Indian Journal of Fibre & Textile Research
Vol. 23, March 1998, pp.25-31

Performance of dyed warp yarns

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Received 19 July 1996; revised received and accepted 11 March 1997

The performance of the grey and dyed sized cotton yarns was studied on the air-jet loom in the industry. To understand the difference in the behaviour of the yarn due to dyeing, the grey, dyed unsized and the corresponding sized yarns were studied in the laboratory on the Reutlingen web tester for their weavability and nature of breakage. Analysis of the result helped in understanding the effect of dyeing on fibre damage, fibre cohesion and size-fibre adhesion. Dyeing causes a change in the yarn cohesion; the dyed yarn requires better sizing material having relatively lower viscosity and higher adhesion compared to that for the corresponding grey sized yarn.

Keywords: Dyed warp yarn, Inter-fibre slippage, Size penetration, Structural disintegration, Weavability

1 Introduction

Dyed yarns are used along with grey yarns in shirting and denim cotton fabrics. Beam warping is an economical technique used in the textile industry for such work; for special warp stripe effects, sectional warping is essential. During sizing, the warp beams for dyed and grey yarns are combined separately and sized through separate sow boxes and dried, splitted separately before combining at the comb of the headstock. For 190 cm air-jet weaving machine, about 8400 ends are obtained by combining about 8 warp beams each of grey and dyed yarns sized and dried separately; usually the same size recipe and sizing conditions are maintained in both the size boxes.

A typical textile mill producing such shirting fabrics has great difficulty in producing fabrics on the air-jet loom. The performance of using dyed and grey yarns together is quite bad compared to sorts having only grey yarn. Handling coloured yarn is difficult compared to the grey yarn on the loom mainly due to the visibility.

There is hardly any research report on the sizing of dyed yarns. However, the following comments concerning dyed yarns have been put together in a book by Hacking[1] purely based on his experience:

- Two-fold dyed and bleached yarns are comparatively insensitive to the amount of size added, specially at the high add-on levels.
- It is possible to reach an 'Oversized' stage with dyed cotton yarn. It is advisable to avoid usually high size in dyed and bleached yarns.
- Some dyed yarns such as black and azo red do not weave as well as the undyed yarn because of the effect of dyestuff, probably due to yarn friction variation.
- Indigo dyed cotton yarns for denim fabrics may prove exception to the general rule. These yarns require as much size or sometimes more compared to the grey yarn.
- Many cotton towels containing stripes of dyed yarn tend to become stiff more easily than those made of grey yarn. At high size percentage, the dyed yarn becomes very stiff.

The present study attempts to investigate the problem faced by textile mills producing cotton shirting fabrics using dyed and grey yarns. For better understanding of the problem, their yarns were sized in the laboratory at lower add-on with different size recipes. Moreover, fibre dyed yarns were included in the study to understand size-dye-fibre interaction.

2 Materials and Methods

2.1 Materials

Yarn dyed warp

50 Ne cotton grey, bleached and some vat dyed yarns.

Fibre dyed warp

20 Ne cotton grey and dyed yarns.

Mill size recipe

Starch ether + PVA + Acrylic + CMC + Plasticizer, gum, etc.
(50%) (20%) (6.5%) (15%)
Add-on = 15%

Laboratory size recipes

50 Ne and 20 Ne cotton yarns were sized in the laboratory Zell sizing machine at low add-on (9%) using the following two size recipes:

Starch ether + PVA + Acrylic
(72%) (21%) (7%)
Starch ether + PVA + Acrylic + Polyester Resin
(70%) (20%) (5%) (5%)

2.2 Methods

2.2.1 Sizing

Sizing was carried out on two sizing machines having twin size boxes, namely (i) conventional sizing machine, and (ii) modern sizing machine with all controls such as let-off tension, squeeze pressure, temperature, concentration, etc.

2.2.2 Testing of Yarn

The yarns were tested for weavablity, tensile properties and surface behaviour under the standard atmospheric conditions (27°C and 65% RH).

2.2.2.1 Weavability

The weaving performance in terms of abrasion cycles of grey/dyed unsized and sized yarns was evaluated in the laboratory on the Reutlingen web tester[2,3]. The abrasion cycles and the yarn elongation at 10th break were evaluated on the web tester under the following conditions : machine speed, 400 rpm; separation of the abrasion pins, 1.5 mm; and yarn tension, 3 cN/tex.

