DIMENSIONAL STABILITY OF COTTON FABRIC WITH EMPHASIS ON SPIRALITY: BETWEEN THE THEORY AND THE PRACTICE

Alaa Arafa Badr
Department of Polymer and Fiber Engineering - Auburn University
Auburn, AL
Elsayed El-Helw
Ibrahim El-Hawary
Abo Baker Mito
Alexandria University
Alexandria, Egypt
Yehia Elmogahzy
Ramsis Farag
Department of Polymer and Fiber Engineering - Auburn University
Auburn, AL

Abstract

This paper focuses on fabric spirality as a key aspect of weft knit dimensional stability. Two key issues are discussed: (a) comparison between different standard methods of fabric spirality, and (b) cause and effect analysis of fabric spirality in the context of the effects of cotton fibers, spinning systems, and yarn structures. These issues are part of a much larger study in which the spirality phenomenon is modeled using qualitative and quantitative approaches and extensive experimental trials were made to verify the models. The results of these analyses will be reported in future papers.

Introduction

One of the key aspects of knitting is to produce a stabilized knit structure. Most knit fabrics can suffer dimensional instability due to numerous reasons or causes. This instability is particularly noticed upon use of knitting garments and after repeated washing and drying. In some cases, repeated laundering can indeed cause fabric distortion. For this reason, knitted garments must be handled carefully during washing and drying and even during storage.

Dimensional instability of knit fabrics can be attributed to numerous causes [Munden, 1963, Munden, 1967, Anand, et al., 2002], some of which are yarn-related, others are knitting-related, and some can be finishing-related. In connection with yarn, raw material is a key factor in determining fabric dimensional stability. This is, indeed, for both woven and knit fabrics. When cotton is the primary raw material, stabilization of knit structure becomes difficult as cotton is a non-thermoplastic fiber and cannot be heat set to stabilize knit fabric dimension. Therefore, natural relaxation of knit fabrics made from cotton yarns is inevitable after knitting, resulting in changing fabric dimensions. This change will depend on the nature and the amount of stress and extension applied on the yarns during knitting. As a result of the dimensional changes of cotton knit fabric upon knitting, it is typically difficult to measure its structural attributes and dimensional stability parameters (e.g. shrinkage, fabric skew, and fabric torquing or spirality) at the grey state.

In contrast with woven fabrics, knitted cotton or polyester/cotton blended fabrics are expected to posses closer fit on human body. However, since yarns in knit fabric are placed under high stresses during knitting and finishing, the fabric is likely to stretch and undergo mechanical deformation during regular use. To make matters additionally complex, internal stresses in the yarns are both in planar and in three dimensions (off fabric plane). Typically, when the fabric is taken off the machine, a great deal of yarn torsion and stretch are generated and the fabric is released in a highly distorted state. In some situations, knitted fabric may never fully recover from these strains. In addition, the strains can be multiplied during use.

Analysis of knit dimensional stability requires fundamental understanding of a number of key aspects. These are: (1) standard knit loop geometry, (2) fabric shrinkage, (3) fabric skew (spirality), (4) machine effects, and (5) yarn effects. In this paper, our focus will be on fabric spirality. The two key aspects discussed here are: (a) comparison between different standard methods of fabric spirality, and (b) cause and effect analysis of fabric spirality in the context of the effects of cotton fibers, spinning systems, and yarn structures.

Weft knit Spirality

One of the key measures determining the dimensional stability of a knit fabric is course/wale alignment. Basically, it is necessary that the wale on the knitted fabric be perpendicular to the course. When this geometrical feature is violated, the fabric will suffer a skew to the right or left. This phenomenon is called "fabric spirality" and it is often observed in cotton single jersey knits, where the fabric exhibits a tendency for the course and wale loops to skew when allowed to relax. Terms such as "fabric skew", "fabric torque" are also used to describe fabric spirality. Figure 1 illustrates comparison between a normal fabric and a skewed fabric in both wale and course direction.

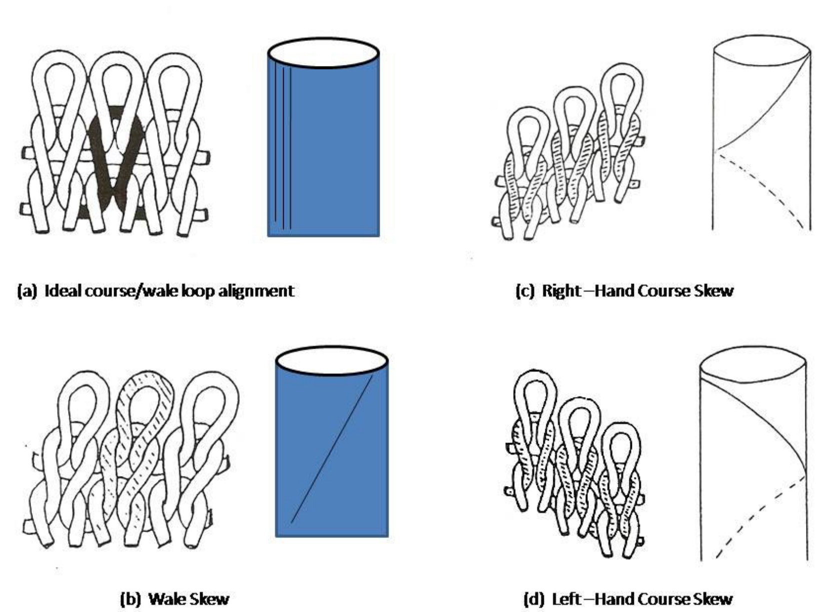

Figure 1. Simple Illustration of Fabric Skew [4]

