Determination of Twist per Inch Value in Doubled Yarns Using Digital Image Processing Techniques.

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Abstract:

The aim of this research paper is to demonstrate the usage of image processing techniques in the determination of twist per inch value for a doubled yarn. In this investigation the coarser counts of 100% pure cotton doubled yarns are analyzed in presence of a specified image capturing hardware and a combination of image processing techniques. The combination of image processing techniques is used for measurement of twist per inch value using the logic of alternating color intensities in the grayscale yarn image. The results are calculated and compared with the standard TPI values of the yarn samples.

Key words: *Twist Measurement, IP (Image Processing), Doubled Yarns, Intensity Variation, Pattern Recoganization.*

1. Introduction

TPI (Twist per inch) value is one of the most important and influenced factor that effects the properties of yarn. It decides various machine settings, quality parameters, and even the properties of the end product. The basic characteristics of yarn that depend on twist per inch value are yarn strength, feel of yarn, moisture absorbency, dye absorbency, wearing properties like abrasion, pilling and aesthetic effects in the garment. So it is quite necessary to determine the value of twist per inch of a yarn to control these quality parameters, hence various methods for determining the TPI values are being used now a days. Some of them are direct counting method, untwist twist method, take-up twist tester and automatic twist tester (Zweigle D302). These testers are quite good at accuracy of results but there are also some drawbacks of these testers which cannot be ignored in this era of high quality consciousness and maximum utilization of raw materials to achieve maximum yield %age in spinning mills. The main problem with all the above described testing mechanisms is that, they are destructive in nature. The sample that is mounted on these testers for the determining TPI values can no more be utilized in the process because these testing methods involve some sort of mechanical approach to check the TPI values like the opening of yarn to individual fibers and re twisting of yarn. This creates an observable change in the properties of yarn and it cannot be used anymore in further processing. Secondly these testers require a definite length of the yarn sample to check TPI value, the specified length is cut from the package and clamped on the tester to get tested for results, in this way it is out of question to reuse that yarn in weaving or knitting a fabric.

Another problem for these type of testers is that, they cannot be used for online testing purposes, because they require sample of a specified length of yarn, then mounting of that sample on tester and then the application of mechanical approach can give results, but now a days for maximum quality assurance, the online testing is emphasized in various operations, and a simple example is auto leveling systems and etc.

The main purpose of this research is to eliminate the above described problems in determining the TPI value of a yarn. In this investigation image processing techniques are used to calculate the TPI value of yarn and in the initial phase of this research calculation of TPI values for the coarser counts of doubled yarns are primarily focused.

2.1 Logical Approach for Image Processing

Perhaps you have ever noticed a pattern of less and more bright regions in a yarn while observing it minutely, especially it can be observed in doubled or cabled yarns. This is due to the spiral structure of yarn that it exhibits the property of diffuse reflection. Due to irregularity of yarn structure more light is absorbed at some regions of yarn comparative to the other regions. This irregular absorbance and diffused reflection of light from the yarn generates a special pattern of bright and dark places that can be observed even by naked eye. The regions where the absorption of light is comparatively more than the other regions, visualize themselves as the dark places (low brightness intensity) and the regions with less absorbency of light exhibit themselves as bright places (high brightness intensity). The yarn structure shows these bright and dark regions alternatively, for example if a single twist is inserted in the fibers assembly it will create two regions of high intensity of brightness and two regions of low intensity of brightness. Due to the alternating intensity phenomena it is possible for human eye to understand a regular pattern in spun yarns else we can never be able to see that where the twist is inserted in yarn. So this phenomena of alternating intensities of brightness is the basic logic for determining the twist per inch value, if by some means the IP software can recognize the bright places or dark places in yarn, the twist per inch value can be determined by it because in a certain length of yarn the no. of bright or dark regions are simply double than no. of twist inserted. So the logical approach is to calculate the no. of dark or bright regions, and this investigation is based on calculating the brighter regions because they can be identified by less complex software calibrations and secondly they are not affected by background illumination as the dark regions can show a disturbance due to non uniform background illumination. The selection of doubled yarn for experimental purpose in the initial phase of research is based on the fact that doubled yarn are more regular than single spun yarns and the alternating intensity pattern will be more obvious in the doubled yarns. Secondly in case of doubled yarn it is possible to calculate TPI value under microscope without any typical instrument that is quite difficult in case of single yarns. So to prove the validity of alternating brightness intensity logic it is preferable to start investigation with a doubled yarn.

