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Phenomenon of warp breakage in weaving

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The phenomenon of warp breakage due to tensile-cum-abrasive failure of yarn is largely influenced by the inter-fibre friction in yarn. Lea CSP has been found to be a reliable test method for assessing the weavability of yarns.

Keywords: Inter-fibre friction, Lea CSP, Warp breakage, Weaving

1 Introduction

In weaving, a warp sheet of parallel sized threads is subjected to various complicated stresses such as cyclic tensile stretching, bending, compression and abrasion. The weavability of a yarn, therefore, depends on the resistance of yarn to these stresses, which, in turn, is influenced by the grey yarn characteristics and the treatment the yarn receives in the processes subsequent to spinning, particularly sizing.

Many attempts have been made earlier to characterize the yarns for their weavability either by using data on yarn quality or by simulation of weaving stresses in laboratory. These studies have helped in identifying some of the factors affecting the weavability of yarns but could not yield a predictor function to assess the actual warp breakage rate in weaving.

In the present work, a combination of both the above approaches has been used to evolve a system to assess the weavability of yarns and to understand the phenomenon of warp breakage in weaving.

2 Weavability of Yarns

The load developed in the warp sheet due to various complex stresses during weaving is unequally distributed among the threads depending upon their modulus/extensibility, the low extension threads sharing more load (Appendix I). A thread that can not provide the imposed extension or withstand the resultant stresses would cause a break. Thus, the frequency of low extension/strength threads in the yarn becomes a prominent source of warp breaks in weaving. A most satisfactory measure of characterizing a yarn for its weavability would, therefore, be one that takes account of such threads in yarn.

This behaviour of yarn in weaving, to a large extent, resembles to the mechanism of 'lea-break' in a lea test. In a lea test, a hank of a number of parallel threads (160) is subjected to tensile extension and the load thus developed is unequally distributed among the threads depending upon their modulus/extensibility. The least extensible threads suffer the most. As the process continues, at any point, a thread which can not withstand that extension breaks first and others follow in the order of their extensibility. Thus, the hank suffers a succession of thread breaks and ultimately becomes unable to sustain any further load. The remaining more extensible threads begin to slip off. It shows that lea test preferentially measures the strength of low-extension threads present in the left-tail of the distribution of yarn. These threads are highly prone to break in weaving. The dependence of warp breakage on yarn CSP for a certain yarn quality was reported by Subramanian *et al.*[1,2]. Thus, lea CSP of yarn can be reliably considered as a measure of weavability of yarn.

CSP can possibly be an indicator of the tensile failure of yarn in weaving but can it also be an indicator of the capacity of the yarn to withstand the loom stresses such as abrasion, etc.? To examine this, some experiments were conducted[3]. In an experiment, five cotton yarn samples of the same count, 40s Ne (15 tex), and twist (4.3 TM) but of different CSP levels (1788-2568) were prepared from suitable fibre mixings. These yarns were then sized to 6% and 12% add-on.

The yarns were tested for their weavability on Reutlinger web tester[4]. This web tester simulates all the important weaving stresses such as cyclic-exten-

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sion and basic tension, bending, and flex-abrasion except the beat-up force and entanglement of threads. Another salient feature of this instrument is that the yarn samples, as in weaving, are mounted in the form of a sheet of fifteen parallel threads. The weavability of yarn was determined as the average number of weaving cycles required to break the first ten threads.

Table 1 shows that there is a good correlation between the average number of weaving cycles required to break the yarn and the yarn CSP. This is true even for sized yarns. This trend can be attributed to better fibre-to-fibre interlocking/packing in the case of high CSP yarns. The magnitude of weaving cycles, apart from CSP, is also influenced by the yarn count and twist; with a change in count or twist, the magnitude of weaving cycles changes. However, the trend with CSP remains intact. Table 1 further shows that the gain in weaving cycles on sizing increases with increase in grey yarn CSP and size add-on and so is the skewness in the distribution of weaving cycles. The low CSP yarns have negative skewness, indicating a high frequency of weak threads in yarn. At 6% add-on, the low CSP yarns show a drop in weaving resistance of yarn while at higher add-on (12%) they show a marginal gain. These findings show that for satisfactory weaving, there is a minimum requirement of yarn quality and the yarns below that quality can not be made weavable by sizing. Thus, the improvement in grey yarn quality on sizing, in a way, is the function of grey yarn quality itself.