Comparison between Different Methods of Testing Fabric Spirality

As indicated earlier, fabric spirality is observed in cotton single jersey knits, where the fabric exhibits a tendency for the course and wale loops to skew when allowed to relax. For measuring the spirality in knitted fabrics, there are different standard methods used to determine the percentage of Spirality. It was important, therefore, to begin the analysis of this study by evaluating the different standard testing methods used for characterizing and measuring fabric spirality. These methods are:

1. ASTM D 3882-99: 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

In order to compare these methods, we used two sets (A and B) of single-jersey fabric, one made from ring-spun of Ne = 36's and the other from ring-spun of Ne = 50's. These were commercial fabrics in which lycra yarns were inserted to provide stretchability. These samples were collected by the investigators in trials made at Kabo Company, Alexandria, Egypt. In these two sets of fabric, loop length was changed through applying two steps: (1) Changing the feeding rate of the feeding yarn. This was accomplished through changing the diameter of the feeding pulley and also by changing the gear giving the motion to the feeding pulley, and (2) Changing the height of the knitting cam track inside the knitting machine with keeping cotton yarn tension at 5 gm. As a result the length of the produced loop will be changed. The working loop lengths for these experiments were 2.75, 2.85, 2.95, 3.05 and 3.15 mm. The machine and yarn specifications for these samples group are shown in Tables 1, 2.

Table 1. Knitting Specifications

Machine type	Single Jersey
Fabric type	Single jersey with Lycra
Manufacturer	M&Cie
Model	4 II
Gauge (Needles/inch)	24
Diameter (Inch)	30
No of feeders	96
No of needles	2268
No of tracks	4

Table 2. Yarn Specifications

	Set A	Set B
Yarn Count	36/1	50/1
Yarn Strength (g/tex)	15.48	19.19
Elongation (%)	4.47	5.36
Twist (TPI)	21.31	26.84
Twist Multiplier	3.50	3.76

Correlation analysis between spirality values obtained by different standard testing methods was performed. The results of this analysis are shown in Tables 3 through 6. Corresponding scatter plots associated with the correlations for bleached fabrics are shown in Figures 2 and 3. These results clearly indicate that different standard methods yield highly correlated values despite the different approaches taken. Correlations for bleached fabrics are higher than those for grey fabrics.

Table 3. Correlation Matrix of Spirality Measures by Different Standard Methods (Grey-Single Jersey with Lycra Samples, Ne =36's taken over 5 different washing cycles)

	Spirality% ASTM-G	Spirality% ISO- G	Spirality% AATCC- G
Spirality% ASTM-G	1	0.9821	0.9615
Spirality% ISO- G	0.9821	1	0.969
Spirality% AATCC- G	0.9615	0.969	1

Table 4. Correlation Matrix of Spirality Measures by Different Standard Methods (Grey- Single Jersey with Lycra Samples, Ne = 50's taken over 5 different washing cycles)

	Spirality% ASTM-G	Spirality% ISO- G	Spirality% AATCC- G
Spirality% ASTM-G	1	0.9726	0.8854
Spirality% ISO- G	0.9726	1	0.8757
Spirality% AATCC- G	0.8854	0.8757	1

Table 5. Correlation Matrix of Spirality Measures by Different Standard Methods (Bleached Single Jersey with Lycra Samples, Ne =36's taken over 5 different washing cycles)

	Spirality% ASTM	Spirality% ISO	Spirality% AATCC
Spirality% ASTM	1	0.9948	0.9786
Spirality% ISO	0.9948	1	0.9745
Spirality% AATCC	0.9786	0.9745	1

Table 6. Correlation Matrix of Spirality Measures by Different Standard Methods (Bleached Single Jersey with Lycra Samples, Ne = 50's taken over 5 different washing cycles)

	Spirality% ASTM	Spirality% ISO	Spirality% AATCC
Spirality% ASTM	1	0.9929	0.9477
Spirality% ISO	0.9929	1	0.9532
Spirality% AATCC	0.9477	0.9532	1

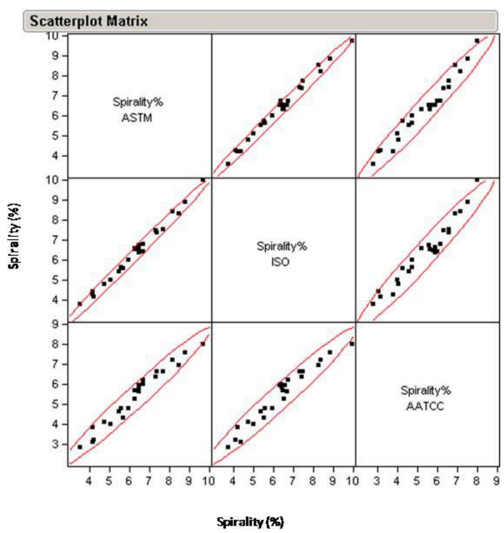

Figure 2. Scatter Plot Matrix of Spirality Measures by Different Standard Methods (Bleached Single Jersey with Lycra Samples, Ne =36's taken over 5 different washing cycles)

