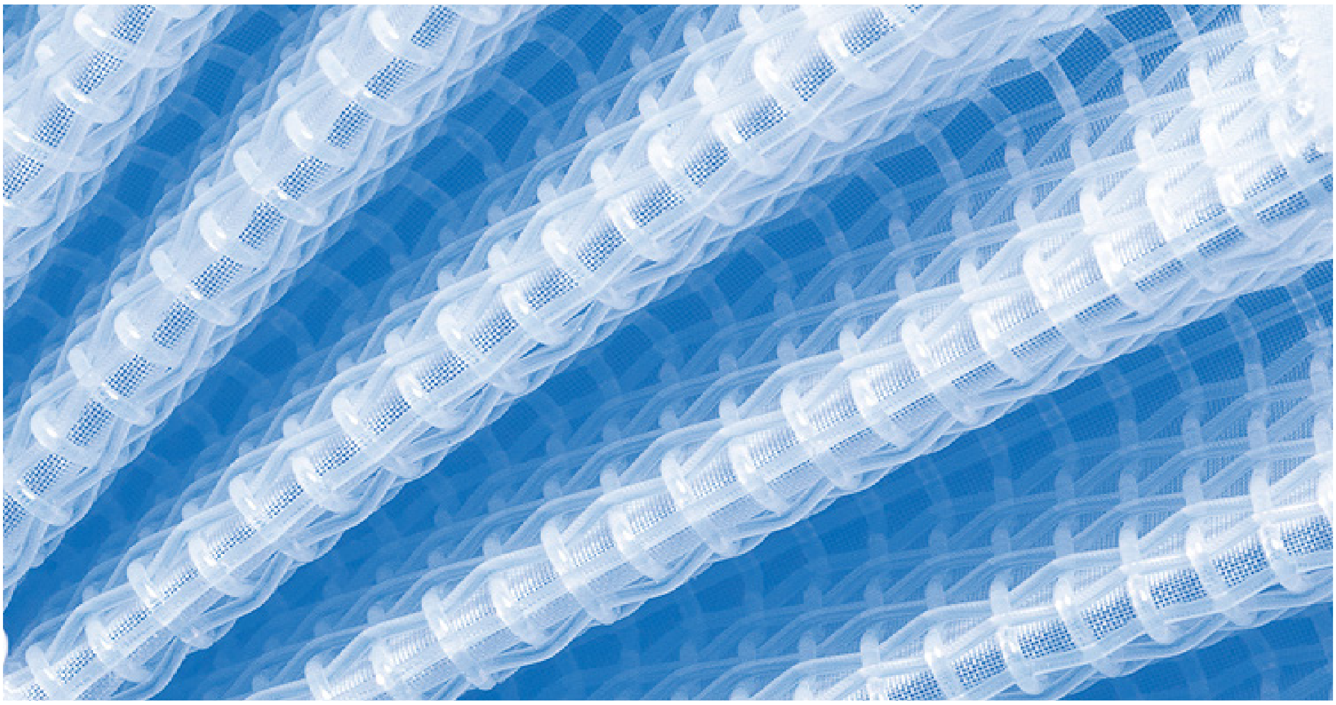




Introduction

Fabrics are one of mankind's oldest products, primarily in the form of clothes and textiles for domestic use. They are found everywhere in daily life, like towels, carpets, cleaning rags etc. Less generally known is the fact that woven textiles are widely used in technical applications. Although such "technical fabrics" are not different from standard fabrics in principle, they must have certain physical, chemical or functional properties that are connected with their intended application. For example, they can be:

- elastic or non-elastic
- tear-resistant
- flexible or stiff
- form-stable (be able to resist changing shape)
- air-permeable
- electrically conductive
- light-resistant
- hydrophilic or hydrophobic
- antistatic
- able to be dyed
- weldable (able to be joined together by a heat process)

As well as many other properties…

When the mesh size, weaving density or other geometric properties are subject to particularly narrow tolerances, one talks about a precision fabric.

An important distinction from woven fabrics exists in so-called non-wovens, which are found in technical and industrial use. These textile constructions are also produced from fibers but without using weaving technology, and therefore do not exhibit a regular structure. Examples of non-wovens are felts and fleeces. Certain paper types, foils and membranes are included in this category.

