Determination of Spirality in Knitted Fabrics by Image Analyses

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Abstract
Spirality is a problem in knitted fabrics, especially in the apparel industry. Even though aspects of spirality have been studied in the literature, no papers have appeared which explicitly determine the angle of spirality in knitted fabrics. Therefore, the goal of this study is to develop an algorithm to determine the angle of spirality using image analyses. The proposed algorithm has yielded fast and accurate results.

Key words: spirality, knitted fabrics, image analyses.

Introduction
It is necessary that the wale on the knitted fabric be perpendicular to the course. However, the wales are not always perpendicular to the course and skew to the right or left, forming a spirality angle as seen in Figure 1 [1, 3]. This creates a serious problem, especially in the apparel industry.

The spirality problem has been investigated by several researchers [1-5]. Araujo and Smith [1, 2] studied the effect of machine, yarn and fabric properties on the fabric spirality. They determined that spirality depends on machine cut, feed density, machine rotation direction, loop shape, yarn twist value (twist liveliness) and yarn twist direction. They suggested using S-twist yarns in machines rotating counterclockwise and Z-twist yarn in machines rotating clockwise. Plied yarns, plating techniques and yarns with different twist directions can be used to solve or reduce this problem. They also presented an empirical model to predict fabric spirality on the fabric. Tao et.al.[3, 4], developed a yarn modification process on rotor-spun and friction-Spun DREF III yarn to eliminate the spirality problem. They concluded that modifying a rotor-spun yarn greatly reduces spirality and improves the fabric handle. However, they also stated that modifying rotor-spun degraded yarn tensile strength, burst strength and fabric pilling. On the other hand, modified friction-spun DREF III yarn reduces yarn snarling and fabric spirality. This modification process has resulted in higher yarn hairiness, fabric weight reduction, an increase in air resistance and reductions in thermal conductivity, yarn tenacity and elongation percentage at break. Banerjee & Alairban [5] have also worked on the spirality problem. They explained that the full relaxation process may decrease or increase spirality, depending on whether the tightness factor of fabric is greater or less than 14.0.

The measurements of spirality on these studies have been carried out by the conventional method. The conventional measuring method takes time, and also depends on human measuring precision. Therefore, in this study, a fast, accurate and objective method has been developed to measure spirality in fabrics by using image analysis techniques which can also be implemented on-line. In the literature, there are several studies to measure the weft and warp yarn placement on woven fabrics by using image analysis techniques [6-9]. Kang et.al. [6] analysed several fabric qualities such as count, cloth cover, fabric thickness, fabric weight, yarn crimp and the orthogonality of the yarn intersecting angle on woven fabric by image processing. They have used the grey values of the minimum points of an average profile in the x and y direction to determine the orthogonality of the yarn intersecting angle. Ravandi & Toriumi [8] measured woven fabric characteristics such as directionality, the density of yarns protruding from the fabric body and yarn spacing, by using an angular Fourier Power spectrum and an/its autocorrelation function for plain weave cotton fabric. Xu [9] applied Fast Fourier Transformation (FFT) on woven fabric

Figure 1. A wale and a course on a knitted fabric.
images to identify weave pattern, fabric count and yarn skewness. Harwood et al. [7] also studied the measurement of the straightness of the weft threads on the back of a woven carpet by analysing the intensity of the signal obtained from a CCD line scan camera and point sensors. Chen et al. [10] studied the detection and classification of defects on woven fabrics using the Fourier transform. In their study, they determined the actual x and y axes of the spectra, because the wefts and warps of the samples are in different directions from that of the x and y axes of the CCD camera. They drew straight lines passing through the centre and having 1° increments. Then, they added the intensity of the power spectrum at every point along each line, until the line with the maximum sum was reached.

All the studies mentioned above focused on the measurement of several woven fabric properties such as weft and warp yarn placement, fabric count, weave pattern, woven fabric skewness, etc. Although several methods have been used to determine skewness on woven fabrics, no study is available in the literature which specifically determines the spirality of knitted fabrics. In general, image analyses of knitted fabrics involve difficulties due to the loop structures and yarn hairiness, compared to woven fabrics consisting of neat warp and weft yarns. Therefore, determining the spirality angle of knitted fabrics using image analyses is quite a challenging problem.

Methods

The cotton-plain-knitted fabric samples used in this study have been prepared as 3×3 cm squares. Images of the samples have been acquired via a scanner and stored as greyscale images of 256×256-pixel resolution. The 256×256-pixel sized images obtained by cropping correspond to a square area smaller than 3×3 cm. Each pixel in the image has a value between 0 and 255, 0 being black and 255 being white. No image filtering has been used.

The proposed method is based on image-processing techniques, specifically the Fast Fourier Transform, for obtaining the directions of the wale and the course in order to measure the angle of spirality.

The first step in the algorithm is to apply the Fast Fourier Transform (FFT) to a two-dimensional discrete function, i.e. the image [9, 10, 11]. By doing so, a power spectrum of the image has been obtained. It is more convenient to observe the power spectrum in terms of logarithmic spectrum [11]. The logarithmic spectrum of a sample fabric image can be seen in Figure 2. The distribution of the peaks in the logarithmic spectrum is related to the direction of wales and courses. The spirality angle can be calculated using this information.

The most visible peaks (white regions) lie in the horizontal direction carrying the information about the periodicity of the wales. Similarly, the most visible peaks which lie in the vertical direction carry the information about the periodicity of the courses. Thus, the lines in the horizontal and vertical directions passing through the most visible peaks and intersecting in the centre have to be determined to lead us to the angle of spirality. Thresholding is applied to pixels of the logarithmic spectrum image so that pixels with intensity values below 128 (in the range of 0-255) are set to 0. This thresholding operation made the most visible peaks more dominant, and prevented false detection of direction. The values of pixels located on a line which passes through the centre peak were summed up by rotating the line in order to find the line with the maximum summation value. The line with maximum summation value represents the direction of the course or the wale.

### Results

10 different plain knitted fabrics with varying fabric properties are used to form 10 groups of data, and 10 samples are prepared for each group. Firstly, the spirality of the fabrics are measured manually [3]. Then, images of all samples are processed with the spirality angle calculating algorithm written in Matlab. The t-test is applied to see the significance of the difference between the measured and calculated spirality angles. The results of the t-test are given in Table 1.

As seen from Table 1, the differences between the calculated and measured spirality angles are not generally greater than one degree. Among 10 sample groups, only 2 groups display significant differences in t-test, and only the last sample group caused incorrect direction detection.

### Conclusion

It can be said that the algorithm is quite satisfactory in determining the angle of spirality in knitted fabrics for 7 groups of fabrics.
fabrics out of 10. In samples with significant differences according to the t-test, the means of measured and calculated spirality angles still differ by about 1.2 degrees. Therefore this algorithm, which is simple, fast, and objective, can be very useful in determining the spirality angle during both laboratory work and manufacturing. Only group 10 appears as a serious problem for the programme, and requires further study.

References


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