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Effect of dyeing process on tensile strength properties of polyester/cotton blended yarns

Vivek Prasad Shaw[a]

Department of Textile Engineering, M.L.V Textile & Engineering College, Bhilwara 311 001, India

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The change in the tensile strength properties of 45 Ne polyester/cotton(40/60) blended yarn after dyeing process has been investigated. The tensile strength properties of the grey yarn have also been tested for comparison. In the blended yarn, the polyester component is first dyed with disperse dye followed by the dyeing of cotton component with reactive dye. After dyeing both of the polyester and cotton parts, wax based softener is used for finishing. It is observed that there is a significant drop in tenacity of the yarn along with the gain in elongation-at-break after the dyeing in comparison of grey yarn. The tensile strength properties are investigated at three stages, viz immediately after dyeing of polyester component, after dyeing of cotton component and then after the application of softener. It is found that the drop in tenacity of the yarn after dyeing of cotton part is much higher than the drop found immediately after polyester dyeing. The value of elongation-at-break has increased very significantly after dyeing of polyester component. The elongation-at-break drops after dyeing of cotton component but remains always higher than the grey yarn. The softener application also plays a role in drop of tenacity and increase in elongation-at-break.

Keywords: Blended yarn, Dyeing, Elongation, Polyester/cotton blend, Tensile strength

Dyeing is the method of imparting beauty to the textiles by using various colors and shades. In recent times the trend of yarn dyed fabrics in shirtings have taken a quantum jump. The dyed yarns are used in various designs like checks, stripes, filafil and chembrey which are attracting the endusers due to their aesthetic appeal. But when a weaver runs the dyed yarn on the loom, he faces the problem of higher breakages level as compared to that during the weaving of grey yarn using similar loom and fabric parameters. Therefore the weaver either has to adjust the looms at reduced speed which results loss in productivity level or have to use a higher quality of yarn for yarn dyed end use. Hence, there is always a need to investigate the effect of dyeing process on the tensile strength properties of the dyed yarn. The investigation will be helpful to understand the impact of the conventional two-step dyeing process on the tensile strength properties of the polyester/cotton blended yarn.

There has been many studies where it is found that the parameters of dyeing like temperature, time and *p*H, have significant role on the reduction in molecular weight of Ingeo fibre and also on the tensile properties of spun Ingeo fibre/cotton blend yarn[1]. It has been found that the increase in temperature during cotton fibre dyeing resulted in decrease in tenacity and elongation of the yarn[2] .The effect of disperse dyeing on the elongation-at-break and initial modulus of polyester fibre has also been reported[3]. In the same study, the effect of reactive dyeing on the mechanical properties of cotton fibre has been reported. The results showed decrease in tensile strength and elongation but an increase in stiffness of both cotton and polyester fibre. Melange yarn produced from cotton dyed fibre showed significant decrease in tenacity of the yarn as the dyed fibre percentage is increased in the ring-spun yarn. In some studies, the bundle strength of cotton fibre did not show any significant change after dyeing[4-6].

A study on the effects of dyeing and printing of a polyester/viscose blended fabric has also been reported[7]. This study showed negative impact on the strength and positive impact on the elongation of the fabric after dyeing and printing. The dyeing parameters also impact the bursting strength and abrasion resistance of a plain single jersey knitted fabric made from cotton yarn[8].

This study specifically focuses on the comparison of tensile strength properties of grey and dyed polyester/cotton blended yarn. The study also includes the amount of change in the tensile strength properties after polyester part dyeing and that when both polyester as well as cotton is dyed. This study will be able to conclude that the two-step method of polyester/cotton blend yarns dyeing has a major impact on the tenacity and elongation. This may be due to the structural as well as chemical changes in the yarn which results in the changes in tensile strength properties. The study also shows the impact of the softener application.

