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A Rapid Measure of Spinning Potential —

"Mean Spindle Speed at Break"

by

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A RAPID MEASURE OF SPINNING POTENTIAL – "MEAN SPINDLE SPEED AT BREAK"

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ABSTRACT

The spindle speed of a 144 spindle ring frame was increased in steps at a given rate during the spinning of wool (circa 21 to 23 µm mean fibre diameter) to relatively fine counts until all ends were down. The mean spindle speed at which these end breaks occurred, defined as the MEAN SPINDLE SPEED (MSS) AT BREAK, could be determined in about 1½ hours and was found to be highly correlated with the spindle speed at which a commercially acceptable end breakage rate occurred. The MSS at break was dependent on several factors such as yarn count, fibre fineness, mean fibre length and possibly tenacity X *extension and could thus be used as a first step to compare the spinning potential of different wool lots. The technique offers a new, rapid and simple approach to the assessment of spinning potential and appears to be worthwhile following up in greater depth.*

KEY WORDS

Ring spinning – end breakage rate – spindle speed – mean spindle speed at break – fine counts – wool.

INTRODUCTION

Spinning performance is generally measured in terms of the number of end breaks which occur over a given period on a given number of spindles. The frequency of end breakages will depend on many factors such as the fibre type, the fibre quality, the quality of the roving, the type and setting and general condition of the spinning frame, the spindle speed, the speed of the ring rail, the amount of twist inserted, the type and amount of lubricant on the fibre and the ambient conditions of temperature and humidity in the spinning shed.

Whenever an end breaks a piecening has to be made. This involves a labour cost and a loss in production. The importance of these factors to the productivity and profitability of a mill will vary from mill to mill and from country to country. Some worsted spinners regard an end breakage rate of 5 per 100 spindle hours for wool as reasonably good and 2 as exceptionally good. A few spinners may be prepared to spin if the end breakage rate is considerably higher. An extreme case of even 40 has been encountered.

If the end breakage rate is lower than normal it is common practice to increase the spindle speed (within limits) to improve both productivity and profitability until a normal end breakage rate is obtained. If the end breakage rate is too high the spindle speed is reduced (within limits). If the latter course of action is inadequate the twist inserted may have to be adjusted or machine settings changed etc. It may be found, however, that the material itself is not suitable for spinning into the particular yarn required due to physical or other limitations.

To partly obviate the above occurrence spinners often specify wool tops which are *"too good"* for the yarns which they require. These tops could *potentially* be spun into much finer counts, for example, at a commercially acceptable end breakage rate. The question arises, however, how does one *measure* or *assess* the spinning potential of a top relatively quickly?

The coefficient of variation for yarn irregularity has been found to be highly correlated with the frequency of thick and thin places, and both these parameters have been found to be critically dependent upon the average number of fibres in the yarn cross-section(1). The end breakage rate is *also* dependent on the average number of fibres in the yarn cross-section. A finer top would, therefore, be expected to have a higher spinning potential and to improve the irregularity of a given yarn.

When the end-breakage rate becomes the maximum permissible the yarn is said to be at its "limiting count" or "maximum count". Townend *et al*(2, 3) define this as 15 or more end breaks occurring during the spinning of 4 000 yards of yarn. While such a large frequency of end breaks could not be tolerated commercially, results of their investigation nevertheless clearly demonstrated that the number of fibres in the yarn cross-section lies within a relatively narrow range (21 to 27) at this limit. This was applicable to a range of fibres from pure wool to wool/Sarille and wool/Terylene mixtures of various diameters. The authors demonstrated that longer fibres also tend to spin to finer counts and produce, within limits, more regular and stronger yarns but that fibre strength is more important than fibre length as far as end breaks, limiting count, yarn strength and yarn uniformity are concerned. While fibre fineness may, therefore, be of great importance in assessing the spinning potential of a top, other factors such as length and strength can play an important role.

Determination of the limiting count is tedious and the value obtained will depend upon the spindle speed selected. While it provides some measure of the spinning potential of a particular lot it is, nevertheless, difficult to translate this value into terms useful to the man in the mill.

