

Spirality in Knitted Fabric

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Abstract

Knit wear industry is growing at a faster rate across the globe and technological innovations contribute a lot in the success of industry. Knitted cotton fabric is considered ideal for next-to-skin wear. Knit wear fabrics are popular because of their excellent properties of comfort, softness, sweat absorption, durability and softness. The dimensional stability is a serious problem with reference to quality. Quality of the fabric is of prime concern in placement of new ties between buyers and manufacturers. Consumers, now days, are becoming increasingly concerned and aware of fabric quality and accept higher quality standards than ever before. Pakistan's knit wear industry is lagging behind the world knitting industry due to its less command and control over quality awareness and implementation of quality standards. Various defects in knitted fabrics affect the quality but spirality is the most common fault that affects the single jersey knit wear fabric. Single jersey fabric is mostly used for T-Shirts, sports wears and under garments, so position of seam is very important in the exact shape of the product, more is spirality, more de shaped is the end product.

Keywords: Spirality; Fabric knitting industry; Garment; Yarn

Introduction

As per encyclopedia, spirality came from the spirals which are "spiral is a flat curve or a series of curves that constantly increase in size circling around a point" [1]. According to Lau et al., the definition of spirality is, Spirality is the angle between the wale line and a line perpendicular to the course line [2]. Davis et al. discussed the spirality as, in hosiery fabrics which are knitted in plain stitch, the length wise rows of stitches called needle lines or wales, should occupy a truly vertical line in the fabric and should always be perpendicular to the cross wise courses of stitches. This is the principle construction and it shows a different effect when it comes to fabrics that are knitted with cotton or wool which shows a prominent bias towards left or right side, its appearance looks like twilled surface. The description of this defect is named as spirality as it occurs more commonly in circular fabrics [3].

Spirality can also be termed as fabric skew or fabric torque. Spirality is the problem which occurs when the wale is not perpendicular to the course direction. As the yarn is bent to form a loop, the outer part extends and inner part compresses. This is the behaviour that results in change in geometry of spirals with in the yarn, which ultimately results in making it unstable. Percentage spirality is considered as sum of the net spirality caused by the yarn torque and the additional spirality caused by all other factors, these can be calculated by two geometrical approaches, we measure spirality in percentage and angle of spirality.

Spirality being a serious problem in quality, there are certain standards and quality parameters for checking of spirality certain parameters are described by Woolmark Test Method TM 276 2000, which are [4]:

1. ASTM D3882-3899: standard Test Method for Bow and skew in woven and Knitted Fabrics.
2. ISO/6330.
3. AATCC Test Method 179-2001-Skewness change in Fabric and Garment Twist Resulting from Automatic Home Laundering.
4. IWS276 Test Method.

Munden [5] classified dimensional instability as, Dimensional instability of knitted fabric is attributed to various causes, but broadly we can classify them under the headers of fiber causes, yarn causes, knit

causes and finishing causes this classification was later on discussed and verified by Anand et al in their studies and it was verified that the causes of instability in the knitted fabrics are fiber, yarn, knit and finishing causes [5-7]. Causes of spirality are fiber causes, yarn causes, knit causes and finishing causes but in present paper will review only fiber and yarn causes.

Fiber Causes

Spirality has a larger relationship and variation with the different types of fiber. The cotton fabrics with cotton fiber as raw material exhibit greater spirality behavior than made from Polyester fiber. Similarly micro-denier fiber produces less spirality. Stabilization of knit wear fabrics is difficult if the raw material is cotton, because it is non-thermoplastic in nature and cannot be heat set to stabilize knitted fabric dimensions. In a study for defining the parameters influencing the spirality, different fibers exhibit different values of both flexural and torsional rigidity. These different values give different levels of fabric spirality. The key fiber parameters influencing rigidity are density, diameter and cross sectional shape. Diameter among the factors is of major importance [8]. Pistle et al. [9] describe that as knit loops are formed by bending and inter looping so flexural rigidity (stiffness) and torsional rigidity of fiber should be considered as they affect knitting tension and loop dimension. [9,10]. For a given fiber type, parameters such as fiber fineness, twist level and yarn count can significantly affect rigidity. A yarn with less rigidity is soft and flexible but balance should be there otherwise loop distortion during knitting will take place. Similarly yarn with low flexibility together with fabric skew (especially if rigidity developed by high twist level) is also harsh to human body (Tables 1 and 2).

Torsional Rigidity can be expressed by the following equation.

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Fiber	Specific Torsion Rigidity	Shear Modulus x 10 10 dynes/cm ²
Cotton	7.9	2.51
Viscose	4.7	1.1
Wool	6.7	1.11
Flax	5.8	1.32
Polyester	4.7	0.9

The Fiber Flexural rigidity (resistance to bending) can be shown in the form of equation as $FR = \frac{1}{4\pi} \cdot k.E.T^2/p \cdot 10^{-3}$ (g/denier) $l/4\pi$. shape factor. Tensile modulus. $tex^2/density$ (g/cm³) 10^{-3} . Shape factor for circular cross-sections is unity.

Table 1: Typical values of torsional rigidity of textile fibers.

