Dye Non-Uniformity in Textured Yarn Fabrics—A Diagnostic Approach

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Three possible causes of non-uniform dyeing of textured yarns, namely defective texturing, post-texturing twist variations and pirn winding tension variation in fabric manufacture, were explored. During texturing, the most common sources of faults cause non-uniform/uniform tension variations along the thread line which are subsequently reflected in crimp contraction force (CCF) variation. A Dynafil assessment of CCF variation has been found to be an effective way of detecting potential non-uniform dyeing behaviour of textured yarns. In the absence of such sophisticated instruments, faults can also be predicted from simple tests on denier and yarn elongation. A variation of 4% and above in denier brings about non-uniform dyed fabrics in the case of twisted textured yarns. The residual elongation or boiling-water shrinkage is effective in segregating yarns with potential for non-uniform dyeing. The defective textured yarns are much more sensitive to pirn winding tension as compared to the normal textured yarns. In normal yarns, a pirn winding tension variation of about 18 g and above causes dye non-uniformity, whereas in defective yarns, even a variation as little as 4 g brings about weft bars.

Keywords: Barre defect, Crimp contraction force, Dye non-uniformity, \( K/S \) value, Textured yarn fabric

1 Introduction
Dye non-uniformity of textured polyester yarn fabric is one of the ever existing problems. Considerable developments in melt spinning technology and textured yarn technology have been made that have resulted in better feed yarns and textured yarns but the problem of non-uniform dyeing of textured yarn has not yet been solved completely. The dyers are resorting to high temperature dyeing with auxiliaries, etc. for overcoming the problem of non-uniform dyeing. Twisting of textured polyester yarns is further aggravating the problem of non-uniform dyeing. Nearly 60% of the faults of dye uniformity referred to our laboratory for analysis were found to be from fabrics made out of high-twist textured yarns. A clear diagnosis of causes of dye non-uniformity is elusive and many attempts at such a diagnosis have led to more complications than solving it. No analytical method can be claimed to be accurate enough to show that the dye differences have occurred due to the feed yarn or due to faulty texturing or faulty post-texturing of yarn. At present, there is no alternative except the segregation of yarn by some means of detecting the potentiality of dyeing fault. Sophisticated instruments like Dynafil-M (Textechno) and textured yarn tester are supposed to assist in quality control of textured yarn, eliminating the tedious knitting and dyeing tests altogether. Besides these, there are simple methods such as denier, boiling-water shrinkage and elongation at break tests which can be used to identify the potential faulty yarns. The present work is aimed at finding the degree of sensitivity of these tests in detecting potential dye differences.

2 Materials and Methods

2.1 Defective Textured Yarns
Eight standard defective yarns were produced on Lohia-FTF 440 pin-type draw texturing machine (Lohia R&D Centre, Kanpur) at a speed of 120 m/min without post-setting treatment. The texturing parameters and the type of defects induced are given in Table 1.

2.2 Twisted Textured Yarns
All the twisted yarns were prepared from the draw textured yarn which was textured using 185°C first heater temperature, 1.65 draw ratio and 3400 tpm. Eight twisted yarns were prepared on a laboratory model Sapru uptwister using 420, 600, 800, 1410, 1620, 1830, 2050 and 2250 twists/m. From each bobbin the actual twist was measured and the samples which varied widely from the nominal twist level were rejected.

2.3 Preparation of Pirn
Conventional pirn winding machine was used. Three pirns were prepared with varying pirn winding tensions from normal textured yarn and one standard defective textured yarn (No. 2). Pirn winding tension was varied by changing the number of
discs on the disc type tensioner. During pirn winding, uniform pirn winding tension was ensured by checking the tension at regular intervals with the help of a tensiometer.

2.4 Measurement of Crimp Contraction Force

The crimp contraction force of all the standard defective textured yarns was measured on Dynafil-M tester (Textechno) with following test conditions: Test speed, 10 m/min; test length, 100 m; heater temp, 150°C; pre-tension, 12 cN; and draw-off godet, -5%.

2.5 Measurement of Tensile Properties

The tensile properties of all the standard defective textured yarns and twisted yarns were measured on Zwick tensile tester using 500 mm gauge length and 100% extension rate. Five tests were carried on each yarn and the average values were taken. Yarns unravelled from dyed fabrics were also tested in the same way.

