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A Statistical Assessment of the Accuracy of the Measurement of Spinning Potential by the "MSS at Break" Technique

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A STATISTICAL ASSESSMENT OF THE ACCURACY OF THE MEASUREMENT OF SPINNING POTENTIAL BY THE "MSS AT BREAK" TECHNIQUE

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ABSTRACT

A statistical assessment of the accuracy of the measurement of the spinning potential of wool yarns by the 'Mean Spindle Speed at Break' (MSS) technique has shown that it could be determined in about 1,5 hours with an accuracy about 30 times greater than that of a conventional end-breakage test.

Regression data from four extensive data sets showed highly significant correlations between the Commercial Spindle Speed (CSS), and the cube of the MSS value.

INTRODUCTION

Assessment of the spinning potential of a given lot of wool is frequently carried out by measuring the end-breakage rate of a representative sub-sample of the lot. Another method involves determination of the "limiting count" or "maximum count"[1]. Such methods as these, however, are generally time-consuming. Other methods have been devised which are shorter. One of these, for example, was designed for assessing the spinnability of cotton and involves spinning for 5,5 hours on 36 spindles and subsequent calculation of a "spinning performance index"[2,3]. This method also involves spinning selected counts under higher-than-normal yarn tensions using a series of low to high twist factors. A different method of assessing spinning potential, which may be of practical interest to spinners, was described by Turpie[4]. In this method the spindle speed of a ring frame was increased in steps (between two practical limits) at a given rate during the spinning of relatively fine counts (below about 45 fibres in the corss-section) and no piecening of any ends permitted, so that finally, in the ideal case, all ends were brought down. The mean spindle speed at which these end breaks occurred was defined as the MEAN SPINDLE SPEED (MSS) AT BREAK. This value could be obtained for a particular yarn in about one and a half hours. Furthermore, for the restricted conditions studied in this report, the MSS at break values were found to be highly correlated with the Commercial Spindle Speeds (CSS) i.e. the spindle speeds at which a commercially acceptable end breakage rate (defined as 5 end breaks per 100 spindle hours) occurred in each case. The technique offered a new, rapid and simple approach to the assessment of spinning potential, and appeared worthwhile following up in greater depth.

In view of the promising results referred to above, the MSS at break was measured on a number of subsequent occasions during various research projects, and, wherever possible, the CSS as well. Some of this data[5,6] together with data as yet unpublished, were used in the present report with the object of obtaining a statistical assessment of the accuracy of the MSS at break technique as applied in a rather wider field than in the earlier investigation. This field, however, has been restricted to wool up to the present time. It was necessary to establish, statistically, with what accuracy an end-breakage rate, a CSS determination and an MSS at break determination could be made on the same spinning frame with the same wool. It was also necessary to establish what the relationship was between the CSS and MSS values for a wide range of wool qualities.

EXPERIMENTAL

All the work which is the subject of the present report was carried out using the same spinning frame, namely a 144-spindle Rieter worsted spinning frame, Model H 6, using 60 mm diameter rings. The work is described in two parts.

A. ACCURACY OF DETERMINATION OF END-BREAKAGE RATE, CSS AND MSS AT BREAK

Three different wool tops (Lots A, B and C) were selected from available stock. The characteristics of these tops are given in Table I.

TABLE I

CHARACTERISTICS OF THE TOPS USED

	LOT A	LOT B	LOT C
Mean fibre diameter (μm)	20,6	21,5	21,7
Mean fibre length (mm)	57,2	51,0	62,4
CV (%)	48,4	48,2	55,1
Fibres shorter than 25 mm (%)	8,9	5,4	8,4
Dichloromethane extractable matter (%)	0,5	1,0	0,5

Each of these tops was passed through a first operation of drawing on an NSC intersecting gill box, type GNP. This was followed by two operations of drawing on an NSC intersecting gill box type GN 4 and one operation on an NSC double-apron high draft drawing frame, type FM 1. The latter machine was set to produce double-meche twistless rovings having a linear density of 350 tex. Twenty-four bobbins were made from each wool top i.e. sufficient to feed 48 spindles on the spinning frame. Sufficient material was wound on to each of these bobbins to enable three separate runs to be carried out. Lots A, B and C were spun simultaneously (each on 48 spindles) to a yarn linear density of 21 tex during each of these runs. The positions of the different wool lots on the machine formed a balanced design (a Latin square) and are summarised in Table II. For purposes of identification the spindles on the frame were numbered from 1 to 144 in an anti-clockwise direction around the frame, thus spindles 1 and 144 were at one end of the machine while spindles 72 and 73 were at the other.