In the process of weaving, on account of weaving stresses, there is a continuous deterioration in almost all the properties of yarn. An assessment of the extent of degradation of yarn on account of weaving stresses can be made by determining the loss in weight of yarn in the case of grey yarn and drop in strength in the case of sized yarn. Table 2 shows that a low CSP (weak) yarn deteriorates at a faster rate on account of weaving stresses than a high CSP yarn [Hari P K, Aggarwal S K & Subramanian T A, unpu-

Table 1—Association between CSP and simulated weavability of grey and sized yarns

[Ne count, 40s]

Parameter	Yarn				
	A	B	C	D	E
CSP	1788	1878	2181	2334	2568
Packing density, g/cm^3	0.553	0.562	0.571	0.578	0.583
Av. weaving cycles					
Grey	146	194	271	321	386
Sized (6%)	104	191	261	430	542
Sized (12%)	163	205	468	658	900
Change on sizing, %					
Sized (6%)	−29	−1	−2	36	39
Sized (12%)	11	8	73	130	126
Skewness in the distribution of weaving cycles					
Grey	−0.23	−0.02	0.28	0.46	0.67
Sized (6%)	−0.38	0.03	−0.10	1.48	0.16
Sized (12%)	−0.41	−0.14	−0.45	0.19	0.39

Table 2—Effect of CSP on rate of degradation of grey and sized yarn

No. of weaving cycles	Loss in weight of grey yarn (%)			Drop in strength of sized yarn(%)	
	1788[a]	2181[a]	2568[a]	2181[a]	2568[a]
50	9.3	5.1	2.2	—	—
75	—	—	—	16.1	1.4
100	30.9	14.0	9.5	—	—
150	59.8	24.2	15.1	49.2	2.5
200	87.4	42.8	24.3	—	—
225	—	—	—	66.5	36.6
300	—	83.1	47.0	78.0	58.1

[a]Grey yarn CSP

blished work]. This finding is of practical significance in understanding the weaving behaviour of yarn. It shows that in actual weaving, a low CSP thread, by the time it reaches the healds and reed zone, becomes more susceptible to break than a high CSP (stronger) thread.

The results reported so far have clearly established that the grey yarn CSP can be reliably considered as an index to assess the yarns for their weavability. However, this technique is applicable only to the yarns having CSP 2400 or less. It has been reported earlier[1] that the frequency of warp breaks due to tensile-cum-abrasive failure exponentially decreases with increase in CSP; in the case of yarns having CSP 2400 or more the occurrence of such breaks is rare. In such cases, the occurrence of warp breaks is mainly due to failure of gross thick places, knots and miscellaneous causes. Thus, the CSP test loses its discriminating power to classify the yarns having CSP 2400 or more for their weavability.

3 Phenomenon of Yarn Breakage in Weaving

The Reutlinger web tester simulates, to a large extent, the weaving stresses. The yarn testing on this instrument can be used to understand the phenomenon of warp-breakage due to tensile-cum-abrasive failure of yarn.

On web tester, cyclic-extension and axial abrasion simultaneously act on the yarn held at constant tension. As a result, the loosening of yarn structure takes place, which, in turn, promotes inter-fibre slippage. As this loosening of yarn structure progresses, the abrading element rubs off the fibres from the yarn structure, causing fibre loss. The fibre loss again enhances inter-fibre slippage. On account of these forces a relaxation of yarn takes place and the tension tends to decrease. Now, the mechanism which is provided to maintain the tension level constant pulls the yarns, subjecting them to elongation. This additional elongation is mostly because of inter-fibre slippage on account of loosening of yarn structure and fibre loss/breakage. The process continues until the yarn breaks.

The simulation test shows that during weaving the yarn break is mainly because of loosening of yarn structure and inter-fibre slippage associated with fibre loss/breakage. During actual weaving, the weaving stresses weaken the size film on the yarn and finally rub it off, exposing the inner layers of fibres to these forces. Consequently, the yarn deteriorates as the weaving proceeds until it dissipates.

The tendency for inter-fibre slippage in a yarn is mostly governed by binding of the fibres inside the yarn and inter-fibre friction[5]. Table 3 shows that the rate of yarn extension/inter-fibre slippage during testing decreases with increase in yarn CSP. This can be attributed to better fibre-to-fibre binding/ packing inside the yarn in the case of high CSP yarns. The high CSP yarns spun out of long and fine fibres are expected to have better fibre-to-fibre binding than a low CSP yarn spun out of short and coarser fibres.

