Terry weaving

Terry Towel:

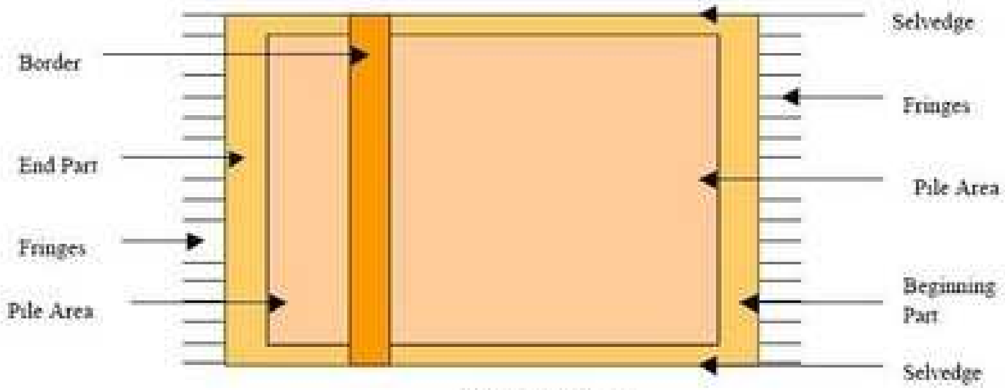
A terry towel is described as a textile product which is made with loop pile on one or both sides generally covering the entire surface or forming strips, checks, or other patterns (with end hems or fringes and side hems or selvages)

History of Terry Weaving:

The name “terry” comes from the French word “tirer” which means to pull out, referring to the pile loops which were pulled out by hand to make absorbent traditional Turkish toweling. Latin “vellus”, meaning hair, has the derivation “velour”, which is the toweling with cut loops. In research conducted on terry weaving by the Manchester Textile Institute, it was concluded that original terry weaving was likely the result of defective weaving. The research indicates that this development occurred in Turkey, probably in Bursa City, one of the major traditional textile centers in Turkey. Terry weaving construction is considered a later development in the evolution of woven fabrics. Terry toweling is still known as "Turk Fabric", "Turkish Toweling" or "Turkish Terry"

Parts of a Conventional Terry:

A woven towel consists of five parts. These are the pile area, fringes, beginning and end part, selvedge, border. Every towel does not have to contain all of these parts. The pile area is considered the toweling part of the towel. Fringes are tied or an untied tasseled part of ground warps and pile warps which are left unwoven at the beginning and the end edges of the towel. The beginning and end sections are the tightly woven areas of a towel which come before or after the pile fabric part and prevent this pile area from unraveling. They are woven without pile loops, in a flat weave construction. The selvedge contains fewer number of warp end s than the pile area, for example 90 comparing to 4000 total warp ends, woven without pile as a flat weave and has the purpose to reinforce the towel sides



Parts of a Towel

Classification of Terry Towels:

The classification of towels can be made according to weight, production, pile presence on fabric surfaces, pile formation, pile structure, and finishing. These classifications are shown in Table

Table Classification of Terry Towels according to Weight, Production Style, Finishing, Weft Count Per PileLoop and Pile Presence on Fabric Surfaces

Weight	Production	Finishing	Weft Pick Count per Pile Loop	Pile Presence on Fabric Surfaces
Very heavy (>550 g/m^2)	Woven	Velour Towel	Two-pick Terry	One side pile
Heavy (450-550 g/m^2)	Weft Knitted	Printed Towel	Three-pick Terry	Both sides pile
Medium (350-450 g/m^2)	Warp Knitted	Towel with Embroidery	Four-pick Terry	
Light (250-350 g/m^2)		Towel with appliqués	Five-pick Terry	
			Six-pick Terry	
			Seven (or more)-pick Terry	

In velour towels pile loops on one side of the fabric are sheared in order to give a smooth cut velvet appearance. Uncut loops of the fabric are sheared in order to give a give the best absorbency, whereas velour gives a luxurious velvety hand. A towel with appliqués is embellished with additional pieces of decorative fabric in a motif which is stitched onto the towel Two-pick terry towels which were woven for bathrobe end-use have lost their importance today due to instability of the loops. Five or more pick terry towels are rarely produced because they need to be beaten for each pile twice. They need to be beaten for each pile twice. and four-pick terry towels. As one sided pile toweling has low water absorbing capacity, it is only used for special purposes such as a limited number of bathrobes. Furthermore weaving one sided pile terry with few or no defects is difficult. In two sided pile terry both sides are covered with pile, whereas all the irregularities are visible in one sided terry fabric as one side is bare without pile. Towels are divided into groups according to end use and size as bath towels, hand towels, face towels, fingertip towels, kitchen towels and washcloths

Formulae for Reproduction calculations for terry towel

- Production of loom(towel/per day/mc)=Rpm×60×24×efficiency/picks per towel
- Finish weight= (Gsm × size of towel in cm)/10000
- Lbs/doz= (finish weight × 12)/ 453.6
- Piece weight = Gsm/size of towel in cm × (wt loss+100/100)
- Picks in fancy = fancy size in cm × picks in fancy per cm
- Total pick/ towel =length of towel+ plain border/cam --fancy size cm – fancy size cm ×picks/cm + picks in fancy × number of fancy borders
- Width of grey towel in inches = pile ends per towel + ends in ribbon / half of reed
- Length of grey towel in inches = length of towel in cm + plain border /2.54
- Weight/Gm2= weight of towel in grams/ width of towel in cm/length of towel in cm × 10000
- Loops in square inch = (picks per inch/3) + (half of reed +2)
- Picks in fancy border = picks in fancy × no of fancy border
- Pile ends/towel = size of towel in inches × 1.17 × half of reed
- Ground ends/towel = pile ends + ends in selvedge
- Wt of pile (gms) = Grey wt of towel in gm – ground wt. in gms – F.B wt in gms –weft wt.

- Ground wt (gms) = ground ends/towel × length of towel in inch × 1.14/36/843/ground count/2.2046/1000
- Weft wt (gms) = total picks in towel – picks in fancy × (width of grey towel in inches+1)/36/840/weft count/2.2046/1000
- F.B wt (gms) = picks in fancy × width of grey towel in inches/36/840/facny border count/2.2046×1000
- Reed space in inches = running towels/ machine × width of grey towel in inches
- Reed utilization % = reed space in inches / max. Reed utilization per machine
- Pile Ratio = pile weight in gms × 2.2046 × 840 × pile count × 36 / pile ends per towel/length of towel/1000
- Pile height= pile ratio/2/ (picks per inch /3) × 25.4-1
- Pile weight %= pile wt in gms/grey wt per towel in gms
- Ground weight % = ground wt in gms / grey wt per towel in gms
- Weft weight % = weft wt in gms / grey wt per towel in gms
- F.B weight % = F.B weight/ grey wt per towel in gms

Structure of a Towel

Fibers used in Towels

According to Acar, the required properties of yarns which are used in terry towels are high absorbency, high wet strength, and ability to dye well, good colorfastness wash-ability, soft hand, and hypoallergenic, low cost, and easy availability. Yarns made of cotton fibres can provide these properties most effectively

Cotton Fibers

Cotton fibres consist of the unicellular seed hairs of the bolls of the cotton plant, the Gossyum plant the chemical composition of typical cotton fiber is as follows: 94.0% of dry weight is cellulose, 1.3% is protein, 1.2% is pectic substance, 0.6% is wax, 1.2% is ash and 4% is other substances. Absorbency refers to a cotton fabric's ability to remove liquid water from the skin as in a towel. Cotton is hydrophilic; it wets easily, and can hold much more water than synthetic fibres can. Cotton releases a considerable amount of heat when absorbing moisture, but it dries slowly. It is not only the amount of water held that is most important, but the water held that is most important, but from the body. The size and distribution of the pores, and capillaries, between and within cotton fibres are uniquely suited for this purpose. Wet strength is one of the crucial properties required in towels, as they are most likely to remain wet as compared to other home textiles. Cotton is stable in water and its wet tenacity is higher than its dry tenacity. The toughness and initial modulus of cotton are lower compared to hemp fibres, whereas its flexibility and its elastic recovery are higher. Cotton is a natural fiber and considered hypoallergenic. This means cotton has a low tendency to cause allergic reactions. It also does not cause skin irritation and can be sterilized. The microbial resistance of cotton is low, but the fibres are highly resistant to moth and beetle damage. The microbial resistance can be improved by antimicrobial finishing. Cotton uses in the medical institutional area are well known for their hypoallergenic characteristic and sterilize- ability. Cotton fabrics are often recommended for persons having skin allergies. Cotton sanitary products and cosmetic aids are promoted for their health benefits. Cotton towels, bedding and baby clothes have all been promoted on the basis of the hypoallergenic nature of cotton. Moreover cotton's resistance to high temperatures of water makes cotton easy to be cleaned as it can be boiled. Cotton fibres are the backbone of the Cotton fibres are the backbone of the It has the highest production and consumption figures among the other natural fibres. It has easy availability as it is grown in more than seventy countries of the world. One other reason cotton is used for toweling is it is the most economical fiber among the natural fibres Shorter staple cotton fibres are generally used in towels because fine yarn counts are not required. The cotton fibres which are used in towels have relatively low fiber length, relatively low fiber strength, relatively low maturity ratio. The micronaire range can be said to be in the middle range