TABLE II

POSITIONS OF DIFFERENT WOOL LOTS ON THE SPINNING FRAME

SPINDLE NUMBERS	1 — 24 AND 73 — 96	25 — 48 AND 97 — 120	49 — 72 AND 121 — 144
RUN 1	A	B	C
RUN 2	C	A	B
RUN 3	B	C	A

The position of each roving bobbin on the machine was changed in an orderly manner from one run to the next. For example Bobbin 1 was used to feed spindles 1 and 2 during Run 1, spindles 25 and 26 during Run 2 and spindles 49 and 50 during Run 3. This applied similarly to the remaining 71 bobbins.

MSS tests:

At the beginning of each run an MSS at break test was carried out. Instead of completing the initial build on the spinning tube before commencing this test, as was done in the very early work carried out using this technique, a nylon form having an appropriate conical shape to simulate an already completed build was fitted onto each tube. This enabled trials to commence almost immediately. In actual fact it was decided to commence all trials after a period of 10 minutes. The MSS at break test was carried out in the normal manner starting with all ends running at 5 000 r/min and increasing the spindle speed in steps of 500 r/min every 5 minutes up to 13 500 r/min. Each time an end break occurred the end was not repaired, but the spindle number and spindle speed were noted. Any ends still spinning after 5 minutes at 13 500 r/min were deemed to have come down at 14 000 r/min. The mean spindle speed at which these end breaks occurred could then be calculated for any given set of spindles within any of the three wool lots.

End breakage and CSS tests:

After completion of the MSS at break test at the beginning of each run, new tubes having nylon forms were placed on all spindles and, after a starting-up period of 10 minutes, an end breakage test was made at a spindle speed of 6 500 r/min for a period of two hours. Each time an end break occurred the end was repaired, and the spindle number was noted on each occasion. After the completion of this test another new set of tubes having nylon forms was placed on the spindles and the procedure repeated at a spindle speed of 7 500 r/min. This was followed, similarly, by two further tests at 8 500 r/min and at 9 500 r/min. From this data on end breakages at the four different spindle speeds two measures of the spinning performance of the wool could be obtained, namely the end breakage rate per 100 spindle hours at a given spindle speed and the CSS.

Repeat MSS tests:

A repeat determination of the MSS at break was carried out after completion of the CSS test in Runs 1 and 2 but not after Run 3 because there was insufficient material available. Accordingly, five sets of MSS data were available.

B. RELATION BETWEEN CSS AND MSS AT BREAK

During the course of various research projects measurements of the CSS and MSS at break had been made on many wool samples. Four such data sets were available for the study of the relation between CSS and MSS at break, and were as follows:

Data set 1:

This data comprised a total of 18 points. These were obtained from the **average** results for four different series of trials which were carried out on 10/12, 9/11 and 8/10 months 64's and 6/7 months 64/70's mixtures of South African wools during an investigation on the influence of style, length and class description on spinning performance and yarn properties. These series involved the use of a total of 64, 32, 144 and 96 spindles respectively. MSS and CSS values were obtained for five different yarns (from 14 tex to 26 tex) in the first series, four different yarns (from 15,5 to 26 tex) in both the second and third series, and five different yarns (from 15,5 to 34 tex) in the fourth series. These values have been published in a technical report[5]. The MSS test in these early trials started at a spindle speed of 4 500 r/min.

Data set 2:

This data set comprised a total of 32 points. These were obtained by pooling the results of (a) a small and (b) a larger experiment in which variations in lubrication had taken place, as follows:

(a) A 100 kg lot of 64's carded sliver was backwashed to remove residual grease and applied lubricants, then re-lubricated with Bevaloid lubricant 4027 to obtain dichloromethane extractable matter levels of 0,3 0,5 and 0,7 *per cent* gilled, combed, drawn and finally spun to linear densities of 15,5 18 and 21 tex. The MSS and CSS values which were obtained provided 8 data points, each obtained on 32 spindles. These are given in Appendix A.

(b) A 400 kg lot of 64's wool tops was divided into four parts and each backwashed under different conditions of pH. The first was carried out with tap water, the second and third with soda ash at pH values of 9,7 and 10,4 and the fourth was carried out twice using sodium hydroxide and soda ash at pH 10,7. Each lot was then divided into three sub-lots each of which was lubricated with one of three different lubricants to obtain dichloromethane extractable matter levels of about 0,8 *per cent* in all cases. Each of these sub-lots was then spun to linear densities of 18 tex and 20 tex. The MSS and CSS values which were obtained provided 24 data points each obtained on 32 spindles. These are given in Appendix B.

Data set 3:

This data comprised a total of 33 points. These were obtained by spinning three different qualities of wool tops to each of three different linear densities and four different twist factors. Characteristics of the tops used are given in Table III. About 180 kg of each lot were drawn and spun. Technical reasons precluded the obtaining of three reliable points at the lowest twist factor giving 33 available points out of a possible 36 each of which was obtained on 32 spindles. The MSS and CSS values which were obtained are given in Appendix C.

