Yarn: the strengths and weaknesses

Alan Parker pinpoints past failings and future possibilities in strength testing

As part of an investigation into ways to increase the strength of friction-spun yarn, I have had cause to examine in great detail yarn produced on the conventional spinning systems of ring and rotor. This investigation has convinced me that, whereas sophisticated electronic means of measuring the characteristics of yarns and analysing the data produced have been available for a number of years, the information obtained has not enabled the spinner to predict accurately the performance of the yarn in subsequent processing.

This article will discuss why traditional yarn strength testing procedures have been unable to predict the performance of yarn and suggest how new procedures and newly-available equipment (for example, the Uster tensojet) might be employed to improve the situation.

Doubts

For many years I have doubted that the present strength testing standards give an indication of the performance of the yarn in subsequent processing. The experiences of Repco self-twist yarn in high bulk acrylic knitting demonstrated conclusively, to what was initially a very doubting industry, that the average strength standards based on ring spinning bore no resemblance to the average strength levels needed for self-twist yarn to perform acceptable. It has been similarly demonstrated that rotor yarn has performed equally, and frequently better, than much stronger ring spun yarn.

The most significant condemnation of existing yarn strength testing procedure was recently made[1], in which for the first time actual weaving performance, yarn stresses imposed in weaving and extensive yarn test results were available for the same yarn. This conclusively demonstrated that existing yarn strength testing procedures give a TOTALLY wrong indication of the number of weak places in a yarn.

Because this is one of the primary functions of single-thread testing there is a requirement to investigate how better forecasting can be achieved.

Existing systems

When assessing present methods of either skein or single thread strength testing, it has to be borne in mind that the present procedures were established many years ago based on the equipment – and, perhaps even more importantly, the yarn quality standards – being achieved at that time. The significance of this is discussed later in the article.

LEA STRENGTH TESTING: This is the traditional method of assessing yarn strength and at the same time checking the count of the yarn. This is still the standard method for some companies, particularly in the USA, although it has been superseded in most places by single-thread testing.

My own experience with this method is that it gives a reasonable correlation to the tensile and tear strength of woven fabrics but has a poor correlation with yarn performance and is not sensitive to small changes, which may, however, be significant in today's quality – conscious world. Because fabric properties depend on the inter-relationship between a number of different yarn threads, it is reasonable to expect that the level at which a skein of yarn breaks should approximate to fabric properties.

SINGLE-THREAD TESTING: Single-thread testing is based on testing a 50cm sample of yarn at either a constant rate of extension or a constant rate of loading. Traditionally the speed was set such that the sample breaks within 20 seconds + or –3 seconds.

Modern single thread testing equipment is already very sophisticated and able to offer a wide variety of parameters related to the breaking load, elongation and work to rupture of yarn and the variability of these parameters.

This information does give a guide to the relative performance of one yarn against another in the fabric making processes and is able to detect yarns that are totally unsuitable. However, with this information it is not possible to predict how well the yarn will perform, nor is it able to distinguish between yarns that will perform extremely well, and those with merely an adequate performance. Modern, capital-intensive, high production fabric forming machines are continuing to make greater and greater demands on yarn to perform with minimum stoppages.

TABLE 1. Presenting Strength Data

MEAN TENACITY = ??? cN/tex
C. OF V. TENACITY = ?? %
PREDICTED OCCURRENCE OF WEAK PLACES PER MILLION METRES OF YARN
Below 10 cN/tex = ???
Below 9 cN/tex = ???
Below 8 cN/tex = ???
Below 7 cN/tex = ???
Below 6 cN/tex = ???
Below 5 cN/tex = ???

The problem

A primary purpose of single-thread testing is to assess how the yarn will perform in subsequent processing and consequently the interest is in the weakest sections of yarn. The difference between a yarn that performs poorly and one that performs well could typically be that thee will be one very weak place in 20,000 x 50cm sample lengths for an unacceptable yarn and one very weak place in 200,000 x 50cm samples for an acceptable yarn.

It is the relative INFREQUENCY of the weak places that makes the comparison difficult to achieve.

To complicate the matter further, a weak place in one process will not be a weak place in another, as for example:

- Knitting and weaving machines apply different stresses on the yarn.
- The type and speed of operation of the fabric forming machine affects the stresses on the yarn.
- The fabric structure changes the stresses applied.

