SAWTRI BULLETIN

SOUTH AFRICAN
WOOL AND TEXTILE RESEARCH INSTITUTE
OF THE CSIR

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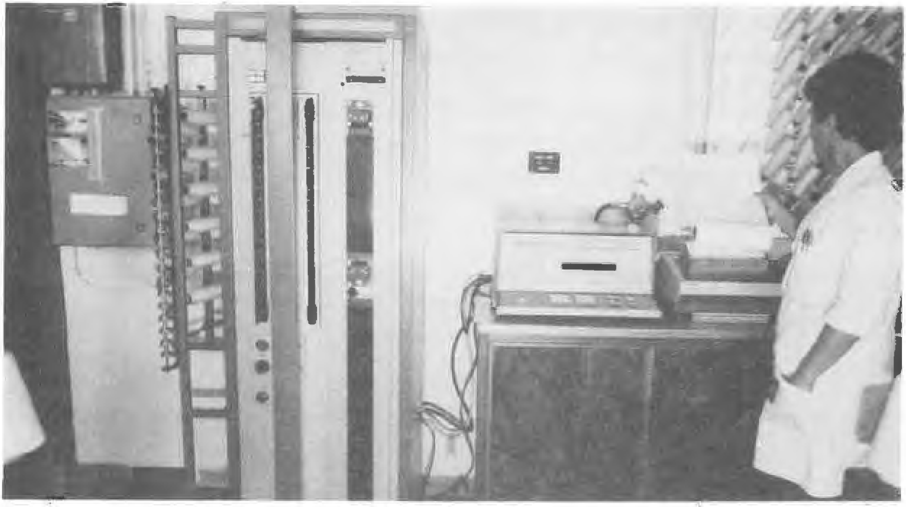
INSTITUTE NEWS

New High Speed Automatic Yarn Tensile Tester Installed at SAWTRI

The tensile properties of a yarn play an important role in determining the subsequent performance of the yarn during winding, warping, knitting and weaving and the efficiencies of these processes, and are therefore monitored as a matter of course in quality control and research laboratories.

SAWTRI recently installed one of these most advanced high speed automatic yarn tensile testers, the Uster Tensorapid. This instrument provides information in terms of print-outs (means and CV's) on yarn strength and tenacity, extension at break and work to break. Frequency distribution and "stroke" diagrams can also be produced by the printer.

The tensorapid greatly extends SAWTRI's capacity to carry out yarn tensile tests for its own research requirements as well as for the South African textile industry.



The Uster Tensorapid High Speed Automatic Yarn Tensile Tester

Overseas Visits

Dr D W F Turpie, Chief Director of SAWTRI, paid a visit to the United Kingdom during the first half of May. While there, he attended a meeting of the International Wool Secretariat (IWS) Research and Development (R & D) Committee. He also visited various textile machine manufacturers and wool and mohair topmakers. The rest of his itinerary included visits to a number of educational institutions.

World Congress on Sheep and Beef Cattle Breeding

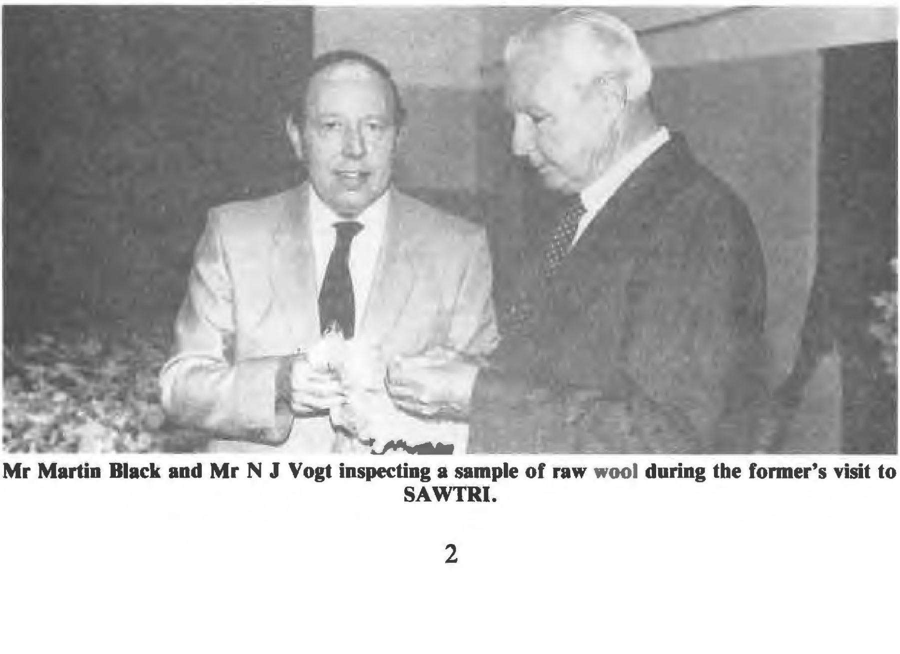
The Second World Congress on Sheep and Cattle Breeding was held at the CSIR in the Conference Centre in Pretoria from 16 to 19 April. SAWTRI was represented by the Director, Dr L Hunter and Mr M A Strydom, Head, Department of Long Staple Processing. Dr Hunter presented a poster paper on SAWTRI's work concerning the relationship between fibre properties, breed of sheep, processing performance and yarn and fabric properties. Some 500 delegates and accompanying persons from over 20 countries attended the Congress.

National Wool Growers' Association Congress

The National Wool Growers' Association Congress was held in Port Elizabeth from 16 to 18 April, SAWTRI being represented by Mr N J Vogt, Group Leader responsible for industrial liaison.

Visitors to SAWTRI

Among the visitors received at SAWTRI since the beginning of April were: Prof Maurice Shelton, an animal scientist concerned with sheep and goat production, from the Texas A & M University; Mr Martin Black, editor of "Wool Record"; Mr T R Hough, Mr D Hough, CISMO, Ciskei, accompanied by Mr Corbett and Mr D G Steyn, Ambassador Plenipotentiary, Special Assignments, to the Republic of Ciskei; Mr S Yamasaki, Director, Development Department, Keisokki Koggo Co Ltd, Osaka and Mr A F Cassie, Group Manager, Raw Wool Services Division of the New Zealand Wool Board.



Mr Martin Black and Mr N J Vogt inspecting a sample of raw wool during the former's visit to SAWTRI.

Mr N J Vogt addressing a group of students from the Port Elizabeth Technical College.

The Institute also received a number of visiting groups, the first of these being from the South Cape Weavers' Guild. This was followed by a group of students from the Port Elizabeth Technical College, who visited the Institute with the view of gaining information on the different processing procedures of wool and mohair and its implications in their prospective careers as interior decorators.

On 15 April 25 delegates to the Second World Congress of Sheep and Cattle Breeders, accompanied by Dr Jan Hofmeyr paid a visit to the Institute. Dr Jan Hofmeyr is at present the Director of the Animal and Dairy Sciences Research Institute at Irene, and he played an important rôle in the organising of this Congress.

On 16 May, a study group of wool farmers from Frankfort in the Orange Free State, were shown around the processing departments and on 17 May, a group of pupils from the Pearson High School in Port Elizabeth, was given a slide show and lecture on the history, structure and functions of the CSIR in general and SAWTRI in particular, followed by a conducted tour of the Institute.

Mr de Wet Olivier, explaining the action of the rectilinear comb in the Long Staple Processing Department to a group of wool producers from Frankfort.

Fire in Library

Early on Sunday evening, 3rd June, a small fire broke out in the Library of the Institute after the apparent malfunctioning of one of the Library's airconditioning units. Thanks to the prompt action of a security guard and the resident caretaker of the Institute, the City Fire Department, the Chief Director, Dr D W F Turpie, and members of SAWTRI's staff responsible for the protection of the Institute, were all alerted and were quickly on the scene. The fire was rapidly extinguished with relatively slight damage to the premises but, more importantly, to the library collection itself.

The damage has been repaired and the Library is again fully operational.