2.2 Logical prove

Given below is a grayscale image of doubled yarn of 1 inch length having a linear density of 8/2 (indirect system) and TPI value of 10.76(indirect system).see figure1 (a), here it is obvious that at some places in the yarn image brightness intensity is comparatively more and at some places in the image the intensity of brightness is quite less with in the yarn boundaries, but these fluctuations are making a regular pattern of less and more intensities that will be called the intensities value spectrum.
it is more clearly demonstrated in figure1 (b), that the alternative dark and bright regions are found in the cropped area of a doubled yarn image, the intensity values in the grayscale image range from 0-255. 0 stands for pure dark pixel and 255 stands for pure white pixels and the intermediate values are according to the brightness. So as in the color spectrum the pixels having a value of 255 are presenting an area of high brightness and the values less then 200 are presenting an area of low brightness relatively, and these regions are located alternatively. The cropped area demonstrates the length of yarn that contains a single twist.

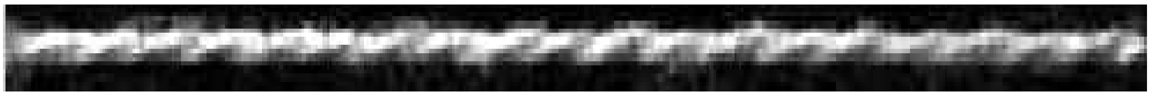


Figure 1 (a) Digital image of a doubled yarn

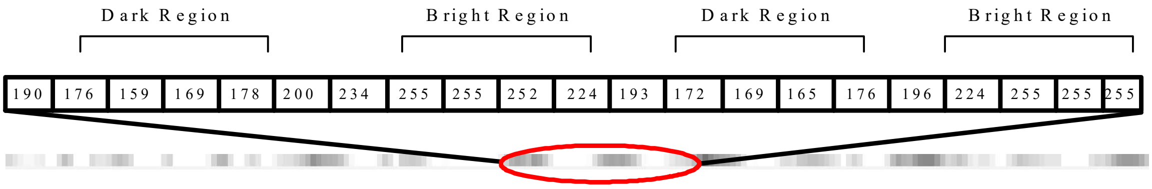


Figure 1 (b) Intensity values spectrum of the yarn image cropped area.

3. Materials and Methods

This section deals with the experimentation held for the image capturing of yarn samples and testing the digital images with image processing software.

3.1 Hardware Design

Three different coarser counts of doubled yarns are selected for the testing, i.e. 8/2, 10/2 and 15/2 (indirect system).The doubling of yarn is carried out by using two for one twisters of VOLKMAN SAURER (Focus-VTS-0905).The TPI of the specified counts are first calculated for reference by using DIGITAL TPI TESTER (AZL MODEL 2008) based on the principle of untwist twist method. JVC GR-D90 live stream camera with USB connectivity is used for image capturing. A black nonreflecting surface is selected for the mounting of sample by dying a piece of wood of specified dimensions in black color. The purpose of the selection of non reflecting black surface is to avoid the brightness disturbances during the image capture that is caused by the reflection of light. The dimensions are engraved on wooden surface to consider desired length for calculating no. of twists in one inch length and it is necessary to input an image of determined length because when the image is captured every dimension can only be calculated in pixels not in inches. Two clamps are adjusted on wooden base at an exact distance of 1 inch, the sample to be checked is gripped in these clamps without cutting from package because no mechanical approach will be used in the test and only the image of specified length is captured. Now a constant source of light is applied to the wooden template in such a way that its details must be as clear as possible and experimentally it is found that the best results are achieved if the light is incidence at an angle of 90^0, to the surface of yarn. The light is incident on one dimension then the image will be taken from the other dimension to resolve the problem of scattered brightness and to get fine details of yarn in image, a simple domestic fluorescent light is used for this purpose because the counts to be tested are not very fine, so in this very phase of research special emphasize on light or lenses can be avoided but for testing the finer counts we must take it in consideration.

