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Assessment of the Spinning Potential on the Short Staple System by the MSS Technique

Part I: An Introductory Study

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ASSESSMENT OF THE SPINNING POTENTIAL ON THE SHORT STAPLE SYSTEM BY THE MSS TECHNIQUE PART I: AN INTRODUCTORY STUDY

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ABSTRACT

The Mean Spindle Speed at Break (MSS) test was developed at SAWTRI for assessing the spinning potential of wool on worsted ring spinning machines. The suitability of this method for the short staple spinning system was studied using six cotton lots of widely differing fibre properties. A high correlation was found between the MSS and the CSS values (Commercial Spindle Speed, i.e. the spindle speed at which a commercially acceptable end breakage rate occurs). The minimum number of spindles necessary for obtaining reproducible MSS results is about 24 spindles. It was concluded that the MSS technique holds potential for the short staple system.

INTRODUCTION

In the processing of textile fibres, ring spinning forms one of the most time consuming and labour intensive processes. Nowadays, since automatic doffing has become standard equipment for ring spinning machines, it is the *end breakage rate* which mainly determines the labour required to run a ring spinning frame. The number of ends down in a given period also has an important effect on spinning efficiency in terms of waste accumulation and yarn quality. In many mills, therefore, end breakage rates are monitored in an attempt to keep spinning efficiency at a high level.

Considering the importance of the end breakage rate in spinning, it follows that there is a need for a reliable, accurate and quick method by which it can be measured or predicted when, for example, there is a choice between different raw materials, additives or spinning conditions. One approach would be to spin yarn under the required conditions and count the number of end breakages over a given period. This is very time consuming when sufficiently accurate results are required. As a result several studies have been undertaken in order to find a quick and reliable method for predicting end breakage rates on ring spinning machines, and several techniques have been developed, most of which involve more severe spinning conditions to accelerate the test. These include increasing yarn spinning tension[1], changing the draft and twist[2] and changing yarn linear density[3] to produce more end breaks in a shorter time. Another technique involves the use of special equipment which measures the force required to pull an end down during the spinning process[4].

At SAWTRI the Mean Spindle Speed at Break (MSS) technique has been developed[5,6] for assessing the spinning potential on a worsted ring spinning frame. A highly significant correlation has been found between MSS and the spinning speed at which a commercially acceptable end breakage rate of 5 per 100 spindle hours occurred (CSS). For this test no special equipment is required and it can be carried out by any mill in about one and a half hours. In this method, the spindle speed of the ring frame was increased step by step at a given rate during the spinning of relatively fine yarns and no piecing of any ends permitted until all ends were down or until the maximum speed of the spinning frame had been reached. The mean spindle speed at which these breaks occurred was defined as the "Mean Spindle Speed at Break" value (MSS).

For the short staple spinning system, the commercially acceptable end breakage rate is considered to be lower than that for the worsted system, but here too, these rates differ widely from mill to mill. Labour costs obviously play an important rôle, a low wage level resulting in a higher acceptable commercial end breakage rate. Uster has published experience values for end break frequency in ring spinning[7] which are given in Table I. This reveals that 10% of cotton spinners operate at an end breakage rate not exceeding 58 per 1000 spindle hours when spinning carded cotton, while 10% are working at an end breakage rate below 14 ends down over 1000 spindle hours. Generally, however, an end breakage rate of 40 per 1000 spindle hours or less is considered to be acceptable and this was adopted for the purpose of this study which was aimed at assessing the suitability of the MSS technique for predicting end breakage rates when spinning cotton.

TABLE I

EXPERIENCE VALUES FOR THE END BREAK FREQUENCY IN RING SPINNING*

Distribution of Spinning Mills in % (worldwide)	END BREAKS PER 1000 SPINDLE HOURS		
	Combed cotton (100% cotton)	Carded Cotton (100% cotton)	Worsted (100% wool)
10	12	14	38
50	23	28	75
90	48	58	150

* According to Uster[7].

high speeds, all travellers were changed after each MSS test in order to keep constant spinning conditions.

The MSS values were calculated according to eq. (1):

$$MSS = \frac{\sum_{i=1}^{k} X_i \cdot n_i}{\sum_{i=1}^{k} X_i} \qquad \text{.......... (1)}$$

where n_i = spindle speed (rev/min.) at the i-th step.