Ranges of Cotton Fiber Properties which are used in Toweling Fabrics according to US Cotton Fiber Chart

Fabric Type	Fiber Length (inch)	Fiber Strength (g/tex)	Micronaire	Maturity Ratio
Toweling	0.93-1.10	20-32	3.5-4.9	0.80-0.90

Other fibres:

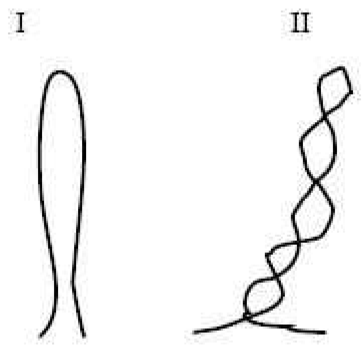
More and more towels are being produced from fibres other than cotton such as Modal®, bamboo, seaweed, Lyocel® and now soybean, corn and other Tri-blend bamboo, silk and cotton blend is also beginning to be used in towels. Bamboo may be the next premium fiber other than high quality cotton fibres. Such as Egyptian, Pima and Supima qualities, bamboo can be used in towels because of its softness, luster, antibacterial properties and greater absorbency. However, it has yet to gain acceptance on a large scale. Flax is also among the natural hydrophilic fibres of cellulose like cotton. The fiber is termed flax, while the fabric made of flax it is called linen. Flax has better dry strength than cotton, and like cotton it gets 25% stronger when wet. It absorbs more moisture, and it wicks. It is longer, smoother, and more lustrous than cotton. However it is not used commonly in towels as it has been limited in supply and it is expensive because of the long processing and intense labor it needs to be turned into a yarn although uncommon, flax towels have a place in the specialty market. In the year place 2004, totally 1,949,421 flax towels were in the specialty market. In the year imported to the U.S., which stands for 0.35% of the total towel import of the U.S. Micro-fiber towels are also pushing into the ultra-touch/high absorbency arena with a manmade synthetic product constructed primarily from a blend of polyester and nylon with polyamide. Through a chemical process, the polyester, nylon and the polyamide are bonded. The result is a cloth that goes through another process to split its fiber into smaller "micro" fibres, creating tiny channels. Micro fiber towels can absorb 5 to 7 times their weight in water. Like cotton, micro- fiber towels are available in various colors and weaves, such as waffle, cut terry and loop terry, with various patterns and in various weights. The heavier the micro- fiber towel, the more water it can absorb. Compared to ring spun cotton, micro-fiber is said to be more absorbent. Several companies are experimenting in combining micro-fiber with cotton to make it softer, give a better hand and perhaps make it more appealing to those who are unsure about having a synthetic towel product.

Yarns which are used in Towels:

In a terry towel there are four groups of yarn. These four groups are the pile warp, ground warp, weft (filling), and border weft.

Pile Warp:

One hundred percent cotton yarns, carded or combed, in sizes of 16/1, 20/1 Ne counts, 240-255 turns/meter twist, are most commonly used. The use of cotton- rayon blends has diminished, because 100% cotton provides a more pleasing hand and texture then the blends. When high quality is required, two or more ply yarns are used. In this case absorbency increases, and the fabric gains resistance to pile lay. The use of two-ply yarns is also on the increase as it improves visual appearance. Plied yarns are used to form upright loops in classic terry, whereas single yarns are used to form spiral loops in fashion terry known as milled or fulled goods. In Figure 2, two types of loops are shown. (I) is an upright loop and (II) is a spiral loop.



In the first type of classic terry patterns are usually created by employing dyed yarns; while towels of the fashion type are mainly piece dyed or printed. In general bulkier and absorbent yarns are used for both types of towels. In real Turkish-toweling, the pile-loops generally consists of a more highly-twisted yarn which, while very absorbent, are quite abrasive, thus actively stimulating the skin during drying. Rotor spun yarns are also used in pile warps low twist cotton

Ground Warp:

Carded yarns of 20/2, or 24/2 Ne count with 550 turns/meter twist, and of 100% cotton are commonly used for ground warp ends. Two ply yarns are preferred because the ground warps ends have the highest tension during weaving. It is common to use a yarn of cotton/polyester blend for greater strength. Rotor spun yarns are also used in ground warps.

Weft:

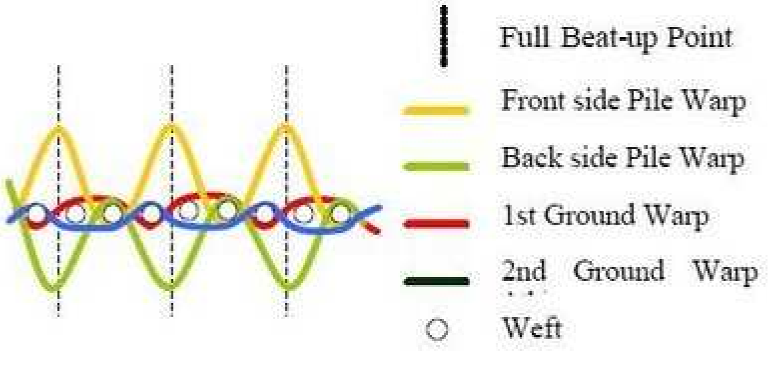
Carded yarns of 16/1, or 20/1 Ne counts with 240 – 255 turns/meter twist, 100% cotton are used usually for weft or filling picks. Rotor spun yarns are also used in wefts.

Border Weft:

Premium or high end hand towels have complex borders with fancy weaves and use a very wide range of filling yarns. Decorative, shiny and bulky yarns of rayon, viscose, polyester, chenille, or mercerized cotton are used at different yarn sizes. Novelty types of yarns may be used as a feature of design

Construction:

Terry towels are woven as 2, 3, 4, 5 or more pick terry weaves. The most common type is 3-pick terry toweling. The cross section of a toweling through the Warps are divided into two systems as shown in Figure 3, pile warps and ground warps, whereas wefts consist of only one system. In basic Turkish Toweling, front side and back side pile warps and 1st and 2nd ground warp ends form a 2/1 rib weave with each other. The rib weaves which is formed by the pile warps is one pick ahead of the rib weave which is formed by ground warp ends. Warps are ordered throughout the fabric width 1:1 or 2:2 piles and ground warps. In 1:1 warp order each ground warp end is followed by a pile warp end while in 2:2 warp order each two ground warp ends are followed by two pile warp ends. In Figures 3a and 3b, the weave notation of 3 weft pile basic Turkish toweling is given in 1:1 and 2:2 warp orders



The cross-section of a towel through the warp

As is seen from the weave diagrams in Figures a and b, the shedding of the ground warps are not synchronized with that of the pile warps. By this, the number of interlacing throughout the warp increases, and this strengthens the fabric. As it has been mentioned before terry towels can have pile loops on one or both faces. Different types of terry weave which have pile on one face and both faces

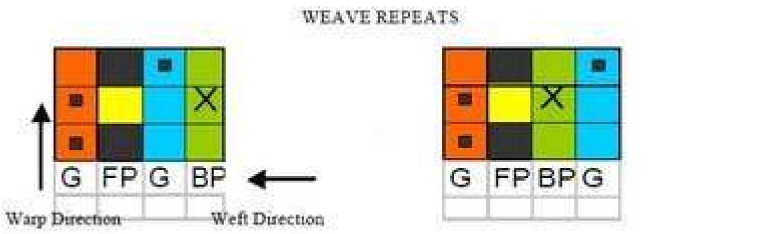


Figure a Basic 3-pick Terry Weave in 1:1 Warp Order

Figure b Basic 3Pick Terry Weave in 2:2 Warp Order

G: Ground Warp
FP: Front Face Pile Warp
BP: Back Face Pile Warp
Little block: Ground warp is over the weft
Shaded: Front Face Pile Warp is raised over the weft
X: Back Face Pile Warp is raised over the weft
Empty space: Warp is lowered behind the weft

The weft count used for toweling is between 15 and 25 picks/cm. And warp count is between 20 and 30 ends/cm. During the weaving of borders, the weft count is increased 3 to 6 times the density in the pile areas Pile/ground ratio is described as the length of pile warp per unit length of fabric in the warp direction. A practical way to find out this ratio is done by measuring a 10 cm length of toweling in the warp direction, then cut the pile warp from either ends of the measured length and measure the total length of the removed pile end per 10 cm length of fabric. Pile warp length per 10 cm fabric is usually between 20-100 cm. This ratio has a direct effect on the fabric weight and thickness. As the ratio increases, the weight and the thickness of the terry fabric increases.

Physical Properties of a Towel

Absorbency:

High absorbency can be achieved in a towel by increasing the surface area with pile yarns and using cotton yarns with twists lower than the ground warps.

Heat Insulation:

Pile yarns make the fabric thicker and give the fabric a high level of heat insulation. Moreover cotton fibres which are used in towels are naturally convoluted and bulked. This serves to trap air within the fabric structure. The air contained between fibres and within them provides thermal insulation. These convolutions plus the tapered fiber ends also hold the fabric away from the skin, adding to the amount of air trapped and contribution to heat insulation According to the results of an experiment which was carried out by Morooka, dry heat loss of toweling fabrics was found to be lower than that of common cotton fabrics on the market. However dry heat loss was found to be higher than is expected from the thickness and apparent density.

Crease Resistance:

Pile yarns give the fabric a third dimension which makes the fabric nearly uncreasable.