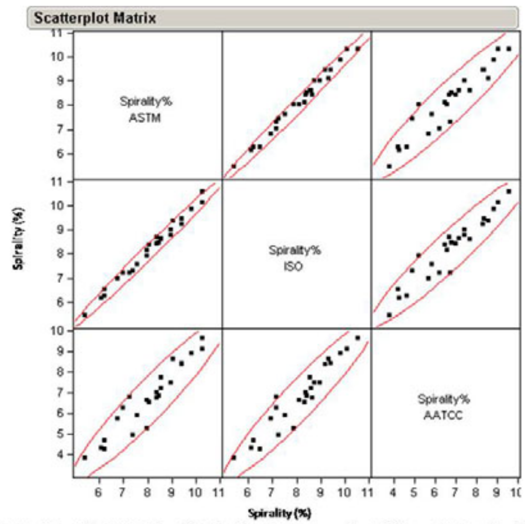

Figure 3. Scatter Plot Matrix of Spirality Measures by Different Standard Methods (Bleached Single Jersey with Lycra Samples, Ne = 50's taken over 5 different washing cycles)

Cause & Effect Analysis of Fabric Spirality

The ultimate benefit of studying the spirality phenomenon is to understand the various factors influencing the dimensional stability of knit fabrics, particularly fabric spirality so that ways to select appropriate levels of these factors that result in optimum dimensional stability can be established. This can be achieved through a cause and effect analysis of the various potential factors influencing fabric spirality. The importance of cause and effect analysis stems from the fact that several theoretical approaches were taken to analyze the spirality phenomenon, yet because of the complexity of the phenomenon, each study focused on a limited number of factors, either for the sake of simplifying the analysis, or due to limited ability to verify the theory using experimental approaches. Other studies dealt with the analysis of spirality from strictly experimental view by examining the effects of a number of factors some of which were machine-related and others were fabric-related on the extent of spirality of knit structures. Obviously, these approaches resulted in many common causes and effects of this critical phenomenon. However, these were scattered in the bulk of literatures presented to such an extent that makes it difficult for researchers to have a complete view of all factors that can potentially result in an increase or a reduction in knit fabric spirality. It was important, therefore to perform this analysis in this study by examining causes and effects of fabric spirality on the basis of observations obtained in this study as well as the findings of the massive literatures available. Figure 4 shows the various causes of fabric spirality and they are divided into four main categories: yarn causes, knit causes, fiber causes, and finishing causes. In this paper, the focus will only be on yarn causes and fiber causes.

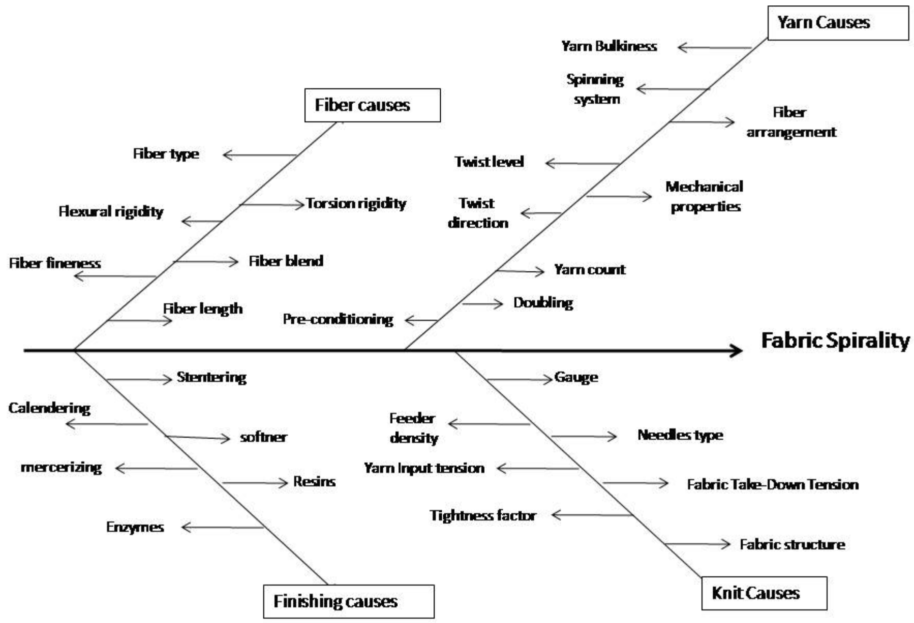

Figure 4. Cause & Effect Diagram of Fabric Spirality

Yarn-Related Causes and Effects of Fabric Spirality

Reviewing the various yarn-related causes and effects presented in various theoretical and experimental studies of the spirality phenomenon clearly indicate that this phenomenon is substantially a yarn-related phenomenon. Indeed, a virtually spirality-free fabric can be made using optimum levels of yarn parameters influencing fabric spirality. As shown in Figure 4, key yarn-related factors influencing knit spirality are: spinning system, yarn bulkiness, fiber arrangement, yarn twist, twist direction, yarn mechanical properties, yarn count, doubling or plying effects, and yarn conditioning. Figures 5 and 6 illustrate these causes of fabric spirality.

