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# Mechanism of yarn break for high-pressure squeezed sized yarn

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The mechanism of yarn break during weaving has been analyzed by studying abrasion resistance and yarn elongation during abrasion. Weaving stresses cause structural disintegration of the yarn due to fibre plucking and inter-fibre slippage. Geometrical parameters of the sized yarn like packing density and size penetration play important role in preventing the structural disintegration of the yarn. Increase in squeeze pressure increases both packing density and size penetration which ultimately improve fibre-to-fibre and fibre-to-size anchorage and hence result in improved surface integrity and weavability.

**Keywords:** Cyclic extension, Inter-fibre slippage, Squeeze pressure, Yarn circularity, Yarn flattening

## 1 Introduction

In addition to the attractive savings[1] in valuable thermal energy, many other advantages such as higher machine speed with the existing drying section, minimum uneven size migration, easier splitting at lease rods and reduction in labour costs[2] have been reported for warps sized at high-pressure squeezing. Regarding the weaving performance of the high-pressure sized yarn, many researchers have given different opinions, most[3-5] of which are conducive for the use of high-pressure squeezing system. On the contrary, this claim for all yarns has been disputed by Hall *et al.*[6] No conclusive technical data is available on the performance of high-pressure sized yarn nor any attempt has been made to understand the better performance of the sized yarns. Yarn break during weaving is usually due to the failure of a weak element of the yarn in its operational part to meet the strain imposed upon it. These stresses cause disintegration of yarn structure due to fibre plucking and inter-fibre slippage. The tendency of inter-fibre slippage in a yarn is mostly governed by the inter-fibre friction and fibre-to-fibre interlocking.

In this paper, an attempt has been made to understand the mechanism of yarn break for high-pressure squeezed sized yarn by laboratory simulation of weaving on the web tester with the help of yarn structure.

## 2 Materials and Methods

40 Ne cotton, 45 Ne polyester/cotton (67 : 33) and 40 Ne polyester/viscose (48 : 52) were used for sizing.

### 2.1 Sizing

Sizing was carried out under controlled conditions on the Laboratory Zell High Pressure Sizing Machine. The sizing agents, squeeze pressure and size add-on employed were as follows:

| | |
|---|---|
| Sizing agent | : Thin boiling starch + mutton tallow (3% of starch)<br>Thin boiling starch + partially hydrolyzed polyvinyl alcohol (85:15) |
| Low squeeze pressure | : 28 pounds/linear inch (PLI) or 5 da N/cm or 22 da N/cm$^2$ |
| High squeeze pressure | : 140 PLI or 25 da N/cm or 33.8 da N/cm$^2$ |
| Size add-on | : 15.3% for P/C<br>15.8% for P/V<br>16% for Cotton |

The size add-on of cotton, P/C and P/V yarns were kept almost constant at both LPS and HPS by varying the machine speed and size liquor concentration.

### 2.2 Weaving Performance

The relative weaving potential of the yarn was studied on the web tester which simulates the most important stresses during weaving such as cyclic extension/bending and axial abrasion under constnat tension. In a test, fifteen yarn samples were mounted on the tester and the number of cycles to break the first ten successive yarns were recorded. The average abrasion cycles of the ten repeats of the test was taken.

### 2.3 Bending Rigidity

The bending rigidity of the yarn was obtained by testing in the Shirley cyclic bending tester. The yarns were kept side by side parallel to each other in sheet form and their ends were pasted on a gum paper so as to give a specimen size of 25 × 12.5 mm. The pendulums of different weights were selected for testing different yarns. The yarn sheet was bent up to a maximum curvature of $\pm 3\ \mathrm{cm}^{-1}$. Four individual tests were performed for each yarn sample and the average values of elastic flexural rigidity ($G_0$) and coercive couple ($C_0$) were calculated.

## 3 Results and Discussion

As described in section **2.2**, the weaving abrasion resistance was determined on the web tester in terms of weavability cycles. The weavability cycles provide the relative weaving potential of different yarns. The behaviour of the unsized and low/high pressure sized yarns was studied from the abrasion curves (Fig. 1) obtained by plotting the weaving abrasion cycles required for successive yarn breaks up to the tenth break. It is observed from Fig. 1 that the unsized yarns give flat curves whereas the sized yarns show comparatively greater slope. However, it may be seen that the behaviour of high-pressure and low-pressure sized yarns is similar; the former shows consistent higher weavability cycles. This abrasion behaviour is clearly visible in the bar diagram (Fig. 2) in which the lower and upper levels represent the average of 1st and 10th yarn breaks respectively with the overall average value (arithmetic mean) being inbetween. Unsized yarn shows low variability in the weavability cycles. Sizing not only improves the weavability but also increases the variability due to the well known fact that sizing reinforces the strongest yarns much more than the weak yarns. High pressure further improves the weavability cycles without affecting the variability.

