SAWTRI TECHNICAL REPORT

NO 192

Some Tensile Properties of Worsted Yarns from Wool Blended with Either Polyamide, Polyester or Acrylic Fibres

by

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P. O. BOX 1124
PORT ELIZABETH
REPUBLIC OF SOUTH AFRICA

ISBN 0 7988 0238 3

SOME TENSILE PROPERTIES OF WORSTED YARNS FROM WOOL BLENDED WITH EITHER POLYAMIDE, POLYESTER OR ACRYLIC FIBRES

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ABSTRACT

Some mechanical properties of wool, wool/polyamide, wool/polyester and wool/acrylic intimately blended yarns were investigated. The addition of 25% acrylic fibre or more, reduced the elongation at break significantly but showed the normal increase in tenacity when compared with pure wool yarns. The amount of twist for maximum yarn strength was found to be lower for wool/polyester and wool/acrylic blended yarns than it was for wool/polyamide blended yarns. Wool/polyester and wool/acrylic fibre blends showed inferior elastic recovery properties from elongations of 4%, 8% and 12% when compared with pure wool and wool/polyamide yarns.

KEY WORDS

Yarns – intimate blends – wool – polyamide – polyester – acrylic – yarn strength – elongation – elastic recovery – twist.

INTRODUCTION

Blending of wool with synthetic fibres has been practised for a long time, and during the last few years it has become of increasing importance. One of the many purposes of blending is to produce yarns with characteristics that cannot be obtained by using one type of fibre alone.

The properties of blended yarns, however, cannot be explained merely in terms of the proportions of the different constituent fibres in the blend. The prediction of yarn properties from a knowledge of the properties of the constituent fibres has, therefore, received the attention of several research workers[1, 2, 3]. Nevertheless owing to the complex factors involved, it is still not possible to predict the properties of blended yarns with great accuracy, from those of the constituent fibres.

Nuding[4] and Sattler[5] emphasised the necessity for fibres being blended to have the same load-elongation characteristics. Nuding also reported that, because of their matched extensibilities, wool and Perlon (polyamide) blends gave stronger yarns than did Perlon blended with one of the stronger viscose, acetate or cupra-ammonium fibres.

From a theoretical analysis Kulikov[6] concluded that the length of man-made fibres to be blended with natural fibres should always be longer than that of the natural fibres. Experiments carried out on both the worsted and cotton spinning systems showed that when the man-made fibre length used is near the prescribed theoretical value the spinning performance and yarn properties are improved.

Data given by Beevers *et al*[7] indicated that as the nylon content in wool/polyamide blends increased, the spinning efficiencies, limiting counts and yarn strengths increased. These findings are in agreement with the results of Thornton and Townend[8].

Work by Townend and Marsden-Smedley[9] has shown that a twist of 787 turns per metre (20 turns per inch) resulted in maximum yarn strength for yarns of 32 Tex for all wool/nylon blends. The decrease in yarn strength after the maximum was more marked for those blends containing higher percentages nylon.

The production and properties of yarns containing nylon staple mixed with cotton, rayon and wool were discussed by Millard and Thornton[10]. These authors also discussed the necessary changes in processing techniques required for producing these yarns on the woollen and worsted systems.

Shepherd[14] investigated the use of wool/synthetic fibre blends in the production of double jersey yarns and fabrics. Comparisons of different synthetic fibres showed that blends of wool with either nylon or polyester are similar in performance. Blends of wool with acrylic fibres gave better spinning performance but inferior knitting performance. The acrylic blends produce yarns with very much the same strengths as those made from low-pill polyester blends. The breaking extensions of the acrylic blend yarns were lower than those of other blended yarns.

In this paper data will be presented on some of the tensile properties of yarns spun from 100% wool and from wool blended in various proportions with either polyamide, polyester and acrylic fibres. It is felt that this data will supplement the data accumulated over recent years for many other yarns.

EXPERIMENTAL

Raw Materials:

The wool tops used in all the blends had a mean fibre length (m.f.l.) of 59,9 mm with a coefficient of variation of fibre length of 49,9%. Standard commercially available tops of polyamide (Nylon), Polyester type 220 (Trevira) and acrylic (Orlon) were used in all the experiments. These tops had a m.f.l. of 106 mm, 108 mm and 90 mm respectively. The tensile properties and fineness of the different fibres used in the blends were measured before spinning and are given in Table 1.

TABLE 1

PROPERTIES OF FIBRES USED IN THE BLENDS

Type of Fibre	Breaking Strength (gf)	Breaking Extension (%)	Fibre Fineness (tex & den)	Tenacity (gf/tex)
Wool	6,6 (36,6)*	29,0 (37,5)	0,44 tex 3,90 den	15,1
Polyamide (nylon)	12,8 (18,7)	32,8 (18,2)	0,34 tex 3,10 den	37,7
Polyester (Trevira)	11,5 (16,9)	19,8 (15,4)	0,37 tex 3,30 den	31,2
Acrylic (Orlon)	6,5 (27,0)	17,7 (30,0)	0,49 tex 4,40 den	13,2

*Figures in parenthesis indicate coefficient of variation (per cent)

Spinning:

Blends of wool with varying percentages (0 to 100%) of either polyamide, polyester or acrylic fibres were prepared by blending top slivers of these fibres in the correct proportion on an intersecting gillbox. All blends, including the pure wool control were given 4 gillings before drawing. Drawing was accomplished in two operations on intersecting gillboxes followed by one operation on a double apron high draft rover. Identical drafts and doublings were used in all cases and resulted in a roving of 400 tex. The yarns were spun on a Rieter ring-spinning frame (Model H6).

In Table 2 the measured values of tex, twist (t.p.m.), irregularity (C.V.%) and nominal composition of the yarns used in the experiments are given.

Testing procedures:

An Almeter was used to determine the mean fibre length of the tops.

Single fibre breaking strength and extension were determined using an Instron tensile tester with a 20 mm test length and a rate of extension of 20 mm per min. Hundred fibres were tested in each case.

