Textile Technology

Warp Knitting

In warp knitting, one or more yarns are fed to each needle and the stitches are made simultaneously, making this a very rapid process. With this technology it is possible to make plain, tubular, spacer and openwork textiles for a variety of applications. Coloured and patterned fabrics are produced using raschel jacquard knitting with independently controlled guide bars.

Formats

- Plain
- Tubular
- Spacer
- Openwork (net and lace)

Materials

- Staple, filament and novelty yarn
- Natural and synthetic

Costs

- Low to moderate unit cost
- Very rapid cycle time

Applications

- Apparel
- Footwear
- Interior
- Technical

Quality

- Intermeshed structure less prone to ravel
- Continuous yarn
- Dimensional stability

Related Technologies

- Fancy loom weaving
- Machine weaving lace
- Weft knitting

INTRODUCTION

Machine warp knitting is a more recent development than weft knitting (page 126). The looped structure is formed between multiple yarns running lengthways (wales), as opposed to a single yarn across the width of the fabric (courses), as is the case in weft knitting. Each needle is fed with one or more yarns. So a long-sleeved t-shirt may consist of up to 5,000 ends, depending on the machine gauge. With each stitch, the yarn is tracked from side to side by the guide bar and so intermeshes with neighbouring yarns to produce a cohesive knitted structure.

With each stitch being formed by a separate yarn, a range of interlocked, inserted yarn and open structures may be produced. And it can be made in a range of densities, from heavy cloth to fine lace. By combining different loop patterns, net may be incorporated into a solid ground, such as used to make upholstery and seamless sportswear.

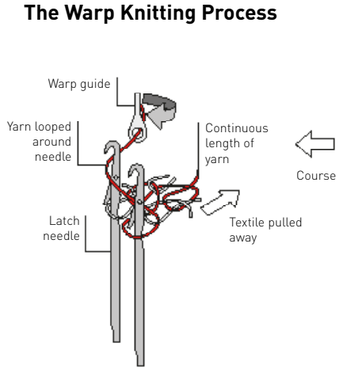
APPLICATIONS

Single needle-bed machines are used to make plain and patterned fabrics that are used flat, or cut and sewn into garments, underwear and upholstery. Lace and nets are used to make garments, underwear, curtains, fishing nets, mosquito nets and packaging. Warp knitting is particularly well suited to produce sequential lengths of fabric with fringed ends, such as scarves.

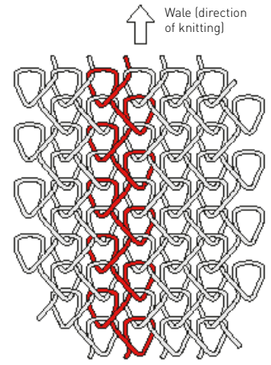
Industrial applications include reinforcing composite laminates, conveyor belts, safety clothing, tarpaulin, advertising banners and awnings.

Double needle-bed machines are used to make all that single beds are capable of, plus seamless and lightweight sportswear, swimwear, underwear, lingerie and gloves. Jacquard knitting is

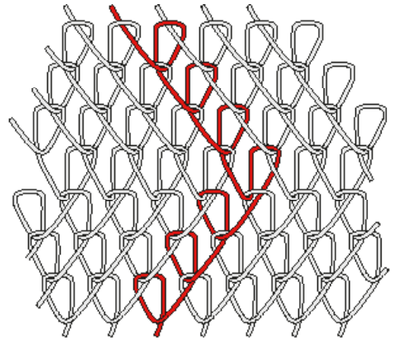
The Warp Knitting Process



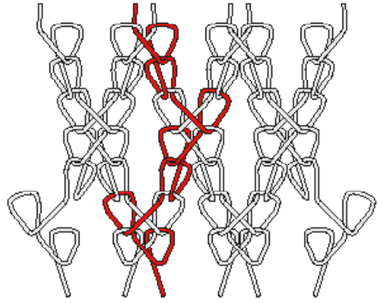
Single-bed warp knitting



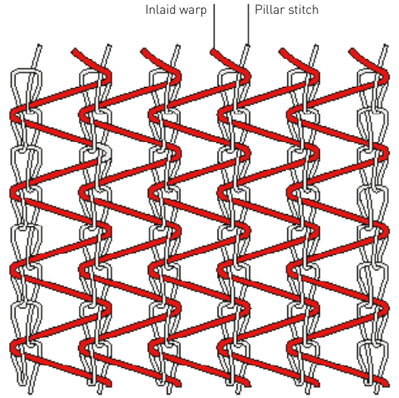
Basic (or half tricot) technical back



Single atlas structure technical back



Diamond net technical back



Pillar stitch with yarn insertion technical back

TECHNICAL DESCRIPTION

Warp knitting forms courses and wales, just like weft knitting. However, the structure of the loops and the range of possibilities for loop formation are different.