### 3.1 Variability of Abrasion Cycles for High-Pressure Sized Yarn

The variation in abrasion cycles for successive yarn breaks of a sample is characteristic of the group test, like in weaving, and is caused by the unequal sharing of stress due to the variability in yarn extension and strength. In fact, the initial yarn breaks are more likely to be due to the faults/imperfections in the yarn. However, the mean abrasion resistance for high-pressure sized yarn is higher than that for unsized and low-pressure sized yarns.

Arithmetic mean is affected by the value of every item and the presence of one or a few ex-

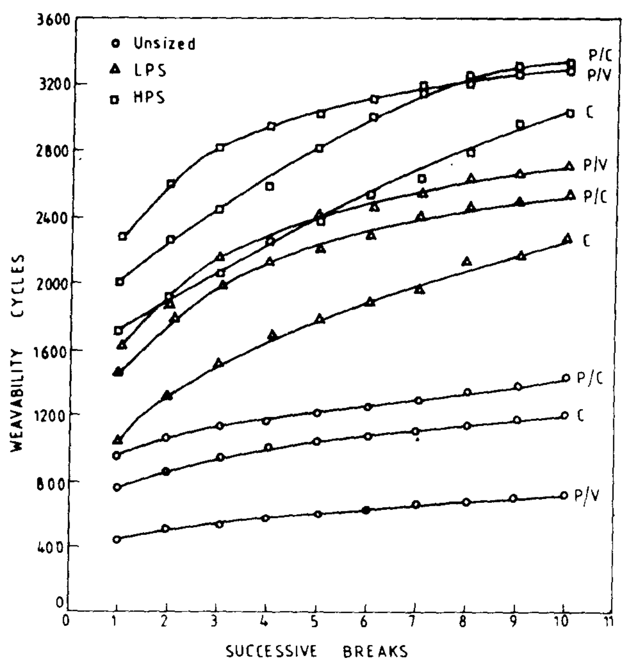


Fig. 1—Abrasion curves of yarns

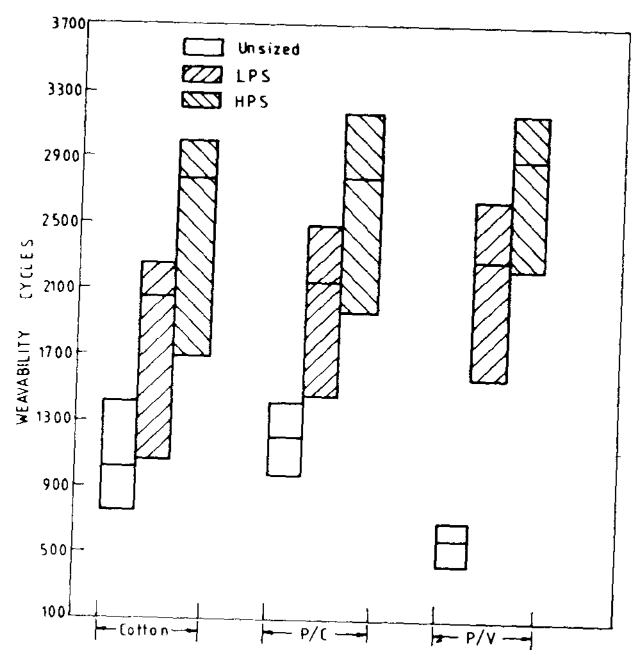


Fig. 2—Abrasion behaviour of yarns

tremely large/small items may result in a misleading mean but the median is not much affected. This causes skewness. One of the statistical approaches in terms of the coefficient of skewness for weavability cycles was determined to study the variability in abrasion behaviour of the unsized vis-a-vis low/high pressure sized yarn. The coefficient of skewness[7] is calculated as follows:

$$S_K = \frac{3(\bar{X} - Me)}{S}$$

where $S_K$ is the coefficient of skewness; $X$, the mean of the abrasion cycles; $Me$, the median; and $S$, the standard deviation.