To illustrate this phenomenon further, two different yarns were considered. In the first yarn, inter-fibre locking and friction were such that the cohesive forces holding the fibres together in the yarn were very strong. In the second yarn, these forces were relatively weak. When subjected to weaving stresses, in the first yarn, forces developed dissipated largely in the fibres by development of tensile and other stresses. In the initial stages, the inter-fibre slippage, if at all, was very less. However, the cyclic weaving stresses for a long time resulted in fibre fatigue, leading to rupture and to some extent fibre slippage in the yarn. However, when the fibre cohesion was relatively weak, as in the second yarn, the stresses developed easily displaced/removed the fibres from their normal position in the yarn (Table 3).

The displacement or slippage of fibres in the yarn creates a new weak place in the yarn structure without appreciable fibre damage. Once a weak place is created the weaving stresses concentrate at that point to intensify the yarn degradation process, the

Table 3—Effect of CSP on yarn packing density and rate of yarn extension on account of weaving stresses

Parameter	Yarn				
	A	B	C	D	E
CSP	1788	1878	2181	2334	2568
Packing density, g/cm^3	0.553	0.562	0.571	0.578	0.583
Yarn extension per cycle $\times 10^{-3}$, mm					
Grey	15.2	11.1	8.3	7.3	7.9
Sized (6%)	4.8	4.3	4.4	2.5	1.8
Sized (12%)	3.0	4.1	2.3	1.1	0.4

less securely bound fibres being more accessible to the abradant parts of loom. As a result of this, the resistance of yarn to withstand weaving stresses reduces considerably. The process continues till the yarn reaches its endurance limit. Once the endurance limit is reached, the stresses dominate to disintegrate the yarn at that point.

4 Conclusions

The phenomenon of warp-breakage due to tensile-cum-abrasive failure of yarn in weaving is largely influenced by inter-fibre friction of the yarn. The low extension/strength threads present in the warp sheet are more prone to break in weaving on account of loom stresses.

The lea-test not only simulates, to a large extent, the weaving behaviour of yarns but also correlates well with (i) the capacity of grey and sized yarn to withstand loom stresses, (ii) degradation behaviour of yarn in weaving, and (iii) actual warp-breakage rate in weaving. Thus, lea CSP can be reliably considered as an index to characterize the cotton yarns for their weavability. However, this technique is applicable only to the cotton yarns having CSP 2400 or less.

References

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Appendix I—Distribution of stresses in a warp sheet containing yarns of varying tensile modulus

In order to have an idea about the distribution of forces in warp sheet, let us consider three yarns having tensile modulus M_1, M_2 and M_3 respectively as shown in Fig. 1.

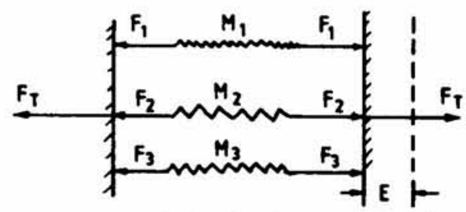

Fig. 1—Stress distribution in yarn of warp sheet

Now when the yarns are subjected to tensile elongation, say by an amount E, then the distribution of force (F_T) developed in warp will be as follows:

$$F_T = F_1 + F_2 + F_3 \quad \text{...(1)}$$

$$F_1 = M_1 E \quad \text{...(2)}$$

$$F_2 = M_2 E \quad \text{...(3)}$$

$$F_3 = M_3 E \quad \text{...(4)}$$

where F_1, F_2 and F_3 are the forces developed in first, second and third yarn respectively. Eqs (2), (3) and (4) show that for a given elongation E, the force developed in a yarn is directly proportional to its modulus; the higher the modulus the more is the force.

$$\text{Stress } (S) = \frac{\text{Force } (F)}{\text{Linear density of yarn } (N)}$$

In this context, Eqs (2), (3) and (4) can be rewritten as:

$$S_1 = M_1 E/N_1 \quad \text{...(5)}$$

$$S_2 = M_2 E/N_2 \quad \text{...(6)}$$

$$S_3 = M_3 E/N_3 \quad \text{...(7)}$$

Eqs (5), (6) and (7) illustrate as to how the stress levels alter with tensile modulus and linear density of yarn.