● Turn to page 27

● From page 25

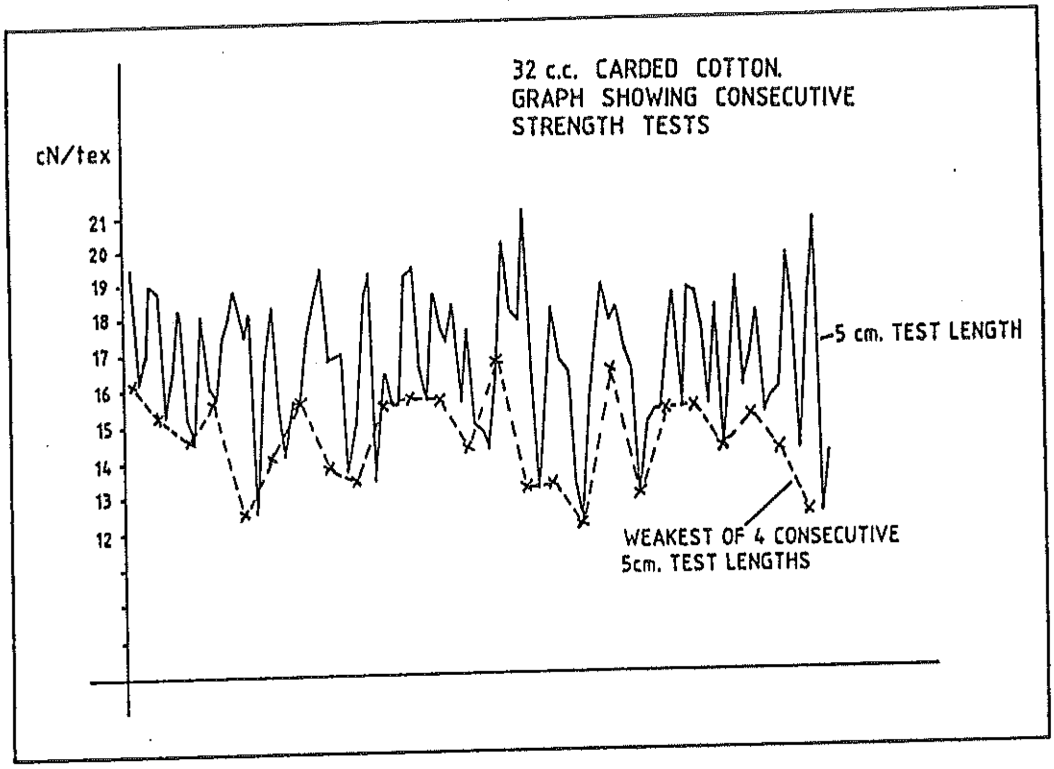
Principles of single-thread testing

The fundamental principle on which single thread testing has been based is that the level at which a yarn breaks takes the form of a normal distribution about the mean level. A normal distribution is completely specified by two parameters, the theoretical mean and the theoretical variance of the population. A distribution curve of yarn strength from a reasonable number of yarn tests resembles a normal distribution curve.

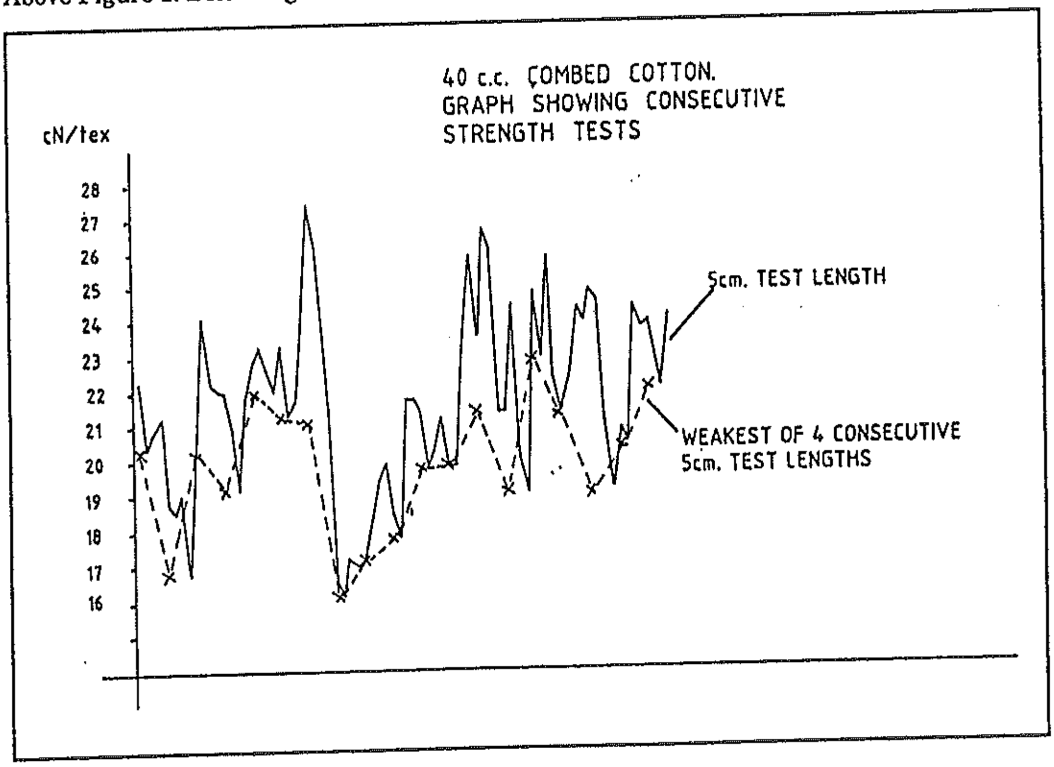
One of the major conclusions to be drawn from the results provided[1] is that, using the present testing procedure, the level at which a yarn breaks does not take the form of a normal distribution about the mean level and thus, knowledge of the mean and coefficient of variation, does not permit the prediction of the weak sections of yarn which occur at the lower extremity of the normal distribution curve.