X_i = number of ends down at n_i rev/min

CSS Test

The CSS test was carried out at three different spindle speeds for each yarn. A spindle speed at which an end breakage rate of 40 per 1000 spindle hours occurred was estimated initially by trial and error and the yarn was spun on 72 spindles for 4 hours at that selected speed. In a four hour cycle a bobbin was usually filled and the machine was doffed. The spindle speed was then increased for estimates too low and decreased if it was too high. The machine was run again for 4 hours. A third trial was carried out for the same time period in order to arrive closer to the end breakage rate of 40 per 1000 spindle hours. To assess the CSS value, a linear regression analysis was carried out on each lot and the spindle speed at which an end breakage rate of 40 per 1000 spindle hours occurs was calculated.

Yarn and roving tests

Single thread strength and extension were measured on an Uster automatic strength tester (constant rate of load). Yarn and roving irregularity and frequencies of imperfections were measured on the Uster range of equipment, using standard settings and following standard procedures. Hairiness was measured on a Shirley Yarn Hairiness Meter at the standard distance of 3 mm . The yarns were tested at 20°C and 65% RH.

Evaluation of data

All data obtained were evaluated statistically, the main purpose being to establish a correlation between the MSS and CSS values obtained. Correlations between fibre, yarn and roving properties and MSS values were also studied.

TABLE III

RESULTS OF MSS TESTS

Test No.	MSS (rev/min.)					
	A	B	C	D	E	F
1	13 535	12 868	8 819	14 479	12 076	10 833
2	13 361	13 229	—	14 618	12 273	11 028
Mean	13 448	13 049	8 819	14 549	12 175	10 930

RESULTS AND DISCUSSION

MSS Tests

The MSS results are given in Table III. To estimate the number of spindles necessary for obtaining reliable results, the data were evaluated statistically. The difference between the two MSS tests carried out on each lot was between 1,4 and 2,8% and it was found that at a 99% significance level this variation should be below 2,85% which represents a difference of about 400 rev/min . depending on the actual MSS value. MSS values were also calculated on a lower number of spindles for each MSS test. Evaluations were made, decreasing the number of spindles to 36, 24, 18, 12 and 6 spindles. This was also done in two ways as illustrated in Fig. 1 for every 6th spindle. The machine was devided into sections, so that the MSS values could be calculated over groups of adjacent spindles (case I). MSS Values were also assessed by calculating the values for every 2nd, 3rd, 4th and 6th spindle over the total length of the machine (case II). The results are given in Table IV. It is evident that a lower variation in MSS values is obtained by using spindles distributed over the whole length of the machine (case II) instead of considering groups of adjacent spindles (case I). In the present case the variation in MSS values for 24 spindles distributed over the whole length of the machine was lower than the variation between the two MSS values before and after the CSS test. It is recommended, therefore, that at least 24 spindles distributed over the whole length of the machine be used. By this method, 3 different batches can be tested simultaneously on the 72 spindles.

CSS Tests

It has been stated[8] that about 3000 spindle hours are required for a sufficiently accurate end breakage test. Uster[3] even recommends several 10 000 spindle hour tests for obtaining reliable results. In the present case the tests had to be restricted to 864 spindle hours to keep the time required for the tests and the

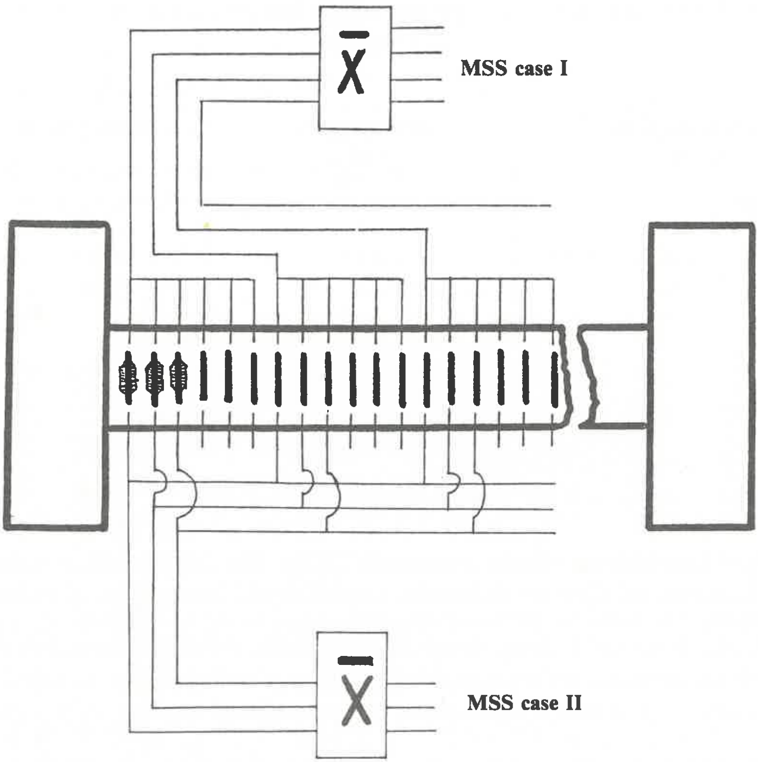

Fig. 1 – Calculation of MSS value for every 6th spindle.