South African Mohair Growers' Association Congress

The 41st annual congress of the South African Mohair Growers' Association was held in Port Elizabeth on the 6th and 7th of June, and SAWTRI was represented by Dr D W F Turpie, and Mr N J Vogt.

Donation to SAWTRI Library

The SAWTRI library recently received a valuable private collection of various textile journals kindly donated by Mr Victor Daitz of Durban who had recently retired from the textile industry. These journals will form a valued part of the existing library collection and we extend our sincere thanks to Mr Daitz for his generosity.

Staff Matters

Mr de Wet Olivier, who originally joined the staff of SAWTRI in 1967 as Head of Publications and Information and initially managing the affairs of the CSIR Eastern Regional Office, retired on May 31st. He is succeeded by Mr Pitout Horn who holds a B.Sc. (Hons.) degree in Physics and was a science teacher at Pearson High School in Port Elizabeth for seven years.

Mr D R Musson has joined the Department of Dyeing and Finishing as a senior researcher. He holds a B.SC. (Hons.) degree from the University of Nottingham.

Miss M Stirk has been appointed as researcher in the Textile Chemistry Department. She holds a B.Sc. (Hons.) degree from Rhodes University which she obtained in 1979 and was employed by a pharmaceutical company before joining SAWTRI.

Miss L Birk, (B.A. Math.), has joined the department of Statistics and Mmes S van Niekerk and S Ferreira are newly appointed members of the administrative staff.

SAWTRI PUBLICATIONS

Since the previous edition of the Bulletin, the following papers have been published by SAWTRI:

Technical Reports

No. 546 Thierron, W., Studies on the Dref III Spinning System, Part II, Yarn Structure and 1 x 1 Rib Fabric Properties.

No. 547 Barella, A., Manich, A.M. and Hunter, L., The Diameter and Hairiness of Singles and Two-ply Wool/Polyester and Wool/Acrylic Worsted Yarns.

No. 549 Strydom, M.A., The Effects of High Density Dumping on Worsted Processing Performance, Part II: The Performance of Scoureds in terms of Storage Time and Regain at Dumping.

Other Papers

Hunter, L., Smuts, S. and Gee, E., The Effect of Wool Fibre Properties on Woven and Knitted Fabric Properties, Second Australia-Japan Bilaterial Science and Technology Symposium on the objective Evaluation of Apparel Fabrics, Sydney, Australia (October 1983).

Hunter, L., Turpie, D.W.F. and Gee, E., The Effect of Wool Fibre Properties and Breed of Sheep on Worsted Processing Performance and on Yarn and Fabric Properties, Proc. 2nd World Congress on Sheep and Beef Cattle Breeding, Pretoria (April 1984).

Barella, A., Manich, A.M. and Hunter, L., Contribuciòn el estudio del diàmetro de los hilos de lana peinada y mohair, medido con el vellosímetro 2 digital, *Investigación e información Textil y de Tensioactivos,* **26** (4), 189 (1983).
Barella, A., Manich, A.M. and Hunter, L., Sobre la correlación existente entre los resultados del 'Shirley Hairiness Meter' y el aparato 'Digital I.T.Q.T.' en la medida de la velosidad de los hilos. *Revista de la Industria Textil* No. 217, 22 (1983).
Tworeck, W.C., Ross, W.R. and Van Rensburg, N.J.J., The use of reclaimed water in the textile industry. *Textile Industries Dyegest* **2** 11 (April 1984).

SAWTRI Information Pamphlet

No. 3: Sanderson, K.W., Cotton Fibre Strength: A Note on the Instruments and the Units of Measurement (June 1984).

THE FLEXURAL RIGIDITY OF POLYESTER/COTTON YARNS SPUN ON THE RING, ROTOR AND DREF III SYSTEMS

by W. Thierron

ABSTRACT

The flexural rigidity of polyester/cotton yarns, spun on ring, rotor and DREF III spinning systems, each at three twist levels, was compared, using the ring loop method. The DREF III yarns were found to have considerably higher flexural rigidity values than the ring and rotor yarns, the ring yarns producing the lowest values. These differences are attributed to differences in yarn structure.

INTRODUCTION

Textile fabrics are constructed by manufacturers for various end uses and the physical properties of the yarns play an important rôle in this process. For the buyer of textile fabrics and garments, however, in many cases the handle and drape, as well as the colour and design are the most important factors. Handle and drape are largely influenced by yarn flexural properties. The influence of yarn flexural rigidity on fabric rigidity has been examined experimentally and theoretically and consistent positive correlations have been found[1–8]. Grosberg[6] found that the bending resistance of a woven fabric is slightly greater than the sum of the bending resistance of the yarns. Recent work at SAWTRI[9] has established that flexural rigidity values of short staple yarns, spun on different spinning systems are highly correlated with the drape and bending length of knitted fabrics.

Yarn flexural rigidity is influenced by the yarn construction and by fibre properties. Until now research work in this field has been related mainly to ring spun yarns in which yarn flexural rigidity was a function mainly of the fibre properties[4,5,10–12], whereas yarn structure (i.e. twist, in this case) was found to play a minor rôle. During an investigation into DREF III and ring spun yarn structure and the properties of the knitted fabrics[9], the yarn structure determined by the arrangement of the fibres in the yarn body was found to have an important influence on yarn and fabric stiffness. To investigate the influence of the spinning system on yarn flexural rigidity, polyester/cotton yarns, spun on ring, rotor and DREF III spinning systems at different twist levels were examined.

TABLE I
SPINNING AND YARN PARAMETERS

Yarn Parameters				Spinning Parameters									
				Dref III			Rotor				Ring		
Yarn No.	Linear density (tex)	Blend poly-ester/cotton	Twist level	Yarn pro-duction speed (m/min)	Spin-ning drum speed (min^{-1})	Card drum speed (min^{-1})	Yarn pro-duction speed (m/min)	Rotor speed (min^{-1})	Opening roller speed (min^{-1})	Twist factor (turns/cm $\sqrt{tex}$)	Yarn pro-duction speed (m/min)	Spindle speed (min^{-1})	Twist factor (turns/cm $\sqrt{tex}$)
1	40	70/30	low	250	4 000	12 000	86,5	45 000	6 000	33,4	21,5	10 000	28,7
2	40	70/30	medium	250	5 000	12 000	72,0	45 000	6 000	38,2	20,9	11 000	33,5
3	40	70/30	high	250	6 000	12 000	64,0	45 000	6 000	45,3	19,8	12 000	38,3

EXPERIMENTAL

For the purposes of this investigation, a selection of 40 tex polyester/cotton yarns, spun on the ring, rotor and DREF III system at different twist levels was chosen (Table I). Yarn flexural rigidity was measured, using the ring loop principle introduced by Peirce[13] and modified by Hunter[14,15], the values being calculated from Owen's tables[16]. Since no significant correlation could be found between the yarn flexural rigidity and variation in linear density (mass of loop) no correction was applied for variation in linear density. The loop diameter was kept constant at 24,2 mm . The mass of the weights applied ranged from 8,5 to 73,7 mg in order to maintain d/L (d = deflection of ring loop, L = circumference of ring) between the recommended limits of 0,005 and 0,09[16]. Ten loops were tested for each yarn and the average flexural rigidity was calculated as well as the confidence limits at a significance level of 95%.

All tests were carried out at 20°C and 65% RH.

RESULTS AND DISCUSSION

The test results given in Fig. 1 are put together with the confidence limits at a 95% significance level. It can be seen that the flexural rigidity results for the DREF III yarns were the highest, being three to four times higher than the values obtained for the ring yarns. The values for the rotor yarns were about 30% higher than those for the ring spun yarns which is in line with the accepted fact that rotor yarns have a harsher handle[17]. For the ring and rotor yarns no significant influence of the twist level on flexural rigidity could be found. For the DREF III yarns the flexural rigidity decreased considerably with increasing twist level. Furthermore the variation in flexural rigidity results for the DREF III yarns was much higher than for the ring and rotor yarns.