The yarn

The basic material of every fabric is the yarn. Yarns are normally produced by spinning. Using this method, natural or synthetic fibers of differing lengths are spun to form a continuous yarn. This type of yarn, which is used mainly for the production of fabrics for clothes, is called staple fiber yarn. More important for technical applications, like in the medical field, is filament yarn that is made out of infinitely long fibers, the filaments. As opposed to the staple fiber yarn, the filaments and the yarn are of the same length. Depending on whether the yarn is made up of a single filament or from many (typically between 20 and 200 µm), one talks about monofilaments or multifilaments.

In technical medical applications, filament yarns are normally used since they are superior in regularity and strength to staple fiber yarns. Due to its regularity and fineness, silk was once the most important technical yarn. However, in the course of the last few decades, its place has been almost completely taken over by synthetic alternatives. Of the synthetic filament yarns, monofilaments are the first choice for precision fabrics due to their perfectly circular cross-section and regular consistency.

The oldest (and still one of the most important) synthetic materials in the production of medical fabrics is polyamide (PA), which came onto the market under the brand names Nylon and Perlon over 60 years ago. However, within the last few years, polyester (PET) has edged polyamide out of first place.

There is not a universally usable synthetic fiber; the choice depends upon the specific requirements of the application. For example, polyamide absorbs more humidity and is less resistant to acids and higher temperatures but is, however, resistant to alkaline chemicals. Polyester is sensitive to alkalis, but resistant to acids. Polypropylene (PP) is acid- and alkali-resistant but has shortcomings in mechanical properties. Fluorinated synthetic materials such as polytetrafluoroethylene (PTFE), ethylene chlorotrifluoroethylene (E-CTFE) and polyvinylidenefluoride (PVDF) have even better chemical properties and show a good thermal resistance. The most temperature-stable but also the most expensive material is polyetheretherketone (PEEK), which resists temperatures up to 250° C. A large variety of materials and materials with special properties is available today and new ones are constantly being added to the list.

Weaving and fabrics

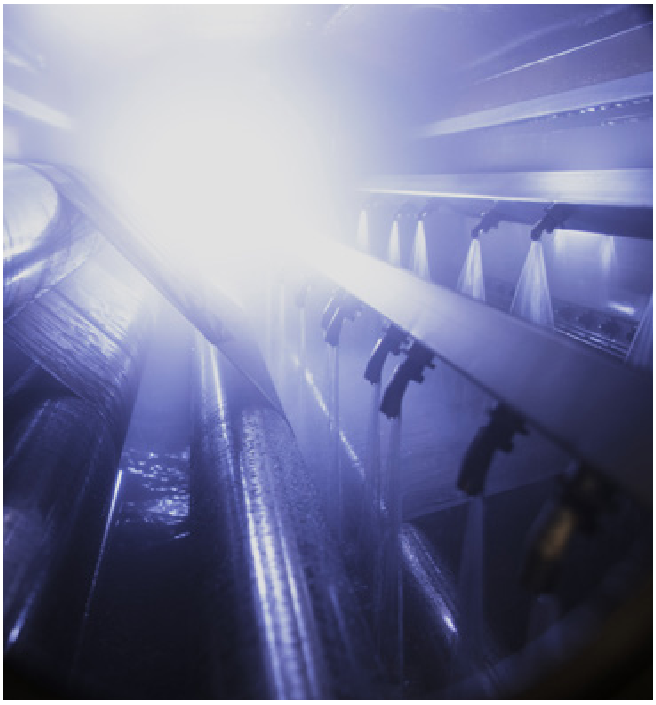
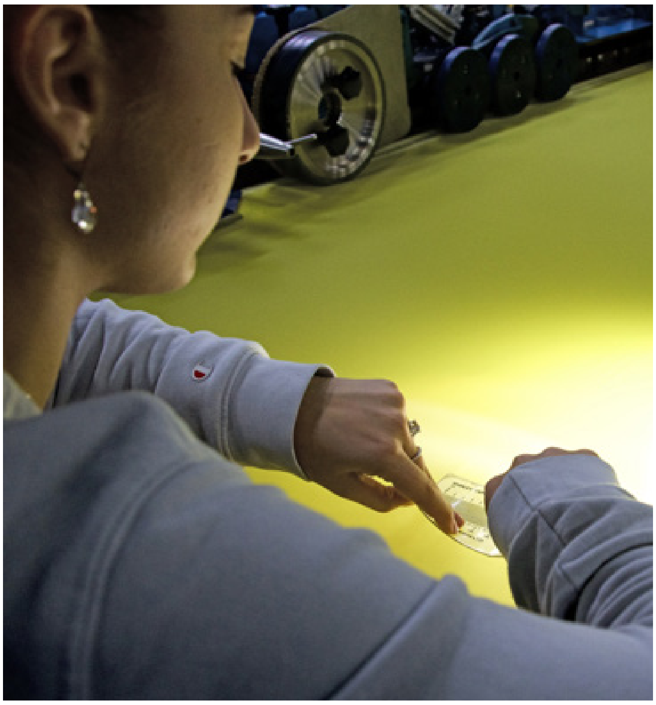
Fabrics are textile products with a regular flat surface and are produced by means of weaving technology. The yarns running lengthways along the weave direction are called warp yarns and the transverse ones, weft yarns. The way in which the warp and weft yarns pass over and under each other is known as the weave. Warp, weft and weave define the structure of a fabric.