Yarn breaking strength and extension were determined on an Instron tensile tester with a test length of 250 mm rate of extension of 100 mm per min. An electronic integrator coupled to the Instron tester was used to determine breaking energy. A minimum of 50 tests, spread over 10 spinning bobbins, were carried out on all yarns.

TABLE 2

CHARACTERISTICS OF YARNS USED

Yarn No.	Tex	Twist Factor	Turns per metre	Irregularity (C. of V.%)	Composition
1	18,2	2489	583	21,7	100% Wool
2	21,4	2500	540	19,4	
3	25,3	2510	499	17,7	
4	29,1	2587	480	16,9	
5	33,4	2526	437	16,1	
6	35,1	2415	408	15,4	
7	17,4	2494	598	21,4	50/50 Wool/Polyamide
8	21,5	2580	556	18,4	
9	25,3	2575	512	17,5	
10	30,9	2647	476	16,3	
11	32,8	2612	456	16,0	
12	37,5	2552	417	15,1	
13	17,7	2458	584	20,6	50/50 Wool/Polyester
14	21,8	2526	541	17,3	
15	26,6	2575	499	14,5	
16	32,0	2660	470	15,3	
17	33,6	2569	443	15,4	
18	37,3	2527	414	15,0	
19	19,5	2683	607	18,6	50/50 Wool/Acrylic
20	21,5	2645	570	17,9	
21	25,4	2646	525	16,7	
22	30,1	2630	479	15,8	
23	33,4	2653	459	15,0	
24	39,4	2694	429	14,5	
25	26,4	2596	505	16,0	100% polyester
26	25,0	2515	503	17,4	75% polyester
27	26,4	2642	512	17,4	50% polyester
28	26,8	2616	505	17,6	25% polyester
29	28,0	2677	505	17,8	100% acrylic
30	27,4	2725	520	17,8	75% acrylic
31	27,0	2642	508	17,1	50% acrylic
32	28,0	2671	504	17,4	25% acrylic
33	26,1	2703	529	19,6	100% polyamide
34	26,4	2627	511	19,9	75% polyamide
35	25,8	2611	514	19,1	50% polyamide
36	27,0	2616	503	18,8	25% polyamide

Yarn twist was determined on a Zweigle twist tester, using the double untwist-twist method.

Cycling tests for the determination of elastic recovery were also carried out on the Instron tensile tester. Cycling was performed between fixed elongations with a rate of elongation and relaxation of 100 mm/min and a test length of 250 mm.

The method used to define recovery behaviour is shown in Figure 1. The yarn was mounted in the Instron jaws and extended along curve AB to a chosen elongation AE, using a specified rate of elongation. Upon reaching the chosen elongation AE the jaws returned immediately at the original rate of elongation. At D the yarn was no longer under any load and recovery continued as the jaws returned to their original position. As soon as the jaws reached their original position at A, the second, third, fourth, etc. cycle started and re-elongation begun again at F, G, H, etc. respectively.

The distances CE, JE, KE etc. may be taken as a measure of the immediate recovery, but it must be realised that a certain amount of delayed recovery is included, since a finite time is necessary to move from B to C, J, K etc. After the fifth cycle the test specimen was removed from the jaws with the exact distance between the jaws accurately marked. These specimens were allowed to relax freely under atmospheric conditions of 65% relative humidity and 20°C, or 85% relative humidity and 30°C. The relaxed length, y of the specimens were then measured with the "Shirley " Crimp Tester under a tension of 0,2 gf/tex.

The recovery properties that are quoted in this report are defined as follows (using Figure 1):

$$\text{Immediate elastic recovery after 5 cycles (\%)} = \frac{\text{Recovered elongation DE}}{\text{Original elongation AE}} \times 100$$

$$\text{Total recovery after 24 hours} = \frac{x - y}{x - 25} \times 100$$

where x is equal to the test length (25 cm) plus the original elongation (1 cm, 2 cm or 3 cm) and y is the relaxed length of the yarn.

To obtain the breaking strength and elongation after a fixed number of cycles between fixed elongations, the yarn was not removed from the jaws of the Instron after the last cycle but immediately stretched to its break point.

All yarns were conditioned for 7 days at 65% relative humidity and 20°C before proceeding with experiments. All tests were carried out under similar conditions.

RESULTS AND DISCUSSION

The average load-elongation curves for 100% wool, 50/50 wool/polyamide, 50/50 wool/polyester and 50/50 wool/acrylic yarns of 26 tex are given in Figure 2. The method described by Beevers[11] was used to calculate the average curves.