The considerable differences in flexural rigidity for the different types of yarns can be explained by yarn structural differences. Fig. 2 shows the arrangement of the fibres in the body of the different yarn types. Ring spun yarns have a twist which is approximately constant over the cross-section and fibres on the yarn surface lie at a specific angle to the yarn axis. For this type of yarn it has been suggested[10–12], that the flexural rigidity approximates the sum of the flexural rigidities of the single fibres, the fibres having virtually complete freedom of movement, even at relatively high twist levels. In the case of the rotor yarns, the freedom of fibre movement is impaired in those places where fibres are wrapped around the yarn (i.e. wrapper fibres), and the fibres are fixed by these wrapping fibres (see Fig. 2). This explains the higher flexural rigidity for this type of yarn. With the DREF III yarn, the fibres in the core lie parallel to the yarn axis and the sheath fibres, which are highly twisted around the core, greatly reduce freedom of fibre movement in the yarn interior (see

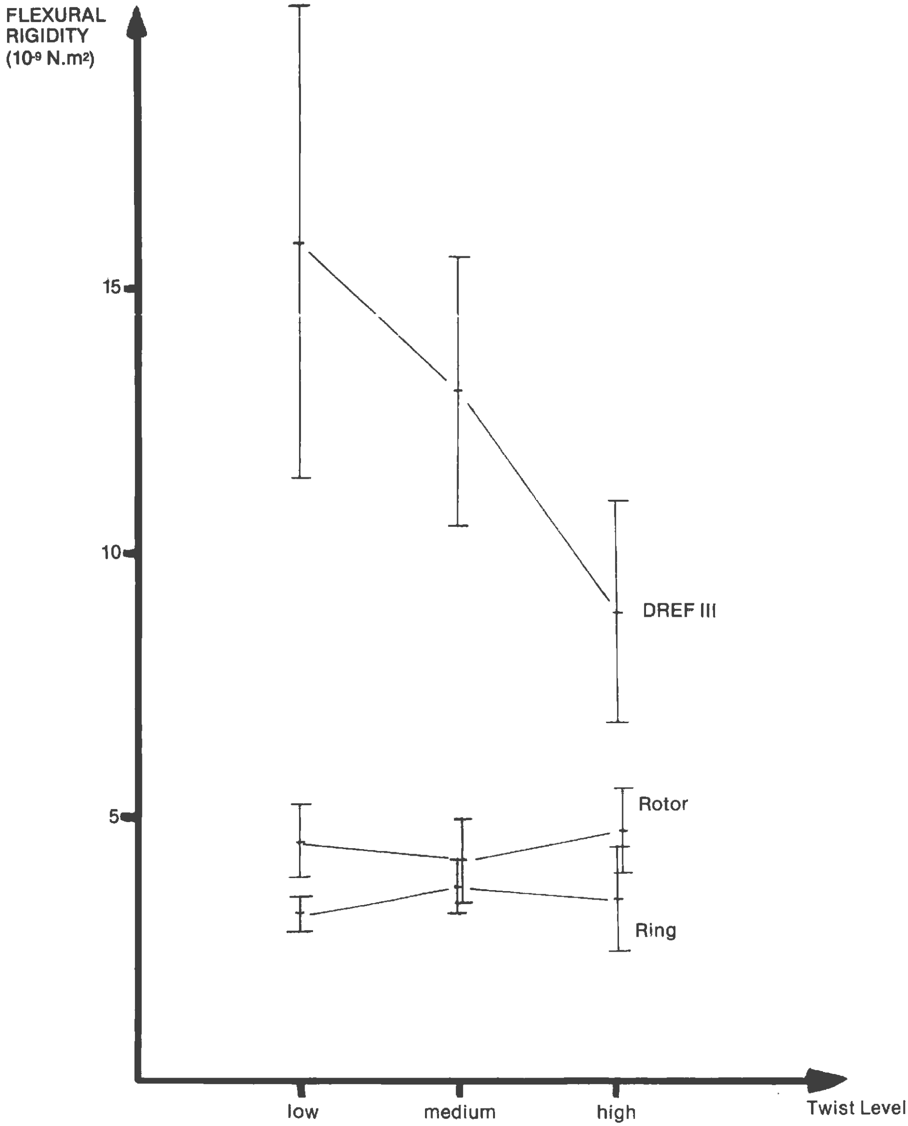


Fig. 1 — Flexural rigidity values for different yarn types.

Fig. 2). Hence the yarn flexural rigidity values are considerably higher than those for the other two yarn types. For no freedom of fibre movement the yarn flexural rigidity value can be estimated[4]. An increase in flexural rigidity by the factor N/y (N = Number of fibres in the cross-section, y = (yarn density)/(fibre density)) would occur, which means that the flexural rigidity in that case should be about 300 times larger than in the case of complete freedom of fibre movement, as assumed in the case of the ring yarns.

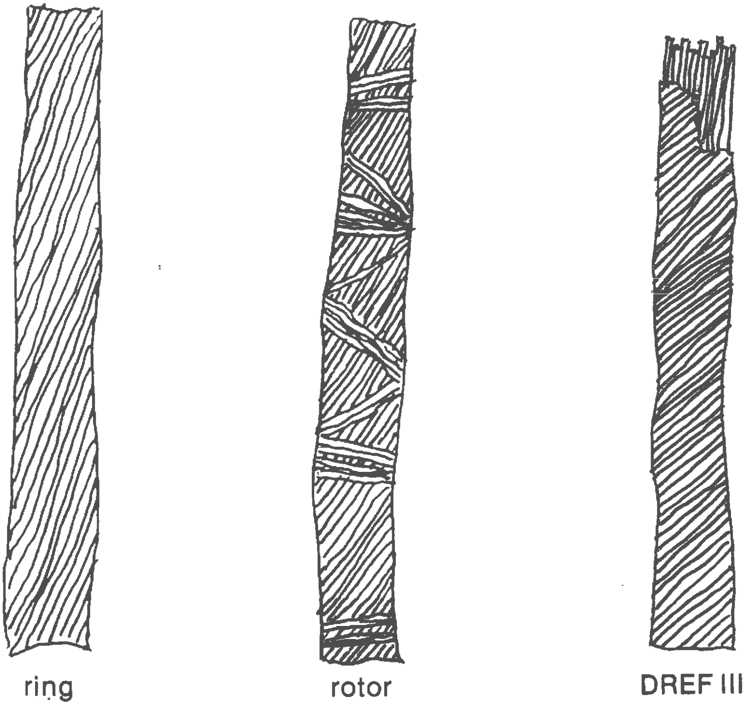


Fig. 2 — Arrangement of fibres in the different yarn types.

In the case of the ring and rotor yarns, twist had no significant influence on yarn flexural rigidity. With the DREF III yarns an increase in twist resulted in a decrease in flexural rigidity. Two phenomena play an important rôle in respect of yarn flexural rigidity. One is the degree of freedom of fibre movement being determined by the fibre to fibre friction. Fibre to fibre friction again is dependent on the friction coefficient of the single fibres and upon radial forces in the yarn. At a higher degree of twist, radial forces are also higher, causing a lower degree of freedom of fibre movement and hence theoretically a higher flexural rigidity. The second phenomenon is due to yarn mechanics. Several workers have found that due to the geometry of the fibres in the yarn, the bending rigidity is lower at a higher yarn twist for thc same degree of freedom of fibre movement[10,12]. In ring yarns, and to a certain degree also in rotor yarns, a higher twist causes a lower degree of freedom of fibre movement due to the higher radial forces in the yarn, but also reduces flexural rigidity due to the higher helix angle as mentioned above. Thus, in a yarn, two opposing mechanisms interact and most research workers have not found consistent effects of twist on flexural rigidity of ring yarns[4,15]. The same applies for the ring and rotor yarns tested in this study. In the case of the DREF III yarns, a higher twist level does not necessarily cause higher frictional forces inside the yarn due to higher radial forces, because only the degree of twist on the wrapping fibres is influenced whereas the fibres in the core (in this case 70%) are not twisted at all. A higher twist in the sheath fibres, however, may result in a lower flexural rigidity according to Backer's theory[10]. Whether the sharp decrease in flexural rigidity for the DREF III yarns can be explained by this theory only or whether other effects play an important rôle as well has to be confirmed by further studies.