[a]E-mail: vshaw09@gmail.com

Experimental

In this study, 45 Ne blended ring-spun yarn consisting of polyester/ cotton (40/60) blend was used. The linear density and staple length of polyester fibre were 1 denier and 34 mm respectively. The cotton fibre having micronaire value of 4.2 and staple length of 29.5 mm (Indian cotton S6 variety) was used. The cotton parameters have been tested in Uster HVI instrument. The ring -spun grey yarn was wound into the cone in Schlaforst AC X-5 winding M/C. The grey yarn from the cone was then re-wound into soft dyeing packages in cheese form in SSM cheese winding machine. The average weight of the packages was 900 ± 10 g and the density of the cheese was 0.39±0.02 g/cc.

Ten such packages were initially tested at grey stage after 24 h of lab conditioning (at 20°C ± 2°C and 65 ± 2% relative humidity). Then these packages were tested for tensile properties in the Uster UTJ instrument. Number of readings for tensile strength was taken as 1000 test per package, resulting in total 10000 readings for each sample type. The Uster UTJ is based on CRE principle, having the testing speed and test length as 400 m/min and 500 mm respectively. The soft packages were then dyed in high temperature high pressure package dyeing machine (Fongs yarn dyeing machine).

The dyeing process was carried out according to the conventional two-step dyeing method. The polyester part of the blended yarn was first dyed with disperse dye at 130°±1°C followed by reduction clearing and washing. The packages were then taken out of the dyeing machine and dried in radio frequency dryer. After drying, the packages were lab conditioned and tested in Uster UTJ instrument. After testing, these packages were again loaded into the dyeing machine. In the second step, cotton fibre was dyed with reactive dyes at 80°±1°C. The packages were again taken out of the dyeing machine and then lab conditioned and tested in Uster UTJ instrument. To study the effect of wax based softener, it was applied after final dyeing i.e. after dyeing of both polyester and cotton part. 2.2% of wax based softener was applied. Then again the packages were tested in Uster UTJ instrument after drying in radio frequency dryer and lab conditioning. To investigate the effects of dyeing and application of softener on the yarn tensile strength properties, *t*-tests were performed at 5 % (0.05) and 10 % (0.1) levels of significance.

Results and Discussion

The sequential effect of dyeing of polyester and cotton parts along with the application of softener on the tenacity and elongation-at-break (%) of the 45 Ne polyester/cotton blended yarn are shown in Table 1.

Statistical Test

The *t*-test is a type of inferential statistics, which is used to determine whether there is a significant difference between the means of two groups. With a*t*-test, it can be stated with some degree of confidence that the obtained difference between the means of the sample groups is too great to be a chance event. If the t - test produces a *t*-value that results in a probability of 0.01, we say that the likelihood of getting the difference we found by chance would be 1 in a 100 times. We can say that it is unlikely that the results we got are by chance, and the difference we found in the sample probably exists in the populations from which it was drawn.

Calculation for the *t*-test was done considering the means of two large samples. Test data are – number of test: N_1 (Sample A) & N_2 (Sample B); mean test results: X_1 (Sample A) & X_2 (Sample B); and standard deviation: SD_1 (Sample A) & SD_2 (Sample B). Following four steps were used:

Table 1 — Changes in yarn tensile strength properties after each sequence of dyeing as compared to the previous stage

Parameter	After dyeing of polyester part (% change as compared to grey yarn)	After dyeing of polyester and cotton part (% change as compared to polyester dyed yarn)	After application of softener (% change as compared to final dyed yarn)
Tenacity, cN/tex			
Mean	-2.3	-7.64	-0.78
CV%	-3.8	-1.24	-1.13
Elongation-at -break, %			
Mean	39.8	-7.38	1.25
CV%	-14.0	7.44	0.15
Min tenacity, cN/tex	-6.1	-12.09	-3.4

Table 2 — Standard error difference and *t* values for tenacity and elongation between the two samples

Parameter	Condition 1	Condition 2	Condition 3
SE difference tenacity	0.02	0.02	0.02
SE difference elongation	0.01	0.01	0.01
Value of *t* (tenacity)	19.9	70	07
Value of *t* (elongation)	346.6	82.8	12.9

Condition 1–Between the grey cheese and after dyeing of polyester part, Condition 2– Between dyeing of polyester part and after dyeing of polyester +cotton part, and Condition 3– Between dyeing of both polyester and cotton part and after dyeing of polyester and cotton part along with softener application.