Louis(4) described a method, devised by the Southern Regional Research Laboratory, for assessing the spinnability of cotton which took only 5½ hours, used only 2 lbs of roving, and was conducted on 36 spindles. The method involved spinning selected counts under higher-than-normal yarn tensions, using a series of low to high twist factors while maintaining a constant selected front roller speed. The relationship between end breakages and twist factor was described as a symmetrical parabolic curve. The point of minimum end-breakage was determined by calculation and differentiation of the curves and was used in the subsequent calculation of spinning performance index. It was later shown by Louis and Fiori(5) that this index correlated well enough with regular mill tests of 5 000 spindle hours to enable it to be used satisfactorily for ranking the performance of different cotton lots.

Louis(4) reported that "when spinning yarns under excessive tension it is very laborious, time consuming and almost impossible to piece up the ends once they are down". He demonstrated, however, that if the ends were allowed to stay down the cumulative percentage of ends down obtained was closely correlated with the cumulative percentage of ends down obtained if the ends were pieced up each time they broke. An additional advantage of the former method is that it avoids the danger of counting repeated breakages caused by mechanical defects.

A different approach to the assessment of spinning potential which may be of practical interest to spinners, is described in this paper.

EXPERIMENTAL

Two series of experiments were carried out.

RAW MATERIALS

Series 1:

Nine different merino tops were selected having characteristics as shown in Table I. It can be seen from this table that the tops could be grouped into three mean fibre diameter categories namely, fine, medium and coarse. These differed in steps of about one micrometre. Within each of these categories the tops could be classed as long, medium or short. All the tops were closely matched with respect to all their other characteristics.

Series 2:

Several different merino tops were selected and divided into four groups according to *length.* The mean fibre lengths of groups 1, 2, 3 and 4 were 69, 61, 55 and 40 mm respectively. These and other characteristics of the four groups are given in Table II. Apart from length the tops appeared to be reasonably well matched, although it should be noted that decreased length was accompanied by increased short fibre content and a tendency for decreased diameter. It should also be noted that group 2 had the lowest value for the product 'Tenacity X Extension', indicating that the work necessary to rupture was probably least for this group.

DRAWING

Each top passed through seven operations before spinning as detailed in Table III. At the first operation a small amount of Duroil (Bevaloid) was sprayed onto the wool (0,4% in Series 1 and 0,2% in Series 2). This was thoroughly blended in by subjecting the wool to two further gillings. Drawing commenced at the fourth operation and comprised four successive stages. Rovings having a linear density of 350 tex were used for all tests on the spinning frame(6).

TABLE I

CHARACTERISTICS OF THE VARIOUS TOPS USED IN SERIES 1

Top	Fineness	Length	Mean Fibre Length (mm)	CV (%)	Fibres < 25 mm (%)	Mean Fibre Diameter (μm)	Dichloro-methane Extractable matter (%)	Neps per 20 g	Veg. Particles per 20 g	With-drawal force (kgf/g)	Irregularity (CV in %)
1	"FINE"	"Long"	85	34	1	21,2	0,8	20	5	6	4
2		"Medium"	73	39	1	20,6	0,8	20	8	8	4
3		"Short"	69	36	2	21,1	0,7	13	5	4	4
		Average	76.	36	1	21,0	0,8	18	6	6	4
4	"MEDIUM"	"Long"	76	37	1	22,0	0,8	13	6	7	3
5		"Medium"	75	36	1	21,8	0,9	7	7	7	4
6		"Short"	70	35	2	22,1	0,6	6	7	4	4
		Average	74	36	1	22,0	0,8	9	7	6	4
7	"COARSE"	"Long"	77	35	1	23,4	0,8	9	5	5	3
8		"Medium"	75	34	1	23,0	1,0	7	7	4	4
9		"Short"	72	35	1	23,2	0,7	8	9	6	4
		Average	75	35	1	23,2	0,8	8	7	5	4
Average for Tops Nos. 1, 4 & 7			79	35	1	22,2	0,8	14	5	6	3
Average for Tops Nos. 2, 5 & 8			74	36	1	21,8	0,9	11	7	6	4
Average for Tops Nos. 3, 6 & 9			70	35	2	22,1	0,7	9	7	5	4

TABLE II

AVERAGE CHARACTERISTICS OF THE TOPS USED IN SERIES 2

	Group 1	Group 2	Group 3	Group 4
Mean fibre length (mm)	69	61	55	40
CV (%)	42	44	41	46
% Fibres $<$ 25 mm	3	5	8	18
Mean fibre diameter (μm)	21,1	20,8	20,7	19,8
CV (%)	24	25	24	25
Dichloromethane extractable matter (%)	0,6	0,6	0,6	0,7
Neps per 20 g	18	23	24	20
Veg. particles per 20 g	11	14	16	18
Withdrawal force (kgf/g)	8	5	6	8
Irregularity (CV in %)	4	4	4	6
Tenacity (gf/tex) X Extension (%) (Bundle test)	181	173	196	192

SPINNING

Spinning was carried out on a 144-spindle Rieter worsted spinning frame Model H6 using 60 mm diameter rings.