2.2.2.2 Tensile Properties

The unbroken samples after the 10th break on the web tester were evaluated along with raw unsized and grey and dyed sized yarns on the Instron tensile tester to find the change in the mechanical properties for the abraded zone as well as other portion of the yarn separately. These are designated as abraded and fatigued portions respectively.

2.2.2.3 Surface Behaviours

The broken ends of the yarn on the web tester, the unsized yarn and the sized yarn were observed on the scanning electron microscope to understand the nature of break and the yarn surface characteristics.

2.2.2.4 Yarn Friction

The yarn surface friction was studied using the Zwigle yarn friction meter.

3 Results and Discussion

3.1 Yarn Abrasion Resistance

Table 1 shows the abrasion cycles for the unsized and sized grey and dyed yarns of the mill. It is observed that dyed unsized yarns give better abrasion resistance than their undyed counterparts. On sizing, the performance of both grey and dyed yarns improves significantly; however, the difference between them is not substantial. At high size add-on (15%), grey unsized yarn shows better abrasion resistance than its corresponding dyed sized yarn. Between the two sizing machines the one with more efficient controls such as let-off tension, squeeze pressure, etc. gives significantly higher abrasion resistance.

It may be concluded from above that the yarn performance is significantly affected by the sizing machine. The unsized dyed yarn gives better abrasion resistance than grey yarn but the grey yarn gives better performance than the dyed sized yarn at high add-on (15%).

The reason for the better performance of dyed unsized yarn can be understood from the examination of yarn elongation on abrasion (Table 2). It is seen that elongation on abrasion decreases significantly on sizing but it is higher for the grey yarn than its counterpart especially in the unsized state.

The yarn elongation at break is an indication of fibre slippage in the yarn structure during abrasion on the web tester and is a reflection of the yarn packing. It may be concluded that the dyeing of yarn improves fibre packing which retards yarn disintegration by abrasion. The improved packing of chemically treated yarn has been observed with the SEM(Fig.1). The following observations can be made from the scanning electron photomicrographs of the grey, bleached and dyed unsized yarns :

Table 1—Abrasion resistance of mill sized 50 Ne cotton yarns
[Size add-on, 15%]

Yarn type	Sizing machine[a]	Abrasion resistance (weavability cycles)					
		Unsized		Sized		% Change	
Dyed (Vat)		Grey	Dyed	Grey	Dyed	Grey	Dyed
Light blue	A	3089	3520	24517	25412	694	622
Dark blue	A	4823	5325	20430	20796	323	291
Dark blue	B	2886	4295	29608	27675	925	544
Red	B	—	4097	—	26853	—	—
Black	B	2027	2027	20380	20380	905	—
Grey (Natural)	B	3871	—	29155	(SBI)[b]	653	—
				32896	(SBII)[c]	749	—

[a]Sizing Machine: A–Conventional sizing machine, and B–Sizing machine with efficient controls
[b] Sow Box 1
[c] Sow Box 2

Table 2—Elongation at 10th break of mill sized 50 Ne cotton yarns

Yarn type	Sizing machine	Elongation, mm			
		Unsized		Sized	
		Grey	Dyed	Grey	Dyed
Dyed (Vat)					
Light blue	A	28.6	7.8	2.8	2.3
Dark blue	A	14.3	6.6	2.4	2.3
Dark blue	B	8.4	6.8	1.0	1.0
Red	B	—	9.6	—	1.0
Bleached	B	10.4	—	2.1	—
Grey (Natural)	B	7.9	—	1.1	—

Grey yarn : yarn structure open and hairy
Bleached yarn : yarn structure compact and less hairy
Dyed yarn : yarn structure compact but hairy.

3.2 Vat Dye Mechanism

It is well known that the process of yarn dyeing involves pretreatments such as scouring, bleaching and aftertreatment to fix the dye. The chemical treatments help the dye molecule to penetrate the fibre and stay in the voids in an aggregated/crystalline form. The scouring (treatment with NaOH) and bleaching (treatment with H_2O_2) remove natural wax, clean the fibre surface and also cause fibre swelling. Thus, it improves wettability/water absorption, packing and alters surface friction. However, it must be remembered that the dye itself is hydrophobic.

This phenomenon explains the better performance of the unsized dyed yarn. The bleached yarn has lowest abrasion resistance which improves significantly on sizing. It may be inferred from the above discussion that at high add-on the dyed yarn should have more coating than penetration compared to grey yarn (this needs investigation). Moreover, the significant improvement in bleached yarn on sizing may be due to improved adhesion as the pretreatment removes the natural waxes.