TABLE III

CHARACTERISTICS OF THE TOPS USED FOR DATA SET 3

	Lot A	Lot B	Lot C
Mean fibre diameter (μ m)	22,7	19,5	21,3
Mean fibre length (mm)	60,6	49,8	60,6
CV (%)	53,9	49,3	49,7
Fibres shorter than 25 mm (%)	9,4	13,0	4,9
Dichloromethane extractable matter (%)	0,9	0,7	0,9

Data set 4:

This data set comprised a total of 63 points. These were obtained from five different 'primary' components (classed on the farm) and ten blends, ranging from 56's/58's to 64's/70's quality which were processed in an identical manner into tops and then spun into a wide range of linear densities from 14 to 24 tex. The coefficient of variation of the mean fibre diameter of these tops varied from about 23 to 28 per cent depending on the components used. The work was carried out during an investigation into the influence of relatively large variations in diameter on the processing performance of South African long wools. The CSS and MSS at break values were obtained for each point on 24 spindles and have been published in a technical report[6].

The range of MSS values obtained in the four data sets is summarised in Table IV.

TABLE IV

RANGE OF MSS VALUES IN THE FOUR DATA SETS

DATA SET	INVESTIGATION INVOLVING	NO. OF POINTS	MSS RANGE (r/min x 10^3)
1	Mixtures of S.A. wools	18	8,4 — 13,1
2	Variations in lubrication	32	9,2 — 13,0
3	Variations in twist factor	33	9,6 — 13,4
4	Mixtures of S.A. wools	65	7,6 — 13,3

Several analysis of the above data sets were made. These involved:-

(i) a study of the relationship between MSS and its CV for data sets 1, 2, 3 and 4; and

(ii) a study of the dependence of CSS on MSS and its CV for data sets 1 and 2, and also 3 and 4.

RESULTS AND DISCUSSION

A. ACCURACY OF DETERMINATIONS

(i) End-breakage rate:

The total number of breaks on each set of 12 adjacent spindles during each run at each of four different spindle speeds were recorded. In the first run, for example, there was one end breakage on spindle numbers 1 — 12 during two hours spinning at 6 500 r/min, giving an end-breakage rate of approximately 4 per 100 spindle hours for the first six bobbins of Wool A. In all there were four such results available for each wool in each run, giving a total of twelve results altogether for each spindle speed.

Each of the above results for a particular wool gave the end-breakage rate based on 12 spindles. Consecutive pairs of the results gave the end-breakage rate based on 24 spindles. Taking the latter results again on consecutive pairs gave the end-breakage rate based on 48 spindles. Finally, the average of all twelve results gave the mean end-breakage rate for that particular wool at that particular spindle speed. In each case the range of values was then halved and expressed as a percentage of the mean value. As the three wools showed similar patterns of variation their ranges were then pooled. These results are given in Table V.

TABLE V

RANGE IN END-BREAKAGE RATE EXPRESSED AS A PERCENTAGE (±) OF THE MEAN OBTAINED ON 144 SPINDLES

NUMBER OF SPINDLES	12	24	48
Spindle speed r/min:			
6 500	140	100	80
7 500	110	120	45
8 500	90	80	30
9 500	100	65	30
AVERAGE FOR ALL SPINDLE SPEEDS	110	90	45

The results given in Table V clearly show that the range in end-breakage values varies considerably within different groups of spindles on a single spinning frame. This range is high when only 12 spindles are used, being about ± 110 *per cent* but is relatively much lower at about ± 45 *per cent* when 48 spindles are used.

An approximate conversion of these ranges into the 95 *per cent* confidence limits is obtained by multiplying the results by 1,5. Thus the end-breakage rate based on 48 spindles running for two hours will have an accuracy of about ± 70 *per cent*. Based on 24 spindles a similar test would be expected to have an accuracy of about ± 135 *per cent* when referred to the performance gauged over two hours on the whole frame.

(ii) Commercial Spinning Speed (CSS):

One value for CSS of wool A was obtained by counting the number of end breakages on spindles 1 to 12 plus 73 to 84 at each of the four speeds from the data for run 1. These were 6, 4, 6 and 24 respectively. The speed at which 5 end breakages occurred was subjectively estimated from a plot of these values. A value of 8 100 r/min was obtained for this CSS value.

By the same process 18 CSS values representing three wools and three runs, in duplicate, were obtained. From an analysis of variance procedure after subtracting the variance associated with the mean effects of wool type, position on machine and test occasion or run, an error of test of 428 r/min was found. When the test occasion variance was included the testing error was 583 r/min.

An attempt was made to improve the method of deriving the CSS value from the experimental data by fitting curves to the four data points.