Dullness:

The pile loops form a very rough textured surface, thus giving the fabric a dull appearance. This situation is true for only un-sheared toweling. Velour toweling has an appearance even brighter than that of a traditional fabric. The cut pile forms a very smooth surface and reflects light evenly. The pile direction on both velour and uncut terry fabric also has an effect on the color appearance. This is related to the reflection angle which changes with the pile direction. This effect is more obvious in velour terry towels. When the pile direction is laid downwards, the fabric offers a smoother surface for light and so appears more lustrous. If the pile is erect, the color is richer because more of the fabric (and color) is visible while looking into the depth of pile loops.

Quality Defects which are Common in Terry Towels

The defects which can be found in toweling are shown on Table

Table Quality Defects which are seen on terry woven towels

Weaving Defects	Wet Processing Defects	Sewing Defects	General Defects
Missing Pile.	Uneven dyeing	Low Stitch number	Crushed pile
Missing filling pick.	Offshade	Widths of parts are out of tolerance	Stain
Thin or thick filling pick.	Print defect	Missing or faulty stitch	Cut, hole, tear or burst
Beginning or end part is missing	Design Defect	Un-reinforced stitching on ends	Any dimension out of standard
Side part is missing	Noxious or offensive odors		
Stop mark.			
Reed mark.			
Wavy selvedge.			
Dense Weft			

Dense weft defect means that the higher density of the border part is used by mistake in the pile part. Out of tolerance parts' widths mean the total width and the folded-in width of the beginning, end and side parts are lower than required by the standard.

TECHNOLOGY of TERRY TOWEL PRODUCTION:

Terry towel production processes include spinning, weaving, dyeing and finishing, and cutting as general steps. Shearing and embroidery are also regarded as necessary sub steps to obtain the final product of a terry woven towel.

Spinning:

The cotton yarns which are used in terry towels are produced by either ring spinning or open-end spinning and by other techniques which are specially developed for producing pile warp yarns for towels

Ring Spinning:

The principle of ring spinning is first blending the fibres, opening them and arranging as much as possible parallel to each other. Second is to give the fibres a twist in order to increase the friction forces between the fibres and assure they stay as a yarn and draw them to the desired size. These are achieved in several steps as follows.

Carding and Prior Processes:

All staple fibres are carded during conventional yarn process sing. After opening of the cotton bales, loose fiber is blended and formed into a picker lap, which goes into the carding machine. Here, fine bent wires on revolving cylinders pull the fibres apart, remove waste and begin to arrange the fibres enough that they can be spun into yarn. Fibers emerge from carding in a fine web, which is gathered together into a loose, fine web called a sliver. After carding, fibres are taken through a number of stages to become yarn.

Combing:

An extra process is introduced called combing for high quality yarns. The purposes of combing are to 1) remove short fiber, and 2) improve fiber orientation

Drawing (Drafting) and Doubling:

This is the process of running slivers between sets of rollers, each moving faster than the ones before, which draw out or draft a number of slivers to the thickness of one: this process is repeated until the fibres are well mixed

Slubbing:

Slubbing draws the sliver out to a strand about the size of a pencil, called roving, which is given a very slight amount of twist. This is the last stage before actual spinning into yarn

Spinning:

During spinning the roving is drawn- out to yarn size and given considerable high twist to become yarn. In ring spinning, twist is inserted as the fibres from the roving are carried by the traveler around the edge of the ring, inside which is the faster rotating spindle

Carded Yarn vs Combed Yarn:

Carded yarn has a fuzzy appearance and is loftier than combed fiber. Fabrics made from carded yarns have a more hairy surface and will pill more than fabrics of combed yarn. Only the “elite” of spun yarns are combed as well as carded. Combing removes any shorter fibres and arranges the remaining longest fibres more or less parallel to each other. During combing, about 15% further weight is lost Combed sliver has a 'silkier' appearance

Open-End Spinning:

The basis of open-end spinning is that fibres are added to an "open end" of a yarn. Twist is applied to newly added fibres converting them into yarn, and the new elements of yarn are continuously removed from the twisting zone.

Low- Twist Yarn:

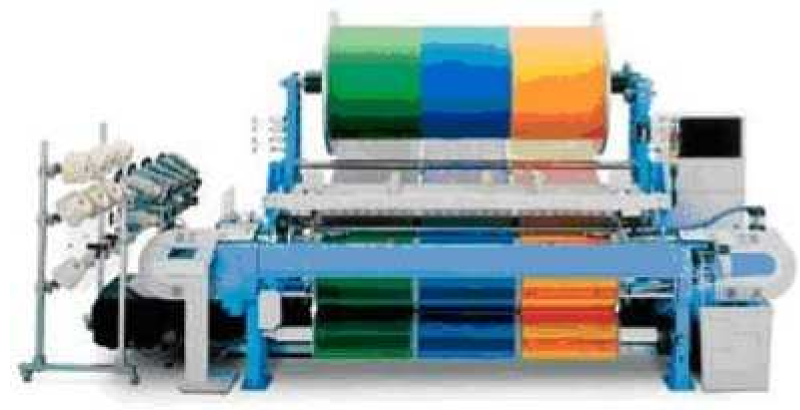
The first basic difference between low - twist and the other cotton yarns is the fibres. While ring spun towels use a combination of long and short staple cotton fiber, low -twist must be constructed only from longer staple cotton yarn. After the fiber is made into "low-twist" yarn, it must be wound with Polyvinyl alcohol (PVA) yarn to keep the cotton intact without the need for twisting. The PVA dissolves during dyeing, leaving the extremely low -twist cotton behind This type of yarns is called low -twist, no-twist, or zero-twist –although it has a very low twist. MicroCotton®, to date the best-known of the branded low –twist labels, is a trademark registered to

HygroCotton®

The spinning technology of Hygro Cotton®, which is a trademark of Welspun, gives each cotton strand a hollow core that wicks moisture, thus makes the towel absorbent. If long staple cotton, like Egyptian or Pima, is used, a soft hand will be gained

Terry Weaving

The production of terry fabrics is a complex process and is only possible on specially equipped weaving machines. Three yarn systems are woven in the terry loom compared to the two system types of traditional weaving: Ground warp, pile warp and weft. The two warps are processed simultaneously: the ground warp, with tightly tensioned ends and the pile warp with lightly tensioned ends. A special weaving method enables loops to be handled with the lightly tensioned warp ends on the surface. Ground warps and pile warps are unwound separately, warped onto two different section beams and sized separately. The processes they undergo show some



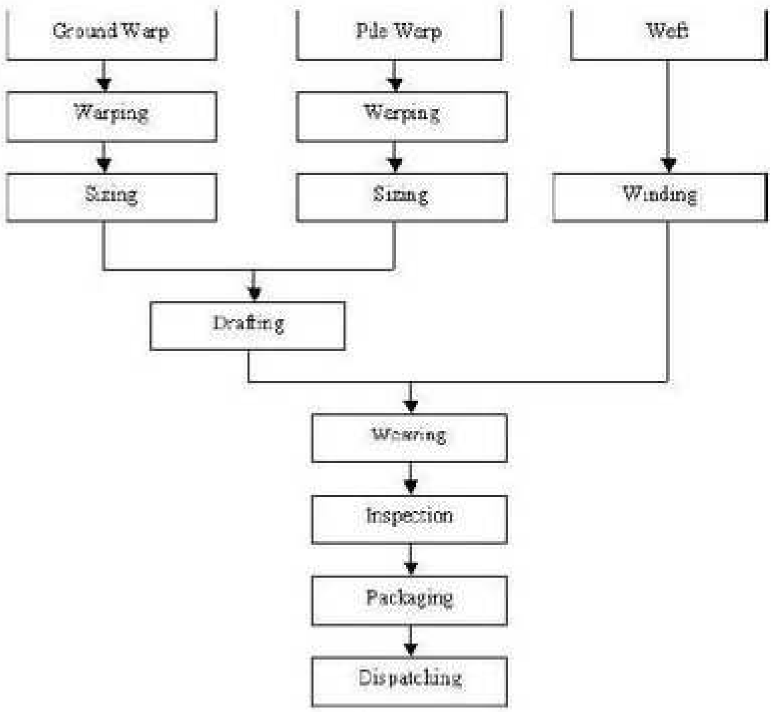
Terry Weaving Machine G6300F

Preparation for Weaving

Increasing demands are being made on warp quality due to the ever increasing speed of looms and weaving machines. Weaving preparation consists of procedures which are carried out before weaving in order to obtain good quality fabric by ensuring warp and weft performance Differences from each other. Weft or filling yarns are wound onto bobbins in required softness and lengths. The flow chart of terry weaving process is In drafting or drawing in, ground and pile warps are passed through heddle eyes in the healed frames or harnesses, through ground and pile drop wires and through special terry reeds which have double teeth. Warps are fed into the loom from two beams: The ground and pile warp beams. The tension of the pile warp beam is lower than that of the ground warp beam; therefore the pile warp beam delivers higher length of warps than does the ground warp beam does. A special reed motion lets this extra length of pile warp form loops. Terry weaving is described as "slack tension warp method".