1st Series:

The nine different lots were spun simultaneously to a linear density of 26 tex (34's worsted) using 16 spindles for each lot. A No. 22 traveller was selected for this particular linear density of yarn. Spinning was commenced on an empty tube and the bobbin allowed to build until the initial build had been completed before any tests were carried out. Soon after this the spindle speed was set at 4 500 r/min (about the lowest practical speed) and a stopwatch was set in motion, while it was made sure that all ends were running. After every 5 minutes the spindle speed was increased by 500 r/min to a maximum of 13 500 r/min (about the highest practical speed). *Each time an end came down it was allowed to stay down and was not pieced up.* A record was kept of the number of ends of each different lot which came down at each spindle speed. If any ends were still spinning after 5 minutes at 13 500 r/min they were deemed to have come down at 14 000 r/min for the purposes of this exercise. The test was thus scheduled to be completed in a maximum time of 95 minutes.

TABLE III

DRAFTING PLAN

Operation	Machine	No. of Doublings	Nominal Draft	Output Linear Density (tex)
1	Schlumberger Intersecting gill type GNP	6	6	22 000
2	-do-	6	6	22 000
3	-do-	6	6	22 000
4	-do-	4	7	12 000
5	Schlumberger Intersecting gill type GN4	3	6	6 000
6	-do-	3	6	3 000
7	Schlumberger Double apron High draft roving frame type FM1	2	17	350

The experiment was repeated for yarn linear densities of 21, 18, 15,5, 14 and 13 tex (42's, 49's, 57's, 63's and 68's worsted) making use of appropriately lighter travellers, namely Nos. 25, 26, 28, 29 and 30 respectively. The bobbins, however, were only built once i.e. for the 21 tex yarn. All further yarns were spun on top of one another and the entire series of tests completed in one day.

Series 2:

The procedure adopted for the first series was repeated for the second series. As before, 16 spindles were used in the case of each lot. Groups 1 and 2 comprised four and two lots respectively and were all spun simultaneously. Group 3 comprised nine lots. These were all spun simultaneously a few days later. Group 4 comprised six lots. These were all spun simultaneously after tests had been completed on Group 3.

After the above trials had been completed the same rovings were used for conventional end-breakage tests. The counts of the yarns spun and the travellers used were the same as previously. These tests were carried out at different spindle speeds so that curves could be drawn of the end-breakage rates versus spindle speed. From these curves the spindle speeds at which an end-breakage rate of 5 per 100 spindle hours occurred was obtained for each group. *This end breakage rate was defined as being commercially acceptable for the purposes of this study.* As the amount of material available was small the tests had to be confined to a period of some 5 hours on 144 spindles at each count. It is possible, therefore, that the values obtained would not correspond to those obtained on much longer trials, but this is inevitable in a research project of this magnitude and a suitable correction should probably be allowed for.

RESULTS AND DISCUSSIONS

When the spindle speed is increased in steps (between two practical limits) at a given rate during the spinning of a particular lot of material, to a particular, relatively fine yarn count, on a ring spinning frame a certain pattern of end breaks emerges. If no piecening of ends is permitted this pattern generally takes the form of a curve which starts at zero (provided all ends are running at the lowest spindle speed), passes through a maximum, and finally ends at zero again (provided no ends are left spinning). The mean spindle speed at which the end breaks occur under this particular set of circumstances is hereby defined as the MEAN SPINDLE SPEED (MSS) AT BREAK. (This mean value may possibly be influenced by the *rate* of increase of spindle speed selected, but this point has not been studied). An example illustrating typical results of a test to determine the MSS at break, and showing how the MSS value is calculated is given in Table IV.

During a series of tests which may be carried out in order to establish MSS values for a particular lot it will possibly be found that, in some cases, some ends will still be spinning when the spindles are running at the highest speed practically attainable. It has already been suggested that in these cases the ends should be deemed to have come down at the next higher spindle speed. The calculated MSS at break values would, however, be below the true values. In other cases it may not be possible to have all the ends running at the lowest practical spindle speed. The calculated MSS at break values in such cases would be above the true values. The latter set of circumstances was not, however, encountered in this investigation.