Firstly, a plot of the four average values for each wool showed smooth curves (Fig 1). Different mathematical models were selected to represent these curves. These were:-

(i) the power curve : $y = ax^b$

(ii) the exponential curve : $y = ae^{bx}$

(iii) the hyperbolic curve : $y^2 = ax^2 + b$

(iv) the quadratic curve : $y = ax^2 + bx + c$

Correlation coefficients for each set of wool data were obtained for each model. The average values were 0,984 0,992 0,976 and 0,998 respectively from which it was concluded that the quadratic model gave the best, and a very good, fit. This model was used to fit the individual sets of 4 data points and then to predict the speed at which five end breakages occurred. Two problems arose:

(i) often two speeds were given by the solution; this was resolved usually by inspection of the data.

(ii) on one occasion no interpolation was possible — the fitted curve had a minimum value greater than five.

However, from the eight pairs of duplicate CSS values so obtained a residual error of 640 r/min was found. This was worse than that given by the subjective assessment of the CSS value and so the method was rejected.

The variation in the estimation of CSS with the number of spindles used was examined. Instead of calculating CSS from 24 spindles as above, it was calculated on eight spindles (1 to 4 plus 73 to 76 etc.) giving 18 CSS values for each wool at each speed. Further the CSS value based on 16 spindles was obtained, by pooling pairs of values from these thus giving nine values per wool per speed. An analysis of variation calculation gave the testing errors, excluding the variation associated with the test occasion.

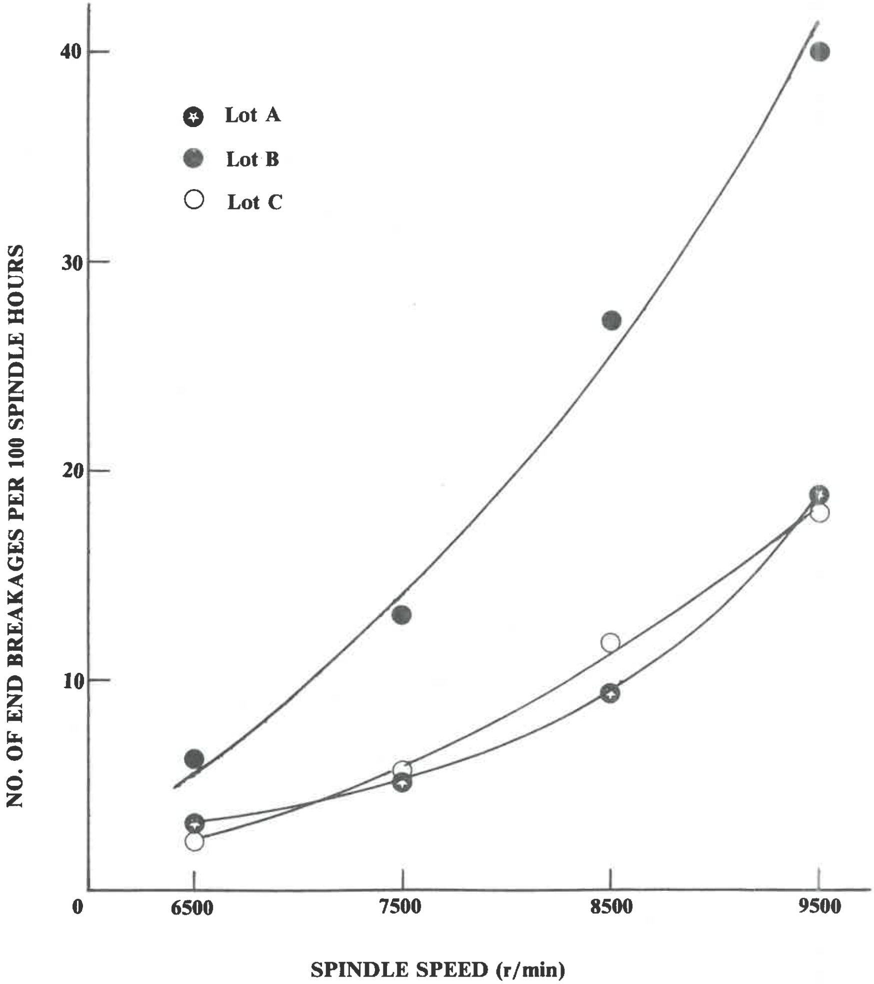

Fig. 1 Average End Breakage Rates for Lots A, B and C at various Spindle Speeds

Table VI summarises the dependence of the testing error for the number of spindles.

TABLE VI

TESTING ERROR OF CSS FOR VARIOUS NUMBER OF SPINDLES

Number of spindles	8	16	24
Testing error (σ_r) r/min.	870	624	428

Clearly shown, and as expected, the CSS can be more accurately measured by using more spindles, or possibly the same number of spindles for a longer time.