Spinning System

Yarns used for knit fabrics can be made from different spinning systems. They can be made from continuous-filament yarns produced via extrusion methods, or from staple-fiber yarns produced via consolidation of staple fibers. In the latter category, the main types of spinning are: ring spinning, open-end spinning, air-jet spinning, and friction spinning. Different spinning systems produce uniquely different yarn structures that can have different effects on fabric physical characteristics and dimensional stability. In the context of fabric spirality, key structural parameters are: yarn density (bulkiness), fiber arrangement, yarn twist, and yarn mechanical properties. These parameters vary substantially between different spinning systems and they can also be varied within a given spinning system. Thus, a cause and effect analysis of the effect of the spinning system should be based on analysis of these effects of these parameters as discussed in the following sections.

Experimental observations of yarns of different spinning systems [Araujo and Smith, 1989] revealed that fabrics made from continuous filament yarns exhibit less spirality than those made from spun yarns. Among the different spun yarns, fabrics made friction-spun yarns has the highest spirality levels, followed by those made from ring-spun yarns, then from open-end spun yarn, and finally from air-jet spun yarns. Explanations of these trends can be made on the basis of the unique structural features of the yarns made from these spinning systems (see Figure 5).

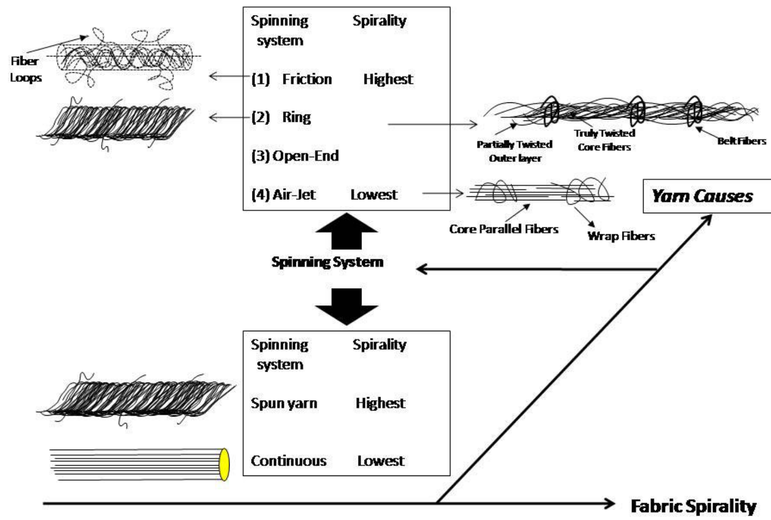

Figure 5. Spinning-Related Causes of Fabric Spirality

Yarn Bulkiness

Knit fabrics are typically formed by forming yarn loops and interlacing these loops to form a fabric network. To form a loop, the yarn must be bent easily and interlacing must done at minimum yarn resistance. These are requirements for a well-defined and smooth loop curvature. Bulkier yarns can satisfy these requirements *as bulkiness eliminates sharp bending and improve structure resiliency, ease of stretch and recovery during* use [Black, 1975,Coban, 1989]. Certain bulkiness levels of yarns can be achieved through three basic design options: spinning system, yarn structure, and yarn compounding.

Different spinning systems produce different levels of yarn bulkiness by virtue of the differences in the consolidation principles and the fiber arrangements associated with these systems. In general, staple fiber yarns and textured yarns normally have lower density (or higher bulkiness) than flat continuous filament yarns made from the same fiber material [Munden, 1967]. In addition, different spinning techniques produce different degrees of yarn density as a result of the different patterns of fiber compactness imposed by yarn twisting and spinning tension. For instance, a ring-spun yarn will typically exhibit higher degree of compactness (lower bulkiness) than a comparable rotor-spun yarn due to the true twist the high tension used in ring spinning.

The extent of fiber compactness can also be altered within the same spinning system through alteration of yarn structure, or the degree of tightness of fibers in the yarn via twisting (as in ring or open end spinning) or wrapping (as in air-jet spinning). A yarn made from fine fibers is likely to be denser (less bulky) than a yarn of the same count made from coarse fibers. A yarn made from fibers of rounded cross-sectional shape is likely to be denser (less bulky) than a yarn of the same count made from fibers of trilobal or triangular cross-sectional shapes. In ring spinning, higher twist levels and higher spinning tension result in greater yarn compactness (low bulkiness). In open-end spinning, higher rotor speed is likely to produce higher fiber compactness in the yarn due to the higher centrifugal force applied on the fibers inside the rotor. Furthermore, the introduction of compact ring spinning has resulted in better compactness of fibers in the yarn [El Mogahzy and Chewning, 2001].