SUMMARY AND CONCLUSIONS

The flexural rigidity values of a number of 40 tex polyester/cotton yarns spun on ring, rotor and DREF III systems were compared. The yarns were spun at three twist levels. Flexural rigidity values were measured using the ring loop method.

DREF III yarns had considerably higher flexural rigidity values than the ring and rotor yarns, those of the ring yarns being the lowest. This was attributed to yarn structural differences since the fibre composition was identical for the different types of yarn. With the DREF III yarns, the sheath fibres, which are twisted around the core of parallel fibres, impair a free fibre movement within the yarn. For the DREF III yarns a sharp decrease of flexural rigidity was observed at increasing twist levels. This is attributed to a higher helix angle of the fibres on the yarn surface, the radial forces in the yarn remaining constant. It appears that DREF III yarns, if spun to a bicomponent structure like this, may be more suitable for end uses where a soft and flexible yarn is not required.

USE OF PROPRIETARY NAMES

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

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SOME PRELIMINARY STUDIES ON MOHAIR LOOP AND BRUSHED LOOP YARNS

by CM Shorthouse and GA Robinson

ABSTRACT

Eight lots of mohair varying in fibre diameter from 25,4 μm to 39,9 μm were processed into loop yarns having a similar construction to that of a commercial mohair loop yarn. The yarns were brushed on a yarn brushing machine using either two, four or six wraps. Both the loop and brushed loop yarns were woven into a blanket construction having the mohair on the face of the fabric. The pile was raised after finishing.

The loop and brushed loop yarns containing the coarser mohair exhibited the lowest number of faults (malformed loops). Fault rates were reduced by increasing the severity of brushing.

Higher percentages of fibre loss were obtained as the fibre diameter increased and also as the number of wraps increased.

INTRODUCTION

Despite the price fluctuations of the fibre, the demand for mohair high fashion merchandise has grown[1]. Loop and brushed loop mohair yarns have contributed to the increased demand[2], their unique properties enabling light-weight garments to be produced which are lofty, warm and fashionable.

Published information[3–7] has shown that fibre diameter, in particular, has an important bearing on the spinning potential and physical properties of conventional spun yarns. There is very little published information about the effect of mohair fibre properties on multi-component fancy yarns, for example a loop yarn, where the mohair yarn component forms the loop, in combination with fine core and wrapper yarns, spun from fibres other than mohair.

This report deals with the effect of mohair fibre diameter on the processing performance of loop and brushed loop yarns as well as the physical properties of the yarns and also the fabrics produced from these yarns.

EXPERIMENTAL

Raw material

Eight lots of S.A. continental-combed mohair tops were selected for this study (see Table 1).

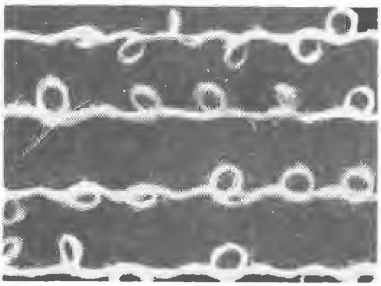
TABLE 1
FIBRE PHYSICAL PROPERTIES

Lot No.	Mean Fibre Diameter (μm)	Mean Fibre Length (mm)
1	25,4	85
2	25,9	69
3	28,7	84
4	29,2	82
5	31,4	82
6	32,3	105
7	36,7	100
8	39,9	84

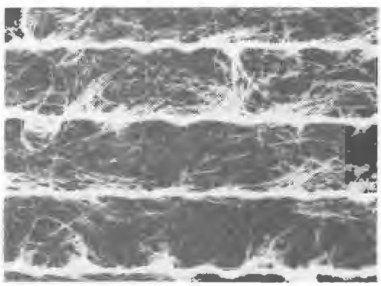
Yarn processing

The eight lots of mohair were each processed to obtain a yarn construction similar to a commercial loop yarn. The mohair was spun into 120 tex Z200 yarn. A 60/40 wool/nylon 40 tex Z400 yarn was used as the ground and wrapper components.

The loop yarns were produced on an Allma fancy twister operating at a spindle speed of 1 600 rev/min as follows:



Loop yarn



Brushed loop yarn

Fig. 1.

TABLE 2
PHYSICAL PROPERTIES OF MOHAIR LOOP AND BRUSHED LOOP YARNS

Yarn	Lot No.	No. of wraps on brushing machine	Resultant Yarn linear density (tex)	Breaking Strength (N)	CV (%)	Extension (%)	CV (%)	Tenacity (cN/tex)
Loop	1	0	445	17,6	11	36,6	11	4,0
	2	0	420	18,3	8	27,8	9	4,4
	3	0	430	17,7	10	27,5	10	4,1
	4	0	410	17,5	10	26,8	12	4,3
	5	0	420	17,3	13	27,2	14	4,1
	6	0	440	16,4	11	26,0	11	3,7
	7	0	420	16,1	11	26,3	13	3,8
	8	0	450	17,0	10	26,2	12	3,8
Brushed loop		2	440	18,6	10	26,7	11	4,2
	1	4	430	17,2	10	25,5	12	4,0
		6	420	16,8	8	24,9	7	4,0
		2	420	18,1	9	27,3	8	4,3
	2	4	420	17,8	8	26,2	8	4,2
		6	420	17,1	8	25,6	10	4,1
		2	420	18,0	8	26,8	9	4,3
	3	4	430	16,2	9	24,7	9	3,8
		6	420	16,5	9	24,3	10	3,9
		2	390	17,8	7	26,2	9	4,6
	4	4	400	17,3	6	25,9	6	4,3
		6	410	16,0	13	23,8	13	3,9
		2	420	18,4	9	27,4	9	4,4
	5	4	420	17,5	9	26,2	7	4,2
		6	410	17,2	10	25,3	10	4,2
		2	430	16,8	9	25,0	10	3,9
	6	4	410	17,0	10	25,3	12	4,1
		6	440	16,9	7	24,6	8	3,8
		2	420	16,7	11	24,7	11	3,9
	7	4	430	16,3	10	24,2	12	3,8
		6	410	15,3	12	23,6	13	3,7
		2	420	15,7	7	22,3	12	3,7
	8	4	440	15,5	10	25,3	11	3,5
		6	430	15,4	10	21,9	9	3,6

First operation: Each of the 100% mohair yarns was combined with two of the wool/nylon (ground) yarns using a feed ratio of 2,37:1 and folded with S450 turns/m .

Second operation: The resultant unstable loop yarn from the first operation was then combined with a third wool/nylon yarn as wrapper using a folding twist of Z150 turns/m . Yarn details are given in Table 2.

Yarn brushing

Each of the eight lots of loop yarn was divided into three sub lots and brushed on a GuMa GAR yarn brushing machine using either two, four or six wraps respectively on the wire cylinder. The yarn delivery speed was 6,6 m/min . All 24 lots were weighed before and after brushing. The percentage fibre loss is given in Table 3. Photographs of mohair loop and brushed loop yarns are shown in Fig. 1.

TABLE 3
FIBRE LOSS AFTER BRUSHING

Lot No.	Fibre loss after brushing (%)		
	No. of Wraps on Brushing Machine		
	2	4	6
1	0,32	0,74	1,11
2	0,48	0,76	1,12
3	0,51	0,58	1,42
4	0,69	1,30	1,89
5	0,54	0,91	1,72
6	0,31	0,86	1,24
7	1,47	3,21	2,57
8	1,01	1,69	3,62

Weaving

A R26tex/2 warp yarn was produced from a polyester/cotton 50/50 blend. The weft yarns used were R26tex/2 polyester/cotton 50/50 blend and the different lots of loop as well as brushed loop mohair yarns in the ratio of 4:1 with a total of 25,2 picks/cm . These yarns were subsequently woven on a

Saurer 190 cm 100 WT loom. The fabric was constructed having a plain weave polyester/cotton back with a mohair pile face[7].