The predicted incidence of breaks per 100 MILLION picks, assuming the data did conform to a NORMAL DISTRIBUTION CURVE, was, in the first example[1], only 2, whereas the actual was 8,000 breaks, and in the other sample, the predicted was 3, and the actual 2,000.

The difference between the theoretical and actual performance is so great that the whole procedure needs to be re-examined and to question whether it has always been flawed.



Above Figure 1. Below Figure 2.



Alternative strategies

It has been demonstrated that, by testing around 50,000 samples from a number of packages, it is possible to get a reasonable assessment of the incidence of weak places in the batch of yarn from which the samples have come by drawing a distribution curve through the results obtained. An important conclusion which can be drawn from this experiment is that the majority of very weak places are extreme examples of normally-occurring variations in the spun yarn process and not due to a specific fault in individual packages of yarn. As a consequence, it is possible to forecast the frequency of occurrence of these very weak places using statistical analysis techniques.

Many in the industry have worked on the philosophy that very weak places are not part of the normally occurring variations in the yarn production process but instead are unrelated and non-predictable events. It must always be understood that since strength testing is a destructive test it must be a sampling system and therefore can only provide probable occurrences.

There are a number of alternative ways to attempt to predict more accurately the occurrence of very weak spots in spun yarns. Some of these are discussed in the following paragraphs.

Retaining the existing test procedure

It will require about two to three weeks of continual testing, using the traditional testing method of 20 seconds to break, to test the 50,000 samples needed to produce a representative distribution curve. Using the faster testing procedure (most yarns break within 1 second) now available on machines such as the Uste

Tensorapid reduces this timescale considerably.

Nevertheless, over a period of time, any mill can generate the level of data needed to produce distribution curves and from these curves to better predict the incidence of very weak places in the yarn produced. However since these curves will NOT BE NORMAL DISTRIBUTION CURVES the present system of using only the average and coefficient of variation of strength to quantify a batch of yarn needs to be amended.

The recent introduction of the Uster Tensojet has dramatically increased the number of strength tests that can be carried out in a given time to such an extent that, with this system, 50,000 tests can be completed in under two hours. As a consequence this will enable mills to generate sufficient strength data to have a very good indication of the incidence of weak spots in the yarn they are supplying.

How to present the data

I believe a similar concept to that used for Classimat would be the best system to employ for presenting strength data in a form that most people, without detailed statistical knowledge, can readily understand. A simple table (Table 1) would enable the differences between batches of yarn to be interpreted.

There can be little doubt that when consideration is given to the expected performance of a yarn, decisions in the past have been based on the average strength of the yarn. The strength data presented in the form above will permit more informed decisions to be made, and both the purchaser, and producer of yarn, will be in a better position to optimise the quality and cost of yarn to meet a particular product requirement.

The level of testing which can be achieved on the Uster Tensojet will allow this type of information to be readily and accurately determined. I believe one major consequence is likely to be that the purchaser of yarn will be in a far better position to more effectively monitor the quality of the yarn he is purchasing. This will undoubtedly increase pressure on suppliers to upgrade the quality of yarn being supplied.

