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Sirospun Yarns
Part I: An Introductory Study

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ABSTRACT

A preliminary study, covering five wool lots, has been carried out to establish the effect of limited changes in either fibre diameter or fibre length on the spinning performance and properties of Sirospun yarns. It emerged that, for the particular ranges of fibre length and diameter covered, changes in both spinning potential (MSS) and yarn properties were almost solely dependent upon changes in fibre diameter (or average number of fibres in the strand cross-section) for both the Sirospun and conventional two-ply yarns.

INTRODUCTION

Spun singles yarns from staple fibres generally exhibit a characteristic hairy appearance compared with the smooth appearance of continuous filament yarns. Such yarns tend to be unsuitable for weaving as warp yarns, not because of a lack of tenacity or inadequate extension, but because of their relatively hairy nature[1]. Surface fibres, especially those only partially bound into the yarn body, are readily abraded by the reciprocal movement of the shed in the loom, and by their movement from the weaver's beam through the healds and the reed[2]. To obviate this problem, such yarns are generally either plied (folded) or sized. Both these processes serve to reduce hairiness and to improve warp weaving efficiencies in general. Although sizing is traditionally the method used in the short staple (cotton) industry, in recent work at SAWTRI attempts have been made to obtain the same effects on fine all-wool singles worsted yarn in order to reduce the yarn linear density constraints for the production of lightweight shirting fabric[3,4]. Plying, however, remains the traditional method of reducing yarn hairiness for worsted singles yarns, despite its cost.

Attempts to eliminate the folding operation between spinning and warping to reduce costs are not new[5-7]. For example, Jaspe or grandrelle yarns are simply double-rove yarns which are produced from two rovings drawn on a single drafting unit and allowed to converge above the twizzle[8]. Despite considerable efforts to analyse the geometry of these so-called "V"-yarns[9], their general acceptance by the spinning industry has been very poor, basically owing to two major problems associated with such systems. Firstly, the spinning geometry (i.e. strand separation and convergence angle) has not yet been optimised and secondly, the elimination of "spinners singles" (i.e. the remaining single strand which spins on its own after one strand breaks[10]) has been a major problem. With these constraints in mind, work was initiated by the CSIRO Division of Textile Industry in Geelong, Australia[11] which culminated in the development and joint promotion and marketing of the ®Sirospun system by

Wool Developments International (a private company wholly owned by the IWS) and Messrs Zinser GmbH, West Germany. By 1981, some 40 000 spindles in the UK, France and West Germany were producing approximately $2x10^6$ kg of Sirospun yarn[12,13] in all-wool and wool/polyester blends. Acrylic Sirospun yarns for furnishing and upholstery fabrics are also currently being produced for the West German market[14,15]. A detailed theoretical model on which this two-strand spinning system is based has also recently been published[16].

In view of the apparent increasing use of Sirospun yarns on the European market and the more-than-likely continuing implementation of the technology by the South African worsted spinning industry, it was decided to initiate studies at SAWTRI on the Sirospun system so as to acquire expertise and scientific knowledge on this system and the yarns and fabrics produced. This paper deals with the results of some preliminary experiments in which the performance of five wool tops, differing in length and diameter, was compared in Sirospun and conventional two-ply yarn production.

MATERIALS AND METHODS

®Sirospun Conversion

One-half of SAWTRI'S Rieter H6 worsted ringframe (72 spindles) was converted to Sirospun by means of the appropriate components. Photographs as well as detailed discussions of these components and each of their individual functions can be found elsewhere[17]. In essence, three of the components (the rear roving guide, the centre roving guide and the front zone condenser) are concerned with separation of the two rovings from behind the back rollers, through the drafting zone to the convergence point between the front rollers and the twizzle. The fourth component is the breakout device and is mounted between the front rollers and the twizzle, just below the yarn convergence point, and serves to prevent spinners singles by breaking the remaining strand should one strand break.

Raw Materials

Five batches of wool, differing in length (Almeter Hauteur) and mean fibre diameter, were selected for the various experiments. The relevant fibre details are given in Table 1.