Each needle is fed a separate yarn via a warp guide. The guide passes the yarn around the needle with each cycle. The warp yarn is passed from one course to the next, thus creating a zigzagging intermeshed structure. Each loop in the same course is formed simultaneously.

Single-bed machines, known as tricot, are used to make flat sheets of textile. The basic warp knit, which is also known as a half tricot, is produced with a single guide bar. Lapping the stitches in the same direction for a specific number of courses, and back again, produces an atlas structure. The sideways movement produces a zigzag pattern down the length of the fabric. Due to the tension on the yarn, only one overlap in either direction is usually permitted.

Overlapping the yarns at intervals forms an openwork structure. With conventional knitting machines, the guide bars move in tandem, so each stitch in a course on the same bar will be the same. This means that only balanced nets are possible, unless knitting on raschel jacquard.

A pillar stitch is made up of chains of stitches that form unconnected wales. They must be connected by an inserted yarn, which is overlapped by a second guide bar (for a detailed description of warp knitting with inlaid weft that does not pass around the loops, see Stitch Bonding, page 196). Other types of two-bar fabric include lock-knit, double atlas (the two guide bars mirror each other's movements to create a balanced fabric) and pile structures (long floats are formed on the technical back, tied into a knitted structure). Tricot machines may have up to four guide bars.

Raschel machines have one or two needle beds. Machines equipped with two needle beds may have up to three guide bars for each bed (six in total). They are set up in a similar way to V-bed weft-knitting machines (page 134) with the needles back to back. With this set-up, yarns may be overlapped between both sets of needles at any point. This is how seamless tubular structures, such as gloves and t-shirts, are produced. With jacquard, each yarn guide is controlled independently. This is how complex patterns are reproduced.

used to make nets and lace employed in all manner of applications, from sportswear and lingerie to shoe uppers, medical products and upholstery.

RELATED TECHNOLOGIES

Warp knitting is not as straightforward to design for as weft knitting, and so remains less widely used. Processes used to join panels into finished garments, such as linking (page 386), are only compatible with the weft-knitted loop structure, although warp-knitted fabrics may be joined by lock stitching (page 355).

Both weft and warp knitting are capable of producing seamless garments in a single operation. A significant advantage of warp knitting is the design opportunities of openwork structures. For example, lightweight garments with localized stretch, support and breathability are produced in a single operation from multiple yarns. In addition to creating openwork structures in a solid ground, the two may be combined in a single sheet to create a honeycomb layer on top of the ground, known as semi-breakthrough.

Warp knitting is faster than weaving and capable of producing larger widths, making it more economical. With regard to lace, there is a wider range of design opportunities, owing to the different loop structures. Machines fitted with independently controlled guide bars (jacquard) are capable of producing very complex and intricate patterns similar to Leavers lace (page 108).

Warp knitting is used to make double-faced and spacer textiles, similar to fancy weaving (page 84). Both technologies are used in composite constructions such as laminating and thermoplastic molding (page 446).

QUALITY

Thanks to the different number of needle beds and guide bar arrangements, a wide variety of fabric qualities can be achieved, ranging from stable to high stretch; dense to open; smooth to lofty; and single- to double-faced.

The amount of stretch depends on the stitch and the yarn. Warp-knitted fabrics have varying amounts of lengthwise stretch and little or no crosswise stretch (weft-knit fabrics stretch more across their width). And certain constructions, such as stitch-bonded nonwovens (page 196) and inlaid weft, may have virtually zero stretch in either direction.

Warp-knitted fabrics are less likely to ravel and run than weft-knitted types, because the loop structure is formed from multiple yarns intermeshed in a zigzag formation.

Lightweight warp knits are common in sleepwear, because they are soft and have good drape. The simplest fabrics are characterized by vertical ribs (wales) on the face and horizontal ribs (courses) on the back.

DESIGN

Basic fabrics, also known as tricot, are knitted with a single set of yarns and single guide bar. Because a stitch is formed on each needle simultaneously, the machine can run at very high speed – up to 2,000 courses per minute. Tricot machines are capable of producing fancy fabrics by floating yarns over up to five wales. For example, satin textiles are soft with high lustre; pile is made by breaking the floats during finishing (see napping, page 216); and nets are constructed by knitting pillars without overlap for one or more courses.