The next step is the adjustment of camera and the wooden template, the camera has the feature of optical zoom but for maximum quality of image zooming feature is disabled, a minimum distance of almost 1-2 inches (depending on focus adjustment) is set between the front lens of camera and wooden template. In presence of constant light source, images for 10 different samples of each count are taken by camera so a total of 30 images will be captured by this hardware setup to measure the TPI values by using the image processing software.

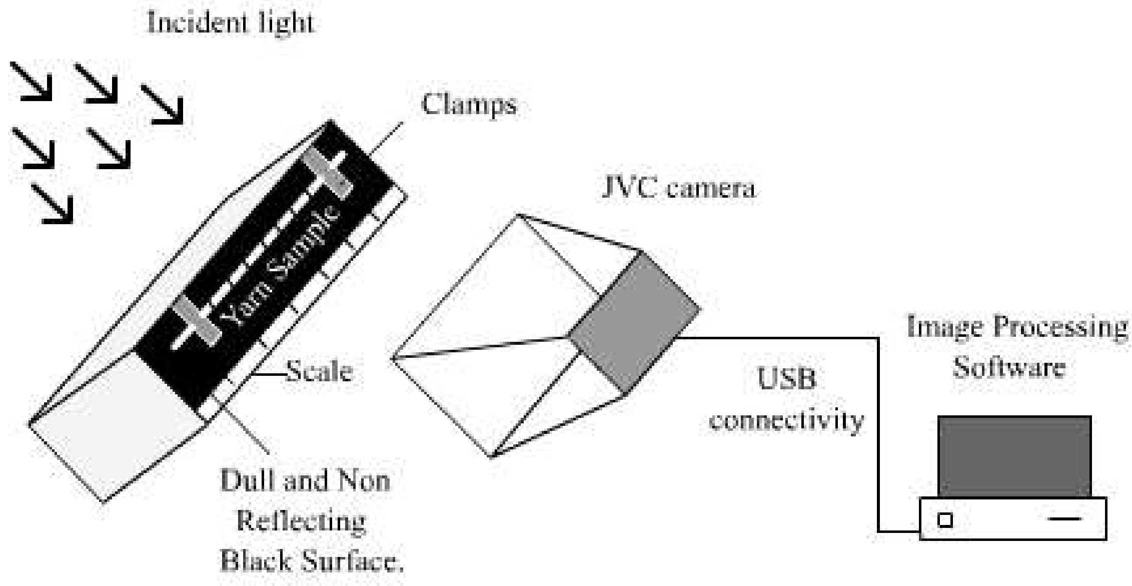


Figure 2 Hardware Demonstrations for Testing Equipment Design

3.2 Pattern Recoganization Techniques and IP Algorithm

Image processing toolbox of MATLAB 7.0 is used for processing digital images to determine the TPI values. Functions like neighbourhood and block processing, morphological operations and region based processing are used in a combination to achieve the results. The image use for the demonstration of image processing algorithm is having a linear density of 10/2(indirect system) and the pre calculated TPI value is 8.6 see figure 3(a).

The first process is the conversion of an RGB image taken from the camera to grayscale image, this step is necessary because grayscale intensity image contains less no of colors than RGB image and gives an accurate view of image details, based on the fact that the conversion eliminates the hue and saturation information from RGB image while retaining the luminance.