Each batch was prepared for spinning by lubricating with 0,3% (o.m.f.) ®Bevaloid 4027 before drawing on a conventional Schlumberger drawing set to the required linear density. The spinning frame was fed by means of double-meche rubbing frame rovings, which had the advantage that each spinning position could be fed from a single bobbin thus obviating expanding of the creel capacity.

TABLE 1

TOP FIBRE DATA

LOT	Fibre Length (Hauteur)		Fibre Diameter	
	Mean (mm)	CV (%)	Mean (μm)	CV (%)
A	55,0	44,6	19,8	14,10
B	64,0	43,1	19,2	23,2
C	57,0	53,1	22,7	22,2
D	68,0	52,8	22,9	20,5
E	66,0	50,7	20,8	22,8

Spinning Tests

Three experiments were carried out, the first two being concerned with the suitability of using the mean spindle speed at break (MSS) test[18,19] on Sirospun and a preliminary assessment of the effects of fibre properties on the MSS data obtained by this test. The third experiments was chiefly concerned with a comparison of yarn properties (Sirospun vs conventional two-ply yarns) and the relative contribution of fibre properties to observed variations in properties of yarns spun on these two systems.

In the first experiment, batch "E" (20,8 μm, 66 mm) was used and the MSS test carried out on at least 36 spindles, using the recommended minimum Sirospun twist factor of 34,8 (110 metric)[12]. The test was commenced under what can be considered commercial spinning conditions (i.e. round 45 fibres per strand cross-section) and repeated at progressively lower numbers of fibres per strand cross-section to establish limit spinning conditions.

In the second experiment, the rest of the wools (lots A to D — see Table 1) were tested under similar conditions (i.e. on either 24 or 36 spindles at a twist factor of 34,8), each at two yarn linear density levels equivalent to around 30 and 45 fibre per strand cross-section, respectively. Each test was repeated and the average MSS calculated.

In the third experiment, each batch was spun to two linear densities (R40/2 and R60/2), using a twist factor of 34,8. The frame was run at 7000 rev/min in each case. The same wools were also spun to conventional two-ply yarns of equivalent linear density and twist in order to compare yarn properties.

These were R40tex S530/2Z825 and R60tex S450/2Z675, respectively. All the yarns were steamed, rewound and Classimat tested before testing for tenacity, regularity, extension at break and hairiness (see Table 5). A Shirley Constant Tension Winding Test[20] was also carried out to obtain a measure of the isolated weak places.

RESULTS AND DISCUSSION

Spinning Performance

The preliminary experiment using batch "E" (20,8 μ m, 66 mm) proved that the MSS technique could be used on Sirospun without major changes to the actual test method. It was found necessary, however, to remove the crowns from the spindles running on Sirospun, since the reduced spinning tensions, which is the purpose of using crowned spindles, were found inadequate to activate the breakout device when the one strand failed. The same effect could also be obtained by simply raising the twizzle by approximately 5 mm to allow the yarn balloon to clear the crown grooves.

Using a fairly typical roving (375 tex), further tests showed that similar to conventional spinning, the MSS decreased rapidly with a decrease in the number of fibres per strand cross-section. Table 2 shows that the MSS value decreased from around 11 500 rev/min under commercial spinning conditions (45 fibres per strand cross-section or more) to just under 6000 rev/min at limit spinning conditions (20 fibres per strand cross-section). Further attempts to reduce the strand linear density were fruitless, underscoring the vital role of number of fibres in the yarn cross-section (or, as in the present case, fibres in the strand cross-section), in determining spinning efficiencies. In saying this, one must of course assume that similar to conventional spinning, the MSS for Sirospun is correlated with the commercial spindle speed at which an end breakage rate of around 5 or 10 per 100 spindle hours[18,21] can be maintained. Experiments are currently being planned to establish the nature of this correlation. Referring again to Table 2, however, regression analysis showed that there was a high positive correlation (r = 0,91) between MSS and fibres per strand cross-section under the conditions pertaining to this particular experiment. This effect is illustrated in Fig. 1. Some 84% of the observed variation in spinnability could be accounted for by variations in the number of fibres per strand cross-section.