Warping:

Warp ends should be wound onto the section beam in accordance with the required weave, total number of ends, length and the required warp density (epi) of the fabric. By setting the yarn tension consistently during warping throughout the warp beam, the sizing may be applied in a more homogenous manner throughout in a more homogenous manner throughout the beam. The objective of the warping systems is to present a continuous length of yarn to the succeeding process with all the ends continuously present and with the integrity and elasticity of the yarn as wound; fully preserved In this process, yarn ends from packages which are placed on the warping creel according to the specified warping plan are wound onto the beam after passing through guides, tension regulators and the accordion comb. Any yarn breakages are determined by tension sensors due to the decrease in warp tension and when a yarn break occurs, the machine stops automatically. Two systems can be used for the warping process: Direct warping and sectional warping. If the creel capacity is sufficient and the number of total warp ends is not very high, the ends which are drawn from the creel can be wound directly onto the warp beam or section beam. This system is known as the direct warping system. If the fabric width is high or the warp density is so high that it necessitates a high number of warp ends or the warp has a color repeat, warping is carried out section by section. In this system which is known as sectional warping a definite number of warp ends are unwound from the creel and are wound on a cone shaped warping drum forming a specified width. The process is repeated until the required end count is reached. In the second step the warp ends which are wound onto the cone drum are transferred to warp beam. In direct warping the warp ends are wound onto a number of beams which will be joined in one weaver's beam after sizing, whereas in sectional drawing all the warp ends can be wound onto a single beam. Direct warping is much faster and thus cheaper than sectional warping as it includes only ones step for the warp ends to be wound on to the warper's beams During warping, the zigzag comb moves upward and downward to the left and to the right as the warp flows in order to prevent warp ends mounting one over other. The warp ends which come through the zigzag comb are wound onto the warp beam with the help of a transferring drum. The pressure drum ensures the tightness of the sizing beam and consistent tension across width and length. The running speed of the warper and the tension of the ends can be increased as the thickness of the yarn increases. The speed of the warper is also affected by the type, the strength, and the friction of the yarn. Also, the speed of the direct warper is higher than that of sectional warper Yarn packages for warp beams are placed on the warping creel, either V- or parallel creel. A parallel creel has the advantage of space saving on the plant floor and the V – creel has the advantage that the tension is kept constant throughout the beam width Packages are arranged on the creel according to the color pattern repeat. Each warp end is tied to the end which was left from the previous beaming work and is passed through the tension regulator. The packages should be in good condition, and all should have the same weight. Packages of different weight run out of yarn at different times: thus they would need to be replaced at different times. This leads to loss of production time. Moreover the yarns left on the package after the work is done are transferred to another to either form a full package or to be sold off at discount prices as yarn waste. This leads to higher costs and loss of profit. Each one of the beams in a set which will be sized is required to contain the same length of warp ends.



Terry Weaving Flow Chart

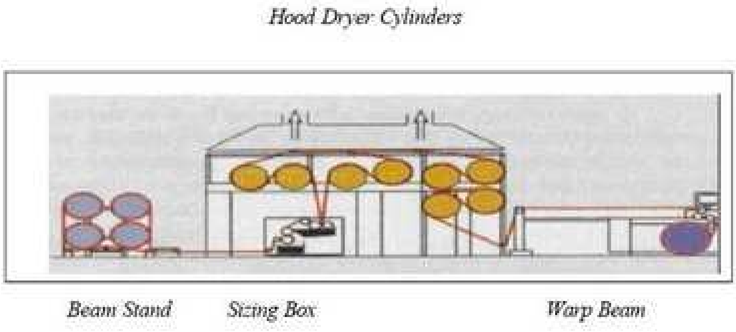
Yarn breakages can occur due to thin places, nappy yarn, fly (the flying fibres from the yarns), bad package winding, or insufficient twist. If the creel is equipped with an air blower, the breakages which are due to fly will be prevented. The zigzag comb also should be equipped with an air blower.

Sizing:

Terry toweling is formed from cotton yarns, and as described earlier these yarns are produced by gathering cotton fibres together and twisting them. Some of the fibres in the yarn are totally in contact with other fibres, while some fibres are loose and protruding. Fibres of the latter type do not contribute to the strength of yarn totally and form a rough yarn surface. Warp ends should be able to withstand great tension and friction forces during shedding and beat-up in the weaving process. As the number of end breakages increase so will the total cost and number of fabric defects increase Sizing is a pre-treatment for yarns to be processed as warps for weaving into textile fabrics. Sizing protects the yarns against mechanical stresses in the weaving process by the application of a film of sizing agent which envelopes the yarn and which subsequently must be removed in finishing. The composition and quantity of the size application must be adapted to the type of yarn. Weaving efficiency is highly dependent on sizing. The type of sizing agent is also important in finishing which is why close cooperation between the weaver and the finisher is desirable. Sizing is carried out in warp form from beam to beam. For the warp sizing process, the size has to be cooked in a kettle after which the size liquor is transferred to a heated storage vessel. The liquor is delivered from the vessel to one or several size boxes for application to the warp sheet. The sizing machine can have one size box or more than one size boxes to increase the effect of sizing. The warp is squeezed between one or several pairs of rollers to remove excess size and to improve size penetration into the yarns. The impregnated warp then passes over drying cylinders supplied with heated steam. During this stage, water evaporates from the wet yarns and is normally collected under a hood and discharged by means of an extractor fan into the atmosphere through the roof. A sizing machine is Sizing liquor consists of three main components, main sizing agents, auxiliary sizing substances and water.

Main Sizing Agents:

The sizing agents which are used today can be either natural sizing agents (starches, starch derivatives, cellulosic sizing agents) or manmade sizing agents (polyvinyl alcohol, acrylic) The most frequently used natural sizing agent is a starch derivative, carboxymethyl cellulose, which forms relatively more elastic but less strong size as compared to other sizing agents. The manmade sizing agent which has a widespread use is polyvinyl alcohol (PVA). The viscosity of the liquor can be adjusted during production. Film strength is high but its sticking ability is a little low. It dissolves in water. The desizing process should be carried out carefully; otherwise problems can occur in the wet agent is acrylic. It is usually used with other sizing agents to improve sticking ability and to prevent the size from settling Terry towelling is a heavy fabric and most of this weight comes from the pile warp. This situation increases size consumption and consequently increases sizing and desizing costs. An industrial application is to use starch or carboxymethyl starch in the ground warp, and carboxymethyl starch which can be removed in water for the pile warp. An industrial application is giving pile warp 3.5-4% size add -on and ground warp 13-14%



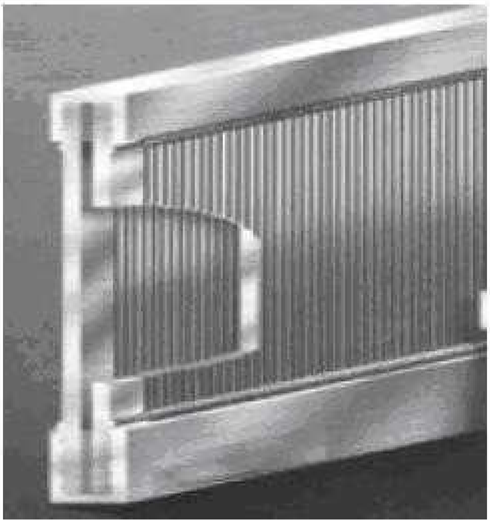
Sizing Machine

Sizing Auxiliary Substances:

Sizing auxiliary substances are tensids, which help yarn absorb the liquor; softeners, which are used in order to soften the size film; lubricators, which are used to decrease the friction coefficient of sizing film, increase elasticity, improve moisture absorption; anti-static agents, which are used to prevent static electric; moisture holders, which are used for sizing film to ensure they hold 7- 8.5 % moisture until the end of weaving; de- foaming agents and antiseptics.

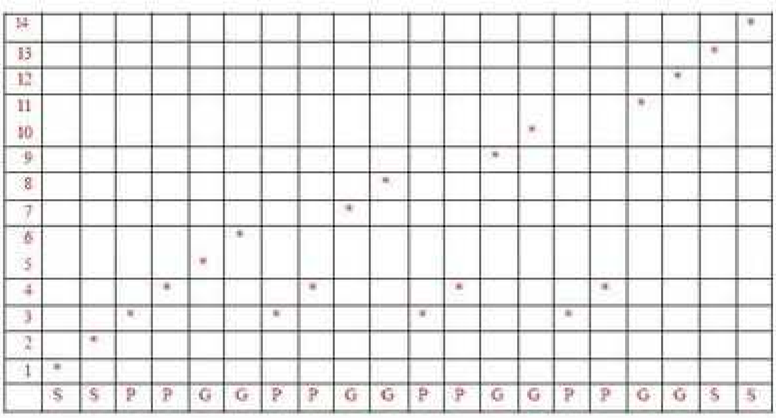
Drafting for Terry Weaving:

Drafting or drawing-in is the process of passing the warp ends through drop wires, heald or heddle eyes and reed dents in the designated order. With this step the warp ends are arranged in the required order, prevented from crossing over each other, and warp density is set. It is one of the most laborious of all textile processes, however, most weaving mills throughout the world continues to do this process by hand. In terry weaving two ends are drawn through each dent. The reed numbers which are most commonly used in terry weaving are 110/2, 115/2, 120/2. Here the first number gives the number of the dents on the reed per 10 cm, and the second number gives the number of warp ends which pass through one dent. The reed which is used for terry weaving is different from that of normal weaving. The distinguishing characteristic of this reed is that its dents are arranged in two rows. This double row prevents entanglement of pile and ground war ends, but this has a disadvantage. Any reed mark on the fabric becomes more obvious. However this makes it easy to distinguish the weave from the 3- or 4- pick terry fabric. In Figure 8, a reed which is used for terry weaving.