The data given in Table 1 show the coefficient of skewness of the weaving abrasion cycles for unsized and low/high pressure sized yarns. The following observations can be made from this table:

- Cotton yarn exhibits positive skewness.
- Unsized P/C and P/V yarns show positive skewness but on sizing they show negative skewness.
- High-pressure squeezing in sizing reduces the skewness.

Positive skewness means most of the values are in the lower range and negative skewness means most of the values are in the upper range Positive skewness is reported[8] for warp breaks per piece length woven on loom. In fact, negative skewness is more as most values are on the higher side of range. The probable reason for the negative skewness in the blend yarn is easy penetration due to lower yarn packing. This means that in blends weaker yarns are strengthened more but in cotton, few strong yarns are strengthened more. However, it can be observed from the result that the skewness is reduced by increasing the pressure during squeezing. This shows that the high-pressure squeezing in sizing provides a more uniform weavability behaviour, presumably due to uniform yarn cross-section and smooth uniform dressing of the sized yarn[9].

### 3.2 Yarn Elongation During Abrasion

It has been mentioned earlier that during weaving, the abrading elements rub off fibres from the yarn structure, causing fibre loss and enhancing inter-fibre slippage. The weaving stresses which act on the yarn cause disintegration of the yarn structure which results in inter-fibre slippage and yarn extension. This extension and its rate depend on the yarn structure. The normalized yarn elongation per cycle ($E_p$) during abrasion is measured as:

$$E_p = \frac{E_2 - E_1}{W_{10}}$$

where $E_1$ is the initial extension due to the applied tension; $E_2$, the final extension at the tenth break; and $W_{10}$, the weaving abrasion cycles at the tenth yarn break.

Table 2 shows that the elongation per cycle is maximum for unsized yarn and it decreases substantially on sizing. The value is further reduced on increasing the squeeze pressure. This shows that the rate of inter-fibre slippage is lower for high-pressure sized yarns compared to low-pressure sized yarns.

The abrasion behaviour is clearly visible from Fig. 3 which shows the progressive yarn extension during abrasion for unsized and low/high pressure sized yarns. However, the yarn extension starts early and at a rapid rate during abrasion for the unsized yarn. Yarn extension decreases substantially on sizing and high-pressure squeezing further decreases it. High-pressure squeezing also delays the collapse of the yarn and hence gives higher weavability cycles. This behaviour can also be explained with the help of yarn compactness and size penetration[7].

### 3.3. Effect of Squeeze Pressure on Weaving Abrasion Resistance

The effect of squeeze pressure on the weaving

Table 1—Coefficient of skewness of weavability cycles for unsized and sized yarns

| Yarn | Coefficient of skewness | | |
|---|---|---|---|
| | Unsized | Sized | |
| | | LPS | HPS |
| Cotton | 0.1563 | 0.8264 | 0.4043 |
| P/C (67 : 33) | 0.8174 | −0.6964 | −0.2161 |
| P/V (48 : 52) | 1.1468 | −0.9779 | −0.8626 |

Table 2—Elongation per cycle for unsized and sized yarns

| Yarn | Elongation per cycle × $10^{-3}$, mm | | |
|---|---|---|---|
| | Unsized | Sized | |
| | | LPS | HPS |
| Cotton | 25.97 | 1.42 | 0.62 |
| P/C (67 : 33) | 23.27 | 8.56 | 3.79 |
| P/V (48 : 52) | 34.63 | 6.43 | 4.01 |