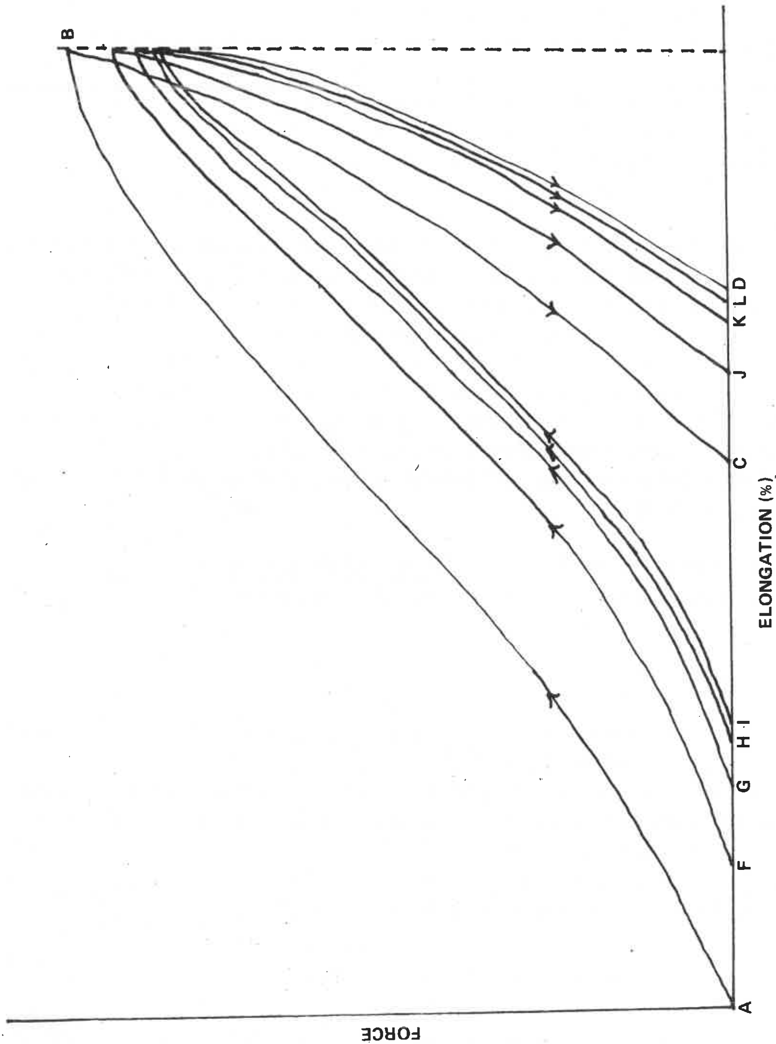

FIGURE 1

The pure wool yarn showed a clear yield point at approximately 3% elongation while the other 3 yarns exhibited no clear yield point. The initial modulus of the pure wool and 50/50 wool/polyester yarns was higher than that of the other two (5 000 and 6 600 gf/tex respectively for wool and wool/polyester yarns against 3 600 and 3 300 gf/tex respectively for wool/acrylic and wool/polyamide yarns). The phenomenal influence of the presence of polyester and polyamide fibres on the breaking force and elongation compared with that of pure wool yarns is clear from Figure 2.

The tenacity (gf/tex), elongation (%), and breaking energy (gf/tex) of the pure wool, 50/50 wool/polyamide, 50/50 wool/polyester and 50/50 wool/acrylic yarns for the tex range 18 to 38 are given in Figures 3, 4 and 5 respectively. Yarns Nos. 1 to 24 were used for these tests (see Table 2).

The tenacity of the pure wool and the wool/acrylic fibre blend showed no trend with increasing tex, while the wool/polyamide and wool/polyester fibre blends showed a slight increase.

In the case of elongation, only the pure wool yarns showed an increase with increasing tex. The breaking energy, being related to the product of tenacity and elongation, increased approximately 30% for the wool/polyamide and wool/polyester fibre blends, and 85% for the pure wool yarns with an increase in tex from 18 to 38. The breaking energy of wool/acrylic fibre blend showed no trend with increasing yarn tex.

The influence of blend composition on the tensile properties is shown in Figures 6, 7 and 8. Yarns Nos. 25 to 36 were used for these tests (see Table 2). The tenacity of all three blends increased with increasing percentage of synthetic fibre. In the case of wool/polyamide and wool/polyester blends the increase in tenacity, with increasing percentage polyamide or polyester, was probably due to the higher fibre tenacities of these fibres compared with those of the wool fibres. The matched fibre elongation in the case of polyamide and wool may also have been a contributary factor.

Interfibre cohesion which is dependent *inter alia* on the interfibre friction and fibre length, is another important factor influencing yarn tenacity. The increase in yarn tenacity of the wool/acrylic fibre blends with increasing percentage of acrylic fibre cannot be explained in terms of fibre tenacity, because the tenacity of the acrylic fibres was slightly lower, and the elongation at break considerably lower (17,7 against 29,0%) than those of the wool fibres. Increased fibre cohesion between the acrylic fibres and between the acrylic and wool fibres could have led to an increased yarn tenacity.

Blend composition showed no significant influence on the elongation at break of wool/polyester yarns, but for wool/polyamide yarns the elongation at break increased by 30% and for wool/acrylic yarns decreased by 60% with the addition of 25% acrylic fibres (see Figure 7). Further increases in the percentage synthetic fibre (25 to 100%) showed relatively small increases in elongation at break for both wool/

