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A STUDY OF THE BREAKING STRENGTH OF WEAK PLACES IN A WORSTED YARN

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ABSTRACT

The relationship between the values obtained on a Shirley Constant Tension Winding Tester and certain yarn properties, such as tensile strength, irregularity, twist etc., has been investigated for a number of wool worsted hosiery yarns.

KEY WORDS

Shirley Constant Tension winding test, breaking strength distribution, weak places, hosiery yarn, irregularity, twist.

INTRODUCTION

Various workers have studied the influence of yarn friction on the forces developed during knitting[1—5]. From these studies it emerged that yarn friction critically affects the knitting forces, and therefore the tension developed in the yarn, especially when knitting without positive feed. Hammersley[6] investigated the relationship between certain yarn properties, such as strength, extension, friction etc., and the number of holes obtained when knitting the yarns on an 18 gauge, double jersey machine. He found a significant (at the 5% level) correlation between the mean yarn breaking strength and the frequency of holes while the correlation between the number of holes and yarn friction was nearly significant at the 5% level. He omitted the results of two "anomolous" yarns from his analyses, however, and had the results of these two yarns been included the correlation between the above properties would have been worse.

The poor correlation observed between the strength of a yarn and its knitting performance is due mainly to the extremal nature of the events involved. Breakage in knitting, or in weaving, is a relatively infrequent event and presumably the influence of yarn strength, if any, will depend upon the shape of the extreme tail of the breaking strength distribution curve. Exact determination of this section of the curve (the 0,1 percentile region) consumes both material and time. An instrument, however, which carries out this task relatively quickly is the Shirley Constant Tension Winding Tester (referred to here as the Shirley Tension Tester). The instrument does not determine the tail of the breaking strength curve in the classic manner i.e. by breaking a given length of yarn, but applies a tension to a yarn running through the machine so as to obtain a certain breakage rate, e.g. 8 breaks per 915 m (1 000 yds) of yarn. Results obtained under such "dynamic" conditions need not be related exactly to results obtained under more "static" conditions and it was of interest to find the relationship between these two test methods. Furthermore the Shirley tension method suffers from the defect that relatively large quantities of material must be tested and it would be valuable if tests requiring less material could be used as a guide to the breaking strength of the extremely weak yarn segments.

EXPERIMENTAL

Thirty-eight lots of dyed wool worsted single hosiery yarns were selected from various mills in the local industry. For each of the yarns the following properties were determined:

Shirley Tension[8] (in gf); count (tex); twist (turns per meter); mean and standard deviation of yarn breaking strength; weakest and second weakest place in 400 tests; yarn irregularity (C. of V. in %); thin places, thick places and neps per 1 000 m; mean fibre length; mean fibre diameter and yarn friction.

The yarn irregularity was determined on the Uster yarn irregularity tester[7] and the yarn friction on the SAWTRI yarn friction tester[10].

The yarn breaking strength was determined on the Uster Automatic Yarn Breaking Strength Tester and the frequency diagram of the loads at break was obtained for each of the 38 lots of yarn, with the number of tests per lot varying from 400 to 800. The skewness and kurtosis were calculated for each of the frequency distributions, using the following formulae:

$$\text{Skewness} = \alpha_3 = \frac{m_3}{m_2^{1,5}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\text{Kurtosis} = \alpha_4 = \frac{m_4}{m_2^{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where m_2, m_3 and m_4 are the second, third and fourth central moments of the distribution.

To test whether the skewness and kurtosis deviated significantly from normal, the following formulae were employed:

$$\text{For skewness}: Z_1 = \alpha_3 \left[\frac{(n+1)\ (n+3)}{6\ (n-2)} \right]^{1/2} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

$$\text{For kurtosis}: Z_2 = (\alpha_4 - 3 + \frac{6}{n+1}) \left[\frac{(n+1)^2\ (n+3)\ (n+5)}{24\, n\, (n-2)\ (n-3)} \right]^{1/2} \quad \ldots\ldots\ldots\ldots\ldots (4)$$

TABLE I

RELATIONSHIP BETWEEN SHIRLEY TENSION RESULTS AND VARIOUS OTHER PARAMETERS

Analysis	t-values										
	Count	Twist	Thin places per 1 000 m	Breaking strength	s.d. of B.S.	Irregularity C.V. %	Fibre diameter	Skewness	Kurtosis	R	S (gf)
1	1,62	-2,44*	-1,44	3,59***	-1,80	—	—	—	—	0,957	14,01
2	1,35	-2,61**	—	5,06***	-2,30*	—	—	—	—	0,954	14,29
3	—	-5,58***	—	5,22***	-0,30	-2,14*	—	—	—	0,9578	13,69
4	—	-6,22***	—	8,06***	—	-3,03**	—	—	—	0,9576	13,52
5	—	-5,44***	—	7,40***	—	-2,63**	-0,63	—	—	0,958	13,64
6	—	—	—	8,09***	—	-3,01**	-2,01*	—	—	0,927	19,02
7	—	-6,12***	—	7,49***	—	-2,68**	—	1,28	0,59	0,961	13,36

* Significant at the 5 per cent level
** Significant at the 1 per cent level
*** Significant at the 0,1 per cent level

where n is the number of breaks in each case. Under the assumption that α_3 and α_4 are normally distributed, both Z_1 and Z_2 are distributed as the standard normal.