TABLE 2: Test Length Comparisons

	Conventional 50cm Test Length		5cm Test Length	
	Strength (cN/tex)	C.V. (%)	Strength (cN/tex)	C.V. (%)
SAMPLE 1	10.6	9.0	13.09	11.52
SAMPLE 2	11.83	10.19	13.18	13.58
SAMPLE 3	9.98	13.32	12.62	15.87
SAMPLE 4	13.1	6.2	15.45	11.50
SAMPLE 5	14.83	8.6	16.73	11.24

TABLE 3: Test Length Comparisons

18 c.c. ROTOR YARN (50% cotton, 50% polyester)		
	50cm test length	5cm test length
Tenacity (cN/tex)	13.13	15.45
Elongation (%)	10.3	13.0
Predicted frequency of weak sections per million metres		
Below 10 cN/tex	200	above 10,000
Below 9 cN/tex	0.1 – 1.0	1,000 – 10,000
Below 8 cN/tex	0.001	100
Below 7 cN/tex	nil	30
Below 6 cN/tex	nil	1.0
32 c.c. RING SPUN YARN (100% cotton)		
	50cm test length	5cm test length
Tenacity (cN/tex)	14.83	16.73
Elongation (%)	6.54	7.49
Predicted frequency of weak sections per million metres		
Below 10 cN/tex	100	5,000
Below 9 cN/tex	3.0	630
Below 8 cN/tex	0.5	70
Below 7 cN/tex	less than 0.001	6.3
Below 6 cN/tex	nil	0.1 – 1.0

Normal distribution curve

Because of the need for such large sample sizes on which comparisons can be made the traditional strength testing system is not very satisfactory for monitoring small batches of yarn that may, for example, be produced on a particular machine, on a particular day, or on a modified fibre blend.

An alternative is to modify the existing testing procedure such that the results conform to a normal distribution curve and thus permit accurate predictions to be made by a much smaller sampling system.

Work I have been carrying out to highlight the cause of weak spots in friction spun yarn has given me a far greater insight into weak spots in all yarns and caused me to question the whole principle on which present strength testing procedures are based.

Test length

The work I have carried out myself has indicated that the shape of the distribution curve for yarn strength results is affected by the following:

- The type of spinning system (e.g. ring, rotor, friction).
- The speed of the spinning system.
- The fibre type, specification and blend composition.
- The twist in the yarn.

The present standard test length for yarn strength is 50cm There would appear to be a case for having as long a test length as possible in order to check the longest possible length of yarn for weak places.

Also, in weaving, the yarn normally breaks when a free length of 50cm and above is subjected to stress and thus, the 50cm is a reasonable simulation to the sort of length that undergoes stress.

In an attempt to simulate the short term loading applied in practical conditions a revised method of testing has been introduced which breaks the yarn in a much shorter timescale than the 20 seconds (typically 0.2–0.4 seconds) which was the norm. As a consequence more tests can also be carried out.

Present procedure is flawed

Examined from a statistical point of view, the study I have carried out has caused me to doubt whether, using any of the existing test procedures, the mean level obtained is in fact the true theoretical mean of the population.

I have had access to an automated strength testing machine on which it was possible to readily change the test length. This has permitted me to obtain a totally different comprehension of the variability of yarn strength within a length of yarn. The minimum test length that could be employed was 5cm which, on short staple yarns, ensures that no fibres can be held in both jaws at the same time (this would give a misleading result).

I will concentrate on the differences in test results between yarns tested using a 50cm sample with a time to break of 20 seconds and a 5cm test length using the same rate of extension as that used for the 50cm sample.

MEAN VALUE: The difference was that the mean value for the 5cm samples was significantly higher than that for the 50cm samples which was to be expected. The differences for a number of different samples are shown in Table 2.

STRENGTH VARIABILITY WITHIN A 50CM LENGTH: On the particular test machine used there was 10cm of yarn between samples. Co-incidentally therefore in a 60cm length of yarn there would be one 50cm test (one 50cm test length and 10cm between samples) and four 5cm samples (four 5cm tests and four 10cm spaces). Figures 1 and 2 are graphs relating to different yarns showing the results from consecutive 5cm tests and what would have happened

● Turn to page 31

the geotextiles and floorcovering products made by Heckmondwike FB are similar: the differences lie in the fibre content and the construction. This has meant that the installation of the new process equipment will benefit both existing product ranges in floorcoverings and newer applications – especially wider widths – in geotextiles.

Sports surfaces, which now account for some 15% of Heckmondwike FB's manufacturing output, are marketed through an associate company, Play Rite Ltd., who have developed expertise in producing playing surfaces for hockey, cricket, golf (tees and putting greens), tennis and both indoor and outdoor bowls.

Contract floorcoverings

Floorcoverings, though, continue to represent the most important product area. Practically all their output – both tiles and broadloom – is for contract applications. Polypropylene is used in up to 80% of products, with the remainder using polyamide as pile fibre.

The original Heckmondwike fibre-bonded range, Iron Duke, was first made 25 years ago, and is still popular today, and is one of some ten separate ranges targeted at specific applications.