terry reed

During weaving the flow of the warp ends should have as few obstacles as possible. Thus straight drafting is applied for pile warp ends. Straight drafting is achieved as the first end through first harness, second end through the second harness, to the final number of harnesses. The order is sequential. If the warp density is high, skipping drafting can be used for both pile and ground ends. In skipping draft the drafting order does not follow the sequential order of ends

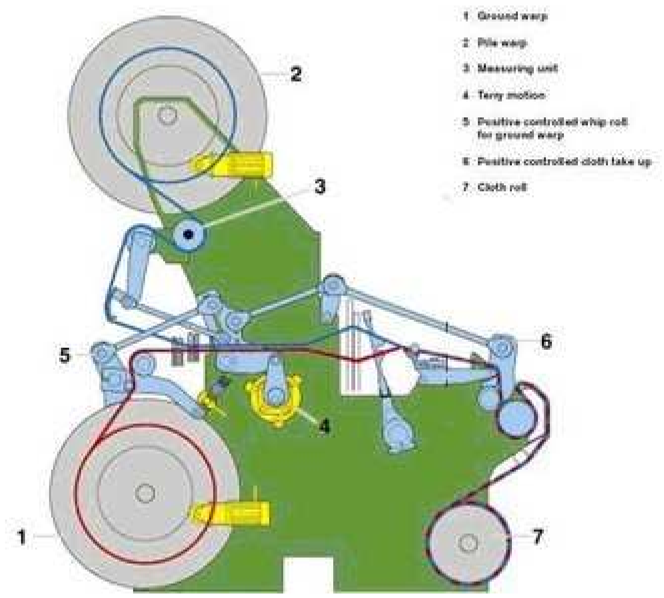


Drafting in Terry Weaving

P: Pile Warp ends,
G: Ground Warp Ends,
S: Warp ends of Selvedge's
Leno selvedge warp ends through heald frames or harnesses 1 and 2,
Pile warp ends through heald frames 3 and 4,
Ground war ends through heald frames 5 to 12,
Leno selvedge warp ends again through heald frames 13 and 14,
Pile warp adds only use two heald frames whereas ground warp threads which have a very close number of ends use 8 heald frames.

Steps of Terry Weaving

The components of an air- jet terry weaving machine are seen. The pile warp ends are let off from the pile warp beam (2), guided through the measuring unit (3), then join with ground warp ends which are let off from ground warp beam (1) and guided through the whip roll. Next, the two warp systems are threaded through the drop wires, the headles, reed and with the control of cloth take up (6) are wound onto cloth roll after weaving(7). Positive controlled whip roll for ground warp (5) determines the length of ground warp to be let off, while terry motion (4) assures integration among pile and ground warp let off and cloth take up.



Basic Movements:

Pile warp threads form loops and patterns through the shedding motion where as the ground warps form the ground with 1/1 plain weave, rib 2/1, rib 2/2, or rib 3/1 weaves. The rib 2/1 weave is the most frequently used weave for pile and ground warp systems separately. The shedding motion can be controlled in three ways for terry weaving as follows

Cam Shedding:

The shedding motion is applied to the warp threads through heald frames or harnesses. The maximum number of frames which is used in terry weaving machines is 10.This system can weave only very basic weaves. Weaving machines can reach very high speeds with an eccentric shedding system. To change the weave it is necessary to change the cam

Dobby Shedding System:

The dobby shedding motion of the warp ends is created by the movement of the heald frames. The maximum practical number of harness frames in terry weaving machines with dobby is 20. Dobby looms can produce weaves in limited numbers and limited designs. The difference of this system from the other traditional dobby looms is that the motion of the pile and ground warps is transferred separately. There are also systems in which the pile warps are given shedding motion by dobby and the ground warp ends by cam

Jacquard Shedding System:

Each warp end is controlled through a separate motion. Very different and very complex structures can be woven. In terry fabric it is the pile warp which shows the design. The ground warp ends are woven 2/1 ribs (most commonly), 2/2 ribs, 1/1 plain weave and 3/3 ribs (the rarest) As these weaves do not require a jacquard shedding system, in some weaving machines, the pile warp ends take the shedding motion from the jacquard system whereas the ground warp ends take from the cam. Jacquard machines may either work in a traditional mechanical system with the help of needles and design cards or a contemporary electronic system which works through electronic transmitting elements with design files and electronic. The pile warp ends are looser than input. The pile warp ends are looser than ground pile ends, thus the shedding of the pile weft ends must be wider than that of ground warps. Otherwise, contact may occur between the pile warp ends and the pick carrying device, which may cause high numbers of end breakages. A wider shed also improves the loop formation. Pile tension rod should guide the pile warp ends from the position which has the same level with the center of the shed. With this, the pile warp ends in the upper and in the lower shed will maintain the same tension. Thus, the pile loops on both sides of the fabric will have the same length.

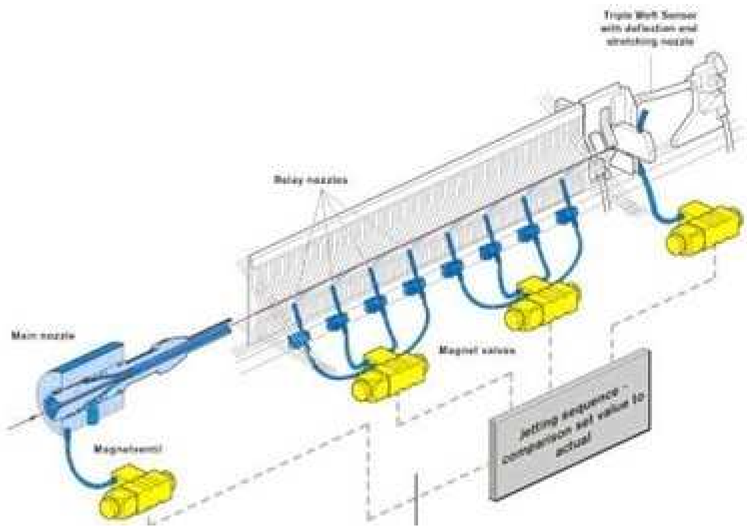
Filling Insertion

Filling Insertion with Rapiers:

Rapiers are popular in the production of terry cloth because of the flexibility they offer for production Rapiers are two hooks which carry the weft picks across the warp sheet. The first giver hook takes the weft pick from the yarn feeder and carries it to the center of the warp width. Meanwhile the taker hook moves from the other side of the weaving machine to the center. There, the two hooks meet and the weft pick is transferred to the taker hook. After that the giver hooks returns empty to the side it came from, and the taker hook carries the weft to the opposite side.

Filling Insertion with Air Jet:

In air jet weaving a puff of compressed air carries the weft yarn across the warp sheet; there are relay nozzles which are arranged in a definite order according to fabric width. These aide nozzles are connected to the main nozzles in groups. The air hoses which go to aide nozzles are also arranged in a row. The pick feeders also work with air and winds according to the fabric width. On the side where the pick arrives there are optical sensors which control the arrival of the filling picks. The maximum filling insertion rate practically achieved in terry weaving is 1800 m/min

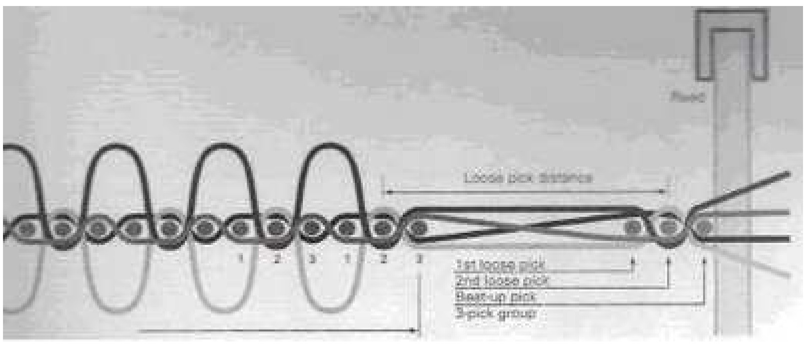


Filling Insertion with Projectile:

A small gripper takes the cut weft yarn across the weaving loom. This system is not very common in terry weaving as rapier and air jet filling insertion system are most commonly used ones Promatech, 2003; Dornier, 2003 Picanol, 2004; Smit Textile, 2005 Tsudakoma, 2005.