TABLE IV

DEVIATION* OF MSS RESULTS FOR DIFFERENT NUMBERS OF SPINDLES

NUMBER OF SPINDLES	DEVIATION* CASE I <... (%)	DEVIATION* CASE II <... (%)
36	2,9	1,3
24	4,5	2,8
18	6,1	2,9
12	5,9	4,5
	deviation* between both MSS tests <...(%)	
72	2,85	

(All data calculated at 99% significance level)

* Forecasted percentage difference between lowest and highest result.

amount of raw material within reasonable limits. This reduced the accuracy of the CSS results but they were regarded as sufficiently accurate to illustrate the main trends. For each set of CSS test results a regression analysis was carried out and the spindle speed at which an end breakage rate of 40 per 1000 spindle hours occurred was determined by a regression analysis as illustrated in Fig. 2.

Table V contains details of the number of end breaks which occurred during each hour of the 4 hour CSS tests and the CSS results. These results varied considerably, depending on the lot and spindle speed. The distribution of the end breaks during the four hour spinning cycle shows that there can be a very high variation in ends down rates from one hour to the next. The average rate of ends down was calculated for each hour of spinning. There appeared to be a trend for the number of end breaks to decrease as the test proceeded but this trend was not consistent.

Correlation between MSS and CSS Results

The results of MSS and CSS tests are given in Tables III and V. Only one MSS test was carried out on lot C and no CSS result could be obtained because even at the lowest spindle speed possible for the machine (5000 rev/min) the end breakage rate was considerably higher than 40 per 1000 spindle hours. The other five lots were processed without problems. The results of the two MSS tests, carried out on each lot were averaged and the mean values were considered for the further evaluation of MSS and CSS values. A regression analysis was carried

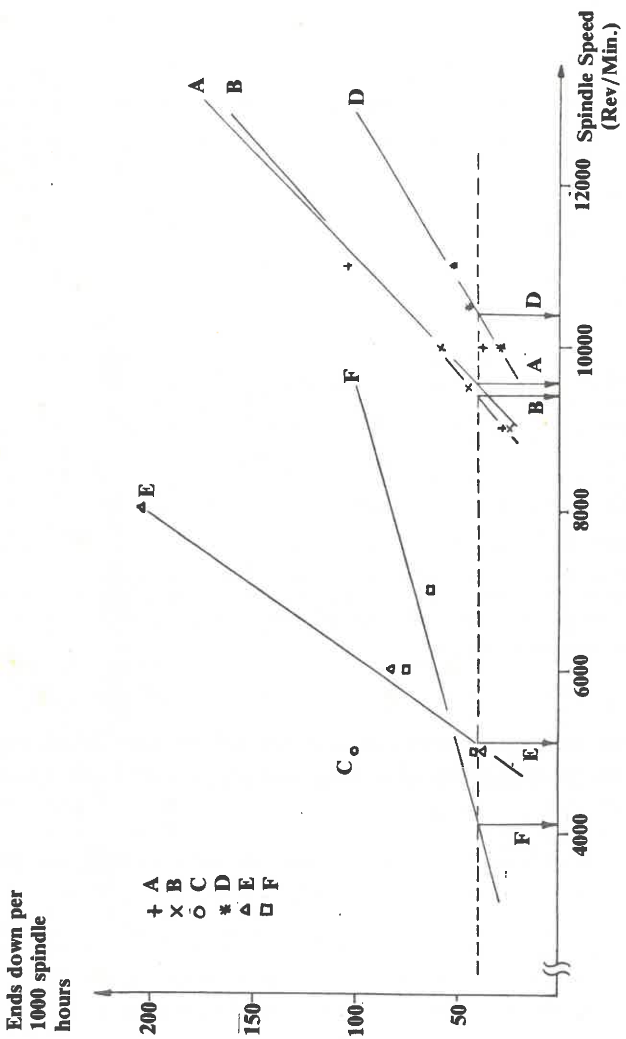

Fig. 2 – Determination of CSS values

TABLE V

ENDS DOWN DISTRIBUTION DURING CSS TESTS

Lot	Spindle Speed (rev/min.)	1.h	2.h	3.h	4.h	CSS (rev/min.)
A	9 000	2	3	2	1	
A	10 000	4	5	1	1	9 561
A	11 000	16	7	4	3	
B	9 000	4	1	1	1	
B	10 000	6	2	5	4	9 424
B	9 500	4	5	3	1	
C*	—	—	—	—	—	—
D	10 000	1	2	5	0	
D	11 000	5	4	1	5	10 431
D	10 500	3	2	7	1	
E	8 000	12	13	14	15	
E	6 000	2	8	6	6	5 117
E	5 000	2	4	3	1	
F	5 000	6	2	2	2	
F	6 000	7	3	7	3	4 121
F	7 000	6	5	5	1	