Raising

After finishing, all the fabric lots were raised in one continuous length on a Tomlinson Auto Zero machine.

Physical tests

The eight lots of loop yarns and 24 lots of brushed loop yarns were tested for yarn linear density, breaking strength and extension. The results are given in Table 2.

The number of faults (malformed loops) in the loop yarns was counted over a constant length of yarn. The brushed loop yarn faults were assessed as partly brushed loops. The results are given in Table 4.

TABLE 4
LOOP AND BRUSHED LOOP YARN FAULTS

Lot No.	Faults per unit length			
	Loop Yarn	Brushed loop yarn		
		No. of wraps		
		2	4	6
1	289	242	160	59
2	280	253	123	58
3	165	197	118	103
4	125	119	44	47
5	127	176	46	38
6	100	154	63	28
7	58	101	15	18
8	58	78	44	12

The finished fabrics were tested for mass, thickness, pile mass and fibre shedding. The results are given in Table 5. Fabric thickness was measured under a pressure of lgf/cm^2 using a Shirley thickness gauge. Fibre shedding was measured on the Atlas Random Tumble pill tester, the mass loss after 15 mins being expressed as a percentage, a modified version of ASTM method D1375-59T being used. The samples were cut parallel to the length and width

TABLE 5
FABRIC PHYSICAL PROPERTIES

Weft yarn	Lot No.	Fabric mass (g/m²)	Fabric thickness (mm)	Pile mass g/m²	Pile mass (%)	Fibre loss (%)
Loop	1	377	3,82	72,4	19,1	3,9
	2	369	3,92	65,5	18,0	3,9
	3	368	3,81	76,3	21,1	3,6
	4	364	3,72	81,8	22,7	3,9
	5	366	3,81	74,6	20,6	5,8
	6	355	3,76	84,0	23,8	4,1
	7	359	3,69	81,8	23,2	4,1
	8	364	3,65	79,4	22,0	3,4

Weft yarn	Lot No.	Fabric mass (g/m²): No. of wraps			Fabric thickness (mm): No. of wraps			Pile mass g/m²: No. of wraps			Pile mass (%): No. of wraps			Fibre loss (%): No. of wraps		
		2	4	6	2	4	6	2	4	6	2	4	6	2	4	6
Brushed loop	1	375	363	352	3,65	3,65	3,60	54,4	57,6	59,7	14,7	16,0	17,3	3,6	3,2	4,5
	2	366	363	361	3,64	3,56	3,48	69,6	59,6	65,2	19,1	16,5	18,3	3,8	3,6	3,9
	3	367	357	365	3,47	3,42	3,34	66,6	78,2	62,4	17,8	21,9	17,2	4,5	4,1	4,0
	4	348	351	352	3,42	3,27	3,28	60,1	51,7	61,3	17,5	15,0	17,6	3,9	3,7	4,0
	5	369	371	357	3,54	3,54	3,37	63,4	65,0	62,5	17,2	17,8	17,8	3,8	3,2	4,0
	6	359	357	352	3,58	3,28	3,13	58,2	45,4	51,7	16,5	12,8	14,8	2,9	3,1	3,1
	7	363	341	345	3,28	2,96	2,93	52,2	43,4	50,1	14,5	13,0	14,7	3,3	10,0	3,8
	8	352	351	345	3,18	3,24	3,07	55,2	56,6	54,2	15,8	16,3	15,5	3,6	3,6	4,2

directions, the edges being overlocked rather than sealed with an adhesive and were tumbled without the addition of lint. To determine pile mass, fabric samples (5cm x 5cm) were conditioned and weighed. The pile was then shorn from each sample with a safety razor taking care not to damage the ground fabric and the shorn pile conditioned and weighed. The results were expressed as the pile mass per unit area (g/m^2) and also as a percentage of the total fabric mass.

RESULTS AND DISCUSSION

Yarn Physical Properties

There were no major differences in yarn physical properties between the eight loop yarns tested, although those yarns containing mohair having fibre diameters coarser than 32 μm had slightly lower tenacities. The tenacities of the brushed loop yarns tended to decrease slightly with increasing severity of brushing (2, 4 or 6 wraps).

Fibre Loss

Table 3 shows the percentage fibre loss after brushing each lot using two, four or six wraps on the machine. These results show that as the severity of brushing and fibre diameter increased there was a progressive increase in the percentage fibre loss.

Yarn Faults

From Table 4 it can be seen that the number of faults in the loop yarns was higher for the yarn produced from 25,4 μm mohair and decreased rapidly as the fibre diameter increased. For the brushed loop yarns, there was a significant drop in the number of yarn faults as the severity of brushing increased. The number of faults also decreased as the fibre diameter increased.

Physical Properties of the Fabric

The fabric physical properties are given in Table 5. As expected the mass per unit area of fabrics containing brushed loop yarns tended to be lower on average than the corresponding fabrics woven using loop yarns. The latter fabrics were also thicker than the equivalent fabrics containing yarns which had been brushed. The pile mass of fabrics woven using loop yarns was greater than the equivalent fabrics woven using brushed loop yarns, particularly those which had been subjected to six wraps on the brushing machine. The pile mass of the fabrics was greater using loop yarns containing the coarser fibre diameters of mohair. This was not the case with the brushed loop yarn fabrics and can only be attributed to the higher fibre losses sustained by the yarns containing the coarser mohair fibre diameters when brushed.

SUMMARY AND CONCLUSIONS

Eight lots of S.A. continental-combed mohair tops having fibre diameters ranging from 25,4 μm to 39,9 μm were processed into loop yarns to a construction similar to that of a commercial loop yarn. The yarns were then brushed using 2, 4 or 6 wraps on a yarn brushing machine.

Both the loop and the brushed loop yarns were woven as weft with R26tex/2 cotton/polyester 50/50 blend yarns in both the warp and weft, the construction producing a plain weave fabric with a polyester/cotton back and with all the loop or brushed loop mohair yarn on the face of the fabric. The fabrics were raised after finishing.

It was found that as the fibre diameter increased, there was a decrease in the number of faults in the loop yarns. The number of faults in the brushed loop yarns decreased as the number of wraps on the brushing machine increased, particularly when using mohair having a mean fibre diameter of 35 μm and coarser.

Fibre loss increased with both an increase in the fibre diameter and the number of wraps on the yarn brushing machine. There were no major differences in the yarn physical properties of the loop and brushed loop yarns.

Fabrics woven using loop yarns had a greater mass per unit area and pile mass and were also thicker than the equivalent fabrics woven using brushed loop yarns, particularly those subjected to six wraps on the brushing machine. The use of coarser mohair in the loop yarns also increased the pile mass of the fabrics.

Based on these results, it would be appropriate to select the coarser grades of mohair to reduce the number of faults when processing loop yarns. The severity of yarn brushing is also a factor which can influence the fault rates of mohair brushed loop yarns.

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THE USE OF PROPRIETARY NAMES

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

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EFFECT OF YARN TO YARN FRICTION ON SEAM SLIPPAGE OF SOME COMMERCIAL LINING FABRICS

by S Galuszynski and GA Robinson

ABSTRACT

The effect of the coefficient of yarn to yarn friction on seam slippage in lining fabrics was investigated. It was found that the amount of seam slippage decreased with an increase in value of the coefficient. The amount of change in seam slippage, due to change in value of the coefficient was much greater in the region of low values of the coefficient. Variation in value of the coefficient of a chosen fabric was obtained through application of various treatments to the fabric.

INTRODUCTION

When a seam (the joining of two or more fabrics by means of one or more rows of stitches) is under some transverse strain, some displacement (called 'seam slippage') of the stitch relative to one or more of the fabrics may occur. The seam slippage, S, produces some displacement of one yarn system against the other (warp against the weft or weft against the warp) causing some opening in the fabric. This negative feature depends upon many factors.