In the second series of experiments, a similar test procedure was followed using the rest of the tops of which the fibre parameters are given in Table 1 and the MSS results are given in Table 3.

By pooling the results of Tables 2 and 3, a data set of 12 points was available for analysis. Because of the relatively small factorial design of this experiment in terms of fibre parameters, it was decided to postpone a detailed regression analysis including four wool variables and the two yarn variables, and

TABLE 2

MSS DATA FOR A 20,8 μm, 66 mm WOOL TOP AT DIFFERENT SIROSPUN LINEAR DENSITIES

Fibres per Strand Cross-section*	Equivalent Strand Linear Density (tex)	MSS (rev/min)
47	22	11 569
32	15	10 666
26	12	7 791
20	10	5 930
15	7	no spin
10	5	no spin

* Calculated from $n = \dfrac{972 \, . \, Tex}{\mu^2(1 + 0{,}0001CV^2)}$

TABLE 3

MSS DATA FOR TOPS DIFFERING IN HAUTEUR AND MEAN FIBRE DIAMETER

Length Category	Diameter Category	Hauteur		Diameter		Average No. of Fibres per Strand Cross-section*	Equivalent Yarn Linear Density (tex)	Average MSS (rev/min)
		Mean (mm)	CV (%)	Mean (μm)	CV (%)			
Medium	Fine	55,0	44,6	19,8	24,0	30	25	9 246
						45	38	10 378
	Medium	57,0	53,1	22,7	20,2	30	35	10 412
						45	50	10 645
Medium to Long	Fine	64,0	43,1	19,2	23,2	30	25	10 041
						45	38	10 082
	Medium	68,0	52,8	22,9	20,5	30	35	10 280
						45	50	10 287

* See footnote Table 2

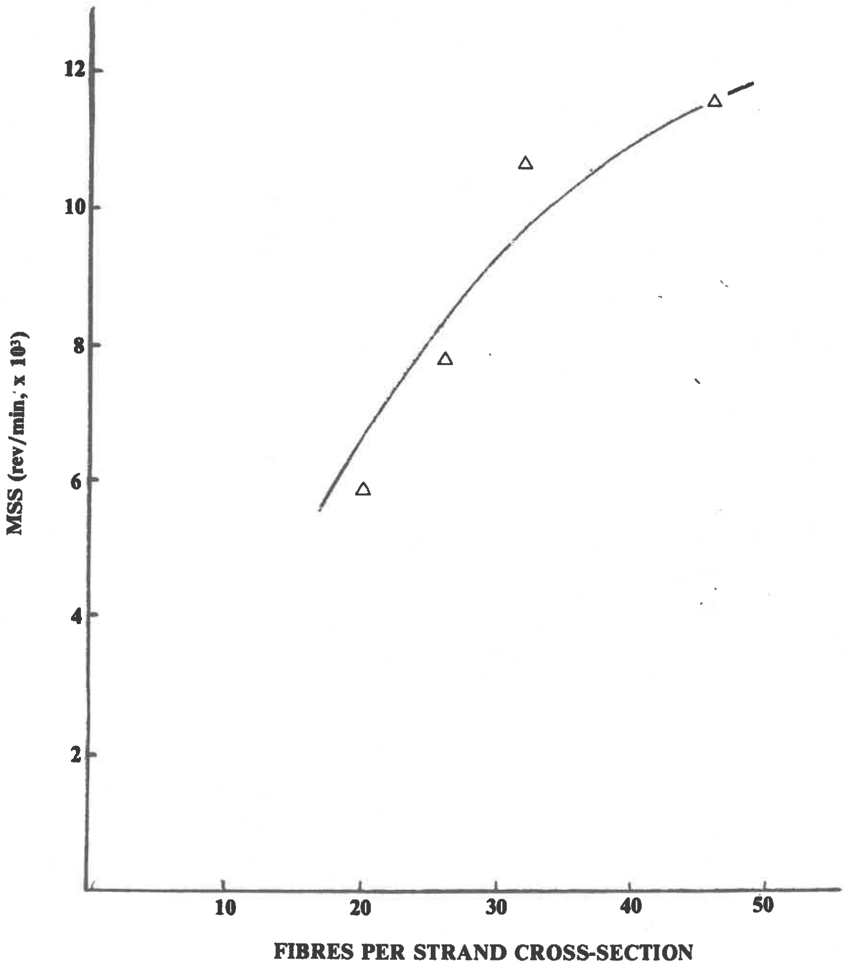

Fig. 1 – The Effect of Average Number of Fibres per Strand Cross-section on Spinnability.