* End breakage rate unacceptably high

out to establish the correlation and relationship between the MSS and CSS values. Different model functions have been considered: the linear regression, the logarithmic regression, the exponential regression, the power curve and the quadratic and cubic regressions. The regression equations and correlation coefficients are given in Table VI. Fig. 3 shows the line corresponding to the linear regression. All correlation coefficients were very similar, the one corresponding to the power curve being the highest. The cubic curve, which turned out to be the best fit for the MSS-CSS relation for the worsted yarns[2], had a lower value in this study. A linear relationship would be the most convenient to use for practical tests in a mill, and the data used in this study is described adequately by eq. (2):

$$CSS = 1{,}982\,MSS - 17\,699 \quad \ldots\ldots (2)$$

correlation coefficient (r) = 0,935 (significant at the 98% level)

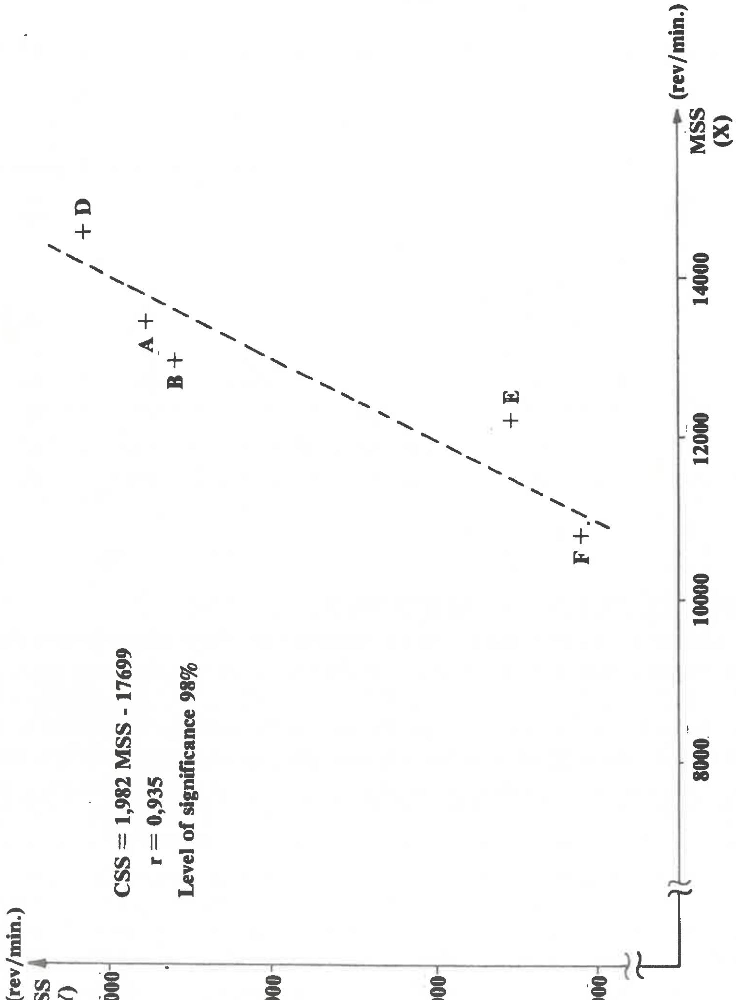

Fig. 3 – Linear regression between MSS and CSS values.

TABLE VI

REGRESSION ANALYSES OF RELATION BETWEEN MSS AND CSS VALUES

Regression Model (X=MSS; Y=CSS)	A	B	Correlation Coefficient (r)	Level of Significance	Percentage Fit
$Y = A+B\cdot X$	- 17699	1,982	0,935	98%	87
$Y = A+B\cdot \ln X$	-229425	25083	0,938	98%	88
$Y = A\cdot e^{B\cdot X}$	-174,5	$2{,}91\cdot 10^{-4}$	0,933	95%	87
$Y = A\cdot X^{B}$	$5{,}25\cdot 10^{-12}$	3,687	0,940	98%	88
$Y = A+B\cdot X^2$	-5131	$7{,}74\cdot 10^{-5}$	0,929	95%	86
$Y = A+B\cdot X^3$	-922,1	$3{,}99\cdot 10^{-9}$	0,921	95%	85
$Y = A+B\cdot X^4$	1203	$2{,}28\cdot 10^{-13}$	0,913	95%	83