Yarn compounding is the process of making bi-component, multi-component, or fancy yarns including sheath-core yarns or doubled yarns. This process can yield different bulkiness levels, which should be called macro-bulkiness to distinguish them from the methods of controlling bulkiness discussed above that can collectively be called micro-bulkiness methods.

In the context of fabric spirality, since bulkier yarns eliminate sharp bending of the knit loop and allow interlacing at minimum yarn resistance, a smooth loop curvature can be obtained, and greater fabric tightness can be achieved. These effects result in a reduction in fabric spirality. A high tightness factor yields lower spirality on the ground that high tightness factor provides less freedom of yarn mobility. High yarn bulkiness also results in greater fabric area shrinkage with wet and full relaxation treatments, greater fabric thickness, and bulkier fabric. The higher area shrinkage values of fabric result in greater stitch density.

Fiber Arrangement

Different spinning systems result in different fiber arrangement by virtue of the way fibers are consolidated into a yarn structure. In general, straighter and more un-deformed fiber arrangement will result in smaller tendency for fabric spirality. Fibers aligned in straight fashion (e.g. continuous filament yarns) are likely to exhibit lower mobility energy in the fabric (no tendency to untwist or move off the yarn body). This should result in lower tendency of fabric spirality. Fibers aligned in a helical path tend to untwist, leading to higher mobility, and higher tendency for fabric spirality. Previous studies of the effect of spinning type revealed that friction-spun yarn fabrics exhibit the highest spirality, followed by ring-spun, open-end, and air-jet spun yarns [El Mogahzy and Chewning, 2002, Sharma et al., 1996, Araujo and Smith, 1996]. This order was applicable for the dry relaxed and fully relaxed states. The author attributed this trend to yarn bulkiness and to the twist levels in the yarns. From a fiber arrangement viewpoint, friction-spun yarns exhibit many truly-twisted fibers and many other fibers that are taking loop shapes in the yarn. This creates the largest opportunity of yarn mobility and the greater tendency for fabric spirality. Ring-spun yarn has a great deal of fibers that are truly twisted in a helical path, increasing the spirality tendency or twist liveliness. Open-end spun yarn has fibers that are truly twisted (in the core) and other fibers that are partially twisted (outer fibers). The presence of belt fibers surrounding the yarn body limits the spirality tendency. Air-jet spun yarn is uniquely different from other spun yarns since it does not have twisted fibers; only straight fibers in the core (most of the fibers), and few fibers wrapping around the yarn body.

Yarn Twist

If there is one common factor in all theoretical and experimental analyses of fabric spirality that is considered the most critical in relation to fabric spirality, it is the yarn twist. In general, knit yarn typically requires lower twist than woven yarns; this is a fact known to all technologists. From a quality viewpoint, lower twist yields softer and more flexible fabric which is a basic necessity of knit structure. From a cost viewpoint, it is well known that lower twist is associated with lower cost. Occasionally, however, higher yarn twist is required on the ground that some knit structures may require stronger yarns for good integrity. High twist levels result in yarns that exhibit high inherent torsion energy as a result of their great tendency to untwist. This results in significant snarling effect, and high liveliness, consequently, poor dimensional stability.

The influence of yarn twist is more pronounced when one considers the behavior of a knit loop in the third dimension or off the fabric plane. Typically, a yarn loop, being formed by a combination of bending and tension, will have a tendency to be raised off the fabric plane. The reason for this tendency is that when a loop is bent in third dimension, for interlacement of loops the arms of the loop are twisted in opposite directions [Doyle, 1952, Doyle, 1953, Bhat, 2003] . The difference in twist between the two arms will vary with yarn count and nominal twist, but it can be significantly high (e.g. 5 to 10 turns per inch). This significant difference in twist and the external stress on the loop can result in loop deformation and dimensional instability. Variations in yarn twist can complicate this instability as a result of the random behavior associated with these variations. Since this variation is higher at smaller yarn lengths, by the finding of this study, also higher for coarser yarn count, appropriate ways to reduce twist variability will be required to reduce fabric spirality.

One of the points raised in previous studies in connection with twist is whether it is the twist level that has the true effect on fabric spirality or is it the twist liveliness, as defined by yarn snarling, or the tendency of yarn to untwist. This point was addressed in many studies, and the common conclusion is that yarn twist is linearly related to twist liveliness. For example, in a previous study by El mogahzy et al [El Mogahzy and Chewning, 2001], it was concluded that the higher the twist multiplier in both ring and open-end spun yarns, the higher the twist liveliness values and that the relationship between the two is a linear relationship with a correlation coefficients reaching 0.96 for ring spun yarns and 0.92 for open end spun yarns. One explanation of this strong relationship is the amount of energy stored due to twisting.