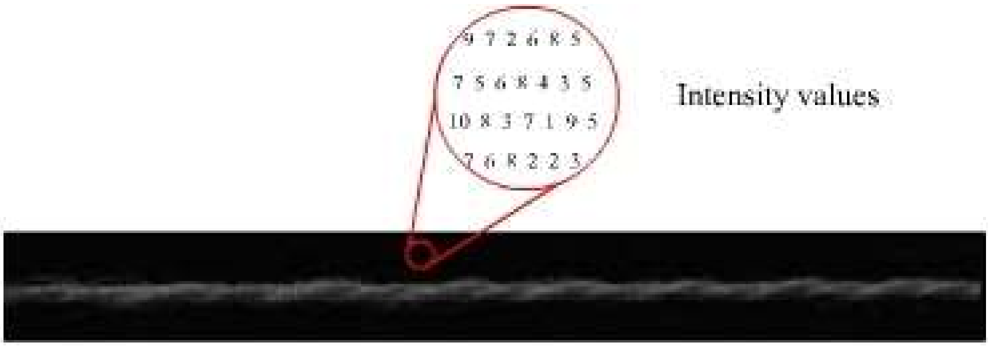


Figure 3(a) Original image that will be processed to determine TPI

To avoid any possible problems in the further processing of image we have to eliminate the background disturbances, shown in figure 3(a), although the fluctuations in the intensity level of background pixels are low but it can affect the precision of results by unwanted variations in processing of image. The STREL function of image processing toolbox will smooth the background intensity values by creating a morphological structuring element of disk shape with a size of 10. After the application of function the results are much better shown in figure 3(b).

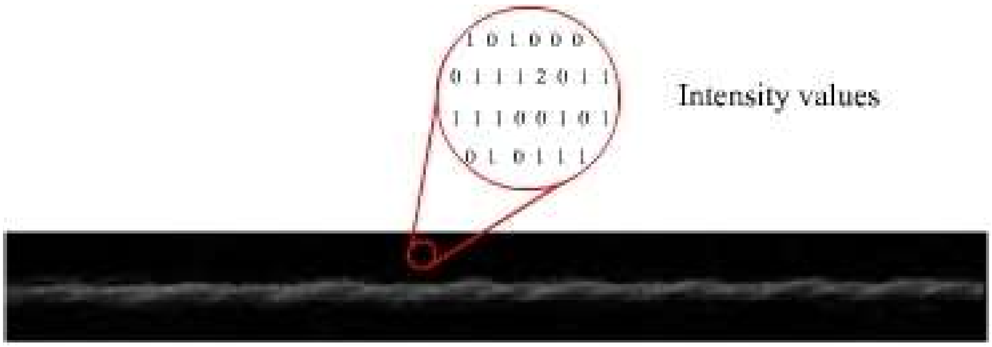


Figure 3(b) Background adjusted by morphological structuring element.

The difference between figure 3(a) and 3(b) is not much obvious from naked eye but the intensity values are revealing the smoothness of background intensity in figure 3(b) that was much fluctuating in figure 3(a). The values like 0, 1 and 2 for background pixels show that the background is almost black. This will be helpful to adjust the intensity of pixels occupied by yarn.

The intensity adjustment of image is the next step in processing that will lead to the clear minute details and a regular pattern of bright and dark places in the image as shown in fig 3(c).

Intensity adjustment is necessary in order to apply further image processing techniques, if the intensity adjustment is not applied it will not be possible for the software to distinguish bright regions from dark ones due to low intensity values of bright regions even.

Figure 3(c) Intensity of Image is Adjusted

Next it is cropping the desired area of image using the IMCROP function, this step is perhaps the most important and results effecting step, the cropping can be automatic and even can be manual, obviously for more versatile way of testing we have to adopt the automatic cropping option, a calibrated value is given to the software so that it can crop the desired dimensions from the yarn image, the thing must remembered while defining the cropping dimensions is to make sure that in the cropped area every bright and dark region must be included in the linear cropping, and this can be done only if the yarn image is highly straight and makes an angle of 0 degree with an imaginary straight line throughout the length. The cropped region is shown in fig 3(d).

Figure 3(d) Cropped region of yarn image

In the cropped image area a clear pattern can be seen consisting on small bright and dark regions. If the intensity values at this level are plotted on a graph the logic of theory will be revealed.