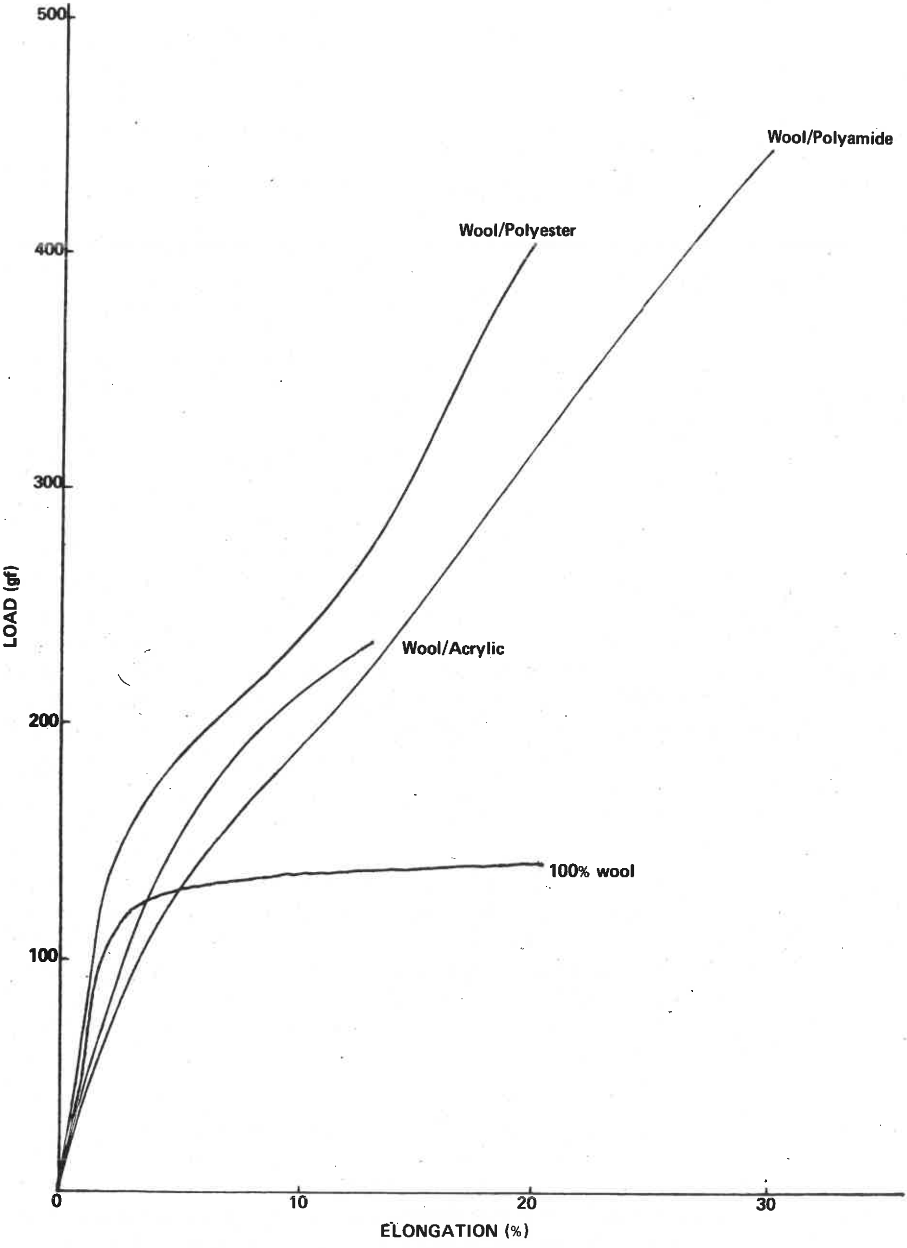

FIGURE 2

Average load-elongation curves

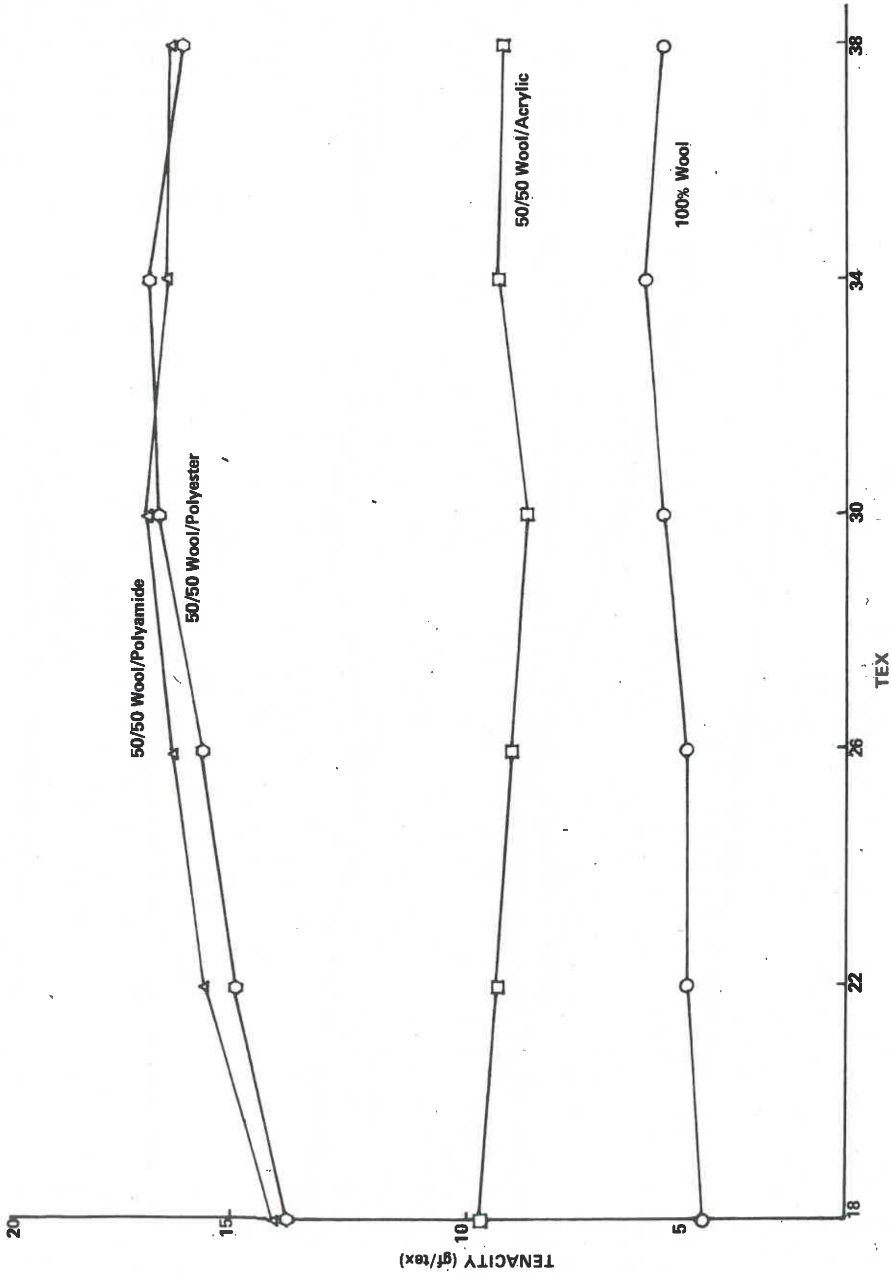

FIGURE 3
Yarn Tenacity versus Tex for different blends

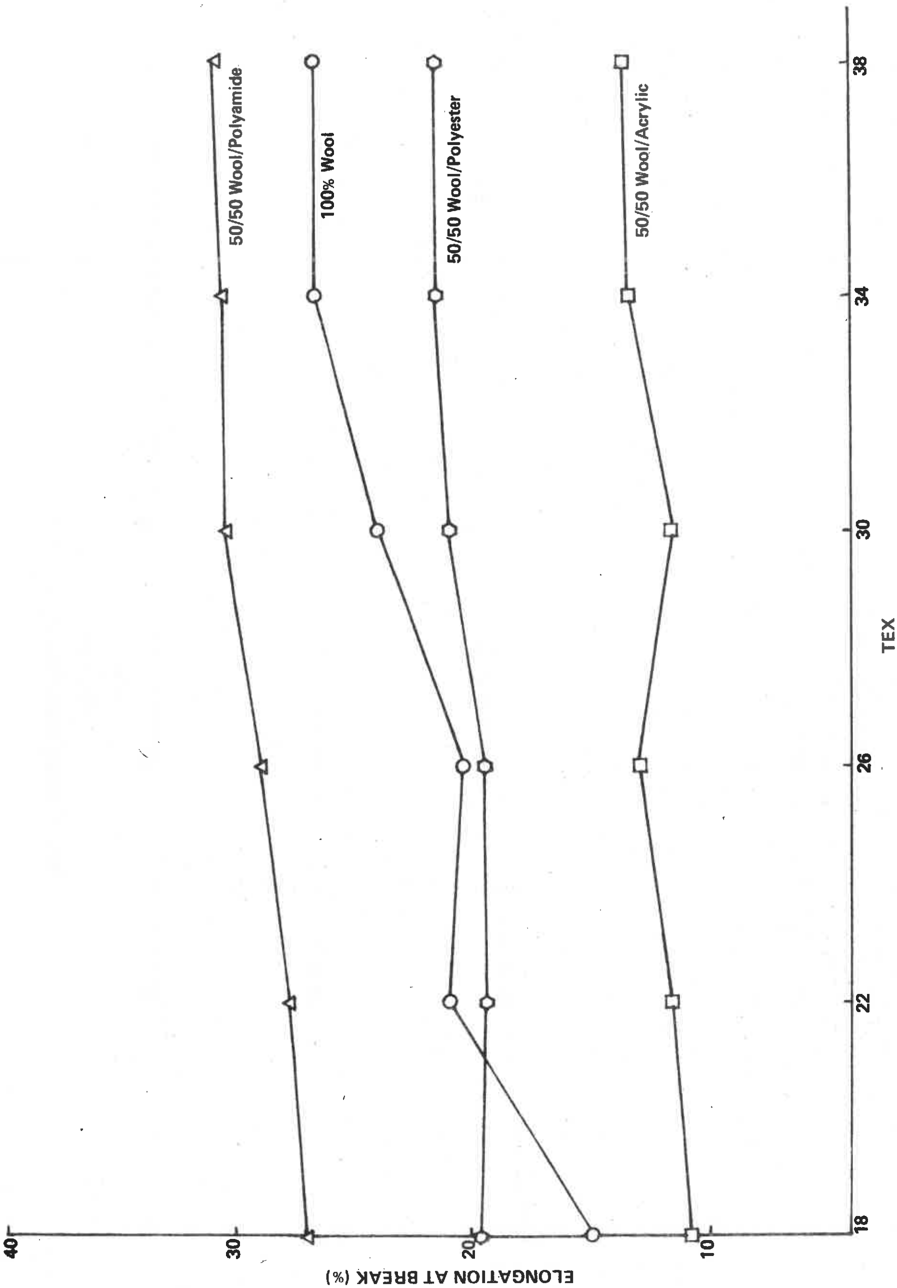

FIGURE 4
Yarn Elongation at break versus tex for different blends

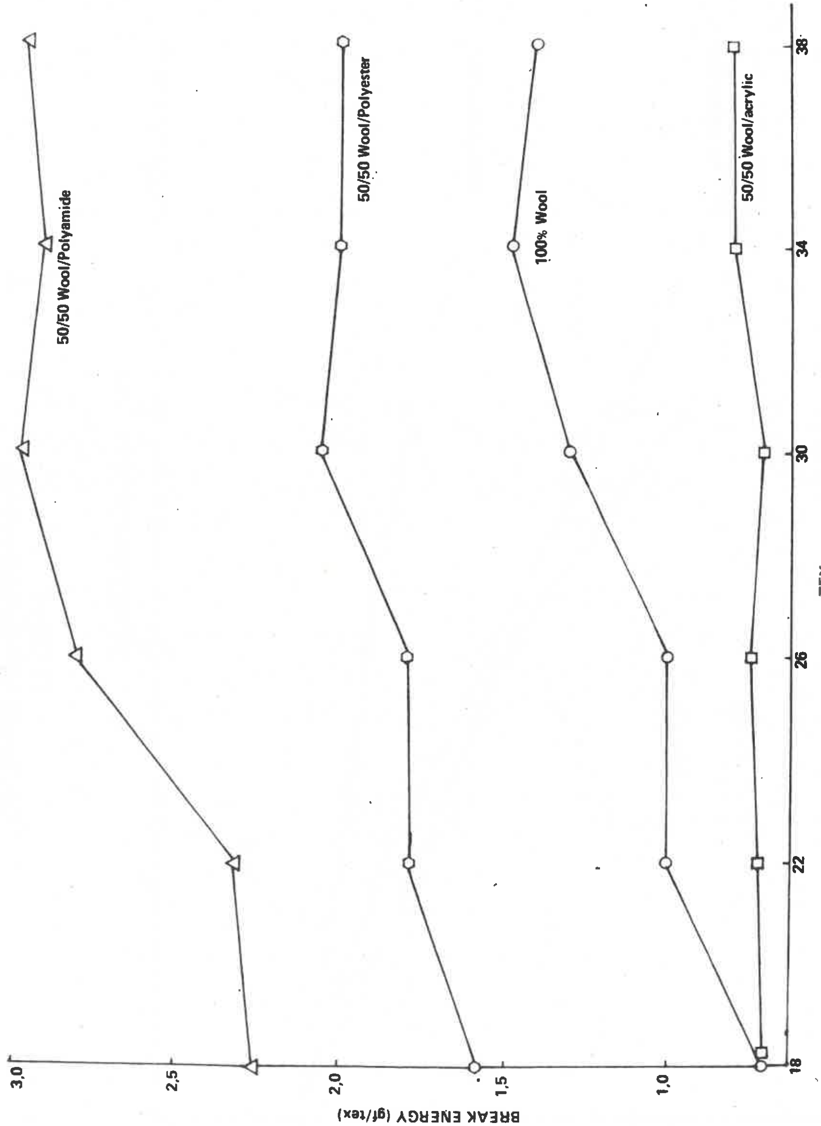

FIGURE 5

Yarn breaking energy versus tex for different blends

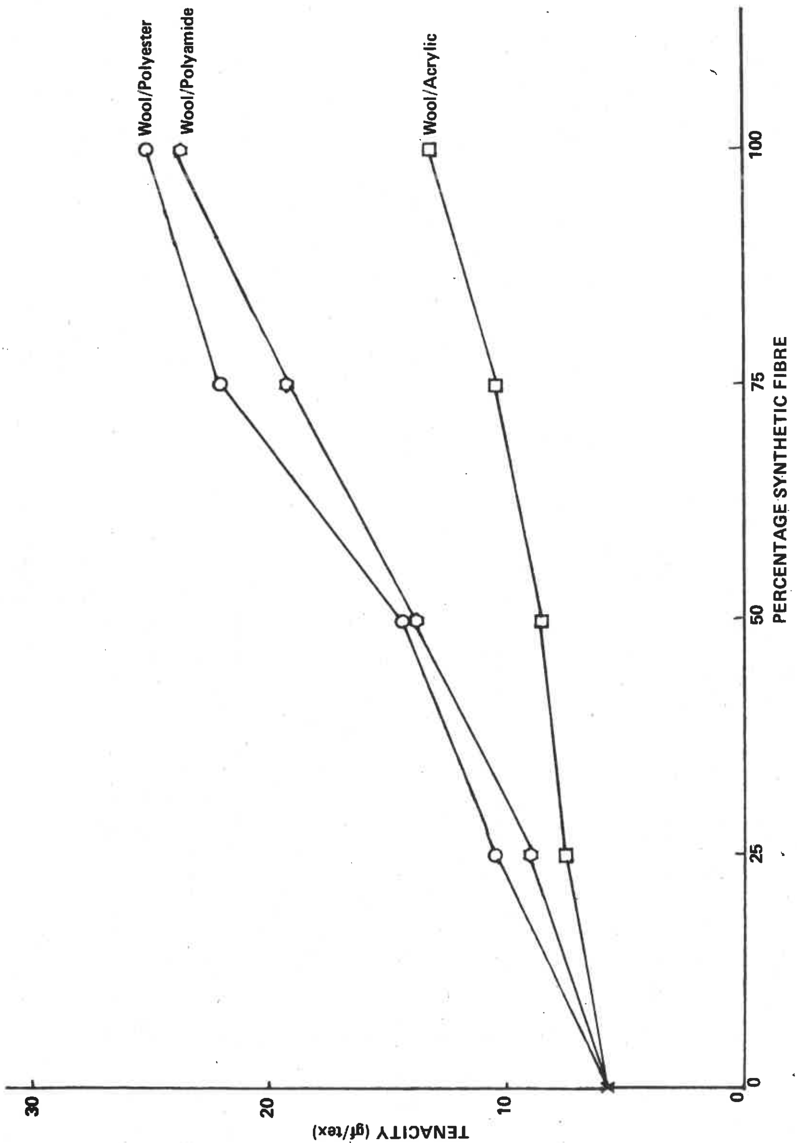

FIGURE 6
Yarn tenacity versus blend composition

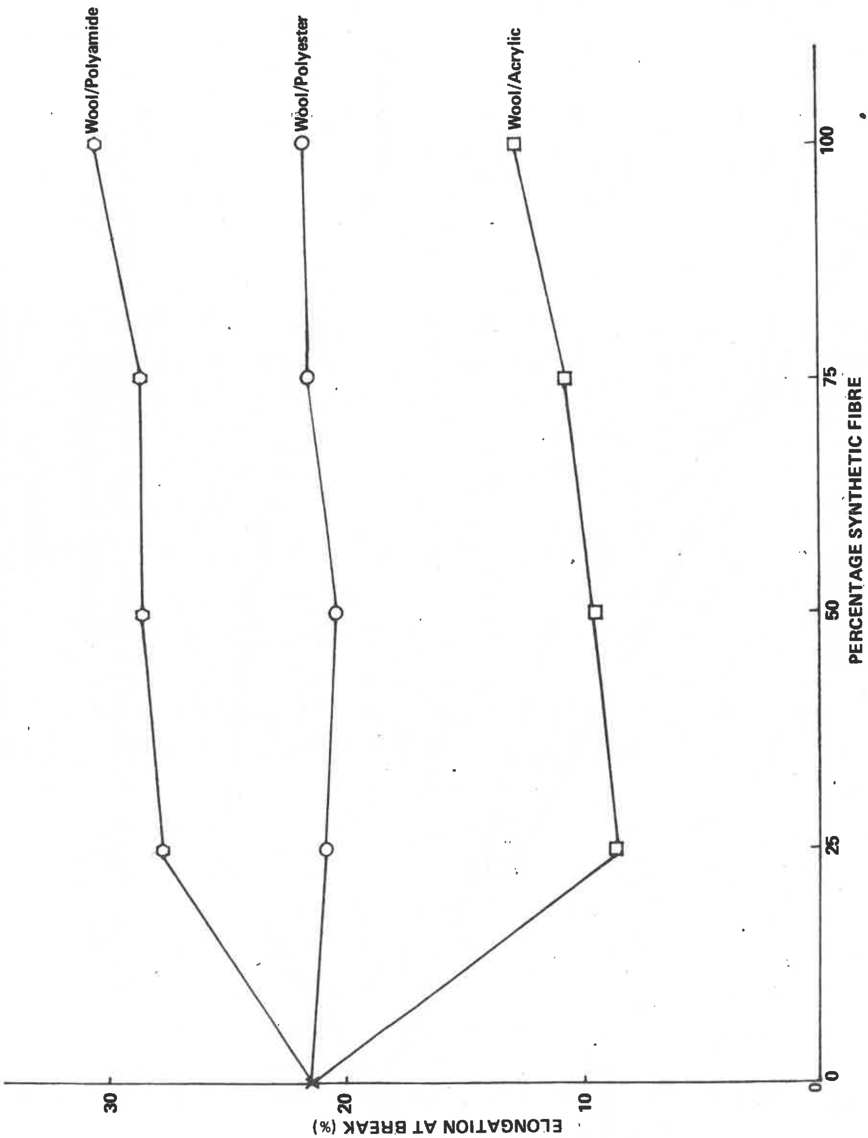

FIGURE 7