From the foregoing it follows that an estimate of the CSS value based on 24 spindles spinning for two hours at each of four spindle speeds would be expected to have an accuracy of $\pm$ 428 x 2 = $\pm$ 856 r/min. Considering the *practical* range of CSS values for spinning wool on this machine, of 5 000 to 10 000 r/min, this is equivalent to an accuracy of from $\pm$ 8 to 17 *per cent.* On average this test would therefore appear to be about 10 times more accurate for determining the spinning potential of a wool than a single end-breakage test for two hours at one specific spindle speed.

(iii) Mean Spindle Speed (MSS):

MSS values based on 24 spindles (spindles 1 to 12 plus 73 to 84, etc.) were calculated for each of the three wools, three positions on the machine and three test runs using the data obtained prior to the CSS test run. From an analysis of variance the testing error was found to be 239 r/min. When the test occasion variation was included the testing error increased to 407 r/min.

The dependence of this error on the number of spindles used in an MSS determination was found by suitably recalculating the MSS values based on 8, 12, 16, 20 and 24 spindles and using data from all five MSS test runs. The testing errors found are given in Table VII.

TABLE VII

TESTING ERROR OF MSS FOR VARIOUS NUMBER OF SPINDLES

Number of spindles	8	12	16	20	24
Testing error (σ_r) r/min	723	651	579	512	439

The error decreased as the number of spindles used in the determination of an MSS value was increased. The value found for 24 spindles was higher than the value given above (239 r.p.m). It was thought that this was due to not keeping a balance from both halves of the machine when compiling these MSS values.

To investigate this point, MSS values based on 8, 16 and 24 spindles, by taking equal numbers from each side of the machine, and again using five sets of MSS data were calculated and analysed. The testing error (σ_r) now found was as given in Table VIII.

TABLE VIII

TESTING ERROR OF MSS FOR VARIOUS NUMBER OF SPINDLES

Number of spindles	8	16	24
Testing error (σ_r) r/min	707	519	248

The value of 248 for 24 spindles compares well with the value of 239 and the improvement in the testing error shows as the number of spindles is increased, but of more importance, the corresponding values are lower for the "balanced" spindles than for the "non-balanced".

(iv) Uniformity of spindle performance:

Because the above analysis suggested that differences existed between the performance of each side of the spinning machine an examination of the performance of individual spindles was made.

The total number of end breakages at each spindle during the four speeds, and three repeats were obtained. Each total represented the number of end breakages in 24 hours running. Table IX shows the pattern obtained.

TABLE IX

PATTERN OF DISTRIBUTION OF END BREAKAGES

NUMBER OF SPINDLES	NUMBER OF FAULTS	NUMBER OF SPINDLES	NUMBER OF FAULTS
16	0	3	8
25	1	0	9
24	2	3	10
23	3	0	11
18	4	1	12
16	5	1	13
8	6	2	14
3	7	1	23

Total number of spindles = 144
Total number of faults = 493

This situation where a fault is a rare event occurring in the very long length of yarn produced can be expected to have a Poisson Distribution. The Chi-squared value of the observed frequencies relative to the expected Poisson value was measured. Its value was too large for the observed distribution to be of the Poisson-type and it was therefore concluded that real differences in performance between individual spindles existed.

The individual spindle configurations were closely examined and a note was made of those which it was thought may have given excessive end breakages and those which may have given too few. There was no relation between these and the above distribution.

From the foregoing it follows that an estimate of the MSS value based on 24 spindles would be expected to have an accuracy of ± 248 x 2 = ± 496 r/min. Considering the *practical* range of MSS values on this machine of 9 500 to 13 500 r/min, this is equivalent to an accuracy of from ± 3,6 to 5,2 *per cent*. On average it would therefore appear that the MSS value of a yarn can be determined in about 1,5 hours with an accuracy about 30 times greater than that of a single end-breakage test for two hours at one specicic spindle speed on the same number of spindles, or three times greater than that of a CSS test for two hours at each of four spindle speeds. It only remains to be proved that the MSS is highly correlated with the CSS value in order to demonstrate that the MSS test can be used as a measure of spinning potential with an accuracy some 30 times better than a single end-breakage test under the above conditions.

B. RELATION BETWEEN CSS AND MSS AT BREAK

(i) MSS and its CV:

As described previously the test to determine the MSS at break (abbreviated simply 'MSS') is such that under- and over-estimates will be made at the low and high speed ends of the scale and hence non-linearity can be expected. This is because the test is restricted to speeds between about 4 500 and 14 000 r/min. Further, the CV of the MSS value will also be affected. This CV will, theoretically, be at zero at both ends of the speed scale and will have a maximum at some intermediate speed.

Curves fitted to data sets 2 and 3 showed reasonable confirmation of the expected zero CV value at the lower and higher theoretical limits, whereas curves fitted to data sets 1 and 4 did not show any curvature which was statistically significant.

(ii) Dependence of CSS on MSS

The multiquadratic regression model having MSS and its CV as the independent variables was used to account for the observed variation in CSS for data set 4. After eliminating those variables which did not make a significant improvement, the best fit equation was found to depend only on the MSS factor. The CV term was thus found to make no useful contribution to the CSS/MSS relation.