The weave pattern determines the basic properties of a fabric such as the strength, permeability and surface texture. Fabrics produced in a simple plain weave – with the same yarn count and the same yarn diameter in warp and weft direction – exhibit an easily recognizable, roughly square mesh. As a rule, in plain weave the mesh size is usually greater than the diameter of the monofilament yarns. Such fabrics are therefore described as open-mesh fabrics. Fabrics with a different kind of weave and greater repeat usually do not have a regularly-shaped mesh but longish, slit-like openings. One calls such fabrics closed-mesh fabrics and their pores are smaller than the diameter of the monofilament yarn used. The properties of an open- or closed-mesh fabric and the respective mesh or pore size define the permeability of a fabric for particles, liquids and gases. Primarily, air permeability plays a decisive role in many applications and determines the fabric choice. The smallest practicable pore size averages 5 µm and thus is approximately four times smaller than the diameter of the finest available monofilament yarn.

Precision fabrics are characterized by exactly defined, reproducible and systematically controlled fabric properties. These requirements mainly concern the geometry of the fabric but are also defined by application-oriented properties, for example:

- yarn diameter
- yarn count
- size, regularity and squareness of the mesh
- open area
- air permeability (as a function of the pore size)
- fabric thickness
- shrinking and stretching behavior
- regularity of the visual aspect of the fabric, including the color and surface finishing (e.g. coating)
- cleanliness and bio-compatibility (in medical, pharmaceutical and food applications)

These requirements affect all phases of the production process from the choice of the raw material to the production of the fabric in the weaving mill and also the finishing and making-up processes. For this reason, only yarns that display a high regularity are possible for use in the production of precision fabrics. If special physical or chemical properties are demanded in the application, then these must comply exactly with the specification. Furthermore, high requirements in cleanliness must be met particularly with fabrics for the food industry or medical applications. To guarantee the demanded precision and reproducibility of the fabric properties, rigorous quality controls are indispensable during the entire production process.

Finishing

For medical applications, precision fabrics are not ready for application straight off the loom. Several post-production steps are required: these are described as the finishing of the fabric. The following table gives a summary of the most important finishing process of medical fabrics.

Finishing process	Method / procedure	Purpose / effect
Cleaning	Medical washing process	Removal of waste material, spinning oil and other contaminants. Removal of microorganisms or pyrogens.
Heat treatment	Heat-setting, stretching	Changing or setting of the weave geometry, deformation of the yarn cross-section.
Calendering	Smoothing and compacting	Production of a smooth surface; changing the mechanical stability, defining the E-modulus; setting of particular polymerspecific properties.
Coloring/ dyeing	High-temperature dyeing, spin-dyeing	Altering the color and light-reflecting properties.
Effect on the surface properties	Coating, plasma treatment	Changing the physical properties (e.g. hydrophilic or hydrophobia, abrasion resistance, adhesive qualities, electrical conduction properties): increasing the surface hardness

Cleaning

The first finishing process is cleaning to remove abrasion particles from the fabric resulting from the weaving and spinning oils that are used to reduce the friction in yarn production and weaving. For medical areas, the fabric requires a high cleanliness. For this reason, the fabric runs through a multistage cleaning unit (dedicated medical washing line) in which it is washed with different chemicals at elevated temperatures, then rinsed with clear water and finally dried on a stenter frame.