Elongation at break versus blend composition

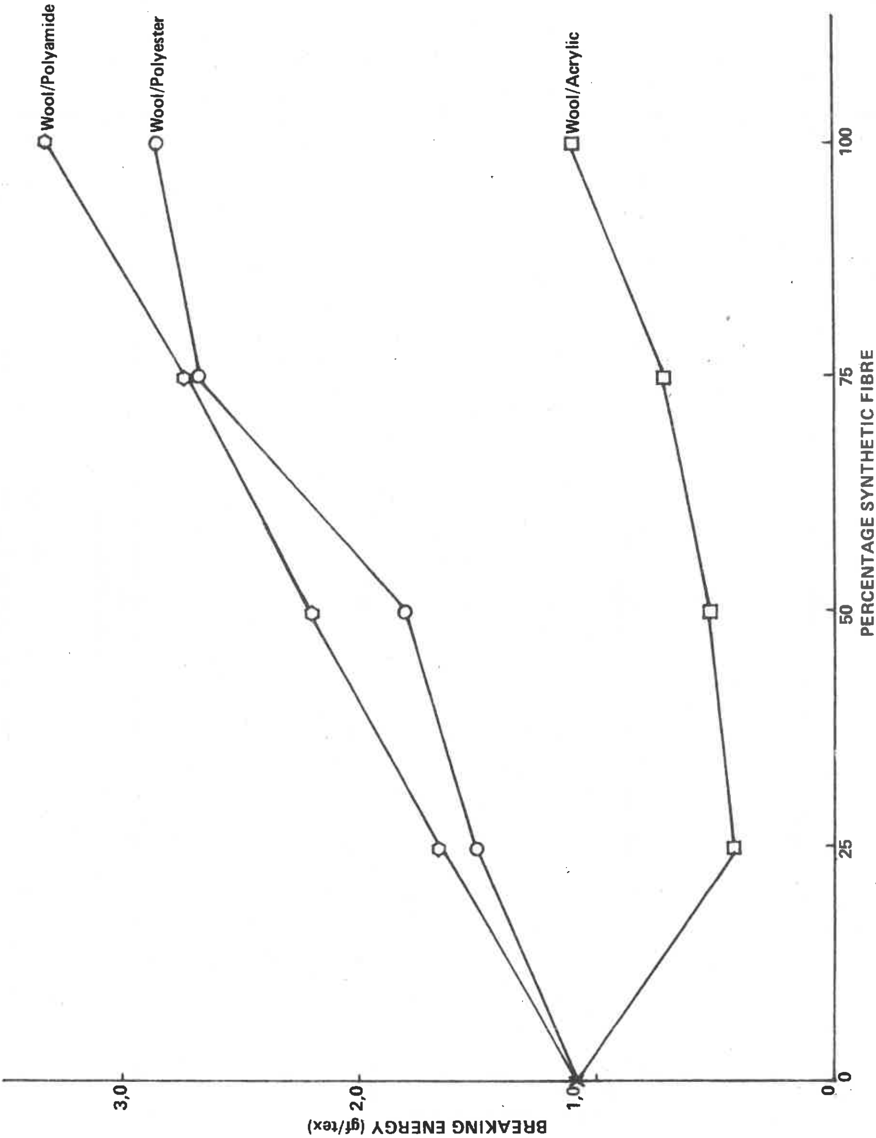

FIGURE 8
Yarn breaking energy versus blend composition

polyamide and wool/acrylic fibre blends. It is evident that the addition of 25% or more polyamide or acrylic fibre has the effect of stabilising the elongation at break of the yarns.

Wool/polyamide and wool/polyester blends showed the expected increase in breaking energy (see Figure 8) but the decrease in elongation at break of wool/acrylic yarns was also reflected in their breaking energy.

The influence of twist on yarn tenacity for 50/50 wool/polyamide, wool/polyester and wool/acrylic blends is shown in Figure 9. The wool/polyester fibre blend did not show a clear breakpoint at 320 turns per metre (t.p.m.) The same is also true to a large extent for the wool/polyamide blend. In both these cases fibre slippage was greatly predominant. In the case of the wool/acrylic fibre blend clear cut breaking points were still obtained at 320 t.p.m. This indicated that fibre cohesion was greater in the case of the wool/acrylic fibre blends than in the case of the wool/polyamide or wool/polyester fibre blends. These results support the argument of cohesion being the reason for the increased yarn tenacity but decreased elongation of wool/acrylic yarns compared with pure wool yarns.

The curves in Figure 9, for yarns of 26 tex, suggest that the optimum twists from a strength point of view for blends including 50% synthetic fibre are in the region of 800 t.p.m. for wool/polyamide and 650 t.p.m. for wool/polyester and wool/acrylic. This result on the wool/polyamide blend is in agreement with that quoted by Townend and Marsden-Smedley[9].