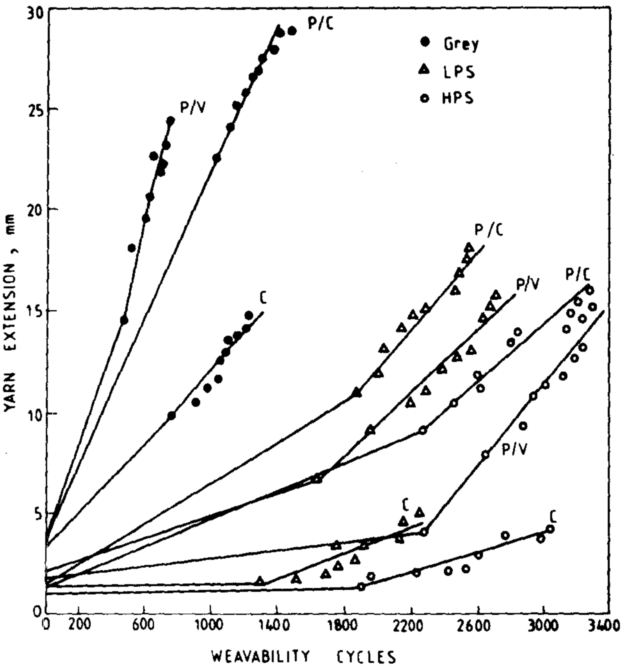


Fig. 3 — Progressive yarn extension during abrasion

Table 3 — Weavability cycles of unsized and sized yarns

| Yarn | Weavability cycles | | | |
|---|---|---|---|---|
| | Unsized | Sized | | |
| | | LPS | HPS | % Increase from LPS to HPS |
| Cotton | 1030 | 1766 | 2411 | 37 |
| P/C (67 : 33) | 1229 | 2183 | 2823 | 29 |
| P/V (48 : 52) | 608 | 2338 | 2961 | 27 |

Table 4 — Flexural rigidity ($G_0$) and coercive couple ($C_0$) of sized and unsized yarns

| Yarn | Cotton | | P/C (67 : 33) | | P/V (48 : 52) | |
|---|---|---|---|---|---|---|
| | $G_0$ | $C_0$ | $G_0$ | $C_0$ | $G_0$ | $C_0$ |
| Unsized | 0.034 | 0.069 | 0.031 | 0.068 | 0.031 | 0.059 |
| LPS | 7.069 | 7.932 | 3.335 | 6.509 | 5.135 | 7.057 |
| HPS | 7.831 | 8.939 | 4.277 | 7.488 | 6.273 | 8.723 |

Flexural rigidity in mN mm$^2$/mm ($10^{-1}$).
Coercive couple in mN mm/mm ($10^{-2}$).

performance of sized yarn is studied by considering the average weaving abrasion resistance. The average weavability cycles of unsized and low/high pressure sized yarns (Table 3) show that weaving abrasion resistance improves significantly on sizing. Increase in squeeze pressure further improves the weaving abrasion resistance of the yarns studied. It is also observed from Table 3 that although the overall weaving abrasion resistance of polyester blend yarns (P/C and P/V) is higher than that of the cotton yarn, the improvement due to high squeeze pressure is higher in case of cotton yarn.

The possible explanation for above observations has been offered based on the geometrical parameters of yarn[9,10]. It has been reported that the increase in squeeze pressure increases size penetration and packing density, and improves yarn circularity. Sizing provides protection to the yarn surface from abrasion by film coating and the penetration of the size in yarn improves the anchorage of the film with fibre and also prevents the structural disintegration. During weaving abrasion, the stresses, such as cyclic extension and axial abrasion with bending, simultaneously act on the yarn and cause loosening of the yarn structure which promotes the inter-fibre slippage and extension. A densely packed high-pressure sized yarn will have more inter-fibre cohesion due to better fibre-to-fibre interlocking than a bulkier unsized or low-pressure sized yarn and would thus give better abrasion resistance and hence improved weavability. Similarly, increased size penetration helps in increasing the fibre-to-fibre and fibre-to-size anchorage and hence results in improved surface integrity and weavability. However, it may be noted that the excess of penetration is harmful for the sized yarn as it would result in higher yarn stiffness and yarn flattening. In fact, the extent of penetration depends on the level of squeeze pressure and the size liquor concentration. Since in this work an optimum squeeze pressure for 40-45s yarns was selected[9] which is considered to be a moderate squeeze pressure compared to the higher squeeze pressure used in overseas countries, this probably explains the improved weavability cycles. It is also supported by the bending rigidity of the yarn (Table 4) in which a small increase was obtained by increasing the squeeze pressure from 5 to 25 daN/cm. Regarding the film thickness, it is well known that the sized yarn needs a minimum film thickness below which the yarn performance deteriorates. In case of high-pressure squeezing, the use of high concentration size liquor gives the required size film thickness with desired size penetration and size add-on.

## 4 Conclusions

High-pressure sized yarn gives consistent higher weavability cycles and more uniform weavability behaviour over low-pressure sized yarn. High squeeze pressure improves surface integrity and reduces inter-fibre slippage due to more size penetration and enhanced packing density which ultimately delay the structural disintegration of the yarn during weaving.

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