(Pre-)shrinking

Almost every precision fabric is subjected to heat-setting on the stenter frame. In this procedure, the fabric is relaxed at a precisely controlled temperature and tension in the warp and weft directions for a particular period and is subjected to a controlled pre-shrinking process in order to avoid a later and uncontrolled shrinkage. The fabric edges are clamped in on both sides of a frame and the fabric is then slowly transported lengthways through a heating and cooling unit. The heating causes the fabric to take the desired form and in the following cooling step, this form is set. A precise adjustment of the transverse tension and speed difference between the rollers (leading and trailing) allows a fine adjustment of the fabric geometry in both the warp and weft direction.

(Pre-)stretching

The fabric can not only be pre-shrunk on the stenter frame but also be pre-stretched. A further process for the pre-stretching the fabric is the stretching unit. With this procedure, the fabric is stretched in order to reduce its elasticity and thus increase its resistance to stretching.

Calendering

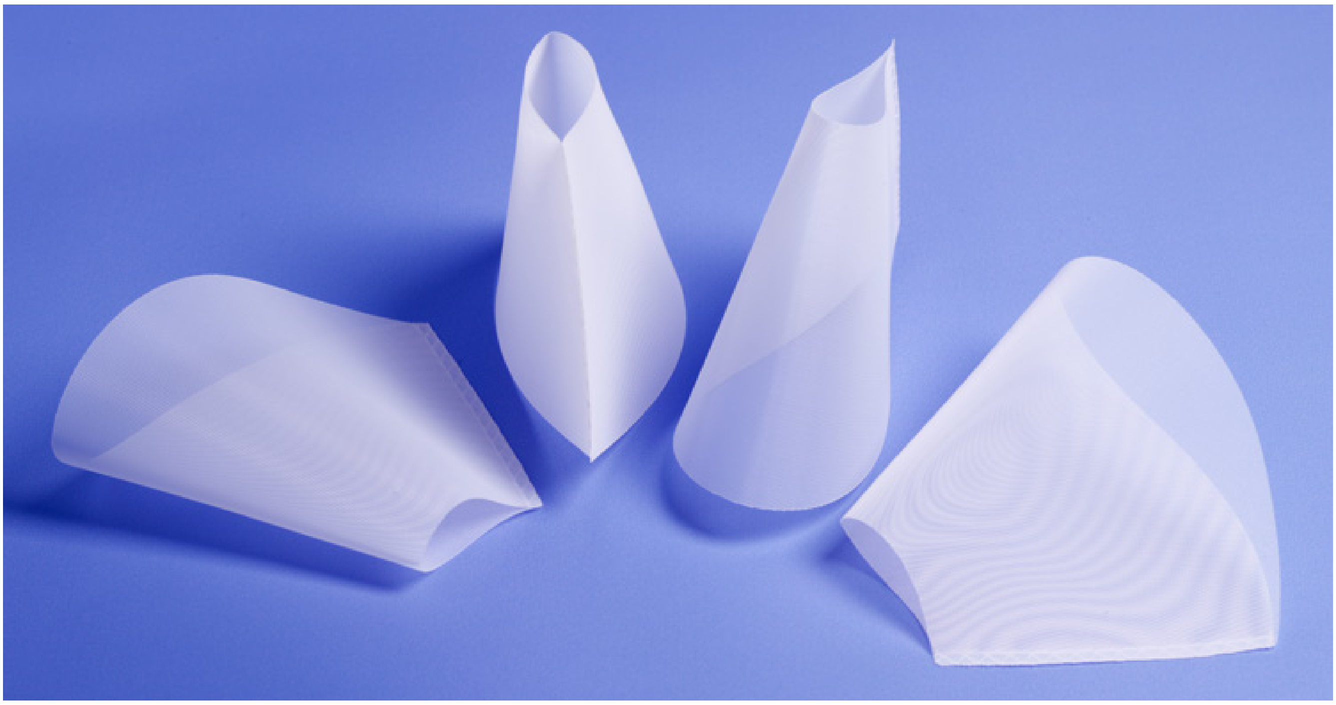
An optional finishing process is calendering, by which means the fabric is smoothed and compacted. The calender (from French calandre, meaning roll) consists of several steel rollers, through which hot oil flows and between which the fabric is drawn under high pressure and at a temperature close to its melting point. The filaments are flattened, the pores in the weave are made smaller, and the fabric surface smoothed.