Beat-up:

The loops in terry fabrics are formed with a special reed motion and warp let- off system. These motions vary according to pick number per loop. In 3-pick terry weaving, two picks are inserted at a variable distance the loose pick distance- from the cloth fell. The loose pick distance is varied according to the desired loop height. When the third pick is beaten up, the reed pushes the pick group which includes the three picks, on the tightly tensioned ground warps, towards the fell and the loose pile warps are woven into the pick group are uprighted and form loops. Depending on the weave, loops are thus formed on one or both sides of the fabric

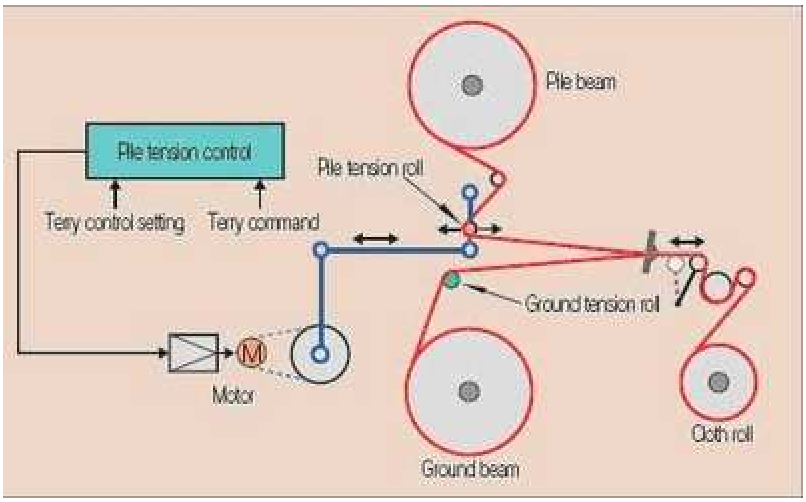


In Figure 12, 3-pick terry fabric formation is seen. The first weft pick is the loop fixing pick, the second pick is binding pick, and the third one is the pile pick or the fast pick. The third pick is inserted into a completely reversed shed, as the pile and ground warp ends which are up, go down, and those which are down go upward, essentially locking the first in place. Thus, this motion prevents the drawing of the loop by the following sheds. There are also systems in which the reed motion is constant but the cloth fell is moving, like Zax-e® Terry loom from Tsudakoma which has terry motion with a cloth fell shifting system or the ATVF ServorTerry® weaving machine from Dornier (Tsudakoma, 2005; Seyam, 2004). Here, a servo motor replaces the traditional terry cam for pile formation, so the reed does not drop back. When the reed is at the front center the fabric is positively driven toward the reed to form pile by the backrest and terry bar in combination with the temples. The disadvantage of this system is that the friction which takes place during the forward-backward motion of the ends can lead to end breakage. Although weaving machines of different makes have different mechanism the main principle is the same. With today's machines, the maximum loose pick distance practically achieved is 24 mm, which gives some less than 12 mm loop height in G6300F® Terry Weaving Machine. It is possible to switch between 3-, 4-, 5-, 6- or 7- pick terry and 8 different pile heights in ServoTerry® (Dornier, 2003) and G6300F Terry Weaving Machines while the machine is running a towel which is woven with different pile heights is seen

Complementary Motions

Let-off

It was mentioned earlier that there are two warp systems including ground warp and pile warp, and thus two warp beams are let off simultaneously in a terry weaving machine. The ground warp ends move forward slowly and under high tension as the ground warp beam turns slowly. At the same time, the pile warp ends move forward quickly and loosely as the pile warp beam turns faster than the ground warp beam. Ground and pile warp beams are propelled by two different independent motors. Rpm's (revolution per minute) of the pile warp beams is proportional to the required pile height. The higher speed delivers more yarn to increase the pile height. During let- off, pile tension is controlled continuously. This decreases yarn breakages, and avoids out-of tolerance loop heights. In Figure the Terry Motion Control System® of Tsudakoma is shown. Here, pile tension is determined by pile tension roll which is propelled by a motor guided by electronic pile tension control system allows, so that it can hold the maximum length of pile warp. Keeping the pile beam's diameter large avoids changing the beam frequently



Pile Tension Control System

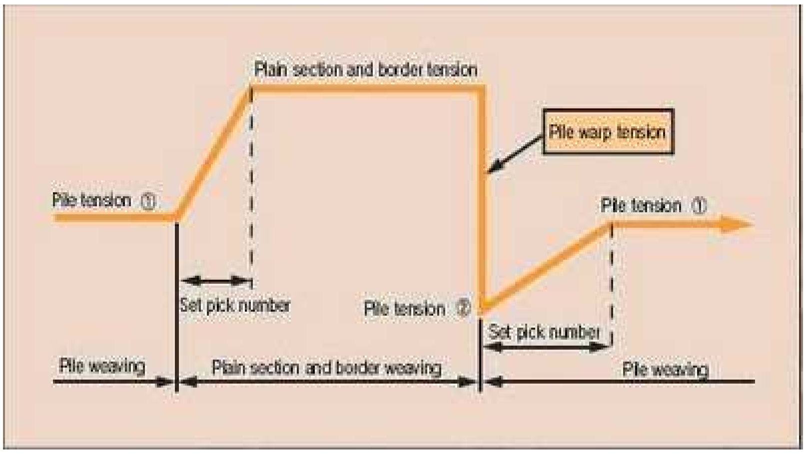


Diagram of Pile Warp Tension during weaving pile, plain and border parts

The width of the pile beam is between 76 – 144 inches (190 - 360 cm) and the diameter of its flange can be up to 50 inches (125 cm), while the flange diameter of the ground beam is up to 40 inches (100 cm). The Pile beam can hold more than 130 cu ft of yarn, with a gross weight exceeding that of many automobiles

Diagram of Pile Warp Tension during weaving pile, plain and border parts
The two warp systems are evenly let- off by a system of constant tension control from full to empty beam. This is controlled by a highly sensitive electronic device. The tensions of the pile and ground warps are detected by force sensors and electronically regulated Elimination of unwanted increase of tension of warp tension during weaving high density border and/or plain section is achieved by reducing let-off speed the diagram of pile warp tension in Zax-e® Terry looms from Tsudakoma during weaving of pile, plain and border areas is shown. In Figure the diagram of loom rpm's in Zax-e® Terry looms of Tsudakoma during pile weaving and border weaving is shown

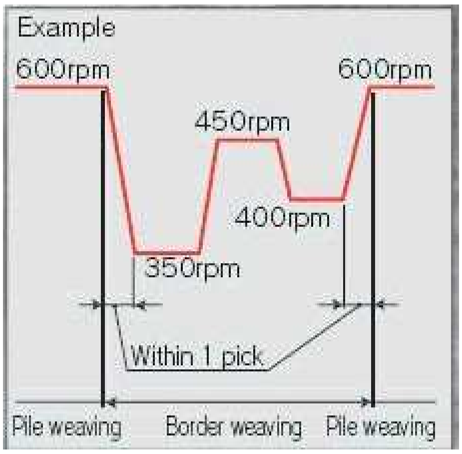


Diagram of Loom Rpm's during weaving pile and border areas

To prevent starting marks or pulling back of the pile loops, the pile warp tension can be reduced during machine standstill. An automatic increase in tension can be programmed for weaving borders to achieve more compact weave construction in order to ensure a rigid border and/or to achieve nice visual effects via jacquard or dobby designs on the border. The way the back rest roller system is controlled depends on the weave. During insertion of the loose picks and during border or plain weaving the warp tension between the open and closed shed is compensated for by negative control. A warp tensioner with torsion bar is used for the ground warp, and a special tension compensating roll is used for the pile warp.

Take-up:

The pick density is automatically controlled by synchronizing the take-up motor rotation with the loom speed. The take-up motor rotates the cloth pulling axle. The cloth pulling axle is covered with needles which pricks the terry fabric and assures that the thick fabric winds on the take-up roll evenly with a constant width. The electronically controlled cloth take-up guarantees exact weft densities in every terry towel and a faultless transition between pile and border. There are five elements of a take-up system. These are

1- **Temple**

The temple holds the width of the fabric as it is woven in front of the reed and assures the fabric to be firm at full width. A temple is seen on Figure.

2- **Length Temple**

Length temple is located on the center of loom width between two side temples. There are groves starting from the center and going to the left and right sides of the temple. It ensures the terry fabric is open to the sides and remains straight and tense throughout the fabric width.

3- **Cloth pulling Axle with Needles**

It ensures the thick terry fabric keep its tension and width while being transferred from the length temple to the cloth transfer axle.

4- **Cloth Transfer Axle**

It increases the contact angle between the terry fabric and cloth pulling axle with needles and transfers the fabric to take-up roll.

5- **Take-up Roll**

The fabric which comes from the transfer axle is wound on take-up roll

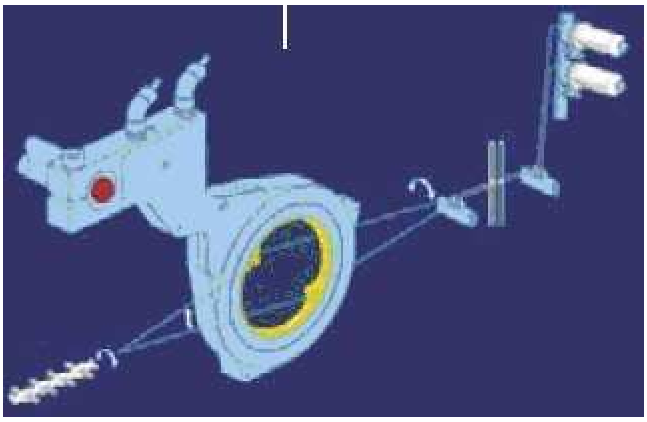
Auxiliary Motions

Selvedge Forming

A length-wise edge of a woven fabric is called selvedge or selvage. The main purpose of the selvedge is to ensure that the edge of fabric will not tear when the cloth is undergoing the stresses and strains of the finishing process. This is achieved by making the selvedge area stronger than the body of the cloth using heavier and plied warp yarns, increasing warp yarns per inch, and applying different weaves. Two types of selvedge are formed during terry weaving