MSS and properties of yarn, roving and fibres

The properties of the yarns, spun during the CSS trials (at medium spindle speed) were tested and are listed, together with the roving irregularity, in Table VII. To find out if there was a correlation between any of these properties and the MSS results, the correlation coefficients were calculated and these are listed in Table VII. Significant positive correlations were found between MSS and both yarn breaking strength and tenacity. This is as expected because at a higher spindle speed (i.e. higher MSS value) the yarn has to withstand a higher spinning tension, so naturally yarns with a higher tenacity at the same linear density will produce higher MSS values as well. A negative correlation was found between thick places and MSS values. Garde and Rottmayr[10] have found that, during ring spinning, yarn breaks are very often caused by the coincidence of a thick place causing a tension peak in the yarn while passing through the balloon and a thin place occurring in the spinning triangle. Therefore, with a high frequency of thick places a high end breakage rate is very likely to occur. A significant negative correlation was also found between roving irregularity and MSS results. It is obvious that a good roving quality results in a good spinning performance. No significant correlation could be established between any of the individual fibre properties or combinations thereof and the MSS values due to the limited varieties of cotton tested.

TABLE VII

YARN AND ROVING PROPERTIES AND THEIR CORRELATION WITH MSS RESULTS

LOT	YARN PROPERTIES													Roving Irregularity (CV %)
	Linear Density			Breaking Strength		Tenacity (cN/tex)	Extension (%)	Irregularity (CV %)	Thin Places per 1000 m	Thick Places per 1000 m	Neps per 1000 m	Hairiness		
	Nominal (tex)	Mean (tex)	CV (%)	Mean (cN)	CV (%)							Mean (Hairs)	CV (%)	
A	15	14,6	0,6	163	10	11,2	5,0	20,3	340	748	660	16	4	6,8
B	15	15,1	1,7	159	12	10,5	4,9	20,0	234	682	1476	15	29	8,1
C	15	15,7	1,8	118	16	7,5	6,0	—	—	—	—	18	14	10,7
D	15	15,0	1,0	174	10	11,6	5,7	21,0	281	774	892	18	17	7,7
E	15	14,9	1,5	161	10	10,8	5,6	21,0	287	1007	1764	12	6	8,5
F	15	15,3	1,1	116	11	7,6	5,3	22,9	556	1388	1662	13	12	9,2
r*	—	—	—	0,907**	—	-0,916**	-0,488	-0,693	-0,725	-0,861	-0,771	0,033	—	-0,982

* Correlation Coefficient between MSS and respective properties

** Significant at 95% level

SUMMARY AND CONCLUSIONS

The application of the Mean Spindle Speed at Break (MSS) technique, previously developed to provide a rapid method for predicting the spinning performance of wool, has been investigated for predicting the spinning performance of cotton.

For the purpose of this investigation, six different cotton lots with widely differing fibre properties were spun on a short staple ring spinning machine. The spinning speed at which a commercially acceptable end breakage rate of 40 per 1000 spindle hours occurred (CSS) was estimated by spinning for four hours at each of three different spindle speeds. The Mean Spindle Speed at Break (MSS) value was obtained by increasing the spindle speed by 500 rev/min. every five minutes, without piecing up. The number of ends down at each spindle speed was noted and the MSS value was calculated. A high correlation was found between MSS and CSS values. The linear regression equation obtained was considered to be accurate enough for practical purposes. For the CSS tests, a high variation was found between the number of end breaks recorded during successive hours of a four hour test. Generally, the accuracy of the CSS values was lower than that of the MSS values. For MSS, 24 spindles were found to be sufficient for a reproducible result, so that several lots can be tested simultaneously on the spinning frame. A highly significant correlation was also found between roving irregularity and MSS values. No significant correlation could be established between any of the cotton fibre properties or combinations thereof and either the MSS or CSS values because of the limited variety of cotton studied. Of the yarn properties, the breaking strength and tenacity were fairly highly correlated with the MSS values.

During this investigation, variations in linear density or twist were not considered. Further applications of the MSS technique will be needed to prove whether the formula found, also applies to yarns which differ in that respect.

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THE USE OF PROPRIETARY NAMES

The names of proprietary products where they appear in this report are mentioned for information only. This does not imply that SAWTRI recommends them to the exclusion of other similar products.

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