TABLE 4

SUMMARY OF STATISTICAL ANALYSIS*

Analysis Based on Tex (X_5)				Analysis Based Upon Average Number of Fibres Per Strand Cross-section (X_4)			
Variable entering	r^2	Increase in r^2	Significant Equation	Variable entering	r^2	Increase in r^2	Significant Equation
X_5	0,507	—	$10,2X_5+6117$	X_4	0,609	—	$127,4X_4+5293$
X_5^2	0,833	0,326	$773,4X_5-9,4X_5^2-4700$	X_4^2	0,891	0,252	$996,7X_4-12,14X_4^2-9236$

* Multiple regression analysis involving forward selection procedure

TABLE 5

YARN PHYSICAL PROPERTIES

Yarn Type and Lot	Linear Density			Breaking Strength		Tenacity (cN/tex)	Extension (%)	Twist (turns/m)	Irregularity (CV %)	Thin Places (per 1000 m)	Thick Places (per 1000 m)	Neps (per 1000 m)	Classimat Faults per 100 km		Shirley Constant Tension Winding (Breaks per 1 000 m)
	Nominal (tex)	Mean (tex)	CV (%)	Mean (cN)	CV (%)								Total ($A_1+B_1+C_1+D_1$)	Objection ($B_4+C_3+D_2$)	
Sirospun															
A	40	40,4	1,2	318	9	7,9	26,0	S550	14,8	8	15	8	217	76	8,75
B	"	41,9	1,3	330	10	7,9	22,8	S550	14,7	13	15	10	189	51	2,61
C	"	40,2	1,5	286	10	7,1	16,0	S550	15,8	26	35	15	292	40	33,0
D	"	42,0	0,5	301	11	7,2	15,6	S550	15,4	16	15	15	656	84	22,35
A	60	58,6	0,9	493	10	8,4	29,3	S450	14,4	4	26	12	789	421	2,33
B	"	61,8	1,7	523	9	8,5	28,6	S450	14,0	2	23	4	510	240	0,94
C	"	58,1	1,1	468	9	8,1	22,9	S450	14,8	7	13	13	316	174	21,7
D	"	60,8	1,9	466	9	7,7	20,2	S450	14,6	1	13	15	678	234	11,6
Conventional 2-Ply															
A	40	39,3	1,0	312	10	7,9	20,2	S550/2Z825	14,0	1	4	14	177	4	2,77
B	"	41,0	1,2	325	8	7,9	19,5	S550/2Z825	13,7	4	3	2	272	16	1,17
C	"	39,7	1,1	280	10	7,1	13,1	S550/2Z825	14,8	14	7	12	212	8	34,8
D	"	41,1	2,4	292	9	7,1	13,2	S550/2Z825	14,3	11	9	16	408	16	14,2
A	60	58,8	1,5	490	8	8,3	25,4	S450/2Z675	12,7	1	12	6	176	35	1,31
B	"	61,5	0,7	517	6	8,4	26,8	S450/2Z675	12,1	1	0	1	90	20	0,28
C	"	60,0	1,1	462	9	7,7	19,4	S450/2Z675	13,0	1	4	6	101	20	6,63
D	"	60,3	1,5	450	8	7,5	16,5	S450/2Z675	13,1	1	5	10	258	6	6,42

their interactions, until such time as a more comprehensive data set becomes available. However, a preliminary analysis on the available data from this experiment was carried out involving mean fibre diameter (X_1), Hauteur (X_2) and either fibre per strand cross-section (X_4) or resultant tex (X_5), and this analysis is summarised in Table 4.