The effect of twist was used to interpret many aspects of fabric spirality. For example Srinivasan et al [Srinivasan et al., 2007] explained the reasons why the change in loop length of fabrics made from micro-denier fibers (less than 1 denier) is much lesser than that of fabrics made from normal denier fiber on the ground that the twist in the micro-denier yarns is typically much lesser than that of normal-denier yarns. This factor contributes to the better dimensional stability of the micro-denier fabric. Furthermore, the lower lint-shedding propensity and lesser hairiness result in lower strain imparted on micro-denier yarns, leading to a better dimensional stability. In Srinivasan et al study, identical single jersey knitted fabric structures were kept for both micro-fiber and normal fibers to study the influence of micro-fibers on single jersey knitted structures.

Under optimum conditions, fine yarns exhibit higher twist levels than coarse yarns. This should result in higher fabric spirality for fabrics made from fine yarns. However, when fine and coarse yarns are made at the same levels of twist, this trend is reversed; coarse yarns will result in greater fabric spirality than fine yarns. According to Tao et al [Tao et al., 1997] , this can be explained on the ground that a coarse yarn has more fibers per yarn cross-section than a fine yarn, thus requiring a higher torque to form if the twist angles are identical for both coarse and fine yarns (identical twist multiplier). Araujo et al [Araujo and Smith, 1999] explained the difference in spirality levels caused by different spinning systems on the basis of the twist levels expected from these systems. For example, friction spinning typically requires higher twist levels than ring spinning, leading to higher levels of spirality. Air-jet spinning and open-end spinning, on the other hand, require low twist levels.

Twist Direction

Twist direction is another critical aspect of twist. The effect of twist direction on fabric spirality will depend on the direction of machine rotation [Knit Fabrics, 2002]. For machines rotating in counterclockwise direction, yarns made using Z twist direction yielded fabric of lower spirality than those made using S direction. Air jet spun yarn made on S twist direction yielded higher fabric spirality than that made on Z direction. When Z and S twisted yarns are alternated, substantial reduction in fabric spirality was obtained. In principle, the skew caused by one set of yarn is countered by that of the other set. The results also indicate that Z-twisted yarns made on a CCW machine rotation give less spirality than Z-twisted yarns made on a CW machine.

The effect of twist direction can also be realized when yarns are doubled or plied for knitting. Doubled yarns are expected to yield lower fabric spirality than single yarns. This however will depend on the twist direction of each yarn. Different twist directions in the single yarns will result in a more balanced fabric [Knit Fabrics, 2002].

Yarn Surface integrity (Friction)

In weaving, warp yarns are treated via chemical coating in a process called “sizing” to improve yarn surface integrity, thus, reducing hairiness and increasing abrasion resistance during weaving. One of the adverse side effects of sizing for woven yarns is the significant loss of flexibility or elongation, as sized yarn is typically very stiff due to the coating effect. In knitting, sizing is not required because it is not possible to lose yarn flexibility or yarn elongation. In addition, the stresses applied on the yarn and the rubbing effects during knitting are much milder than those in case of weaving.

Instead of sizing, knit yarns are sometimes treated with a wax material to ease their rubbing effects during knitting by preparing a yarn of lower coefficient of friction. In addition, wax coating reduces the effect of hairiness and fly generation during knitting. The primary measure of wax effectiveness is the yarn coefficient of friction. Depending on the friction method used, static friction test gives typical friction coefficients of cotton yarns in the range from 0.23 to 0.3 depending on fiber material, yarn type, twist level, and yarn diameter[15]. Waxed yarns can typically have values in the range from 0.14 to 0.24.

In the context of dimensional stability, an optimum friction is critical for stable loop geometry. In addition, high variation in friction can certainly change knitting tension and loop dimensions. The sensitiveness of knitting process and loop dimension to yarn friction is well established [Banerjee and Bhat, 2005] .

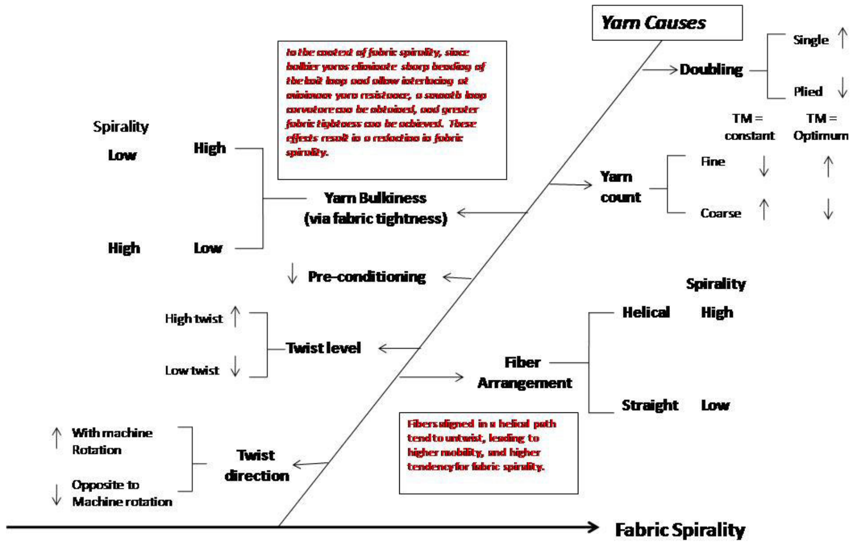

Figure 6. Key Yarn Properties influencing Fabric Spirality

Fiber-Related Causes and Effects of Fabric Spirality

Figure 7 shows the cause and effect diagram of fiber-related causes of fabric spirality. Discussions of these causes are presented below.