Because of the restriction of the MSS test to a practical range of spindle speeds, as noted previously, it was decided to include a cubic term in the model.

The best fit equation which was obtained was:

$$y = 0{,}0298\,x^3 + 2{,}548$$

where y = CSS (expressed in r/min x 10^{-3})

x = MSS (expressed in r/min x 10^{-3}).

This had a fit of 87,1 *per cent* and a correlation coefficient of 0,937 which was very highly significant. From the residual standard deviation of 584 r/min, the 95 *per cent* confidence limits of a future prediction of CSS near the mean value of this data were ± 1 170 r/min.

Regression data for the model CSS = f (MSS)[3] were then calculated for the other data sets and their combinations. The results of these analyses are given in Table X.

It can be seen from Table X that all the regressions were very highly significant (better than 99,9 *per cent* significance level), thus confirming the conclusion drawn in the initial investigation previously reported[4] that a highly significant correlation existed between the CSS and MSS values of different wool lots. It will be noted from the results given in the table that the slopes of the various regressions tend to fall into three groups, at approximately 0,002 0,003 and 0,004. The twist factor data tends to 0,002, the data on lubricants and the mixtures of data set 4 tend to the 0,003 group, and the data on the mixtures of data set 1 tend to 0,004. The confidence limits of these slopes, as can be seen from column 9, are about one-fifth of the value of the slope. This implies, firstly, that the slopes are real i.e. not zero and, secondly, that there is considerable overlapping of the slope values. The relatively large difference in the slope values given in the table give a somewhat false picture, since the intercept values have a counter-balancing influence. The actual regression lines are shown in Figure 2 from which it can be seen that there is, in fact, a considerable overlapping. Indeed, the regression on the pooled data of all four data sets is still very highly significant (r = 0,899).

Having demonstrated the high correlations between MSS and CSS, the usefulness of the MSS, which is relatively easy to measure, in predicting the CSS, or spinning potential, of the wool must now be considered. The last column in Table X shows the 95 *per cent* confidence limits of the prediction at a CSS value of about 7 000 r/min. The values are approximately 1 000 r/min. These are derived directly from the residual error (about the regression) shown in column 6. The latter values are very similar to the standard deviation of a CSS measurement (see under A (ii), Table VI). Indeed, the measurement of CSS and MSS can account for the residual error of the regression and hence the confidence limits of the prediction.

The differences between the regression lines shown in Fig 3 may also reflect some relatively minor changes in the collation of the data and the performance and settings of the spinning machine. For instance, there was a time lapse of two years between the collection of data sets 1 and 4. Also, the amount of initial build on the bobbins before the tests were commenced may have differed between the series. (More recently, as in series 4, an attempt has been made to obviate this by using nylon forms on the spinning tubes to simulate a constant build.)

TABLE X

REGRESSION DATA OBTAINED FOR DIFFERENT DATA SETS

Data set	Slope	Intercept	'r' value	% fit	Residual error (r/min x 10^3)	Predicted CSS at MSS (r/min x 10^3)		C.L. of slope	C.L. of predicted CSS at mean (r/min x 10^3)
						9 000	13 000		
1	0,00387	1,948	0,973	94,7	0,468	4,77	10,45	0,0005	0,93
2	0,00320	2,638	0,898	80,6	0,611	4,97	9,69	0,0006	1,23
3	0,00196	4,658	0,748	56,0	0,687	6,09	8,96	0,0006	1,37
4	0,00298	2,548	0,937	87,1	0,584	4,72	9,10	0,0003	1,17
1, 2, 3 & 4	0,00302	2,750	0,899	81,0	0,682	4,95	9,38	0,0002	1,37
1, 2 & 4	0,00298	2,910	0,890	79,2	0,691	5,08	9,46	0,0003	1,38