3.3 Damage to Fibre

The extent of pretreatment (scouring and bleaching) depends on the depth of shade and colour, being maximum for white and progressively decreases for the dark colours.

To investigate the damage to the fibres in the dyed yarn, the fibres were extracted from the unsized grey and corresponding dyed yarns and the tensile properties studied (Table 3). It is clear from the results that there is no significant change in the tenacity/elongation of the fibres on dyeing.

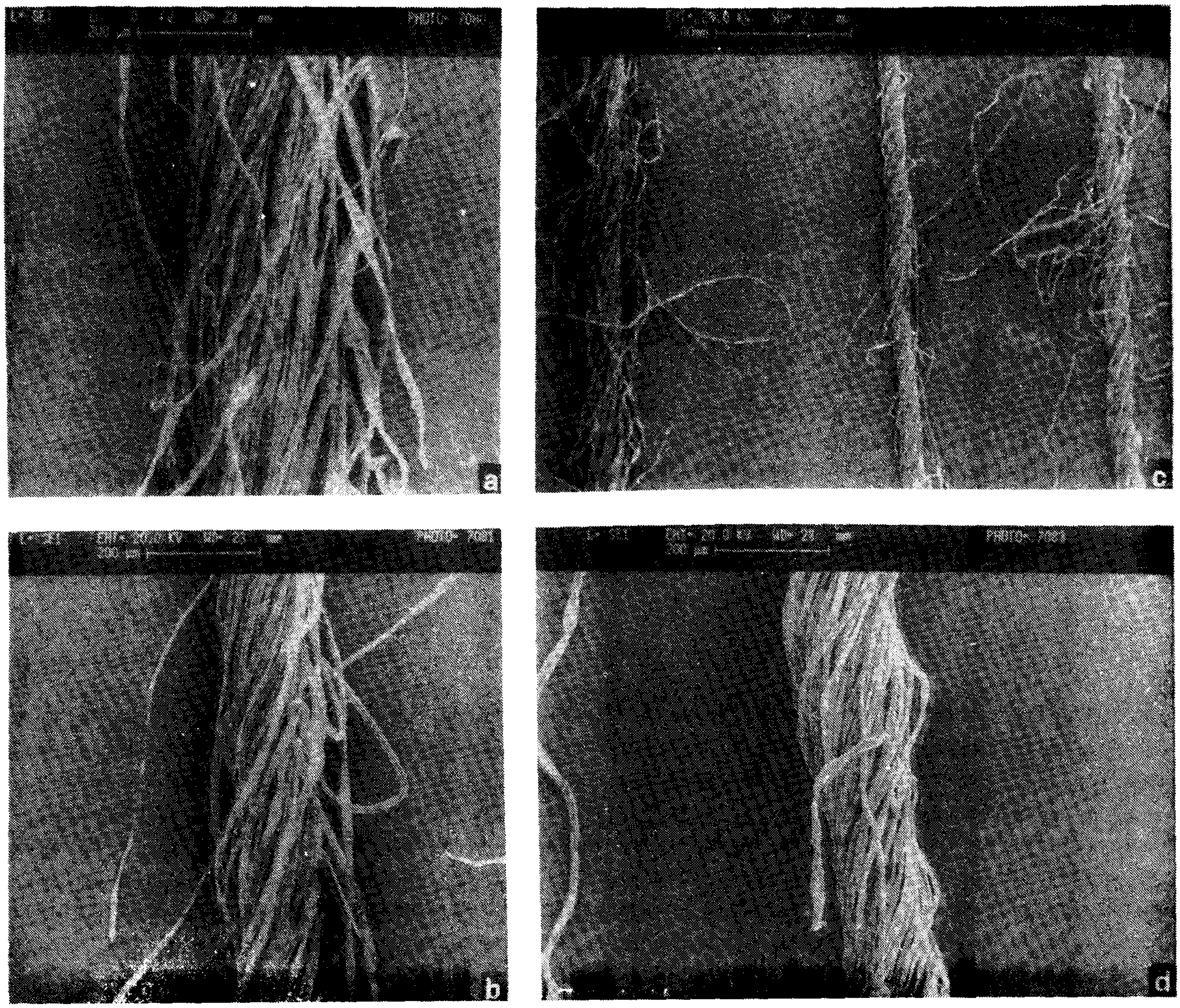

Fig 1—Scanning electron photomicrographs of (a) unsized grey yarn, (b) unsized bleached yarn, (c) unsized dyed yarn, and (d) sized yarn