Knitting with two sets of yarn requires two or more guide bars, which provides greater design freedom. As in weft knitting, the two needle beds are set up in a V configuration. Known as raschel, this technique is capable of producing double-faced, tubular and openwork structures. And by adding jacquard (independent guide bars), complex and intricate patterns may be introduced into the structure. Termed raschel jacquard, this is the most versatile form of knitting, but because of the complexity of movement it is very challenging to design for.

Warp knitting is the most versatile process for making nets. They can range from semi-breakthrough to wide open, depending on the structure. Like other warp-knitted structures, they are resistant to slipping, ravelling and runs. Therefore, they are used to produce many types of net, including lightweight packaging, industrial linings and geotextiles.

Spacer textile is made up of two face fabrics connected by spacer yarn, which is perpendicular to the outer face fabrics. The thickness, density and resistance to compression are determined by stitch and yarn selection.

Yarns are inserted to provide visual or performance-enhancing properties (see also stitch bonding with inlaid weft, page 201). Weft-insertion fabrics have yarn laid in across the wales, and warp-insertion knits have yarns laid in-line with the vertical chains. There are many benefits of using these techniques, such as introducing yarns that otherwise would be impractical to knit (too delicate, too coarse or too fine) and reducing or increasing stretch and recovery, handle, surface or weight. Combined with jacquard, different yarns and configurations are used to provide colour, pattern, graphics, stretch, bulk and so on.

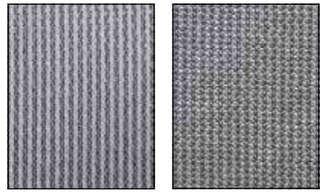
With the yarn insertion technique, it is possible to make uni-, bi- and multiaxial textiles, such as for high-performance composite laminates. One or more sets of yarns may be inserted into the secure knitted structure.

Compared to weft knitting, there is less stress applied to the yarn during production. Therefore, warp knitting is used to construct fabrics from relatively less-flexible yarns, such as glass, aramid and carbon.

The surface of warp-knitted fabrics is finished with conventional techniques, such as calendering (page 220). Pile is made using inserted yarns, or with floating stitches, which are tied into the ground structure to form secure loops. Cut pile may be made by cutting looped pile, or by splitting double-faced fabric to make two cut-pile fabrics. These techniques are used to make velvet, velour and fake fur.

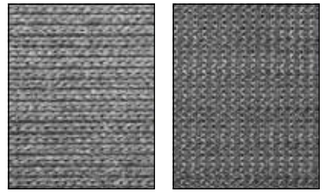
Colour is applied in one of three ways: knitting coloured yarn, piece dyeing (page 240) the knitted item, or printing (pages 256–79). Setting up warp-knitting machines is a lengthy process, because one or more ends are threaded for each needle. Therefore, it is more efficient to knit plain-coloured yarn and dye the finished garment. By mixing two types

VISUAL GLOSSARY: WARP-KNITTED FABRICS



Technical face | Technical back

Half Tricot
Material: Polyester
Application: Apparel lining
Notes: Half tricot is a sheer fabric produced with a single guide bar making repeated lapping motions.



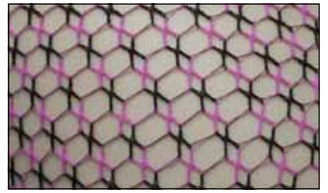
Technical face | Technical back

Tricot
Material: Polyester
Application: Sports shoe
Notes: Full tricot has a smooth face with good cover, making it an ideal fabric for printing.

Atlas
Material: Polyester
Application: Laminating
Notes: The lapping movement back and forth produces a zigzag pattern down the fabric.

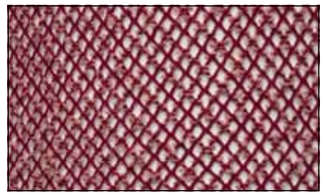
Technical face | Technical back

Two-Colour Raschel Jacquard
Material: Polyester, nylon and elastane
Application: Sportswear
Notes: Two types of yarn are jacquard knitted and plated to either bring the colour to the front, or hide it inside.



Two-Colour Net
Material: Polyester, nylon and elastane
Application: Hosiery
Notes: The two different types of yarn react to different dye types, so can be coloured after knitting.