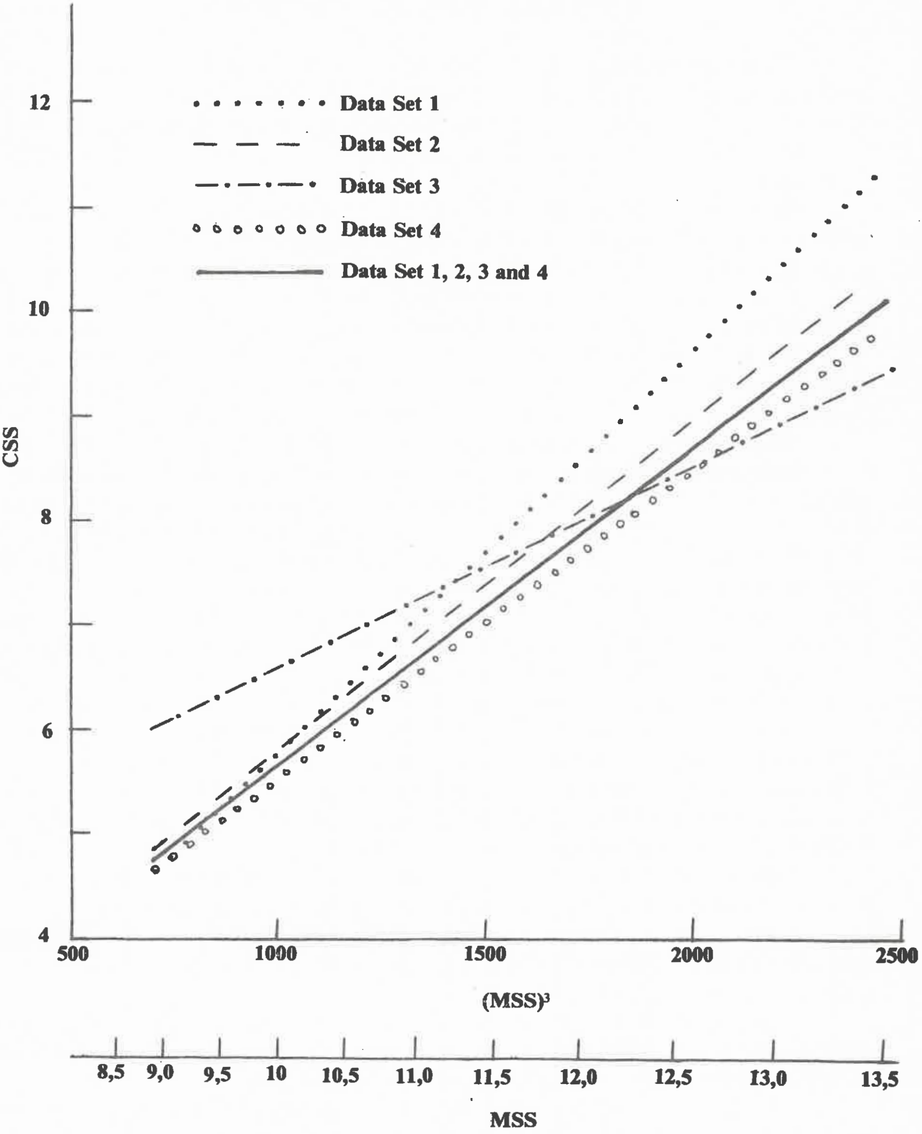

Fig. 2 Regression Lines for CSS versus (MSS)³ for the various data sets. (both CSS and MSS expressed in r/min x 10³)

SUMMARY AND CONCLUSIONS

Some preliminary work involving a new, rapid and simple approach to the assessment of the spinning potential of a wool was followed up in greater depth in the present report so that a statistical assessment of its accuracy could be made. A 144-spindle ring spinning frame was used throughout these investigations.

Initially, an experiment was carried out in which three different wool lots were spun simultaneously in several different predetermined positions on the spinning frame, and the performance of each individual spindle noted in each case. End breakage rates were determined over two hours at each of four different spindle speeds and the commercial spindle speed (CSS), i.e. the speed at which an end breakage rate of 5 per 100 spindle hours occurred was estimated from these results. In addition tests were carried out to determine the Mean Spindle Speed at Break (MSS), each test being completed in about 1,5 hours.

Results of the above experiments showed that, based on 24 spindles, an end-breakage test at one specific spindle speed could only be expected to have an accuracy of ± 135 *per cent* when referred to the performance gauged over two hours on the whole frame. On the other hand the MSS value could be determined in about 1,5 hours with an accuracy about 30 times greater than this, or three times greater than that pertaining to a CSS test for 2 hours at each of 4 spindle speeds. It only remained to show that the MSS value was highly correlated with the CSS value under widely differing conditions in order to demonstrate that the test could be used as an effective measure of spinning potential. Four such data sets were available from various research projects.

The multiquadratic regression model having MSS and its CV as independent variables was used to account for the observed variation in the largest and most recent data set, comprising 63 points, but the best fit equation was found only to depend on the MSS factor. Because of the restriction of the MSS test to a practical range of spindle speeds there was good reason to believe that a cubic relation should be fitted, and in fact it was found that the best fit equation simply related the CSS value to the cube of the MSS value.

Regression data similar to this was then obtained for all the other data sets and for combinations of the sets and in all cases very highly significant correlations were found.

The conclusion to be drawn from the above highly significant correlations is that MSS measurements can be used to indicate the performance of a wool yarn under commercial spinning conditions.

The obvious situation of deciding at what speed to spin a certain yarn, neglecting other important criteria such as economics and productivity of the average process unit, can usually be handled by an experienced man without recourse to this relation. Where a comparison of two or more yarns is required, or where the influence of different factors on the spinning performance is the object of the study, the MSS test, with its relative ease and speed of measurement, would be most useful and considerably more accurate than the conventional end-breakage test in the assessment of spinning potential.