Table 3—Tensile properties of fibres from mill sized 50 Ne cotton yarns

Fibre extracted from vat dyed yarn	Sizing machine	Breaking load cN		Strain at break %	
		Grey	Dyed	Grey	Dyed
Light blue	A	3.23	3.26	7.64	7.10
Dark blue	B	3.23	3.25	7.75	7.15
Dark blue	B	3.31	3.34	7.31	6.85

3.4 Effect of Low Size Add-on

In the section 3.2 it was inferred that at high add-on the size coating should be higher in the dyed yarn. Therefore, size was applied at lower add-on with two size recipes (One for the dyed yarn and the other for fibre dyed yarn) in the laboratory. The results are given in Table 4. The difference in the coefficient of friction between the grey and some coloured yarn is significant. In the case of unsized yarns it is seen that the bleached yarn gives lowest abrasion cycles and the lemon yellow dyed yarn the highest, whereas the other coloured yarns give abrasion cycle values close to that of grey (Natural yarn). The coefficient of friction values of yarns partly help to explain these differences. The highest coefficient of friction for bleached and the lowest coefficient of friction for the light yellow dyed correspond to the abrasion cycles. Again, in the case of fibre dyed yarn the improvement in the abrasion cycles for grey (Natural) yarn is insignificant whereas coloured yarn shows good improvement.

It may be seen from Table 5 that the yarn elongation at break in the sized yarn (both grey and

Table 4—Abrasion resistance of laboratory sized yarns

Yarn type	Coefficient of friction of unsized yarn	Abrasion cycles			% Change	
		Unsized	Sized 1	Sized 2	Sized 1	Sized 2
50 Ne Cotton Yarns						
Grey (Natural)	0.194	2445	8061	14721	230	502
Bleached	0.210	1221	10327	11229	745	820
Dyed (Vat)						
Lemon yellow	0.169	3889	14293	13910	267	258
Golden yellow	0.199	2464	12508	16226	408	558
Grey	0.170	2406	18141	19467	654	709
Green	0.1197	2568	16261	17019	533	563
Black	—	2545	15623	16451	514	546
20 Ne Cotton Yarns						
Grey (Natural)	0.127	728	754	775	3.5	6.5
Fibre dyed (Vat)						
Blue	0.183	432	1246	1281	188	196

Sized 1: Ordinary size mix
Sized 2: Rich size mix

coloured) decreases significantly, being even lower than that for high add-on sized yarn discussed earlier.

It may be inferred that being low concentration size, penetration is facilitated in the yarns and thus inter-fibre slippage is reduced. However, lower abrasion cycles in the sized yarn are due to insufficient size coating on the yarn. Interestingly, size penetration in relatively more packed dyed yarn is facilitated for benefit. Therefore, it appears that for dyed yarns a low viscosity size is beneficial for penetration but at the same time for size coating, desired concentration will be required.

In the case of fibre yarn the abrasion cycles in unsized yarn are lower than that in the grey yarn. But after sizing, the dyed yarn has much higher abrasion cycles. The elongation at break for the dyed yarn is significantly lower than that for grey (Natural) yarn in the unsized and sized stages. The difficulty in mechanical processing of dyed fibres in spinning is well known to the textile technologists. The probable reason is the increase in the inter-fibre friction which alters the surface characteristics and thus harms the unsized fibre dyed yarn from surface abrasion point of view, but on sizing, the yarn surface characteristics get modified to give benefit.

Table 5—Elongation of laboratory sized yarns at 10th break

Yarn type	Elongation, mm		
	Unsized	Sized 1	Sized 2
50 Ne Cotton yarns			
Grey (Natural)	11.8	1.8	0.9
Bleached	5.2	0.5	0.6
Dyed (Vat)			
Lemon yellow	6.5	0.8	0.7
Golden yellow	6.9	0.9	0.9
Grey	6.3	0.8	0.5
Green	6.5	1.0	0.7
Black	6.5	0.9	0.9
20 Ne Cotton yarns			
Grey (Natural)	32.3	8.7	6.3
Fibre dyed (Vat)			
Blue	22.5	1.4	1.1

3.5 Degradation of Yarn on Web Tester

The yarn on the web tester is subjected to cyclic extension and abrasion. The former causes fatigue and the later disintegration of the yarn structure. The change in the tenacity and elongation of the yarn subjected to these deformations was investigated to know the extent of damage separately due to these deformations. Table 6 gives the results for the unsized and sized yarns.