Regression analyses were carried out on the data mentioned above as well as on the skewness and kurtosis. A summary of the relevant results are given in Table I under *Results.*

In order to investigate the effect of a difference in Shirley tension only on knittability, two pairs of yarns with the same breaking strength and friction, but of different Shirley tension values were selected and knitted under identical conditions on a Lawson Fibre Analyses Knitter[4, 9].

RESULTS AND DISCUSSION

In Table I a summary of some of the analyses carried out is given. In all cases the dependent variable was the Shirley Tension result while various combinations of independent variables were selected to try and explain the variation of this yarn property. The table gives the *t* values of the regression coefficients of the multivariate regression analyses as well as the total correlation coefficient (R) and the square root of the residual variance (S). For all the analyses there were 38 sets of results.

The first choice of variables was yarn count, twist, mean breaking strength, standard deviation (s.d.) of breaking strength and thin places per 1 000 m. Only the t values of twist and mean breaking strength were significant and it was thought that the contribution of count may have been non-significant due to its correlation with thin places. This latter variable was therefore eliminated, but the effect of count remained non-significant. The frequency of thin places contributed significantly to the reduction in the residual variance when count was omitted, but as this variable is prone to relatively large sampling variation and experimental error, it was felt that by replacing it with a more consistent variable, such as the coefficient of variation of linear density (irregularity C.V.%), an improvement in the correlation may be effected. This is precisely what happened in the third analysis but the inclusion of C.V. had now made the s.d. of breaking strength redundant. Hence at this stage of the work the final set of variables were those given in analysis 4.

What was surprising about the results in analysis 4 was the presence of twist and the absence of count from the set of variables. It was reasoned that the effect of twist may be significant because the spinners had altered the twist according to the mean fibre diameter and mean fibre length and that it was actually these variables which were the physical cause of the correlation. Analyses of the results showed that the twist inserted in the yarn was dependent on the yarn count, as could be expected, and upon fibre diameter, but not upon fibre length. Accordingly these two new variables were either added to the three variables in analysis 4 or substituted for twist, but in all these analyses the residual variance either increased or was not significantly reduced (as, for example, in analyses 5 and 6). Therefore

TABLE II

	Pair A		Pair B	
	1	2	3	2
Breaking strength (gf)	174	176	197	201
Count (tex)	30,6	30,5	35,1	30,9
Kinetic friction (g)	35	37	38	37
Shirley Tension (gf)	250	190	280	240
Cover factor = $\left[\frac{(\text{tex})^{1/2}}{\text{stitch length in cm}}\right]$	19,9	19,9	18,7	18,7

the relationship between Shirley Tension and twist could not be explained in this manner and, at this stage, no alternative explanation can be suggested.

As can be seen from Table I, the spread (i.e. standard deviation) of the breaking strength histogram had been eliminated as non-significant. This did not discount the possibility that the shape of the curve could have had some influence on the expected breaking strength of its extreme values as represented by the Shirley tension results. Skewness and kurtosis were therefore included as additional variables, but neither variable seemed to influence the Shirley Tension results (Analysis 7).

The results from the Shirley Constant Tension Winding apparatus were scrutinised and outlying points of the Shirley tension – breaking strength relationship were found. From these results two pairs of yarns were selected, each having different Shirley tension values, but which were similar in other properties as illustrated in Table II. The two pairs of yarns were knitted to high cover factors (as shown in Table II) on the Lawson Fibre Analyser but no significant difference in knitting performance (number of holes formed) could be observed. This observation obviously does not invalidate the Shirley Constant Tension Winding tester but merely indicates that, given the breaking strength of the yarn, the Shirley Tension results will not consistently contribute additional information as regards the knitting performance of the yarn. Furthermore, the four yarns selected were of a high quality and were knitted with positive feed, and it is possible that if yarns of a poorer quality had been selected or if the yarns had been knitted without positive feed differences in knitting performances of the yarns may have been obtained.

In conclusion, therefore, it seems that Twist, irregularity (C.V.) and breaking strength would give a reasonable estimate (minimum 95% confidence limits of ± 27 gf) of the expected Shirley Tension result. The regression equation

$$Y = 313,6 - 0,41x_1 - 3,76x_2 + 0,90x_3 \quad \text{.............................(5)}$$

where x_1 is the twist in tpm, x_2 is the C.V. in per cent and x_3 is the mean breaking strength in gf, should prove useful in reducing the quantity of testing material and, if the above quantities are to be determined by a laboratory for other reasons, also the testing time. This equation may also be used as an initial discriminant function to distinguish between "knittable" and "non-knittable" yarns of the same kinetic friction. It is also obvious that the discriminant function chosen finally will not contain the above constants, but may be another linear function of the above three variables.

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