The form of the two equations given in Table 4 is very similar to those obtained by Turpie and Gee[22] for MSS data on conventional spinning in the sense that again MSS appeared to be a quadratic function of either fibres per strand cross-section or tex. The fact that fibre properties did not enter the regressions was not surprising in view of the very small selection of wools used in the preliminary experiments. However, it may be deduced from Table 4 (i.e. by putting $\frac{dy}{dX_5} = 0$ or $\frac{dy}{dX_4} = 0$ and solving for X) that, for the approximate range of linear densities covered, the MSS increased by around 300 rev/min per unit increase in the yarn linear density being spun. Similarly, up to about 40 fibres per strand cross-section the MSS value increased by about 85 rev/min per additional fibre in the strand cross-section.

Yarn Properties

According to the results of the yarn properties (Table 5), both the Sirospun and two-ply yarns were affected by fibre diameter (no. of fibres in yarn cross-section) rather than by fibre length for the particular ranges covered in this study.

The tenacities of the Sirospun and two-ply yarns were very similar while the former generally had higher extension at break, irregularity and frequencies of imperfections, faults and isolated weak places (Shirley Constant Tension Winding Test) than the former. These differences can probably be ascribed to the fact that thin and thick places caused by the spinning drafting system would tend to coincide for the two strands in the case of the Sirospun yarns, and therefore be accentuated, while this is far less likely to happen when the yarn is spun in singles form and plied afterwards. According to Fig. 2 there was a good correlation between the Shirley Constant Tension winding test results obtained on the 40 and 60 tex yarns respectively, in spite of the fact that relatively short lengths of yarn were tested. Fig. 3 illustrates the general trend for the number of yarn breaks during the constant tension winding test, to increase fairly sharply as the average number of fibres in the yarn cross-section (total in the two-ply or two strands) decreased.

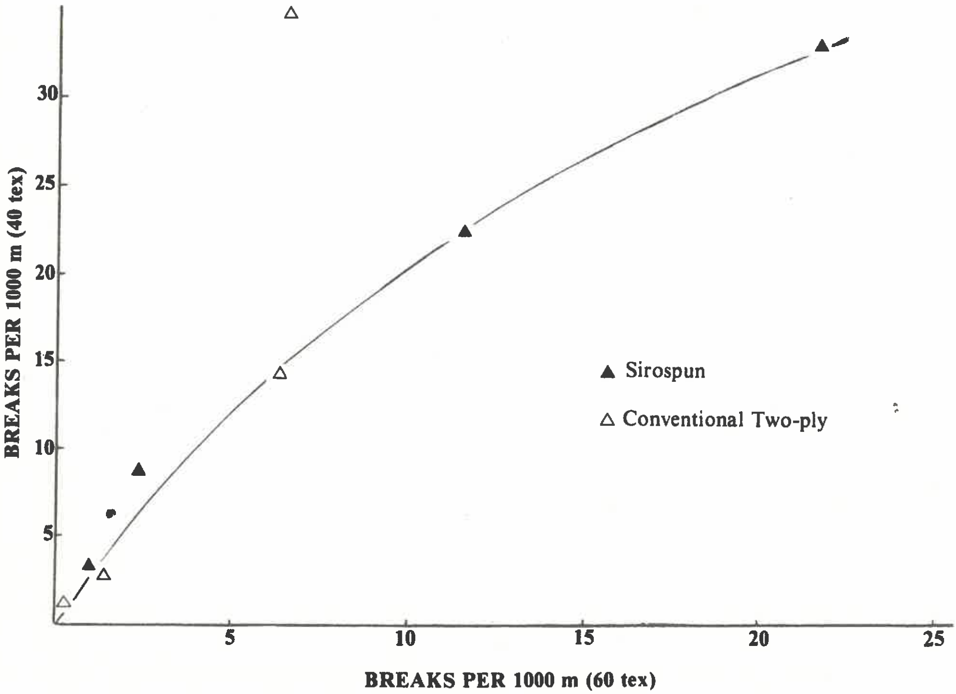

Fig. 2 – The Relationship between the Frequency of Isolated Weak Places (Shirley Constant Tension Winding Test) for 40 tex and 60 tex Yarns, Respectively.