Experimental investigations[1–3] have shown that the amount of seam slippage mainly depends on: weave, fabric raw material, type of seam and stitch density. A theoretical consideration[4] of the mechanism of seam slippage indicated that the amount of slippage also depends on such factors as yarn to yarn friction, yarn flexural rigidity, needle size, etc. In practice, some of the fabrics with low resistance to seam slippage are treated with anti-slip agents[5] in order to improve their resistance to seam slippage. An example of such an agent is a silicone elastomer[6]. This report deals with the effect of yarn to yarn coefficient of friction, μ, on seam slippage.

EXPERIMENTAL

An experiment was carried out on commercial lining fabrics, the specifications of which are shown in Table 1. Variations in the coefficient of yarn to yarn friction were obtained through application of different treatments (without sealing the fabric) to the fabric samples. Four different treatments

TABLE 1
FABRIC DETAILS

Fabric	Weave	Warp			Weft		
		Yarn linear density (dtex)	**Crimp (%)**	**Sett (thread/ 10cm)**	**Yarn linear density (dtex)**	**Crimp (%)**	**Sett (thread/ 10cm)**
1	Plain	85 (flat polyester)	4,5	433	85 (textured polyester)	2,2	244
2	Plain	85 (flat polyester)	5,3	400	167 (textured polyester)	3,0	200
3	2/1 Twill	133 (viscose)	5,3	512	167 (viscose)	4,8	252

TABLE 2
SEAM SLIPPAGE DETAILS

Fabric Code	Coefficient of friction		Seam slippage (mm) (warp direction)					Seam slippage (mm) (weft direction)				
			78N		2,5N			78N		2,5N		
	Warp over Weft	Weft over Warp	Imm.*	After 2 min.	Imm.	After 2 min.	Average	Imm.	After 2 min.	Imm.	After 2 min.	Average
1,0	0,171	0,193	3,0	3,5	3,0	3,0	3,14	Seam	failure	Seam	failure	
1,1	0,158	0,231	4,0	4,0	3,0	3,0	3,50	16,8	17,3	16,5	16,5	16,77
1,2	0,103	0,124	7,0	7,0	6,0	6,0	6,50	Seam	failure	Seam	failure	
1,3	0,161	0,164	3,8	3,8	3,0	3,0	3,40	21,0	22,0	20,0	20,0	20,75
1,4	0,164	0,254	3,0	3,0	3,0	3,0	3,00	14,0	14,0	12,0	12,0	13,00
2,0	0,151	0,222	3,5	3,5	3,3	3,0	3,32	12,3	12,3	11,3	11,3	11,80
2,1	0,124	0,218	4,0	4,0	4,0	4,0	4,00	14,0	14,7	14,3	14,3	14,32
2,2	0,093	0,121	8,3	8,3	8,3	7,8	8,20	37,8	39,3	38,0	37,0	37,27
2,3	0,117	0,200	4,0	4,0	4,0	3,8	3,95	17,0	17,0	16,0	16,0	16,50
2,4	0,148	0,212	3,3	3,3	3,0	3,0	3,15	12,3	12,3	11,0	11,0	11,65
3,0	0,200	0,310	1,8	2,8	2,8	2,8	2,80	6,3	7,3	6,5	6,5	6,65
3,1	0,240	0,260	2,8	3,0	2,8	2,8	2,85	6,3	10,8	10,3	10,0	9,35
3,2	0,124	0,117	4,0	4,0	3,5	3,5	3,75	20,0	23,0	22,0	22,0	21,75
3,3	0,184	0,187	3,0	3,0	2,8	2,8	2,90	10,0	11,0	10,5	10,3	10,45
3,4	0,161	0,18	3,0	3,5	3,0	3,0	3,12	11,0	14,5	14,0	13,5	13,25

*Imm. = Immediate reading

were used and they are denoted in Table 2 by the second figures in the fabric figure code.

The treatments were as follows:

0. No treatment
1. Acrylic co-polymer
2. Silicone elastomer
3. Polyethylene emulsion
4. Dimethylol dihydroxyethylene-urea derivative

The value of the coefficient of yarn to yarn friction was obtained by measuring the values of frictional forces and then applying the capstan equation. The forces were measured on an Instron tester by means of a special device[7] which allowed the simulation of the yarn assembly as in a woven fabric. During measurements the speed, tension and contact angle were kept constant for all investigated yarns. The values of these parameters were: speed — 50 cm/min, tension — 490 mN and contact angle — 60°. The results are shown in Table 2.

Samples were sewn with mercerised cotton thread No. 60 (R30 tex) on an industrial sewing machine with a speed of 1 500 stitches per minute, 5,5 stitches per cm using needle blade diameter 0,75 mm .

The amount of seam slippage was measured by applying the method described by BS 3320: 1970, "Determination of seam slippage of woven fabrics".

RESULTS AND DISCUSSION

The various treatments applied to the fabric samples altered the values of the coefficient of yarn to yarn friction as shown in Table 2. The lowest value of the coefficient was obtained from treatment No.2, whereas the fabrics without any treatment, on average, had the highest coefficient. The two polyester fabrics followed the same trend in change of value of the coefficient in terms of treatment.

According to the theoretical analysis of the mechanism of seam slippage[4], the amount of slippage should decrease with an increase in value of the coefficient of yarn to yarn friction. Such a trend was obtained here as shown in Fig. 1 for average values of seam slippage. The greater the value of the coefficient, the smaller the amount of seam slippage. This trend was shown by both warp and weft yarn systems, although the amount of seam slippage in the weft direction (displacement of warp threads) was much greater than that for the warp direction (displacement of weft threads). This is not surprising when the difference in the yarn linear density and sett between warp and weft is taken into account. The warp system having higher values of sett and crimp compared with the weft, produces greater values in both frictional and yarn flexural rigidity components of fabric resistance to seam slippage. The former

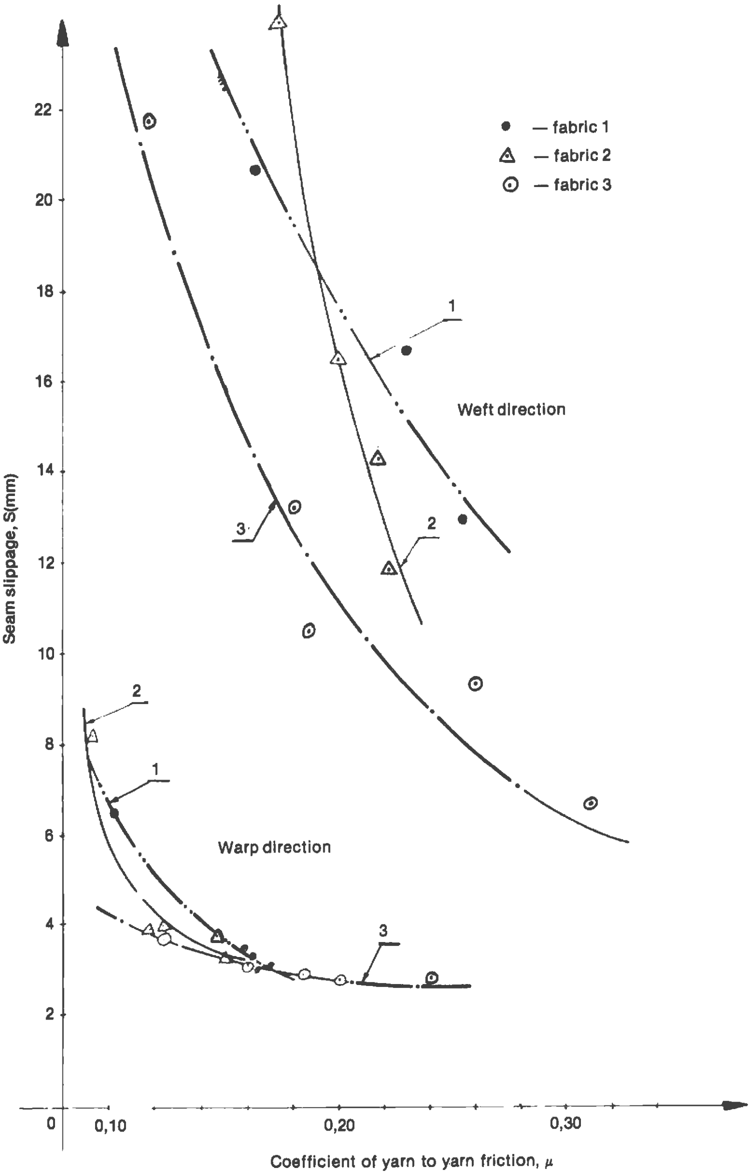

Fig. 1 — Effect of the coefficient of yarn to yarn friction on seam slippage (average values).