Table 3 — Effect of dyeing process on the tenacity, elongation-at-break and minimum tenacity of yarn

Dyeing process	Tenacity, cN/tex	Elongation-at-break, %	Minimum tenacity, cN/tex
Grey cheese	21.42	6.2	14.27
Polyester dyeing	20.93	8.67	13.4
Polyester + cotton dyeing	19.33	8.03	11.78
Polyester + cotton dyeing + softener application	19.18	8.13	11.38

- Step 1– Calculation of standard error (SE) of the means
  $SE_1 = SD_1/\sqrt{N_1}$ SE_1= Standard error of Sample A
  $SE_2 = SD_2/\sqrt{N_2}$ SE_2= Standard error of Sample B
- Step 2– Calculation of SE difference between the means
  S.E difference=$\sqrt{(SE_1^2 + SE_2^2)}$
- Step 3– Calculation of the *t* value
  $t = \left| X_1\text{-}X_2 \right| /\text{S.E difference}$
  $= \left| X_1\text{-}X_2 \right| /\sqrt{(SE_1^2 + SE_2^2)}$
  If sample size is more than 30, the degree of freedom is considered as (v) =∞. Now *t* value at 5% level = 1.96 and at 1% level it is 2.58.
- Step 4– Inference

If the *t* calculated value is more than the 2.58, then it may be concluded that the difference between the mean is significant at 1% significance level[9]. Standard error differences and *t*-values for tenacity and elongation are shown in Table 2.

Table 1 shows that after each stage of dyeing there is a significant drop in tenacity of the yarn. There is a drop of 2.3% of tenacity as compared to the grey yarn when the polyester part is dyed. In the second stage, after dyeing of cotton part of the polyester dyed blended yarn, the drop in tenacity is quite higher, i.e. 7.64 %. Again after the application of softener in the third stage, there is further drop of 0.78 % in tenacity. The CV% of tenacity has improved after each stage of dyeing.

The drop in tenacity might be due to the fact that polyester fibre gets damaged due to the reduction clearing treatment in polyester dyeing process[7]. A higher drop in tenacity after cotton part dyeing of the blended yarn might be due to the breaking of internal structural elements of the cellulose polymer during reactive dyeing[3].

It can also be seen that after dyeing of polyester part, there is drastic increase of 39.8% in the value of elongation-at-break. Then as the cotton part is dyed there is again a drop of 7.38% in the elongation-at-break value. After application of softener, there is an increase of 1.25% as compared to the final dyed yarn but still the value is lower than that of polyester part dyed yarn.

Table 3 shows that minimum tenacity has a similar trend as that of the tenacity. The drop in minimum tenacity is highest after the dyeing of cotton part. Table 2 shows the *t*-test of means of samples at subsequent stages. It can be inferred that each stage of dyeing have significant effect on the tenacity and elongation of the yarn sample as compared to its previous state sample. From the results obtained in the study following conclusions are drawn:

- There is a decrease in tenacity of the polyester/cotton blended yarn after dyeing.
- The elongation-at-break increases after dyeing.
- The decrease in tenacity is higher immediately after cotton part dyeing of the polyester/ cotton blend yarn as compared to the drop in tenacity after polyester part dyeing.
- The increase in elongation-at-break is very high as soon as the polyester part is dyed and then it decreases as the cotton part is dyed. The application of softener shows a little increase in elongation as compared to the final dyed yarn.

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