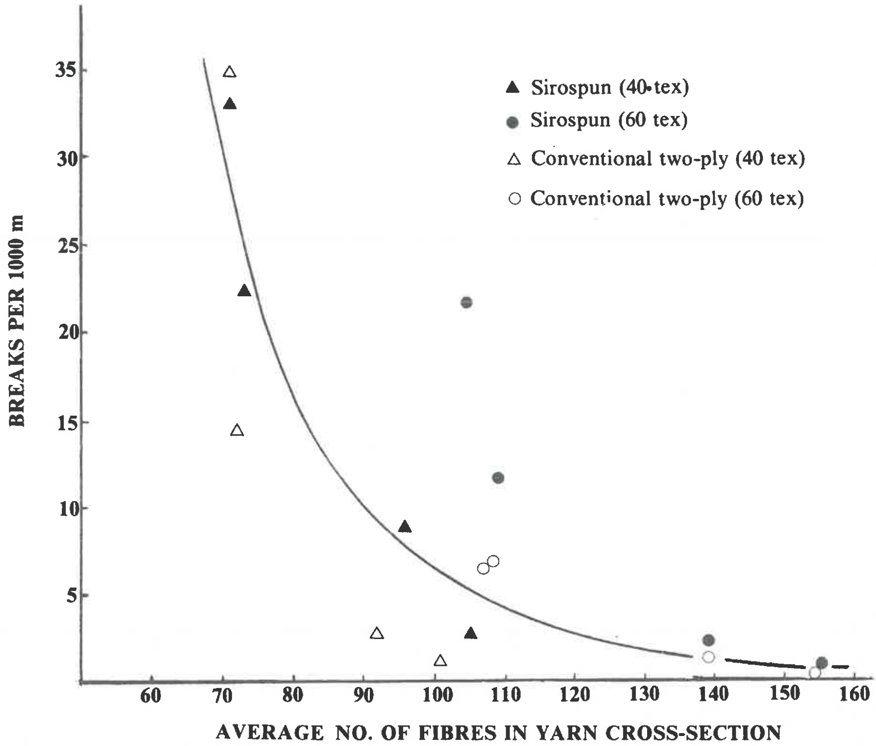

Fig. 3 – The Relationship between Frequency of Isolated Weak Places (Shirley Constant Tension Winding Test) and average no. of Fibres in the Yarn Cross-section.

SUMMARY AND CONCLUSIONS

A preliminary study was undertaken to determine the effect of limited changes in wool fibre diameter (from ≈ 19,5 μ m to 22,5 μ m) and fibre length (≈ 55 mm to 65 mm) on the spinning and properties of Sirospun yarns and to compare the trends with those obtained for conventional two-ply yarns. Spinnability was tested by means of the Mean Spindle Speed at Break (MSS) test.

As in the case with conventional single yarns, the MSS values for the Sirospun yarns decreased rapidly as the number of fibres in the yarn cross-section decreased, with about 20 fibres in the cross-section of each of the two strands appearing to represent limit spinning conditions. The MSS was found to be essentially a function of the number of fibres in the yarn cross-section and was thus affected by mean fibre diameter, and not mean fibre length, for the limited ranges and number of samples investigated.

For both the Sirospun and conventional two-ply yarns the various yarn properties measured were found to be affected by mean fibre diameter, with mean fibre length having little effect. The Sirospun yarns generally had similar tenacities but higher extension, irregularity and frequencies of isolated weak places, imperfections and faults than the corresponding conventional two-ply yarns. The observed differences between the Sirospun and conventional two-ply yarns, in terms of irregularity and weak places were ascribed to the fact that any yarn imperfections and irregularities introduced by the spinning drafting system would tend to coincide in the two strands of the Sirospun yarns but not in the two ends of the two-ply yarns. A more detailed study on Sirospun yarns is at present in progress.

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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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