3.5.1 Tenacity

It is seen from Table 6 that the reduction in tenacity is significantly higher due to abrasion than

Table 6—Tensile properties of cotton yarns

Yarn type	Property	Unsized			Sized 1			Sized 2		
		N	% decrease		N	% decrease		N	% decrease	
			F	A		F	A		F	A
					50 Ne Cotton Yarns					
Grey	Tenacity	17.4	12.0	47.0	19.8	14.6	33.3	20.0	4.5	3.5
(Natural)	Elongation	6.5	10.7	24.6	4.6	35.3	24.0	4.5	26.6	28.5
Bleached	Tenacity	14.6	8.9	6.8	19.5	5.1	10.7	19.9	3.0	5.0
	Elongation	8.0	28.7	17.5	4.3	9.3	11.6	4.1	19.5	19.5
Dyed(Vat)										
Lemon yellow	Tenacity	16.5	1.8	21.8	21.7	11.0	8.3	22.0	4.1	8.6
	Elongation	7.9	3.4	26.5	4.3	4.6	0	4.2	4.8	2.3
Grey	Tenacity	16.5	12.7	30.3	2.3	9.86	14.3	22.8	6.5	19.7
	Elongation	6.9	42.0	21.7	4.8	6.25	14.5	4.5	4.4	8.8
Green	Tenacity	18.1	7.1	37.5	21.2	4.2	9.0	21.5	4.6	4.6
	Elongation	7.2	25.0	15.2	4.4	0	0	4.2	19	23
Black	Tenacity	20.4	7.3	39.7	22.3	12.5	17.9	22.8	15.3	18.4
	Elongation	8.0	17.5	37.5	4.5	6.6	10.4	4.3	6.9	4.6
					20 Ne Cotton Yarns					
Grey (Natural)	Tenacity	13.0	65	87	18.7	14.9	64.1	18.8	13.8	51.0
	Elongation	6.3	31.7	31.7	4.8	0	23.0	4.6	8.6	21.7
Fibre dyed (Vat)										
Blue	Tenacity	9.6	86	94	18.7	2.6	2.6	18.7	12.8	19.8
	Elongation	5.3	41	30	5.7	21	7	5.3	11.0	9.4

N–normal, F–fatigued, and A–abraded

fatigue both in unsized and sized yarns. Moreover, the reduction in the dyed yarn is lower compared to that in grey yarn. However, the grey colour and black dyed yarns show significantly higher reduction in tenacity compared to other light and dark dyed yarns [4].

In the case of fibre dyed unsized yarn the reduction in tenacity is higher than that for grey (Natural) yarns but on sizing, the fibre dyed unsized yarn exhibits significantly lower reduction in tenacity.

These results support the earlier observation of improved packing of yarn structure on dyeing, whereas fibre dyed yarn will have lower yarn packing. These yarn structural differences along with surface modifications must be kept in mind while deciding on the selection of the sizing material.

3.5.2 Elongation

The unsized grey (Natural) yarn shows more elongation reduction due to abrasion than fatigue, whereas most of the dyed unsized yarns give more elongation loss due to fatigue than abrasion. The decrease in elongation due to abrasion and fatigue gets reduced on sizing. In the case of grey (Natural) yarn, the reduction in elongation due to fatigue is significantly higher than that due to abrasion. It may be inferred that in the unsized dyed yarn and in the yarn after sizing, fibre slippage is reduced due to yarn compactness in the former and penetration in the later. Thus, fibre plucking out is reduced which is the main cause of yarn disintegration in weaving.

4 Conclusions

Chemical treatments (scouring/bleaching/ dyeing) improve yarn packing/ compactness. The fibres constituting the yarn do not get damaged by dyeing. The coefficient of friction is highest for the bleached yarn and its value depends on the colour in the dyed yarn. At higher add-on, bleached/dyed yarns give lower performance compared to the grey yarn whereas at lower add-on, bleached/dyed yarns give better performance than the grey yarn. Fibre dyed sized yarn gives better performance that the grey sized yarn at low add-on. There is a significant reduction in the strength and elongation of the unsized yarn due to abrasion but in the sized yarn the reduction in the strength and elongation is similar due to fatigue and abrasion. SEM photographs show that in fine counts, fibre rupture is dominant even in the unsized yarn. Better dressing/size coating with appropriate sizing material having better adhesion with the dyed yarn should be selected. Effective size at low add-on is appropriate for the dyed yarn.

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