Fiber Type

Different fibers are likely to behave differently in knit structures through their different effects on the knitting process and yarn properties. This point is illustrated below.

Fiber Flexural and Torsion Rigidity

The fact that knit loops are formed via bending and interlacing makes it natural to consider the flexural rigidity (resistance to bending) and the torsion rigidity (resistance to torquing) of the fiber, which directly influence the mechanical properties of the yarn. These two factors were found to significantly influence knitting tension and loop dimension [Postle et al., 1964] .
The flexural or bending behavior of fiber can be expressed by the following equation [Morton and Hearle, 1964] :

$$FR = \frac{1}{4\pi} \cdot \frac{k . E . T^2}{\rho} 10^{-3} \ gwt.cm^2 \qquad (1)$$

where E is the tensile modulus, T is the tex, ρ is the fiber density in g/cm^3, and k is a shape factor of a value of unity for circular cross-sections. Table 7 shows values of flexural rigidity of some textile fibers.

Table 7. Typical Values of Flexural Rigidity of Textile Fibers [Morton and Hearle, 1964]

Fiber	Flexural Rigidity (g/denier)
Cotton	60-70
Viscose Rayon	4-30
Wool	3.5
Flax	175
Polyester	40-65

Torsion rigidity can be expressed by the following equation [Morton and Hearle, 1964]：

$$TR = \frac{\varepsilon . G . T^2}{\rho} \ gwt. cm^2 \qquad (2)$$

where G is the shear modulus, T is the tex, ρ is the fiber density in g/cm^3, and ε is a shape factor of a value of unity for circular cross-sections. Table 8 shows values of torsion rigidity of some textile fibers.

Table 8 Typical Values of Torsional Rigidity of Textile Fibers [Morton and Hearle, 1964]

Fiber	Specific Torsional Rigidity , TR (g-wt cm^2/tex^2) x 10^{-4}	Shear Modulus x 10^{10} dyn/cm^2
Cotton	7.9	2.51
Viscose	4.7	1.10
Wool	6.7	1.11
Flax	5.8	1.32
Polyester	4.7	0.9

Based on equations 1 and 2, as well as Tables 7 and 8, different fibers certainly exhibit different values of both flexural and torsion rigidity. The key fiber parameters influencing rigidity are density, diameter, and cross-sectional shape. Among these, the diameter has the greatest impact. Indeed, by virtue of equations 1 and 2, torsion and flexural rigidity are proportional to the diameter of a power 4. This concept extends also to the yarn. For a given fiber type, parameters such as fiber fineness, twist level, and yarn count can significantly influence rigidity. In addition, a yarn that is flexible, easy to bend, and easy o twist, will likely to make a soft and flexible fabric. However, the problem is to maintain a balance, as too much flexibility (very low torsion and flexural rigidity) can easily result in loop distortion during knitting, and too low flexibility can result in a stiff and harsh fabric against human body; it can also result in significant fabric skew, particularly when rigidity is increased via increasing yarn twist.

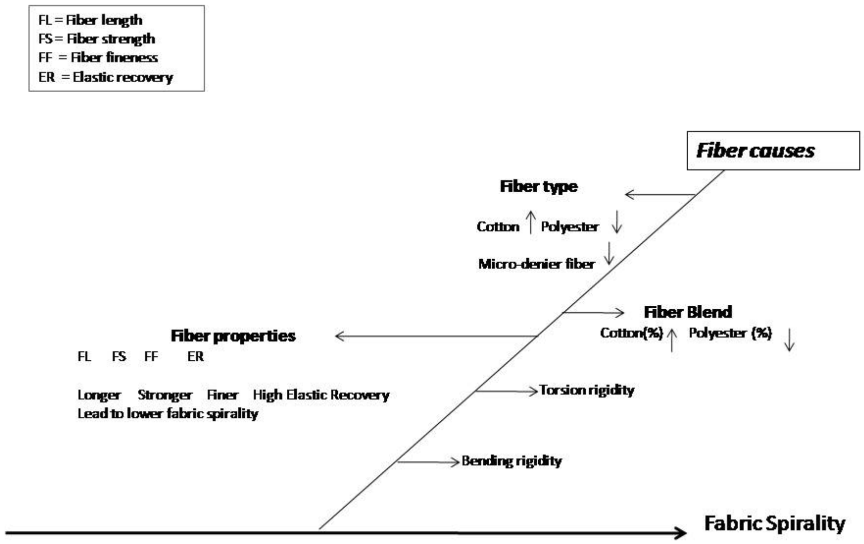

Figure 7. Key Fiber Properties influencing Fabric Spirality

Conclusions

This paper is a part of a larger study focusing on the phenomenon of fabric spirality. Two key issues were addressed: comparison of standard methods used to determine fabric spirality, and cause and effect analysis of fabric spirality. The key conclusions are as follows:

1. Different standard methods yield highly correlated values despite the different approaches taken. Correlations for bleached fabrics are higher than those for grey fabrics.