1-Leno Selvedge

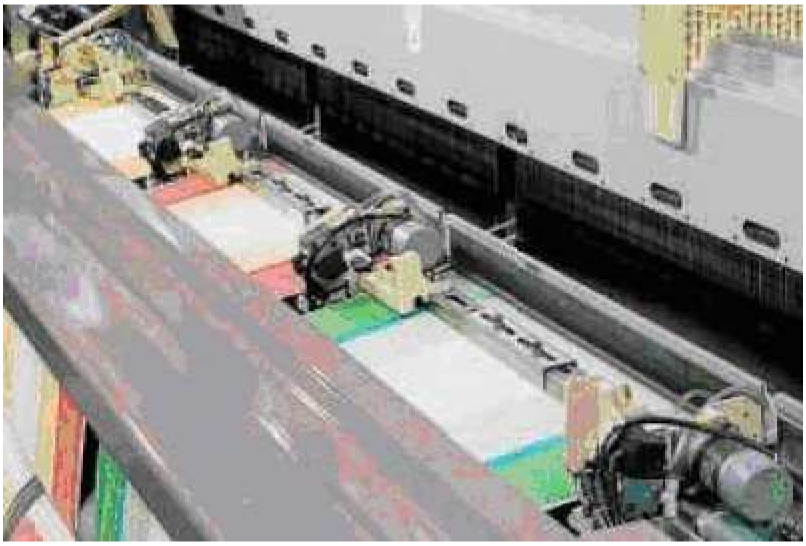
A leno weave at the edges of the fabric locks in the warp yarns by twisting the last two warp yarns back and forth around each pick. They are made with special leno weaving harnesses. Leno selvedges predominate in terry weaving In below Figure, a leno selvedge forming system for terry weaving is shown.



In Figure 20 (I), the diagram of a leno selvedge is shown.

2-Tuck-in Selvedge

The fringed edges of the filling yarns are woven back into the body of the fabric using a special tuck-in device. As a result the filling density is doubled in the selvedge area. In below Figure, the ZTN™ needless tuck-in devices which are used in Zax- e™ terry looms from Tsudakoma is shown. In Figure 20 (II), the diagram of the tuck-in selvedge is shown



As the width of the towels is usually much narrower than that of the weaving machine width, more than one towel may be woven at the same time. Thus, selvedges are formed not only at the sides but also several selvedges should be formed on the sides of each Leno Selvedge Tuck-in Selvedge.

Weft Color Choosing Motion

There are special color selection systems for inserting the required pick color while weaving different filling colors. Terry weaving machines have weft maximum twelve different colors or type of filling to be woven, including novelty yarns like chenille.

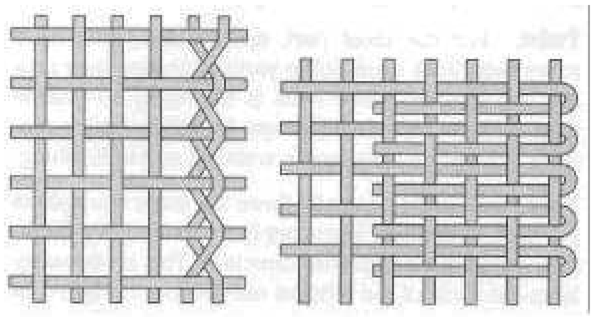


Figure leno & Tucked-in selvedge

Pick Control

The pick control mechanism or pick finder detects the weft breakage. At a filling break, the machine stops and moves at reverse slow motion – automatically – to free the broken pick. It has a significant role in reducing the down times for repairing filling breaks and thus the starting marks can be avoided

End Control

Drop wires which are hung individually on each warp end, fall down when a warp end is broken or is very loose, closes down the electric circuit and thus shutting down the weaving machine

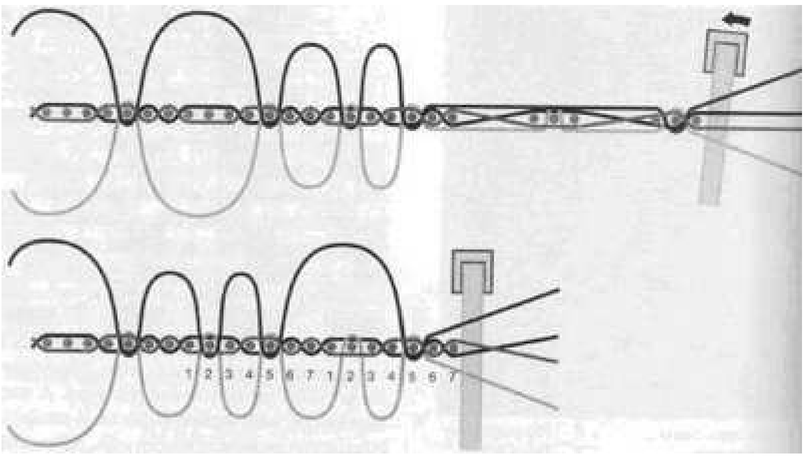
Weft Measuring and Feeding Motion

During terry weaving in shuttle – less looms, the weft is inserted from one side with the help of rapiers, or air jet nozzles. A predetermined length of weft yarn under the necessary tension should be inserted during each picking. Before each picking motion, a definite length of weft pick is measure, stored usually on drum accumulators and released for picking. The weft feeders carry out this function. They pull the weft picks from the yarn packages and wind them helically over a turning cylinder. Winding speed determines the weft length.

Terry Designing

Terry fabrics are often very complex with different colored warp ends in combination with loop patterns. They are subject to changing fashions, and the market is constantly demanding new qualities and designs. The rapid development of electronics has enabled fabric designers to produce completely different patterns. Via a servo motor, the beat-up position for each pick, and, thus the type of terry and the pile height can be freely programmed from one pick group to another. In this way nearly 200 different loose pick distances, and hence the same number of pile heights, can be programmed in any order. For example, three- and four-pick terry and even fancy types of terry can be combined in the same fabric. This gives the fabric designer a broad range of patterning options and the weaving engineer the weaving structure for improving fabric performance, because transition from one pattern element to the next can be woven with greater precision With these capabilities, a new patterning method, called sculptured terry, has been developed. At each full beat -up, two pile loops of different heights can be formed in the filling direction. The secret of this method of pattern formation lies in the fact that two loose pick groups formed at distances corresponding to the pile heights are beaten up to the cloth fell together. For two short loops the pile yarns are woven into both loose pick groups and for one large loop into the second loose pick group only. The greatest challenge is to develop a basic weave which results in neat loops without excessive friction between warp and filling at full beat -up. The solution is found in a special seven pick weave combined with full beat -ups at the sixth and seventh pick. In this way, a second pile height is also formed in filling direction, making sculptured patterning possible by the difference in pile height in warp and filling direction. In Figure 21, a terry towel pattern which is produced with this technique is shown. In Figure 22, the diagram of seven pick terry design is shown. A requirement for this kind of pattern formation is a freely programmable sley traveling on a rapier weaving machine. Microprocessor control allows the loose pick distance to be

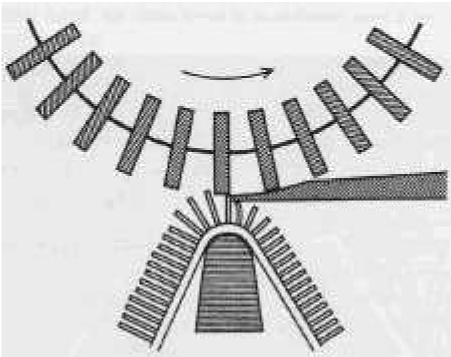
Figure 21 A terry pattern achieved by weaving two different heights of loops programmed easily and individually for each pick. The loop formation system with full electronic control lets you alter the height of the loop by accompanying the electronic weft ratio variator device on jacquard looms to program different weft ratios like 3-pick terry, 4-pick terry and so. By this method, different heights of loops can be achieved in the same shed.



Special seven filling terry design with two-pick groups and full beat-up.

Shearing:

It is quite common practice to shear the terry loops after manufacture in order to create a cut-pile effect. Many hand towels are sold with one face showing the traditional terry loop, whilst the other side shorn to give the velour effect



Shearing is applied to the pile fabric, by passing it over a cylinder with blades like a giant cylindrical lawnmower. The velour fabric is then brushed with bristles set in a cylinder to remove cut bits of fiber. Brushing leaves the surface fiber lying in one direction so care must be taken to have all the fabrics in the same batch laid out in the same direction, or light will reflect off various pieces differently In above Figure, a simplified diagram of the shearing process is given. The pile fabric is guided across the shearing table and is sheared between the shearing blades mounted on a cylinder and a fixed blade.

Sculptured or carved design

Sculptured design is different from the one which is achieved during weaving by using long and short loops. This involves considerably more processing after weaving. The pile fabric which has been woven with single pile loop height I embossed, then the pile left upstanding is sheared off, and that which was flattened is brushed up, leaving the sculptured or carved design.

Dyeing and Finishing of Terry Towel

As discussed earlier the main fiber which is used in towels is cotton. As cotton fiber is not sensitive to alkali or chlorine bleach but is to acids, all the dyeing and finishing processes must be planned with these conditions. Like other textile materials the dyeing and finishing stage of terry towels generally follow the workflow shown below

· Pretreatment
· Coloration (Dyeing or Printing)

Finishing

Pretreatment:

Fibrous textile materials need a pretreatment before dyeing. Fiber preparation ordinarily involves scouring to remove foreign material and thus ensures even access to dye liquor from the dye bath. Cotton must be boiled and bleached to remove pectin and cotton seeds Sizing substances also must be eliminated. The steps of pretreatment are shown below:

-Desizing
-Scouring
-Bleaching

Desizing:
Desizing is intended to remove size from the fabric to ensure even bleaching, level dyeing and soft handle Desizing processes differentiate according to the sizing agent used.