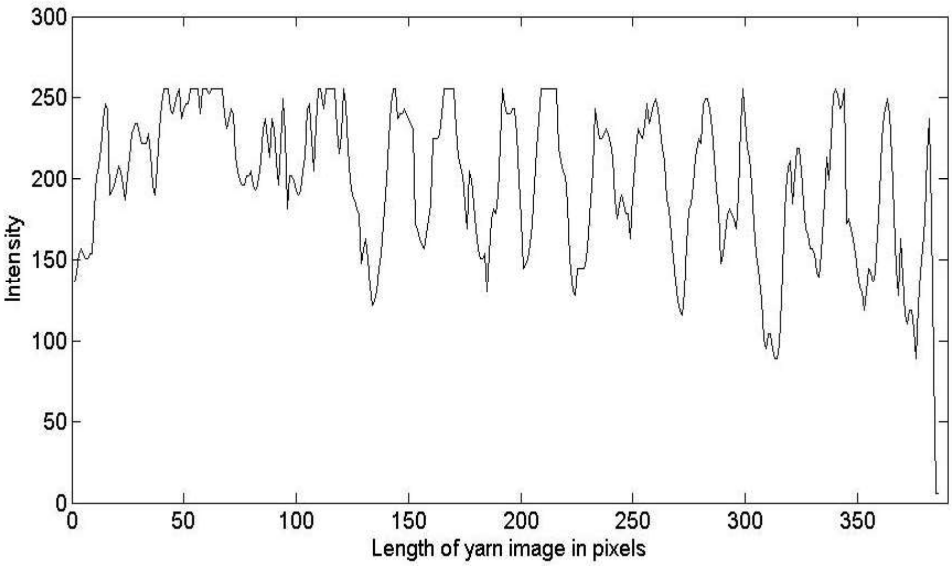


Figure 3(e) Intensity Values Graph of Cropped Region

Finally some peaks are obvious in the graph showing the high intensity areas in the cropped image, and the number of peaks shown in graph is equal to double of number of twists in specified length of yarn. But due to irregularity of intensity values a definite pattern cannot be defined to the software to compute the number of peaks or the high intensity areas in the image so some additional operations are required to make the pattern computable for the software.

In order to achieve results two further operations must be implemented, first one is region of interest selection on the base of intensity values, in this operation a range of intensity is specified to the software and all the pixels that are included in that range will be extracted from the cropped image area, the intensity range is determined experimentally and vary from count to count. For processing coarser counts the range is a bit narrow and for processing finer counts the range is a bit wide. For testing yarns of different linear densities the predefined calibrations must be loaded for accuracy of results.

The implementation of region of interest processing will result in a binary image (the image that has a pixel value of 0 and 1) and it will assign 1 to the pixels having an intensity value in the given range and 0 will be assigned to all other pixels. See figure 3(f).

Figure 3(f): Region of interest filtering on basis of intensity values

The results above are quite encouraging but the again the variations in yarn are responsible for creating small additional white regions in image that will disturb the final results because the labeling of the binary image will also label every small group of white pixels as an individual bright region. To avoid this problem we have to adjust these small groups with adjacent bright regions so that they become a part of them by using the neighborhood and block operation, the value of each pixel in the output image is computed by passing the corresponding input pixel's neighborhood to the function NFILTER and pixel connectivity of 8 is defined to the software to compute the values using [3×3] matrix. After the implementation of this function the results achieved are almost desirable. Figure 3(g)

Figure 3(g): Implementation of neighborhood processing to precise the results

The plotting of above shown image Figure 3(g) will show the number of peaks in the binary image in form of a linear pattern, the peaks in graph shown in Figure 3(h) will be in much smooth state as compared to graph shown in Figure 3(e), so it will be feasible for software to label the various groups of bright regions for quantitative measurement of TPI value.