Fiber	Flexural Rigidity(g/Denier)
Cotton	60-70
Viscose Rayon	Apr-30
Wool	3.5
Flax	175
Polyester	40-65

Table 2: Typical values of flexural rigidity of textile fibers.

$$TR = \frac{\epsilon \cdot G \cdot T^2}{P}$$

$$TR = \frac{\text{Shape Factor} \times \text{Shear Modulus (g-wt cm}^2/\text{tex}^2) \times 10^{-4}}{\text{Density}}$$

Fiber parameters significantly influencing rigidity are density, diameter, and cross-sectional shape. Among these, the diameter has the greatest impact (flexural and torsional rigidity are proportional to the diameter of power 4.) as flexural rigidity of fiber is less, less will be angle of spirality. Lower torsion and flexural rigidity will result in fabric production in which loop distortion can be easily seen. Very low flexibility can make the fabric stiff and harsh, which may significantly increase skew; this is more prominent when yarn twist is increased. It is also known that knitted yarn with elastomeric component in raw material (core spun cotton/spandex .97%/7%) will increase the fabric tightness, which has significant effect on fabric dimensional stability i.e., it will show decreased spirality of single jersey fabric as compared to fabric of same specifications produced with 100% cotton yarn. In another study conducted by Marmarali, based on use of cotton spandex blend against 100% cotton yarn, it was found that presence of spandex in raw material, with same value of loop length, the course and Wales spacing was decreased [11]. Fabric with cotton spandex blend showed more tightness factor and the spirality behaviour was seen to be improved.

Later on Chathura N Herath and Bok Choon Kang extended the research work and did noticeable work over the study of different raw materials and dimensional stability of single jersey knit fabrics. With their study, it was concluded that the yarns with elastomeric components increase tightness factors which have a significant effect on dimensional behaviors giving better dimensional stability to single jersey knitted fabrics [12]. In another study by Mikucioniene, further elaboration was done by adding wet and dry relaxed stages behaviour along with the raw material contribution over spirality. It was concluded that Tightness factor increase for both 100% cotton and core spun cotton/spandex i.e., regardless of raw material, as we move from dry relaxation stage to wet relaxation stage to fully relaxation stage. Later on Marmarali did the work on elaboration of dry and wet relaxed stages and raw material contribution over spirality [13-15]. Pile loop knit fabrics, an important structure which is in use now a days on wider scale due to its comfort properties, this is preferred over other structures as comfort and aesthetic properties are needed

for sports wears. Tao et al. studied yarn types and effect of the raw material on structure of fabric that will affect spirality [16]. Later on Nuray Ucar and Hale Canbaz Karakas studied pile types, compared lycell and cotton blended yarns (50%/50% cotton/Loycell) and 100% cotton at dry relaxation and wash & dry relaxation stage. Loycell is fiber that is preferred and mostly used due to its comfort and eco-friendly properties. The conclusion of the study was that pile loops fabrics have more spirality than cut pile loop fabrics. This is due to difference of torsion on fabric structure. As in pile loop fabric torsion is present on ground yarn as well as on pile yarn due to closed structure, but in cut pile loop fabric as loop is cut, torsion is only on ground fabric as torsion on pile yarn is released. Wash and dry relaxed fabric have more spirality than dry relaxed fabric. For fully relaxed fabrics, fabrics with blended raw material (loycell/cotton) have greater spirality than 100% cotton fabric [15,16]. In a study by Araujo and Smith, effect of 100% cotton and 50/50 polyester cotton blend as raw material and their impact on spirality was studied. The study of knit wear was done in dry and fully relaxed stages. It was found by their study that 50/50 polyester cotton blends have less spirality [17]. A yarn made from fine fibers is likely to be denser actually less bulky than of the yarn of same count made from coarser fiber. A yarn made from fibers of rounded cross-sectional shape is less bulky or denser than a yarn of same count made from fibers of triangular or trilobal cross sectional shape [18].

Yarn Causes

Yarn used for making knitted fabric can be continuous filament or staple yarn. Filaments yarns are man-made fiber except silk and produce by extrusions methods or from staple yarns that are normally natural fibers and produced by consolidation/integrating of staple fibers. Continuous filament yarns exhibit less spirality than those made from spun yarn. In general straighter and more un-deformed fiber arrangement will result in smaller tendency for fabric spirality. As in continuous yarn, fibers are aligned in straight fashion, less mobility because no tendency to untwist or move off the yarn body. But in spun yarn fibers are aligned in helical path tend to untwist, leading to higher mobility. Lord et al. studied open end, twist less and ring yarns with 100% cotton and polyester cotton blends and made singly jersey fabrics and assessed their performances for spirality [19]. They found that open end yarn has maximum spirality and zero twisted yarns have minimum or zero spirality. The reason for that is residual torque which is responsible for spirality. Residual torque depends on twist multiple, yarn count, fiber type as well as manner and extent of yarn relaxation. Twist less yarns has no residual torque. Secondly they studied blends and found that polyester cotton yarns have less spirality and that decreases further with steam setting. Finally they took knitted samples and conditioned them to measure spirality. The conclusion was washing, heating, agitating and dry tumbling result in decrease of angle of spirality. This is due to moisture absorption by fibers and swelling of fibers. Another interesting fact was with three weeks of fabric stacking in dry relaxed form, angle of spirality increased by 7 degrees. There seems to be considerable advantage in autoclaving the yarns to kill the torque, waxing appears to provide no advantage in that regard [19]. In contrast to Lord's work, David H Black said that in altogether different manner, he did his experimental work by using open end and ring spun yarn and produced warp knitted fabrics. Open end yarns are usually produced with higher twist multiples and this is necessary as the open end yarns require higher strengths and these can be only obtained by inserting higher values of twist. He studied the fabric results to see the spirality results. They found the interesting value of spirality as OE fabrics gave lower value of