(frictional component) is produced by yarn to yarn friction, whereas the latter comes from bending of the yarn.

The amount of change in the value of seam slippage due to change in value of the coefficient of yarn to yarn friction, μ, varied with the region of values of μ. The results obtained showed that at low values of μ (0,1 — 0,22) a small change in μ gave a larger change in seam slippage (Fig. 1), whereas a smaller change was observed in the region where μ was greater than 0,22.
The results indicate that:

— the coefficient of yarn to yarn friction is one of the factors which determines the amount of seam slippage;
— seam failure due to slippage can be reduced by treatment of the fabric, as a whole, or simply at the seam, in order to give an increase in the coefficient of yarn to yarn friction;
— the effect of change in value of the coefficient of friction on the amount of change in seam slippage depends on the region of value of the coefficient. It is greater in the region of low values of the coefficient.

SUMMARY AND CONCLUSIONS

The effect of the coefficient of yarn to yarn friction on seam slippage in commercial lining fabrics has been investigated. Variation in the value of the coefficient of yarn to yarn friction was obtained by applying different treatments to the fabric. The results obtained indicate that:

— the amount of seam slippage increased with the decrease of value of the coefficient of yarn to yarn friction;
— the effect of change in value of the coefficient on the amount of seam slippage was greater in the lower region of values of the coefficient and in fabrics with low resistance to seam slippage;
— the amount of slippage in the weft direction was much greater than that in the warp direction.

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THE USE OF PROPRIETARY NAMES

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TYPICAL TENSILE AND CRIMP PROPERTIES OF SOME STAPLE SYNTHETIC FIBRES

by L Hunter, S. Smuts and Williena Leeuwner

ABSTRACT

The tensile, crimp and bulk resistance to compression of 72 different lots of staple synthetic fibres, mainly polyester but also including nylon, acrylic and a few polypropylene fibre lots, were measured. From the data a table of "average" or "typical" values was prepared for the various fibre types and properties.

INTRODUCTION

The dimensions and physical properties of textile fibres are widely tested for both quality control and research purposes, since these fibre characteristics largely determine the performance of the fibre during textile processing and in the yarn and end product[1—7]. The values so obtained are compared with either similar values obtained on a "control" sample or with "experience" values, "average" (or typical) values, "standard" values or "specifications", where these are available. Often, in industry, tests are conducted in the quality control laboratory mainly to ensure consistency of delivery or to compare the product of one manufacturer with those of others. In such cases, internal "standards" or "control" values are generally available and adequate. Sometimes, however, it is important to have available independent values to use as a basis of reference, for example, when disputes arise.

Backe[8] published some useful information on the type of variations which can be expected for various synthetic fibres produced in the United States. Although synthetic fibre manufacturers provide some basic information about the properties of their fibres, and information of a general nature is also available[3,7,9—27], very little up to date independent information of a specific nature, is available, particularly for synthetic fibres available in South Africa. It was therefore decided to measure the physical properties of a range of synthetic fibres, predominantly polyester, to establish "average" or "typical" reference values.

EXPERIMENTAL

Fibres were obtained from various synthetic fibre manufacturers and altogether 45 polyester (7 high tenacity, 27 medium tenacity and 11 low tenacity), 12 nylon, 12 acrylic and 3 polypropylene staple fibre samples were tested[28]. All the samples were undyed and most were in staple (i.e. unprocessed) form, the others being in top form.

The following tests were carried out on the samples, all tests being carried out under standard atmospheric conditions (20 ± 2°C and 65 ± 2% RH).

Diameter

Fibre diameter was measured on a projection microscope, two operators each reading at least 50 fibre snippets on each of three slides (i.e. a total of at least 300 readings per sample).

Fineness

Fibre linear density was measured on a vibroscope (Zweigle Vibroskop S151/2) according to a method similar to ASTM D1577—79, using the **maximum** tension at which a reading could be obtained. This ensured the smallest error in the measurement of the fibre linear density due to any crimp remaining in the fibre.

Staple Crimp

Thirty staples were selected at random from each sample and the crimp frequency determined over 25 mm of the unrestrained (relaxed) staples, by each of three operators using a counting glass.

Single Fibre Crimp Frequency

The crimp frequency (%) was determined on single fibres according to the ASTM-D3937-80 method, the crimp frequency being the number of crimp units divided by the extended length. The number of crimp units in the full fibre length was measured on ten fibres, in a slightly stretched state, each of the fibres being drawn from a different staple.

Percentage Crimped Length

Another measure of fibre crimp, termed crimped length (%), was obtained by measuring the unstretched length of ten staples and then the straightened length of two fibres from each staple. The percentage crimped length was calculated as follows:

$$\text{Crimped Length}(\%) = 100 \times \frac{(\text{Straightened Fibre Length} - \text{Staple Length})}{\text{Straightened Fibre Length}}$$

Single Fibre Crimp and Tensile Properties

The single fibre crimp and tensile properties were measured, as described before[28], using an Instron Tensile Tester, on single fibres, 20 fibres being tested from each sample. Because these tests are time consuming, only a selected number of samples were tested. Briefly, the method consisted of mounting the fibres between plug type jaws, under a pre-tension of 0,03 cN/tex, so that the

uncrimped fibre length between the jaws would be approximately 20 mm . The rate of extension was 20 mm/min .

The properties measured included breaking strength (in cN), extension at break (in %), initial (pre-yield) modulus (cN/tex), crimp (in %) and uncrimping energy (arbitrary units) at both one fifth and one tenth of the uncrimping force (it being **assumed** that at the uncrimping force the fibre is fully straightened).

Bundle Tensile Tests

The bundle tensile tests were carried out on a Stelometer at 3,2 mm (1/8″) gauge according to IWTO test method 32-1982, leather linings being used. Bundle tenacity was also determined on the Stelometer at zero-gauge.

Bulk Resistance to Compression

The bulk resistance to compression of a randomised 2,5 g fibre sample was measured on a SAWTRI Compressibility Tester as described previously[28].

RESULTS AND DISCUSSION

Because of the large number of results involved, the results obtained on the individual fibre lots have been omitted. Table 1 contains the average or typical values for the various fibre properties and the associated CV values. The values in Table 1 generally agree with those values which are available for fibres of the same generic types and provide a useful basis of reference when synthetic fibres corresponding to the types covered here, particularly polyester, are being tested and evaluated. The results illustrate the higher tenacity and modulus but lower extension at break values of the high tenacity polyester. It can also be seen that the nylon fibres tested were coarse and were probably mostly carpet type fibres.

Table 2 presents the correlation matrix for the various polyester fibre properties and illustrates the interdependence of certain of the fibre properties.