Results for MSS at break obtained in the first series of experiments are shown in Figs 1 and 2. In Fig. 1 values for the different lengths have been averaged for each diameter, whereas in Fig. 2 values for the different diameters have been averaged for each length.

Clearly the influence of linear density on the MSS at break was highly significant, the latter decreasing rapidly as the linear density decreased. The curves showed an asymtotic tendency towards an MSS value of around 12 000 r/min at

TABLE IV

EXAMPLE ILLUSTRATING TYPICAL RESULTS OF A TEST TO DETERMINE THE MSS AT BREAK AND SHOWING HOW THE MSS VALUE IS CALCULATED. (TOTAL NO. OF ENDS SPINNING AT COMMENCEMENT OF TEST – 144)

SPINDLE SPEED (r/min) (A)	NO. OF END BREAKS (B)	PRODUCT A X B
4 500	0	–
5 000	0	–
5 500	1	5 500
6 000	4	24 000
6 500	4	26 000
7 000	4	28 000
7 500	3	22 500
8 000	6	48 000
8 500	6	51 000
9 000	14	126 000
9 500	17	161 500
10 000	14	140 000
10 500	12	126 000
11 000	24	264 000
11 500	12	138 000
12 000	7	84 000
12 500	9	112 500
13 000	6	78 000
13 500	1	13 500
TOTAL	144	1 448 500

$$\text{MSS at break} = \frac{1\,448\,500}{144} = \text{approx. } 10\,100 \text{ r/min}$$

FIGURE 1

The Influence of Yarn Linear Density on the MSS at break for tops of similar length but different fineness