When the MSS is measured once only on 24 spindles, differences in CSS which are greater than 1 000 r/min will be detected by the test. Repeat measurements will enable smaller differences to be detected. For example, four repeats will halve this difference.

Further work is in progress on the measurement of MSS and CSS during other research projects and will enable a further statistical evaluation in due course. In the meantime it is recommended that the following formula be used as an indication of the CSS value for 100 *per cent* wool yarns under the specific conditions pertaining to this investigation:

$$y = 0{,}00302x^3 + 2{,}748$$

where y = CSS (expressed in r/min x 10^{-3})

x = MSS (expressed in r/min x 10^{-3}).

Further work would have to be carried out to determine the relation for other fibres. It is further recommended that, in future, MSS tests should be carried out on not less than 24 spindles. If several tests are being done simultaneously on the same frame, then spindles on both sides of the frame should be used for each different lot. One or more repeat tests would be an added advantage.

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THE USE OF PROPRIETARY NAMES

The fact that chemicals with proprietary names have been used in this investigation in no way implies that SAWTRI recommends them or that there are not substitutes which may be of equal value or even better.

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APPENDIX A

RESULTS FOR DATA SET 2(a)

DICHLOROMETHANE EXTRACTABLE MATTER (%)	YARN LINEAR DENSITY (tex)	MSS AT BREAK (r/min)	CV (%)	CSS (r/min)
0,3	15,5	8 953	20,2	—
	18	10 422	16,1	6 700
	21	12 875	9,7	9 200
0,6	15,5	9 265	20,1	4 980
	18	10 656	17,2	7 000
	21	12 609	8,8	8 700
0,9	15,5	9 390	18,5	5 600
	18	11 484	8,9	7 700
	21	12 875	7,8	9 500

APPENDIX B

RESULTS FOR DATA SET 2(b)

pH DURING BACK-WASHING	LUBRICANT	YARN LINEAR DENSITY (tex)	MSS AT BREAK (r/min)	CV (%)	CSS (r/min)
8,5	A	18	11 765	19,6	8 050
		20	12 625	10,4	9 300
	B	18	11 703	16,9	8 000
		20	12 595	9,6	9 300
	C	18	11 921	18,0	7 450
		20	12 078	17,2	8 700
9,7	A	18	11 265	19,8	7 500
		20	12 677	9,9	8 600
	B	18	11 687	16,2	7 500
		20	12 968	8,6	9 400
	C	18	11 703	14,8	6 000
		20	11 828	12,9	8 100
10,4	A	18	12 062	10,9	7 400
		20	12 609	15,0	8 900
	B	18	11 234	18,5	7 200
		20	11 531	24,5	8 400
	C	18	11 484	16,5	6 650
		20	11 796	13,1	7 800
10,7	A	18	11 671	25,3	8 250
		20	12 531	22,2	9 800
	B	18	11 609	24,9	8 700
		20	13 015	13,5	9 300
	C	18	12 312	14,9	8 000
		20	12 500	17,8	9 650

APPENDIX C

RESULTS FOR DATA SET 3

TWIST FACTOR (Worsted)	YARN LINEAR DENSITY (tex)	WOOL LOT	MSS AT BREAK (r/min)	CV (%)	CSS (r/min)
2,0	18	A	9 125	22,4	—
		B	8 687	14,8	—
		C	11 156	27,8	7 200
	21	A	10 844	18,5	7 600
		B	8 875	18,3	—
		C	11 765	24,1	8 000
	24	A	11 312	15,8	8 500
		B	10 796	14,6	8 200
		C	12 703	12,3	8 400
2,4	18	A	11 328	16,8	6 200
		B	10 796	22,7	6 950
		C	12 593	12,4	7 750
	21	A	11 675	20,0	8 600
		B	11 500	10,1	8 100
		C	12 953	15,3	9 200
	24	A	12 828	8,9	9 350
		B	11 703	20,1	8 300
		C	13 171	12,6	10 000
2,8	18	A	10 640	14,6	6 200
		B	11 046	16,7	6 600
		C	12 328	9,8	6 900
	21	A	12 687	13,5	7 850
		B	12 671	13,5	8 200
		C	13 250	11,8	8 750
	24	A	12 328	14,3	9 200
		B	12 578	15,4	9 200
		C	13 359	5,8	9 400
3,0	18	A	9 656	23,0	6 200
		B	10 593	19,2	6 800
		C	11 750	8,8	7 100
	21	A	12 062	15,4	8 400
		B	12 328	13,8	8 550
		C	12 218	15,0	9 050
	24	A	11 875	12,8	8 400
		B	12 437	18,1	8 000
		C	13 328	4,7	8 900

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