The firm claim to offer the widest range of broadloom fibre-bonded sheet and tile available from a British manufacturer.

The product range is designed to meet the needs of the low-to-medium end of the contract market, where schools, in particular, appreciate the hard-wearing qualities of the carpeting.

Other advantages of the fibre-bonded carpets and tiles over vinyl and hard floor options include:

- Softer and more attractive.
- Sound-deadening, with acoustics suitable for use in lecture theatres etc.
- Fire retardant, through a special finishing process.
- Better grip.
- Greater warmth.
- Easier to clean.
- Ease of application.
- Texture finish which hides any imperfections in subfloor.
- Antistatic properties.

Designs, largely geometric, are based on a standard pattern card, making optimum use of the melange effects produced by blending different-coloured fibres before processing. ■

● From page 37

if the weakest of 4 consecutive 5cm samples was taken as being a representation of a 50cm test sample (in practice the weakest result for the 50cm section might have been in the sections not tested on the 5cm tests and thus some of the levels for the 50cm simulation would have been even lower).

Referring to Figures 1 and 2, examination of the curve for the 5cm test length indicates that there were frequently very wide differences between consecutive results. The weakest result in a 50cm length is clearly therefore not in any way representative of the 50cm length as a whole.

I believe there is therefore a fundamental flaw in the existing procedure in that it treats, say, a weak section of 5cm as though it was 50cms long and an extremely strong section of less than 50cms. in length is not even incorporated into the strength results.

Detailed comparisons

To indicate more clearly the differences between results from the two systems I have examined a ring spun 32cc, 100% carded cotton yarn and a rotor spun 18 cc 50% polyester 50% cotton yarn. For each sample I have examined the predicted frequency of breaks below a certain strength level assuming a normal distribution curve in each case. The results are shown in Table 3.

It is evident, that, even though the average level is much higher for the shorter test length, the predicted incidence of weak spots, based on a normal distribution curve, is far greater, and much closer to the level of results indicated in earlier work.[1]

Variation between cops

The tests above are based on an individual package of yarn. The assumption that strength tests take the form of a normal distribution curve was established many years ago based on including tests from at least 10 cops of yarn. Historically, with a wide variation between different cops of yarn it is probable that the results were far nearer to a normal distribution curve many years ago. Because of the dramatic improvements in sliver regularity that have taken place in recent years there is far less variability between bobbins than there was even 20 years ago.

It is inevitable that, in STATISTICAL terms, this will have made a dramatic difference to the type of strength distribution curves that are prevalent today.

With this greater uniformity between bobbins the short term strength variability, that I have highlighted in this article, on individual cops and packages of yarn, will undoubtedly have a more important influence than when the procedure was initially set up.

Conclusions

It would clearly be major step forward if a weaver or knitter was in a position to specify the maximum stresses to be imposed on a yarn for a particular end product and the spinner was able to predict the incidence of breakdowns caused by weak sections in the yarn he is proposing to supply for this particular end use.

I believe there are very strong arguments in favour of having strength data presented in such a way that the predicted incidence of very weak spots is readily accessible and easy to interpret for BOTH THE PRODUCER AND USER OF YARN. It would be naive to believe that the predicted results will exactly conform to the actual number of breakdowns at the weaving or knitting process but they should certainly be of the same order of magnitude. The relative performance of different batches of yarn should be also be able to be determined with a good degree of accuracy.

Many mills who supply yarn in reasonably large batch sizes should already be carrying out sufficient yarn strength testing, using the established test procedure on existing equipment, to be able to carry out the necessary statistical analysis techniques to enable them to provide reliable estimates of the incidence of weak spots in yarn being supplied to customers.

The introduction of the Uster Tensojet allows sufficient data to be accumulated that there should be the opportunity to obtain very reliable estimates of the incidence of weak spots in yarn being supplied.

With the limited amount of work carried out it would be premature to say that, using shorter length test samples, will produce strength results which conform to a normal distribution curve and thus be able to accurately predict the frequency of sections of yarn below a specified strength without the need for such large-scale testing as can be achieved on the Uster Tensojet. I do believe there is sufficient evidence to warrant a much deeper investigation on commercial size quantities.

As a consequence of this investigation I believe I now have a far closer understanding of the causes of weak spots. Although the ability to predict the frequency of weak spots in a yarn will be a major step forward it remains a sampling technique and does not eliminate the incidence of weak spots. I am now working on a system which will be able to detect weak spots on an on line process and as a consequence to be able to eliminate them altogether. ■

REFERENCE

1. Do higher speeds demand better yarns ?, Textile Month, July 1990