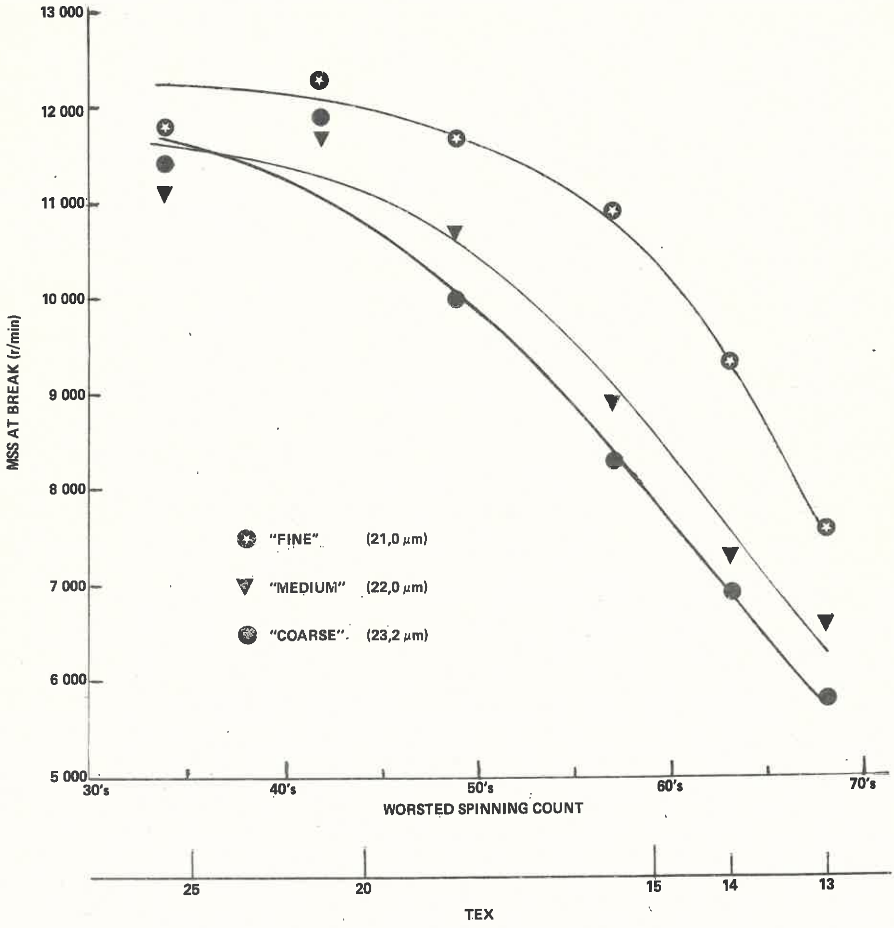
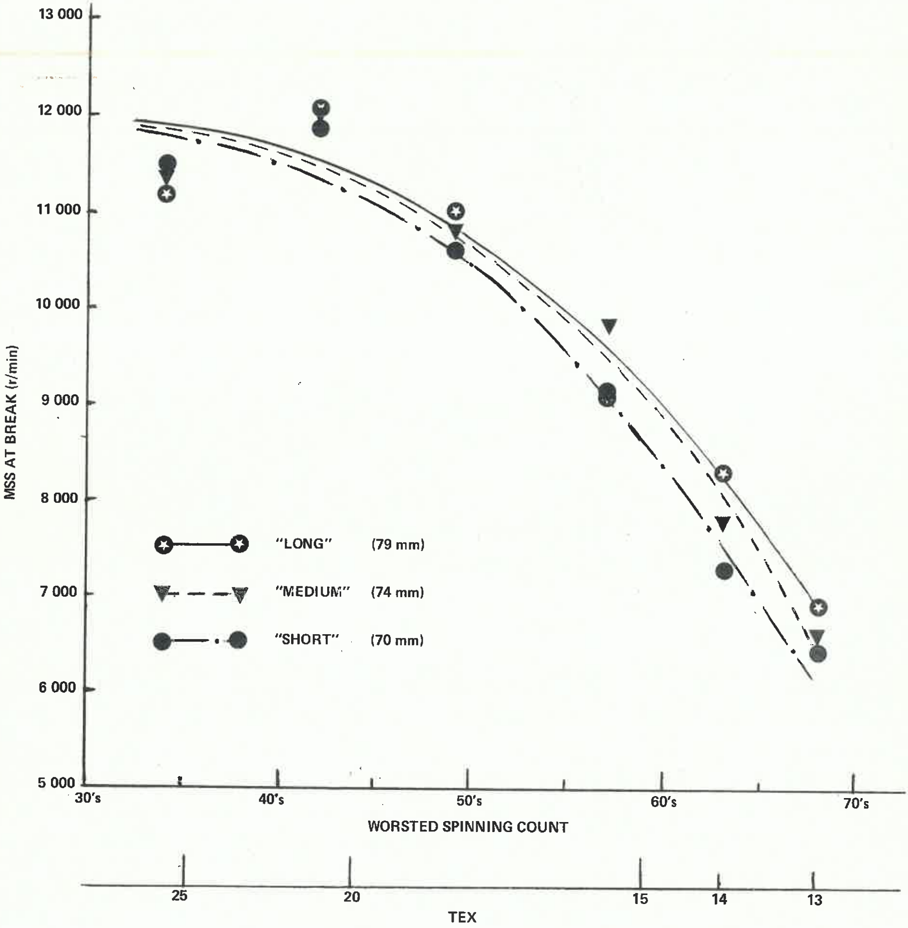


FIGURE 2

The Influence of Yarn Linear Density on the MSS at break for tops of similar fineness but different length



linear densities greater than about 22 tex, but this was expected since several ends were often still spinning at 13 500 r/min when spinning these counts.

It is clear from Fig. 1 that a decrease in diameter of as small as one micrometre resulted in significantly higher values for the MSS at break. It is clear from Fig. 2, however, that although increased length tended to produce higher values for the MSS at break, the effect was much less pronounced than in the case of diameter over the range covered by this investigation.

The influence of linear density on the MSS at break for the second series of experiments is illustrated by the results given in Fig. 3. As before, the MSS at break decreased rapidly as the linear density decreased. Each group of tops produced its own characteristic curve, with values of group 1 (the longest) being highest and for group 4 (the shortest) being lowest. Results for group 3 were higher in value than those for group 2 in spite of the tops in group 3 being about 6 mm shorter. The explanation for this may be found in Table II where it is shown that the product of fibre tenacity and extension (measured in bundle form) is significantly higher for the tops in group 3.