Type	Effective temperature range	Effective pH range
Cold	20°C – 30°C (room temperature)	6 – 8
Warm	60°C - 70°C	6 – 8
Hot	90°C and above	6 – 8

I- **Enzymatic Desizing:** This classical desizing process consists of removing the starch from towel fabric using enzymes. This desizing process simply involves liquefying the film of size on the product. Bacterial, malt and pancreas amylases are used as desizing agents. Enzymatic desizing is the classical desizing process of degrading starch size on cotton fabrics using enzymes. Enzymes are complex organic, soluble bio-catalysts, formed by living organisms that catalyze chemical reaction in biological processes. Enzymes are quite specific in their action on a particular substance. A small quantity of enzyme is able to decompose a large quantity of the substance it acts upon. Enzymes are usually named by the kind of substance degraded in the reaction it catalyzes.
The enzymes generally employed for desizing are:
· α – amylase
· β – amylase
· amyloglucosidase
Amylase is the enzyme that hydrolyses and reduced the molecular weight of amylose and amylopectin molecules in starch, rendering it water soluble enough to be washed off the fabric. Effective enzymatic desizing requires strict control of pH, temperature, water hardness, electrolyte addition and choice of surfactant. Enzyme sources are either from animal origin (slaughter house waste – pancreas, clotted blood, liver etc.), vegetable origin (malt extract – made from germinated barley), and bacterial (produced by growing cultures of certain micro organisms). Bacterial enzymes are preferred because of their activity over a wider pH range and tolerance to variations in pH. Since desizing is carried out on grey fabric, which is essentially non-absorbent, a wetting and penetrating agent is incorporated into the desizing liquor. Bacterial enzymes are commercially available in three grades:

JUSTIFICATION FOR THE USE OF REACTIVE DYES IN THE DYEING OF TOWEL

It is over thirty years since reactive dyes for cellulose were introduced and they now account for about 25% of the total dye consumption on that fibre. There emerged after the results of the work on the mechanisms of organic reactions were in place and their enabled their development to be characterized by the study and application of reaction mechanisms involved in the dye-fibre reaction. This factor has paid handsome dividends. The work continues, increasingly gaining cost-effectiveness by enhancing reaction mechanisms, such as polymerization, have met with little success and the simple nucleophilic substitution and addition mechanisms of dye fixation remain totally dominant.

The following factors rightly justify the usage of reactive dyes world wide

Bright shades
Good Fastness properties
Easy application
Moderate cost
Eco-friendliness

Bright shades

The reactive dyes are the brightest dyes available for the cellulosic fibres and have a full range of shades.

Good Fastness properties

Colour Fastness may be defined as"the resistance of a material to change in any of its color characteristics, to transfer its colorant(s) to adjacent materials, or both, as a result of the exposure of the material to any environment that might be encountered during the processing, testing, storage, or use of the material"

Wash Fastness:

Textile materials coloured with reactive dyes have very good wash fastness properties. The wash fastness rating is about 4-5. This is attributed to the very stable covalent bond that exists between the dye molecule and the fibre.

Light Fastness:

Textile materials coloured with reactive dyes have very good light fastness. The light fastness rating being about 6. These dyes have a very stable electron arrangement and provide very good resistence to the degrading effect of the U.V component of sunlight. There are, however, some reactive dyes with only fair light fastness

Bleaching fastness:

The reactive dyes are stable to peroxide bleaching and so are suitable for dyeing cotton yarns to be used as effect threads. Strong reducing agents and chlorine, however, destroy the chromogens.

Easy application

Reactive dyes offer a great flexibility in application methods with a wide choice of equipment and process sequences and so have become very popular. These are applied through exhaust and continuous systems both very comfortably. Following is the list of equipments used for the application of these dyes:

a) Exhaust/Batch/Dis-Continuous Dyeing Systems

Jigger Open Width 3-5:1
Winch Rope Form 20:1
Jet/Soft Flow Rope Form 15:1
Beam Dyeing Open Width 10:1
Star Frame Open Width

b) Semi-Continuous Dyeing Systems

Pad-Batch
Pad-Jig
Pad-Roll

c) Continuous Dyeing Systems

Pad-Thermosol
Pad-Steam

Moderate cost

Reactive dyes as compared to vats are of lesser costs considering the fastness properties of both. The dyeing process involved in vat dyeing is also costly which involves certain steps like reduction and oxidation. On the other hand reactive dyeing is free from these steps.

Eco-friendliness

Many consumers also appreciate the eco-friendliness of fiber reactive dyes. Some companies process the dyes with natural ingredients and materials, focusing on creating a product with a minimum of harmful waste. Since the dyes are colorfast, they will not bleed into wash water, leading to a reduction in dye-laden water runoff, which can be harmful for the environment.

Printing:

Printing is local dyeing in zones according to patterns. Thickeners ensure that these zones defined by the engraved pattern are adhered to. The type and size of the artistic design determine the printing process and method of dye paste application. Various printing types like direct printing, discharge printing and resist printing and techniques like roller printing and full screen printing are available for the colorist to realize the print idea.

Package Dyeing:

For package dyeing, yarn is wound on dye tubes as packages, each with a hollow center that allows liquid to flow through it. The packages are stacked on perforated, hollow posts, and dye liquor is pumped through these. Package machines are enclosed and can be pressurized so dye liquor can reach temperatures above atmospheric boiling point (100 C) for faster dyeing. The term yarn-dyed is associated with quality in woven fabrics. A pattern with dyed yarns looks sharper than one printed.

The fabric will probably be more colorfast, and it is also reversible. The yarn dyeing process takes place between spinning and weaving steps

Final Finishing of Terry Towels:

Final finishing includes all the finishing treatments applied to the fabric after dyeing and printing it can be divided into two:

1- Chemical (or Wet) Treatments
2-Mechanical (or Decorative), Treatments

Chemical Treatments:

Softening, hydrophilling and antimicrobial treatments are among the chemical finishing processes of terry towels

Hydrophilic Treatment:

Silicones are added to the towel to give hydrophilic properties. It is also used to give a soft handle.

Softening:

The three basic types of softeners which are used on towels are cationic softeners, non- ionic softeners and silicones. Cationic softeners give good softness, but also some yellowness, so are only used for colored towels. Non-ionic softeners have less softening effect but are used in white towels due to the colorlessness of the chemicals. Silicones are the best and the most expensive of the softeners Hydrophilic silicones also affect the hydrophility of the towel positively. There are also applications of enzymatic softening using cellulases.

Antimicrobial Treatment:

Towels can be treated with antimicrobial finishes in order to prevent mold and mildew, reduce odor and minimize spread of harmful organisms Two types of antibacterial and deodorant finishes are available The first is applied during fiber-forming process, whereas the other is incorporated into the finishing process. The second approach is more versatile and widely adapted. Chemical entities are responsible for imparting antibacterial attributes including fungicides and bactericides. Obtaining antimicrobial properties by using antimicrobial fibres is achieved by anchoring the antimicrobial agent in the fiber. Trevira Bioactive (R) is an example of antimicrobial fiber used in towels which has proven to fully retain its antimicrobial effect after 100 domestic or 50 commercial wash cycles.

Mechanical Treatments:

The main aims of dry treatments are to give the towels fuller volume, and dimensional stability and dryness

Tumble Drying:

The towel is given a fluffy and soft hand, and some particles are removed during drying. The common way is to use continuous tumbler dryer generally called Turbang®, which is the brand name of the machine brand. The second way is to use tumble dryers which are a huge version of domestic tumble dryers.

Stentering:
Stentering or tentering is a controlled straightening and stretching process of cloth which has been pulled out of shape due to the many vigorous finishing processes. The selvedges of the cloth are attached to a series of pins/hooks/clips as it is fed through a stenter machine which is an oven of controlled temperature. During the process, as the pins/hooks/clips are gradually placed further apart width ways, the cloth is slowly and permanently brought out to the desired width. Stentering gives the fabric particular dimensions of length and width, and eliminates creasing.

Cutting and Sewing:

In this stage, towels pass through four steps

- Longitudinal cutting
- Longitudinal hemming
- Cross cutting
- Cross hemming

These processes are achieved by scissors and standard sewing machines by workers or by machines specialized in towel cutting or sewing or even by automatic machines which can carry out some of or all of the mentioned processes Lengthwise cutting machines are used for the first step of this stage, longitudinal cutting of towels which have been produced on the weaving loom as several panels joined side by side. In these machines, there are several cutters which cut lengthwise between adjacent towel panels in order to separate them. The cutting process can be carried out by means of a pressing blade on a motorized roll in the lengthwise cutter. a longitudinal cutting machine is shown

Next, longitudinal hemming is achieved by lengthwise hemming machines, most of which are usually equipped with two 401 chain stitch sewing machines, one on the right side and one on the left side, for the longitudinal hemming of towels. Labels can be attached during lengthwise hemming. In a longitudinal hemming machine is shown.

After lengthwise hemming, towels pass through cross cutting as the third step. Transversal cutting machines carry out product stacking and automatic discharge. The cut product is stacked in layers one on the other.