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TABLE 1
AVERAGE FIBRE PROPERTIES

Fibre Properties	Polyester High Tenacity	Polyester Medium Tenacity	Polyester Low Tenacity	Polyester Overall	Nylon	Acrylic	Polypropylene
No. of Samples	7	27	11	45	12	12	3
Fibre Fineness							
Linear Density:							
Mean (dtex)	2,4	4,7	4,6	4,3	10,9	4,3	8,9
(CV %)	78	96	52	89	49	69	70
Fibre Diameter:							
Mean (μm)	13,7	18,8	20,7	18,5	34,4	26,1	32,8
(CV %)	35	42	34	41	28	23	33
Single Fibre Tensile and Crimp Properties							
Breaking Strength:							
Mean (cN)	12,6	19,0	13,3	16,4	35,9	10,1*	21,2
(CV %)	80	75	48	74	47	50	16
Tenacity:							
Mean (cN/tex)	53	43	30	42	37	23*	28
(CV %)	8	10	17	22	21	8	10
Extension:							
Mean (%)	19	28	25	26	58	34*	51
(CV %)	21	32	41	36	28	20	22
Initial Pre-yield Modulus:							
Mean (cN/tex)	377	341	313	340	101	436*	187
(CV %)	16	17	28	20	54	0	9
Uncrimping Force:							
Mean (cN)	0,28	0,52	0,39	0,44	0,46	0,38*	0,49
(CV %)	62	95	60	91	50	42	33
Uncrimping Stress:							
Mean (cN/tex)	1,25	1,00	0,85	1,00	0,46	0,88*	0,63
(CV %)	22	10	17	20	22	2	8
Crimp at 0,2 x Uncrimping Force:							
Mean (%)	1,9	2,5	2,3	2,3	3,9	1,3*	2,7
(CV %)	34	27	42	33	37	3	26
Crimp at 0,1 x Uncrimping Force:							
Mean (%)	3,8	5,0	4,4	4,7	6,8	2,7*	4,9
(CV %)	34	26	46	34	38	2	28
Uncrimping Energy at 0,2 x Uncrimping Force:							
Mean	0,024	0,025	0,019	0,023	0,018	0,012*	0,017
(CV %)	28	31	43	34	39	4	33
Uncrimping Energy at 0,1 x Uncrimping Force:							
Mean	0,046	0,050	0,037	0,046	0,031	0,023*	0,032
(CV %)	27	29	44	34	40	3	35
Toughness:							
Mean (cN/tex)**	5,0	6,1	3,5	5,2	10,4	3,9*	7,2
(CV %)	22	30	29	36	21	28	12
Resistance to Compression:							
Mean (mm)	24	24	19	23	14	23	24
(CV %)	11	15	24	19	10	12	17
Staple Crimp:							
Mean (cm^{-1})	6,3	5,4	5,1	5,5	5,5	5,2	4,4
(CV %)	12	18	22	19	14	22	4
Staple Crimp x Fineness:							
Mean (cm^{-1} x dtex)	14	22	26	22	65	21	48
(CV %)	63	67	46	65	32	51	56
Crimp Frequency Percentage:							
Mean	41	42	40	41	47	46	52
(CV %)	17	25	17	25	17	25	52
Crimp*** $\left(\frac{FL - SL}{FL}\right) \times 100$:							
Mean (%)	39	34	35	35	28	23	26
(CV %)	8	17	15	16	21	26	31
Bundle Tensile Properties:							
O-Gauge Tenacity:							
Mean (cN/tex)	39	35	29	35	31	25	30
(CV %)	11	12	14	16	20	6	27
1/8″-Gauge Tenacity:							
Mean (cN/tex)	33	31	25	30	24	20	31
(CV %)	9	10	14	14	25	11	10
1/8″-Gauge Extension:							
Mean (%)	28	32	30	31	33	27	29
(CV %)	11	12	9	12	18	13	32

* Two samples tested ** Toughness $= \frac{\text{Tenacity x Extension (\%)}}{2 \times 100}$

*** FL and SL are the straightened fibre length and staple length, respectively

TABLE 2: CORRELATION COEFFICIENTS (r) FOR THE VARIOUS FIBRE PROPERTIES

	X_1	X_2	X_3	X_4*	X_5**	X_6**	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}*	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}
X_1	1,000	0,993	-0,592	-0,800	-0,503	-0,251	0,968	-0,350	0,711	0,668	0,464	0,449	0,971	-0,951	-0,843	0,515	-0,769	-0,502	0,666	0,356	-0,214	0,573	0,424
X_2		1,000	-0,591	-0,801	-0,520	-0,231	0,973	-0,357	0,717	0,677	0,466	0,453	0,979	-0,961	-0,839	0,509	-0,768	-0,469	0,687	0,390	-0,176	-0,548	0,451
X_3			1,000	0,324	0,092	-0,063	-0,583	0,176	-0,673	-0,569	-0,529	-0,439	-0,671	0,538	0,445	-0,391	0,723	0,267	-0,658	-0,462	0,217	0,356	-0,643
X_4*				1,000	0,653	0,260	-0,759	0,454	-0,495	-0,510	-0,256	-0,296	-0,663	0,867	0,916	-0,269	0,638	0,653	-0,634	-0,342	0,176	0,517	-0,292
X_5**					1,000	0,149	-0,518	0,183	-0,163	-0,149	-0,029	-0,029	-0,415	0,553	0,534	-0,133	0,334	0,206	-0,387	-0,279	-0,002	0,191	-0,050
X_6**						1,000	-0,175	0,259	-0,067	-0,080	0,132	0,111	-0,196	0,279	0,339	0,073	0,492	0,184	-0,382	-0,289	0,172	0,254	-0,199
X_7							1,000	-0,134	0,760	0,722	0,609	0,591	0,970	-0,898	-0,744	0,613	-0,751	-0,363	0,693	0,448	-0,070	-0,445	0,427
X_8								1,000	-0,003	0,014	0,468	0,452	-0,349	0,496	0,594	0,296	0,262	0,552	-0,143	0,140	0,465	0,552	-0,214
X_9									1,000	0,985	0,881	0,880	0,883	-0,535	-0,298	0,846	-0,713	0,007	0,759	0,686	0,066	-0,157	0,646
X_{10}										1,000	0,873	0,897	0,870	-0,484	-0,237	0,863	-0,667	0,054	0,740	0,692	0,100	-0,090	0,612
X_{11}											1,000	0,988	0,717	-0,240	0,015	0,886	-0,512	0,265	0,605	0,673	0,275	0,121	0,480
X_{12}												1,000	0,741	-0,219	0,045	0,905	-0,486	0,295	0,600	0,683	0,300	0,156	0,451
X_{13}*													1,000	-0,942	-0,858	0,837	-0,832	-0,487	0,760	0,567	-0,176	-0,626	0,505
X_{14}														1,000	0,951	-0,252	0,687	0,614	-0,578	-0,222	0,281	0,650	-0,388
X_{15}															1,000	0,027	0,554	0,755	-0,398	0,008	0,414	0,734	-0,263
X_{16}																1,000	-0,547	0,271	0,605	0,676	0,264	0,105	0,368
X_{17}																	1,000	0,299	-0,863	-0,631	0,188	0,409	-0,595
X_{18}																		1,000	-0,052	0,439	0,723	0,837	-0,092
X_{19}																			1,000	0,874	-0,055	-0,164	0,573
X_{20}																				1,000	0,301	0,259	0,471
X_{21}																					1,000	0,708	-0,122
X_{22}																						1,000	-0,133
X_{23}																							1,000

n = 36
* n = 31
** n = 38

X_1 = Fibre Diameter (μm)
X_2 = Linear Density (dtex)
X_3 = Initial Pre-yield Modulus (cN/tex)
X_4 = Staple Crimp (cm^{-1})
X_5 = Crimp Frequency Percentage
X_6 = Crimped Length (%)
X_7 = Uncrimping Force (cN)
X_8 = Uncrimping Stress (cN/tex)
X_9 = Crimp at 0,2 x Uncrimping Force (%)
X_{10} = Crimp at 0,1 x Uncrimping Force (%)
X_{11} = Uncrimping Energy at 0,2 x Uncrimping Force (arbitrary units)
X_{12} = Uncrimping Energy at 0,1 x Uncrimping Force (arbitrary units)
X_{13} = Crimp (cm^{-1}) x dtex
X_{14} = Bulk/Linear density Ratio (mm/dtex)
X_{15} = Bulk/diameter Ratio (mm/μm)
X_{16} = Resistance to Compression (mm)
X_{17} = Overall Pre-yield Modulus (cN/tex)
X_{18} = Tenacity (cN/tex)
X_{19} = Extension at Break (%)
X_{20} = Toughness (cN/tex)
X_{21} = Bundle Tenacity — O-Gauge (cN/tex)
X_{22} = Bundle Tenacity — ⅛"-Gauge (cN/tex)
X_{23} = Bundle Extension — ⅛"-Gauge (%)

r = 0,33 for 95% significance
r = 0,42 for 99% significance

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