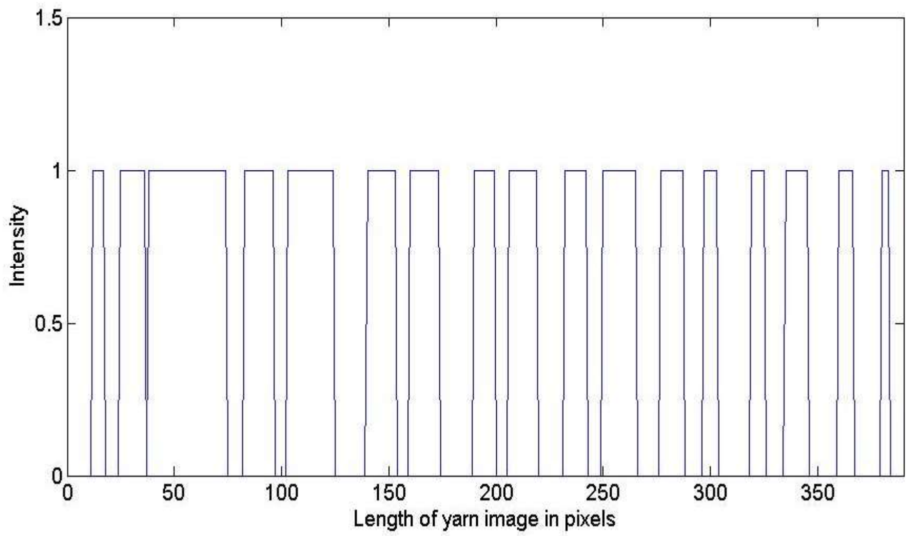


Figure 3(h) Identifiable dark and bright places in binary image of cropped area

The last function that will be applied to the binary image is the labeling by using BWLABEL, so that the number of bright places can be computed and as it is clear from the graph above that no. of peaks present in specified length of yarn is 17, the software generates the same result 17 peaks and it is already stated that number of peaks will equal to double of TPI. So the calculated TPI will be 8.5

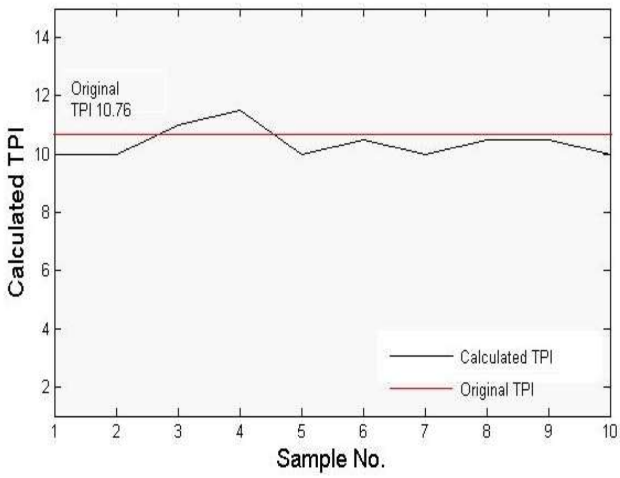
4. Results, Calculations and Conclusion

This section contains the results of the experimental analysis and their graphical representations for 30 samples of 3 different counts that will demonstrate the accuracy of approach used for testing, CV% and the deviation from the original results i.e. 8.6 TPI calculated by DIGITAL TPI TESTER (AZL MODEL 2008).
There is a limitation in this method of calculating TPI values that it not able to give the values in decimals, because it only calculates the number of bright regions that is a whole number, and then dividing it by 2 gives the TPI value. So this algorithm is not able to determine the size of bright regions that can give an idea of decimal values.

4.1 Results for 8/2 doubled yarn

The following table shows the TPI values calculated from the image processing software and the graph is illustrating the deviation of the calculated values from the pre determined standard value of TPI.

Sample No.	Calculated TPI
1	10
2	10
3	11
4	11.5
5	10
6	10.5
7	10
8	10.5
9	10.5
10	10