spirality before finishing than the ring fabrics and found the results that due to difference of conditioning in spinning plant, this variation was observed [20]. Sharma et al. took different counts and produced single jersey fabrics. Their work was different in the sense that they concentrated on manmade fiber for their research [21]. The used grasic rimp yarn for the first time which is a manmade high performance cellulosic origin fiber with high pronounced properties. They found after their work that, the angle of spirality increases with twist factor. They also concluded that spirality increases in wet relaxed state [21]. Arujo and Smith used 100% cotton yarn with variable techniques for production of knitting fabric and then concluded certain things [22]. According to them, as TM increases angle of spirality increases, similarly angle of spirality increases with residual torque. According to practical implementation of techniques, yarn dyeing was found as a promising way to reduce spirality; this was due to moisture absorption. Moisture absorption acts as secondary thermal transition in fibers by causing dry, rigid hydrogen bonded structure into unbounded and mobile. They concluded that the major causes are yarn twist instability and the number of feeds of knitting machine. According to their study, hot treatment of yarns before knitting results in decreasing spirality. Their conclusion was the use of yarn with twist direction opposite to feeder helps in decreasing spirality. In addition to that plied yarn and plaiting techniques were suggested to reduce the spirality. They produced a three ends fleece fabric with substantially reduced spirality to prove their hypothesis that balancing the twist results in reduction of spirality [22]. Another study Primentas, used ring spun Z twisted yarn with different tex counts and twist per cm to produce single jersey knit fabric [23]. He tested the specimens for spirality and found that the main reason for spirality was balance as well as residual torque of yarn as major reasons for spirality. He concluded that more is the twist liveliness more will be spirality [23]. Palaniswamy and Mohamed, worked on 50/1 combed cotton yarn, made a tow ply yarn and varied the amount of twist in the yarns, produced single jersey knit fabric with the ply yarns which were 100% cotton [24]. They found that two ply yarn with $\frac{1}{2}$ of single yarn twist do not show spirality whereas fabric produced with two ply yarn $\frac{1}{3}$ and $\frac{3}{4}$ single yarn twist show spirality in Z and S direction respectively and magnitude of spirality when measured in wet relaxed condition was found to be increasing. The reason is, when yarn is dry, most of bending, torsional and tensional strains are locked in by fiber to fiber frictional forces that is the inter fiber binding forces, but when the same yarn that was observed in dry state, was dipped in water, water penetrates between the fibers causing a weakening of the inter fiber forces and raises all the resultant stresses [24]. TY LO, studied yarn counts ranging from 17 to 31 Tex with a yarn twist ranging from 3.2 to 4.2, and studied that Wales carry spirality in any case. As in zero spirality means, the wale line and course line make a perpendicular angle that is a 90 degrees angle with each other. It is known that smaller the wale spirality better will be resultant spirality of fabric. He categorized different angles of spirality as per acceptance of standards of the fabric. He studied the fabrics after washing and found wale spirality to be increasing. He concluded his work as every fabric has a wale spirality and his study shown that half of the specimens were unaffected by the washing [24].

Conclusion

Main reason of spirality in knit wear fabrics is the presence of residual torque. This residual torque is responsible for loop displacement, formation of skew. There are other contributing factors too but the major factor is residual torque. The problem of spirality was studied under two of its major causes which are fiber causes and yarn

causes. These two causes were studied in detail to see the impact and elimination or reduction method. The key conclusions are:-

- As far as the reference of fibers is concerned, it is quite evident that spirality is more commonly found with cotton fibers so use of blends with cotton will reduce the spirality to certain extent.
- Fibers blended with different values of flexural and torsional rigidity when used in fabric or yarn formation produce better results against single nature of fibers.
- Fibers that can be heat set should be used for knitting fabrics as heat setting results in gelling up of the fibers with the blended fibers giving it a stiffer feel and that helps in reduction of spirality.
- Thermoplastic fibers should be preferred over other fibers for the reduction of spirality.
- Air jet spun yarns exhibit better performance against spirality problem than the other spinning techniques for yarn production so recommendation should be use of air jet spun yarns.
- Low twist yarns should be used for knitting as higher the twist is, more is the tendency of yarn to untwist, this will lead to significant snarling effect and high dimensional instability will be seen in case of high twist yarns.
- Fabrics produced with spun yarns are better against the spirality as compared to continuous filament yarns.
- Plied yarns are better against the spirality behaviour than the single yarns.

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