2.6 Measurement of Denier/Tex

Denier/tex values of each defective textured yarn and twisted yarn were measured by preparing three hanks from each yarn and weighing them.

2.7 Preparation of Fabrics

From all the standard defective textured yarns and twisted yarns, fabrics were prepared by using the yarns in the weft-way direction on a plain loom. Similarly, fabrics were prepared from the pirns which were wound with varying pirn winding tension.

2.8 Dyeing of Fabrics

The fabrics, scoured with normal soda ash and detergent solutions for 1 h and bleached with hydrogen peroxide solution for 1 h, were dyed in the same dye bath at 100°C for 1 h with Foron Blue SE 2 RI (Sandoz) disperse dye using 0.5% shade without any carrier.

2.9 Computer Colour Matching System

Colour differences and reflectance measurements were carried out on all the defective textured yarn fabrics and twisted yarn fabrics using Data Colour 3890 computer colour matching system. The reflectance values were measured in the visible wavelength range of 400-700 nm. From these values, K/S values were calculated using Kubelka-Munk equation as follows:

\[ K/S = \frac{(1 - R)^2}{2R} \]

where \( R \) is % reflectance at wavelength maximum (\( \lambda_{\text{max}} \)). Similarly, fabrics prepared from weft yarns, which were wound with varying pirn winding tension, were also tested for reflectance measurements and colour differences.

3 Results and Discussion

3.1 Defective Textured Yarns

Table 2 shows the CCF values of the defective yarns. Both the mean value and the coefficient of variation in CCF seems to be important in determining the potentiality of the barre defect. Practically, it is seen that in all the defective yarns, dye uptake (K/S) is higher as compared to that in the normal yarns. However, it is not possible to ascertain the degree of change in CCF required to bring about a detectable barre. Excepting the sample No. 4, in all the other cases, whenever the coefficient of variation in CCF was more than 5%, barre in the fabric
was prominent. The sample No. 4 showed no barre despite a variation > 5%. It was observed in laboratory that when defective yarn samples with coefficient of variation less or more than 5% were chosen for fabric preparation and subsequently dyed, the same results were obtained, i.e. when variation was more than 5%, barre appeared more frequently than in the case when variation was less than 5%. A careful observation of the Dynafil CCF charts revealed that not only the variation in CCF is important but the non-uniform variation in CCF from the mean value is also important in determining the potentiality of barre. It is shown schematically in Fig. 1. Usually two different kinds of CCF spectrum are observed in all the defective yarns. The spectrum A shows that even in normal yarn, CCF shows considerable but uniform variation from the mean value. In the type 1 defective yarns (spectrum B1), the amplitudes of variation may be higher or lower than that in the normal yarns but still uniform variation in the mean value is observed which means the CCF along the length of the yarn varies more uniformly at very short intervals (10 min). In the type 2 defective yarns (spectrum B2), not only the amplitudes of CCF peaks vary non-uniformly but also there is a considerable shift of the spectrum above and below the mean value at longer intervals. It is observed that yarns, 4, 7 and 8 are of type 1 and yarns 1, 2, 3, 5 and 6 are of type 2. The type 2 yarns are the ones which gave reproducible barre defect. It is understandable that short-term uniform variations will not result in detectable barre because a few picks with different dye uptake occurring at regular short intervals may not produce noticeable barre defect. However, irregular long-term variation along the length of yarn can cause frequent barre because there is more probability of occurrence of groups of picks with different dyeability at long irregular intervals.

3.2 Effect of Twist on Textured Yarns

In twisted textured yarns, the effect of difference in twisting on dye uptake of yarns was examined. Variations in twist are reflected as corresponding variations in elongation at break and tex or denier. In Fig. 2, the linear regression of colour difference is plotted against the square of percentage difference in tex value. The relationship between them is almost linear with correlation coefficient of 0.99. From the regression equation, it is possible to estimate the degree of required difference in tex to cause a perceptible change in dye uptake (colour difference of 1). A variation of 4.4% in tex causes a detectable dye uptake difference in twisted textured yarns. For confirmation, we selected twisted yarns with difference in denier below and above 4% of the normal with corresponding colour difference of 0.7 and 1.5 and obtained the reflectance curves (Fig. 3). The curves clearly show that the yarns with higher difference in denier are having different reflectance properties.