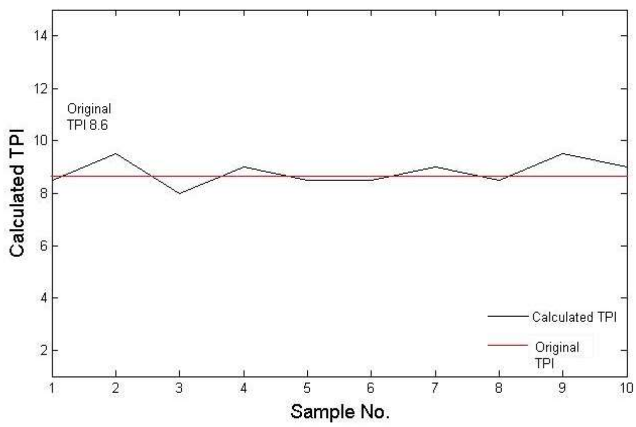


Mean Calculated Twist = 10.4
Actual Twist = 10.76

Standard Deviation = 0.516
CV %age = 4.96%

4.2 Results for 10/2 doubled yarn

Sample No.	Calculated TPI
1	8.5
2	9.5
3	8
4	9
5	8.5
6	8.5
7	9
8	8.5
9	9.5
10	9

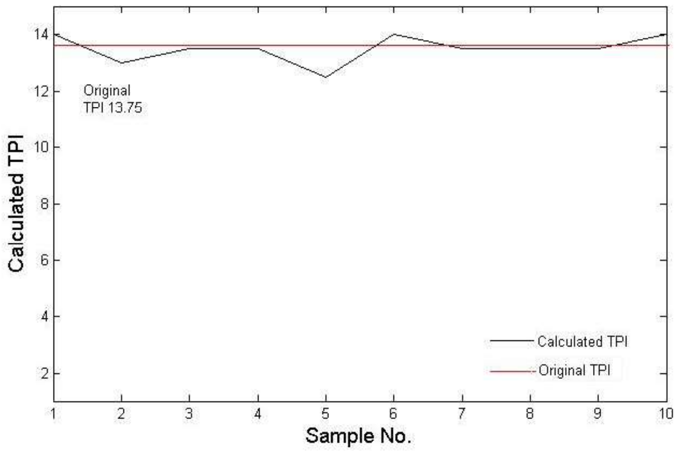


Mean Calculated Twist = 8.8
Actual TPI = 8.6

Standard Deviation = 0.483
CV %age = 5.49%

4.3 Results for 15/2 doubled yarn

Sample No.	Calculated TPI
1	14
2	13
3	13.5
4	13.5
5	12.5
6	14
7	13.5
8	13.5
9	13.5
10	14



Mean Calculated Twist = 13.5
Actual Twist = 13.75

Standard Deviation = 0.471
CV %age = 3.49%

4.4 Conclusion

As it is clear from the above calculated values of TPI, comparison of reference values and calculated values, standard deviation from mean value and CV %age of TPI calculated, the image processing technique can be used in the determination of twist per inch values of doubled yarns on commercial level. Although there are variations from the average value and also there are limitations in this image processing algorithm but these variations can be fixed with more precise hardware setup and fine tuned IP algorithm. That means a combination of simple setup of hardware and user friendly software can eliminate the conventional testing techniques and their drawbacks for measurement of TPI values of yarn. This investigation has opened a new horizon for researchers to make this technique usable on the professional grounds to test TPI values of yarn without application of mechanical factors and to enter the era of non destructive and online testing.

5. Future Prospects

The results described above are very encouraging to continue the research on finer counts of doubled yarns and even single yarns can be focused with this technique. So it is intended in the future to focus finer and even blended yarns for calculation of TPI value,

Most challenging objective is to fine tune the software algorithm in such a way that it can gives accuracy up to two decimal values because the algorithm currently used in the image processing is designed to provide the whole number figure of TPI value, in order to achieve highly précised figure the algorithm should be fine tuned.

Another issue is to design a user friendly graphical user interface (GUI) by using the IP algorithm to be used on professional scale. The GUI named I-QAR FTM 1 (Image Quantitative Analyzer and Region of Interest Processor for Twist Measurement) is under construction and demo version will be available soon.

From professional point of view it is important to design testing equipment for determination of TPI values and online testing setups by using image processing techniques so that the research can be beneficial on the commercial scales.

References:

- Adams, R. (September, 1993). ‘Radial Decomposition of Discs and Spheres’ Computer Vision, Graphics, and Image Processing: *Graphical Models and Image Processing, Vol. 55,* No. 5, pp. 325-332.

- Cybulska, M. (1999). ‘Assessing Yarn Structure with Image Analysis Methods 1’, *Textile Res J. 69(5),* 369-373.

- Savialle, B. P. (1999). *Physical testing of textiles.* (pp. 85-94). England: Woodhead Publishing Ltd.

- Schwarz, E.R. (1938). ‘Twist Measurements in Single Yarns’, *Textile Res. J. 8,* 157-164.

- Young, H. D., & Freedman, R.A. (2000). *University Physics with Modern Physics* (10th ed.). USA: Addison-Wesley Publishing Company.

- *Matlab image processing toolbox online Documentation.* Retrieved May 16, 2008, from http://www.mathworks.com/access/helpdesk/help/toolbox/images