2. Key yarn-related factors influencing knit spirality are: spinning system, yarn bulkiness, fiber arrangement, yarn twist, twist direction, yarn mechanical properties, yarn count, doubling or plying effects, and yarn conditioning

3. Fabrics made from continuous filament yarns exhibit less spirality than those made from spun yarns.

4. Among the different spun yarns, fabrics made friction-spun yarns has the highest spirality levels, followed by those made from ring-spun yarns, then from open-end spun yarn, and finally from air-jet spun yarns.

5. Since bulkier yarns eliminate sharp bending of the knit loop and allow interlacing at minimum yarn resistance, a smooth loop curvature can be obtained, and greater fabric tightness can be achieved. These effects result in a reduction in fabric spirality.

6. A high tightness factor yields lower spirality on the ground that high tightness factor provides less freedom of yarn mobility.

7. High yarn bulkiness also results in greater fabric area shrinkage with wet and full relaxation treatments, greater fabric thickness, and bulkier fabric. The higher area shrinkage values of fabric result in greater stitch density.

8. High twist levels result in yarns that exhibit high inherent torsion energy as a result of their great tendency to untwist. This results in significant snarling effect, and high liveliness, consequently, poor dimensional stability and high fabric spirality.

9. For machines rotating in counterclockwise direction, yarns made using Z twist direction yielded fabric of lower spirality than those made using S direction.

10. Air jet spun yarn made on S twist direction yielded higher fabric spirality than that made on Z direction. When Z and S twisted yarns are alternated, substantial reduction in fabric spirality was obtained.

11. Doubled yarns are expected to yield lower fabric spirality than single yarns. This however will depend on the twist direction of each yarn. Different twist directions in the single yarns will result in a more balanced fabric.

12. Different fibers are likely to behave differently in knit structures through their different effects on the knitting process and yarn properties.

13. Different fibers certainly exhibit different values of both flexural and torsion rigidity. This leads to different levels of fabric spirality.

14. The key fiber parameters influencing rigidity are density, diameter, and cross-sectional shape. Among these, the diameter has the greatest impact.

References

Araujo M. D. De, Smith G., "Spirality of Knitted Fabrics", Part II: the Effect of Yarn Spinning Technology on Spirality, Textile Research Journal, P350-356, June 1989.

Banerjee, P.K. and Prabhakar Bhat, Torsional Properties of Cotton Yarns, IJFTR, March 2005.

Black, D. H., Knitting with Cotton and Cotton Blend Open-End Spun Yarns, Textile Res. J. 45, 48-53 (1975).

Coban, S., Opportunities for Keeping the Dimensional Stability and Shrinkage of Knitted Fabrics, Tekstil Tek. 4, 67-75 (1989).

Doyle. P. J., Fundamental Aspects of the Design of Knitted Fabrics. J. Textile Inst. 4(84), 561-578 (1953).

Doyle, P. J., Some Fundamental Properties of Hosiery Yams and Their Relation to the Mechanical Characteristics of Knitted Fabrics. J. Textile Inst. 43, 19-35 (1952).

J. Srinivasan, G. Ramakrishnan, S. Mukhopadhyay and S. Manoharan, "A Study of Knitted Fabrics from Polyester Microdenier Fibres", JOTI, Vol. 98 No. 1, pp. 31–35, 2007.

Knit Fabrics and The Reduction of Torque-Technical Bulletin, Cotton Incorporated, TRI 2002.

Morton, W. S., and Hearle, J. W. S., Physical Properties of Textile Fibers, The Textile Institute-Butterworths, Manchester and London, 1962.

Munden, D. L., Geometry of Knitted Structures, Textile Inst., Review of Textile Progress, Vol. 14, 250-256, 1963.

Munden, D. L., Geometry of Knitted Structures, Textile Inst., Review of Textile Progress, Vol. 17, 266-269, 1967.

Postle, R., Burton, P., and Chaokin, The Torque in Twisted Singles Yarns, Journal of Textile Institute, 55, T448, 1964.

Prabhakar Bhat, A Study on the Role of Yarn Properties in Double Jersey Loops, Ph.D. Thesis, Dept. of Textile Technology, IIT Delhi, 2003.

S. C. Anand, K. S. M. Brown, L. G. Higgins, D. A. Holmes, M. E. Hall and D. Conrad, Effect of Laundering on the Dimensional Stability and Distortion of Knitted Fabrics, AUTEX Research Journal, Vol. 2, No2, June 2002.

Sharma I. C., Mukhopadhyay D., and Agarwal B. R., “Feasibility of Single Jersey Fabric From Open End Spun Blended Yarn”, Textile Research Journal, P249 – 253, April 1996.

Tao X. M., Lo K., and Lau Y. M., “Torque Balanced Singles Knitting Yarns Spun by Unconventional Systems”, Part I: Cotton Rotor Spun Yarn, Textile Res. J. 67(10), 739-746 (1997).

Yehia Elmogahzy, and Charles Chewning, “Fiber To Yarn Manufacturing Technology", Cotton Incorporated, Cary, NC, U.S.A, 2001.