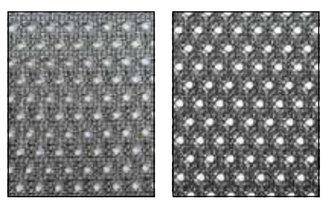
Printed Net
Material: Polyester and elastane
Application: Hosiery
Notes: Complex and intricate patterns are reproduced by transfer printing.



Novelty Yarn
Material: Wool, nylon and elastane
Application: Hosiery
Notes: Novelty yarns are incorporated in the knitted structure to create a unique look and feel.

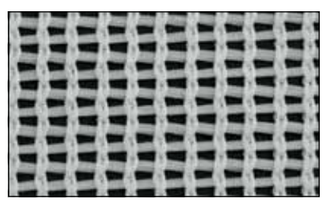
Diamond Net
Material: PE
Application: Fruit packaging
Notes: Plastic strip is knitted together to form strong and lightweight packaging for fruit and vegetables.

Spacer Textile
Material: PP
Application: Upholstery
Notes: A double-faced diamond net structure is held together by spacer yarns to produce a cushioning fabric.

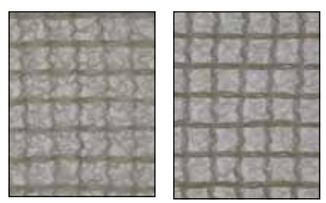


Technical face | Technical back

Honeycomb Mesh
Material: Titanium-coated polyester
Application: Apparel lining
Notes: Nanometal-coated meshes are used for technical applications, such as heat retention lining.



Pillar Stitch Mesh
Material: Polyester
Application: Technical apparel
Notes: Horizontal underlapping reduces stretch particularly in openwork structures.



Technical face | Technical back

Pillar Stitch with Textured Inlay
Material: Ramie and nylon
Application: Bath cloth
Notes: Pillar stitches are combined with inlaid warp to form a grid. The textured yarn creates a wavy structure.

Case Study

Warping

In preparation for warp knitting, filament yarn is wound onto cones. From a creel, 256 ends are gathered together with a fine comb (**image 1**). The yarn is coated with a layer of synthetic oil (natural yarns are coated with paraffin wax) as it passes over a roll (**image 2**). The coating reduces friction between the yarns and so improves knitting efficiency.

It takes roughly an hour to fill a beam (**image 3**). The northern Italian company Cifra uses machines with 3 m (9.8 ft) beds. Six beams are required to cover the length of the bed (**image 4**). The double-bed machines use up to three beams on either side, so 36 in total.

Each end is carefully threaded through the machine and into the guide bar (**image 5**). It is a delicate process and can take several operators half a day or more to replace the yarns on a machine (**image 6**). Therefore, Cifra warp knits all of its garments in plain white and dyes the finished items if colour is required. Using two different types of yarn, such as polyester and nylon, means that two different colours can be achieved with dyeing (page 240).

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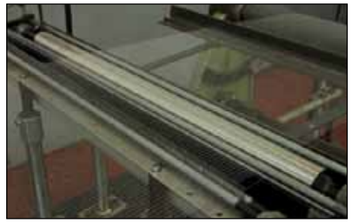

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of yarn that are affected by different types of dye, multicoloured patterns can be achieved.

MATERIALS

Man-made filament yarns (page 50) are the most commonly utilized, owing to the high consistency required, although staple and novelty yarns are also used. Frequently used filament yarns include silk, nylon, polyester, polypropylene (PP), polyethylene (PE), viscose and elastane.

Technical yarns are warp knitted for high-performance applications, such as composite-laminated structures. These include carbon, aramid and glass.

COSTS

Warp knitting is a very rapid process, able to produce hundreds of courses per minute. It is possible to produce wide lengths of fabric or several narrow strips. In this way, a single machine may be capable of producing several garments at once, further reducing cycle time.

The high consistency of yarn required increases costs slightly.

Setting up the machine takes longer than weft knitting if the yarns need to be changed, because each needle is fed with a separate end. Knitting a single colour and piece dyeing finished garments saves time and cost by reducing machine downtime.

ENVIRONMENTAL IMPACTS

Like weft knitting, this is an efficient process and generates very little waste. Producing garments in a single operation removes pattern cutting and sewing, further reducing or even eliminating waste completely. Warp-knitted spacer fabrics are used in place of polymer foams, such as polyurethane (PU) in cushioning applications.

The source of yarn is important; natural yarns should be from sustainable sources and processed with consideration for people and the environment. The amount of recycled content in synthetic yarns varies according to the type of plastic and the supplier.