The influence of linear density on the spindle speed at which a commercially acceptable end breakage rate occurs is also illustrated in Fig. 3. It can be seen that a family of curves representing the results for the four groups of tops was obtained, and that this family of curves appears to be similar to the family of curves representing the MSS at break results except that it is displaced nearer to the abscissa. This apparent correlation between the two families of results was tested statistically and the results are shown in Table V. From this table it is clear that values for MSS at break and for the spindle speed at which a commercially acceptable end breakage rate occurred were significantly correlated in the case of each group of tops. This correlation was highly significant when all the data (18 points) was considered and produced the formula:–

$y = 1{,}386\,x - 7\,913$

where y = spindle speed at which a commercially acceptable end breakage rate occurs when spinning a particular yarn (SS)

x = the mean spindle speed (MSS) at break for that same yarn.

A line representing the above equation has been drawn in Fig. 4 and the values for the 95% confidence limits obtained from the experimental data have been used to produce the shaded area on either side of the line into which 95% of the results would be expected to fall. Graphs such as this can be constructed by individual mills and can be used to establish minimum criteria for MSS values to suit their particular conditions.

TABLE V

CORRELATION BETWEEN VALUES OBTAINED FOR THE MEAN SPINDLE SPEED (MSS) AT BREAK AND THE SPINDLE SPEED (SS) AT WHICH A COMMERCIALLY ACCEPTABLE* END BREAKAGE RATE OCCURS

Group	Mean Fibre Length (mm)	Correlation Coefficient between MSS and SS for commercial end breakage rate	Level of Significance of Correlation Coefficient (%)	Correlation Coefficient between MSS and SS for all data (Groups 1, 2, 3 & 4) r =	Level of Significance of Correlation Coefficient (%)
1	69	0,983	99	0,978	99,9
2	61	0,986	98		
3	55	0,985	98		
4	40	0,979	95		

*In this case taken to be 5 end breaks per 100 spindle hours

FIGURE 3

The Influence of Yarn Linear Density on (i) the MSS at break and (ii) the Spindle Speed at which a commercially acceptable end breakage rate occurs (SS) for four groups of tops differing principally in length

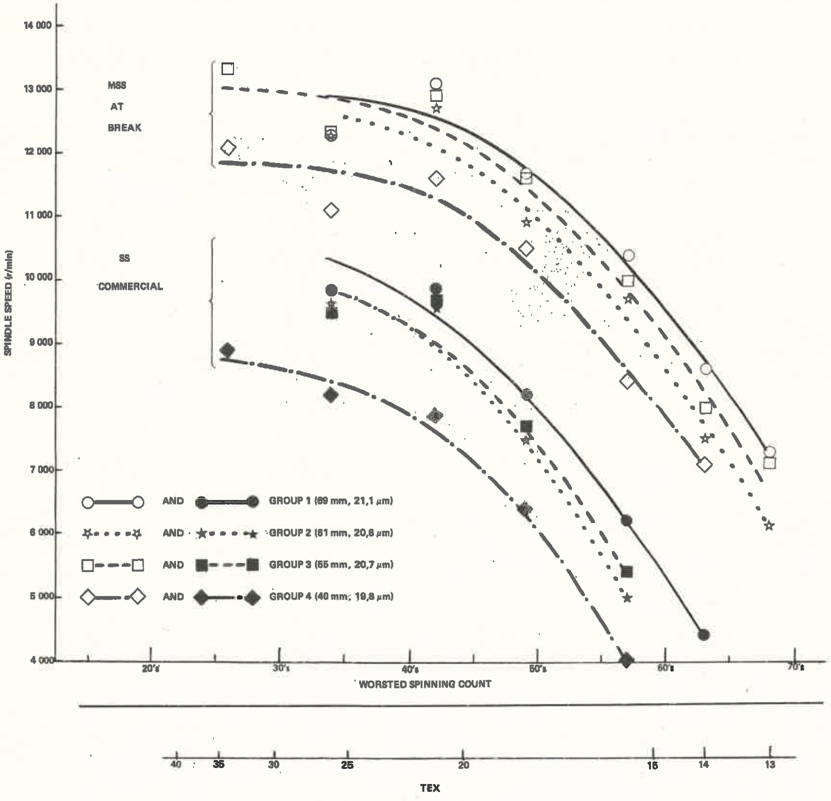
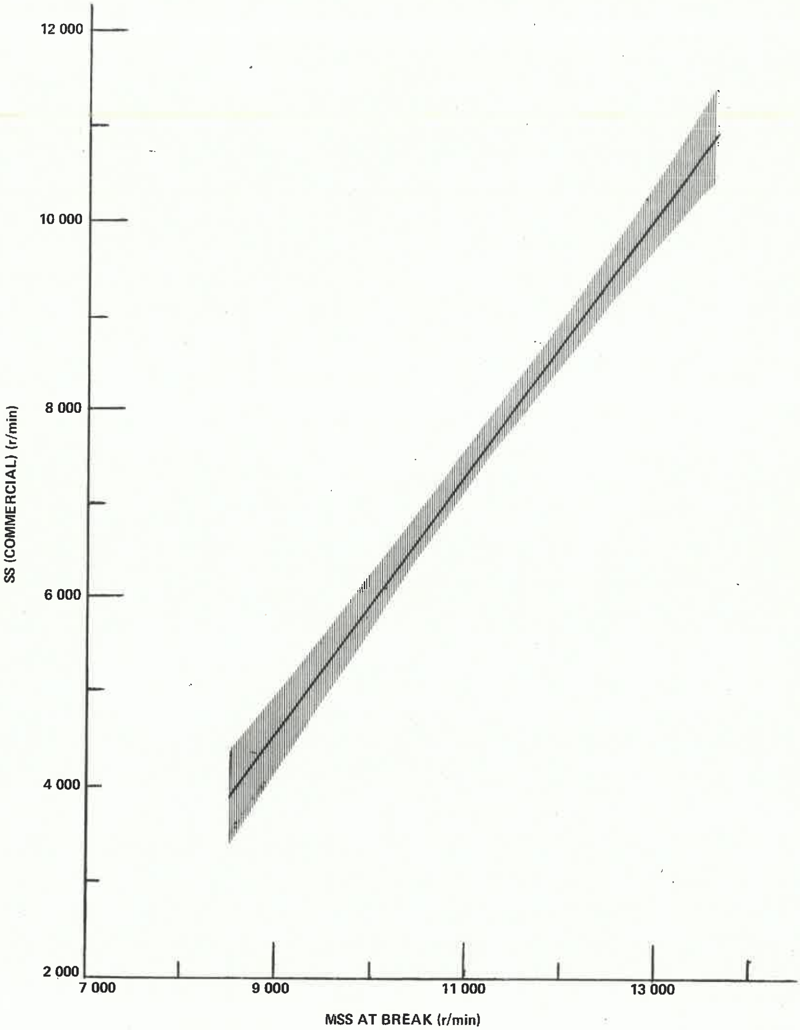