Coloring / Dyeing

Before drying, the fabric can be dyed if required – either for aesthetic considerations or for technical application reasons. The dyeing process cannot guarantee biocompatibility of the fabric.

Wet-chemical or physical treatments

When necessary, and as an alternative or complementary process in addition to the finishing processes described above, wet-chemical or plasma treatments can give the fabric the physical or chemical properties required for its intended application. In this fashion, it can be made water-repellent (hydrophobic), for example, or be made particularly absorbent (hydrophilic) so that liquids will quickly and evenly spread out in it. Also antistatic, oleophobic, electrically conductive or luminescent fabrics can be produced.



Making-up / converting

Just as in the case of standard fabrics, the precision fabric on the fabric roller is not the end product for medical applications. The fabrics are made "application ready" by further processing such as cutting, stitching, gluing, welding, laser cutting etc. into the form requested by the user. These application-specific processing steps are called making-up. The spectrum covers everything from fabric ribbons of different widths and stamp-formed fabric pieces to intricately-folded three-dimensional sewn or welded cylindrical filter pads for pleated elements. Medical parts require strict cleanliness control and are fabricated in a clean room.

Laser cutting

Laser cutting is used to produce highly precise fabric parts with a heat-sealed edge. Fusing the fibers along the edges removes all loose filaments. Different laser cutting systems are used depending on the size. Dimensional verification and inspection for defect features is performed by semi-automated vision systems with AI programming.

Heat slitting

Heated knives are used to produce fabric strips for many applications – from high volume injection molding to diagnostic test strips. Heat-slit mesh edges are melted or fused to increase durability and minimize fraying. Hot cutting is the most economical method for cutting tapes. The measurement of the ribbon width including tolerances is measured with the help of optical measuring systems.

Ultrasonic slitting

Ultrasonic slitting is also used for manufacturing fabric strips and produces a closed edge with very little material build up at the edge. Ultrasonic cutting is in demand everywhere where a highly precise and clean edge quality is required. The measurement of the strip width including tolerances is measured with the help of optical measuring systems.

Ultrasonic stamping

Ultrasonic stamping is often used for highly precise fabric parts because it ensures tight geometric tolerances for fabrics with mesh openings < 400 microns. Ultrasonically sealed edges are non-fraying and have no edge build-up. One, two and multi-layer flat parts can be punched and firmly joined at the edge via the parting line. One tool is used for punching and is therefore suitable for larger quantities. The measurement of dimensions and tolerances is made by optical measuring systems.

Tubes and tube cuts

There are a variety of processes for the production of tubes and tube cuts. Depending on the application, a distinction is made between a functional seam and a transport seam. The classic functional seam is an ultrasonically welded overlap seam. Transport seams are mostly flat seams and can be produced very economically using hot cutting technology. Higher strength can be achieved with ultrasonic cut-off welding technology in a one or two seam design.

Ultrasonic welding

Ultrasonic welds are accurate, clean and made without the introduction of secondary materials to the welded area. Precision sleeves and bags for blood filtration are examples of applications that benefit from this technology.

Pleating

A highly effective way of increasing the filter surface is to pleat the filter itself. To form a pleated element, fabrics are welded, then pleated together and cut to a defined number of pleats. Single and multilayer pleated elements (up to four layers) are possible, as are various pleated designs. Round pleated blinds are cleanly welded at the ends using ultrasound.

Conclusion

Technical fabric can be used for a wide range of applications in the medical sector. The de-velopment of fabrics has a wide variety of process steps; synthetic yarns made of polyamide and polyester are predominantly used. When these yarns are woven on a loom, medically washed and thermofixed, biocompatibility can be guaranteed. When other finishing processes are used, the fabric can lose its biocompatibility, but it can still be used for medical applica-tions. The figure below shows the various process steps involved in developing a medical component made of a fabric.

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For further information or technical advice please contact your local Sefar representative.