Featured Company

Cifra S.p.A.
www.cifra-spa.net

Case Study

Seamless Warp Knitting

Seamless garments are produced on raschel jacquard machines. The fabric is made up of pillar stitches, underlapped and overlapped with inserted yarn. With this technique, openwork structures are seamlessly combined with plain fabric to make fitted garments (**image 1**).

Plain white yarn, in this case polyester, is fed from the beams into the guide bars (**image 2**). These are fine-gauge machines with 24 needles per 25.4 mm (1 in.). The more needles per inch, the lower the diameter of yarn that can be knitted and the higher the density of fabric that can be produced.

Each guide bar moves through three actions with each stitch. When the needle has cleared the previous loop the guide bars move forwards (**image 3**). Each guide bar is independently computer-guided. They move sideways and pass the yarn around a designated needle, either in front or behind (**image 4**). The needle is pulled downwards, catching the yarns placed in front and forming a stitch (**image 5**). The second bed of needles rises up and the sequence is repeated in reverse.

The process is very rapid: up to 600 courses are completed every minute and the knitted item is drawn downwards under tension (**image 6**). The finished garment emerges from the machine and is ready to be dyed (**image 7**).

Garments are checked to make sure the knitting process is running without errors (**image 8**). A long-sleeved t-shirt like this comprises around 1,322,000 stitches and a single one out of place will show up on the finished product. It is made oversize to allow for shrinkage during dyeing and finishing. The outline is knitted into the garment and the waste is removed (**image 9**).


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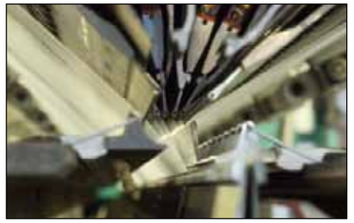
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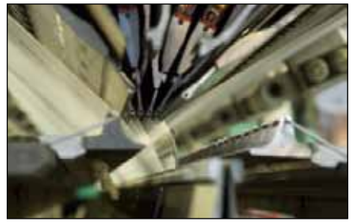
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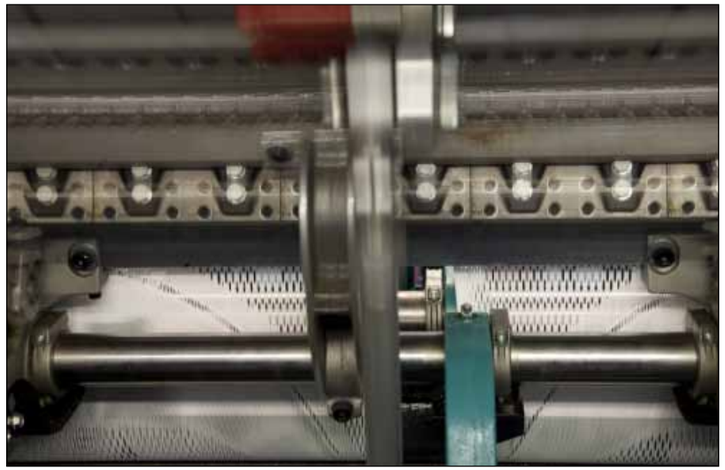
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Case Study

Warp Knitting with Novelty Yarn

Yarns are inserted for decorative and functional reasons. In this case, a gold-metallized yarn is being inserted into jacquard-knitted hosiery (**image 1**). The yarn would be too fragile to knit as part of the loop structure and so is inserted into the loops as an additional warp.

The fancy yarn is introduced from the front on both sides of the machine (**image 2**). It is knitted into the fabric and the finished item is drawn away under tension (**image 3**). The areas that will be open are visible as long slots. This is how they are knitted: a needle is missed out for a given number of courses and so a window is formed. Once the fabric has relaxed the openwork structure is revealed.

On this narrow-bed knitting machine eight pairs of stockings are knitted simultaneously (**image 4**).


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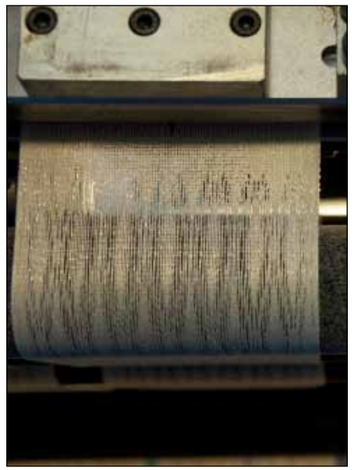
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