The difference in elongation after dyeing (DEAD) and the difference in elongation before

![Fig. 1—Schematic diagram of Dynafil CCF spectra](image)

![Fig. 2—Effect of twisted textured yarn tex on colour difference](image)

![Fig. 3—Reflectance curves of dyed twisted textured yarns (A—twisted with 420 tpm, C—twisted with 800 tpm, and F—twisted with 1830 tpm)](image)
and after dyeing (DEBAD) are well correlated with colour difference values. Fig. 4 shows the linear regression of colour difference against the square of difference in elongation after dyeing. The relationship is linear with correlation coefficient of 0.98. From the regression equation in Fig. 4, the percentage DEAD required to produce colour difference 1 is 18.6% whereas from the regression equation in Fig. 5 the percentage DEBAD required for producing colour difference 1 is 11.2%. As dyeing was carried at 100°C, this can be practically useful in segregating yarns with potential for non-uniform dyeing by giving simple boiling-water treatment to the textured yarn and conducting the tensile tests before and after the boiling-water treatment. Subsequently, from the value of difference in elongation before and after the boiling-water treatment, dyeing potential of textured yarn can be studied. Similarly, for comparing two different textured yarn packages for their dyeing behaviour, simply the value of difference in elongations of two textured yarns after boiling-water treatment can also be useful. If the DEAD value is more than 18.6%, then these packages can cause a detectable dye uptake difference in a dyed fabric and will produce a barre defect.

3.3 Effect of Pim Winding Tension

The effect of pim winding tension was studied both on normal and defective textured yarns. Fig. 6 shows that the relationship between colour difference and the difference in pim winding tension is linear for normal yarns (Curve A) whereas for defective yarn it is of exponential type (Curve B). Curve C shows linear regressions of colour difference against the square root of difference in pim winding tension for defective yarn. This shows that defective yarns are much more sensitive to pim winding tension in comparison to normal yarns. The correlation coefficient for normal and defective yarns are 0.985 and 0.998 respectively. From the regression equations it has been found that a difference in pim winding tension of 18.5 g in the case of normal yarn causes colour difference of 1, whereas a difference as less as 4.4 g in pim winding tension in the case of defective yarn produces colour difference of 1. This is interesting considering the fact that many previous workers have reported negligible effect of pim winding tension on textured yarn dye uptake for tensions below 60 g. To confirm our ob-

![Graph](image)

Fig. 6—Effect on pim winding tension on colour difference (A—normal textured yarn, B—defective textured yarn, and C—modification of curve B by using square root of difference in pim winding tension instead of difference in pim winding tension)

<table>
<thead>
<tr>
<th>Type of yarn</th>
<th>Sample No. of discs on tensioner</th>
<th>Pim winding tension</th>
<th>Colour difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>1</td>
<td>2</td>
<td>6.6</td>
</tr>
<tr>
<td>textured</td>
<td>2</td>
<td>3</td>
<td>9.9</td>
</tr>
<tr>
<td>yarns</td>
<td>3</td>
<td>9</td>
<td>29.7</td>
</tr>
<tr>
<td>Defective</td>
<td>4</td>
<td>4</td>
<td>13.2</td>
</tr>
<tr>
<td>textured</td>
<td>5</td>
<td>3</td>
<td>9.9</td>
</tr>
<tr>
<td>yarns</td>
<td>6</td>
<td>2</td>
<td>6.6</td>
</tr>
</tbody>
</table>

*For normal yarns the sample No. 1 and for defective yarns the sample No. 4 taken as references.
servation, we further conducted some experiments wherein we prepared knitted hose with yarns on pirns wound with regularly increasing tensions. Table 3 shows the results of these experiments, confirming our above findings.

4 Conclusion

The difference in dye affinity in textured yarns due to defective texturing, twisting, and pirn winding tension is related to corresponding variation in CCF spectrum and coefficient of variation in CCF, variation in elongation at break and tex due to twisting, and variation in pirn winding tension. Long-term non-uniform CCF variation indicates potential dye uptake variation. When the coefficient of variation in CCF is more than 5%, barre appears more frequently. A variation of 4.4% in tex or denier causes a detectable dye uptake difference in twisted textured yarns. Correspondingly, 18.6% difference in DEAD and 11.2% in DEBAD can produce same colour difference as by 4.4% difference in tex. Pirn winding tension affects differently the dye uptake properties of normal and defective textured yarns. Defective textured yarns are more sensitive to pirn winding tension, i.e. even a 4.4 g difference in pirn winding tension produces a barre defect.

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