FIGURE 4

Relationship between the Mean Spindle Speed (MSS) at break and the Spindle Speed at which a commercially acceptable end breakage rate occurs (SS) (shaded area indicates 95% confidence limits



SUMMARY AND CONCLUSION

Two series of experiments were carried out to demonstrate a new approach to the assessment of spinning potential. The spindle speed of a ring frame is increased in steps (between two practical limits) at a given rate and no piecening of any ends permitted, so that finally, in the ideal case, all ends are brought down. The mean spindle speed at which these end breaks occurred is defined as the MEAN SPINDLE SPEED (MSS) AT BREAK. This value can be obtained for a particular yarn in about one and a half hours.

It was shown that the MSS at break values were dependent on the yarn linear density, mean fibre diameter, and mean fibre length and also possibly on the product of tenacity and extension. Furthermore, the MSS at break value correlated highly with the spindle speeds at which a commercially acceptable end breakage rate (defined here as 5 end breaks per 100 spindle hours) occurred in each case. It appears, therefore, that the MSS at break values for a particular lot can be used to calculate the spindle speed at which a commercially acceptable end-breakage rate will occur on a particular frame, or can be used as a basis of comparison with that of another lot. In other words the value obtained for the MSS at break is a first step in the measurement of the spinning potential of a lot as far as spinning a specific yarn is concerned. Lots having a higher potential offer a greater resistance to breakage as the spindle speed is increased or, to put it another way, tend to continue spinning for a longer period of time at a given spindle speed. Their values for MSS at break are therefore higher. As a first step in establishing the spinning potential of a lot over a whole range of counts the MSS values at a few specific counts can be measured and a curve constructed between the points. The effect of other parameters such as twist factor has yet to be investigated. The effect of the CV of the MSS values on the correlation with commercial spindle speeds has also to be investigated.

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PROPRIETARY NAMES

The fact that proprietary names have been mentioned in this report does not in any way imply that SAWTRI recommends them or that there are not substitutes which may be of equal value or even better.

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