Elastic Tensile Properties:

The effect of cycling between fixed percentages of elongation on the tenacity and elongation at break is shown in Table 3. The tenacity of the yarns after 5 cycles between the given elongations showed no significant tendency, except perhaps in the case of the wool/polyamide blend where there was a slight reduction. The elongation at break, however, did show significant decreases in all four cases. This decrease in elongation at break is to be expected as only a certain amount of recovery could take place as the yarns were immediately stretched to their break point after the first or fifth cycle.

The elastic recoveries of wool and wool/synthetic yarns differing in blend composition and tested under different conditions are illustrated in Figures 10, 11 and 12. Figure 10 illustrates the immediate recovery after 5 cycles. The addition of polyamide fibre to wool yarns improved the immediate elastic recovery performance of the yarns, while the addition of both polyester and acrylic fibre had a detrimental effect on the elastic recovery.

After relaxing for 24 hours at 65% relative humidity and 20°C the elastic recovery improved for all blends (see Figure 11). The ranking for the pure wool, wool/polyamide and wool/polyester blends remained the same, but the 100% Orlon and 50/50 wool/acrylic recovered more. Relaxing for 24 hours at 85% relative humidity and 30°C improved the recovery further (see Figure 12). The pure wool yarn showed a 98% recovery which was more than that of 100% polyamide

TABLE 3

THE INFLUENCE OF CYCLING BETWEEN FIXED PERCENTAGES ELONGATION ON TENACITY AND ELONGATION AT BREAK

Percentage elongation	Number of cycles	100% Wool		50/50 Wool/Polyamide		50/50 Wool/Polyester		50/50 Wool/Acrylic	
		Tenacity (gf/tex)	Elongation at break (%)	Tenacity (gf/tex)	Elongation at break (%)	Tenacity (gf/tex)	Elongation at break (%)	Tenacity (gf/tex)	Elongation at break (%)
0	0	5,4	20,4	16,2	29,4	15,6	19,6	9,1	13,0
0 – 4	1	5,6	19,5	15,0	31,4	15,5	19,7	9,2	11,2
0 – 4	5	5,5	19,5	15,0	29,4	15,5	19,3	9,4	12,4
0 – 8	1	5,6	19,7	14,2	29,5	14,7	17,0	9,1	10,0
0 – 8	5	5,5	16,9	16,3	30,3	15,6	16,7	9,4	9,7
0 – 12	1	5,6	17,4	14,9	26,8	16,2	15,9	–	–
0 – 12	5	5,5	15,8	14,8	27,1	15,9	14,5	–	–

Yarn Count – 26 Tex
Twist – 510 t.p.m.

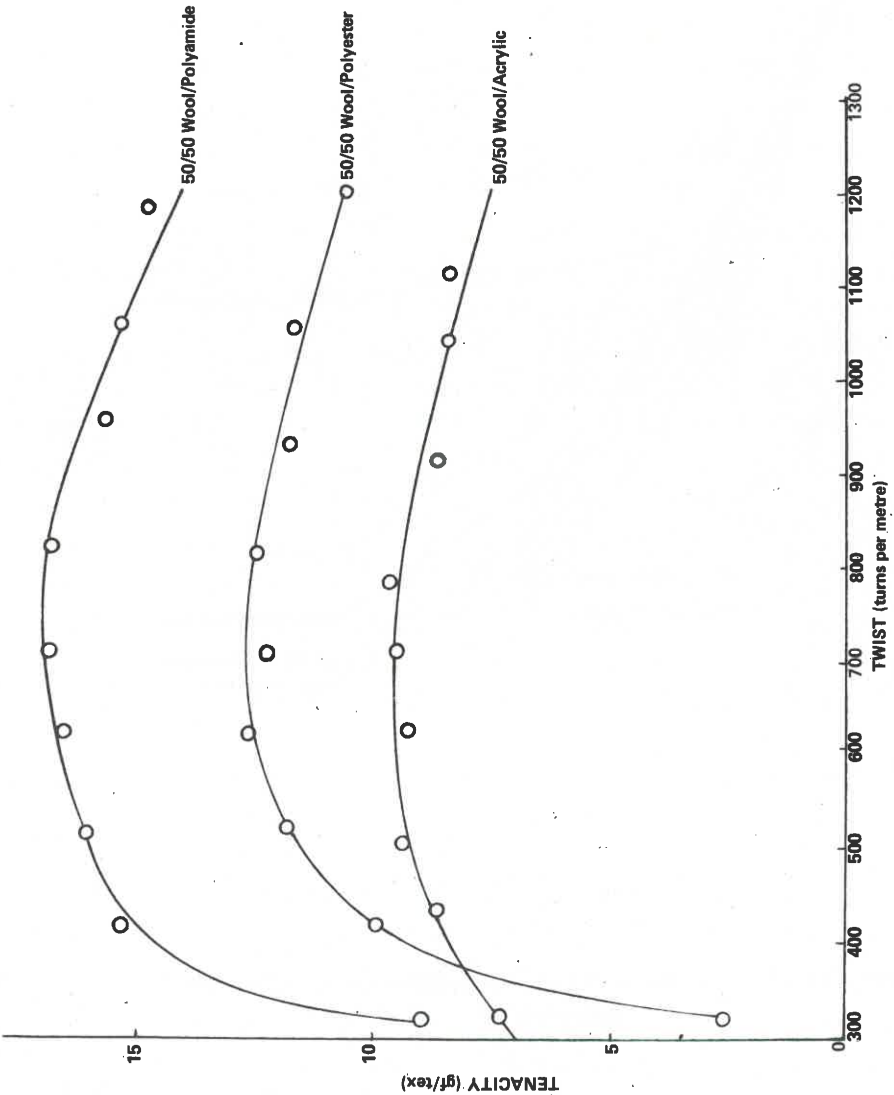

FIGURE 9
Yarn tenacity versus twist (t.p.m.) (Yarn count = 26 tex)

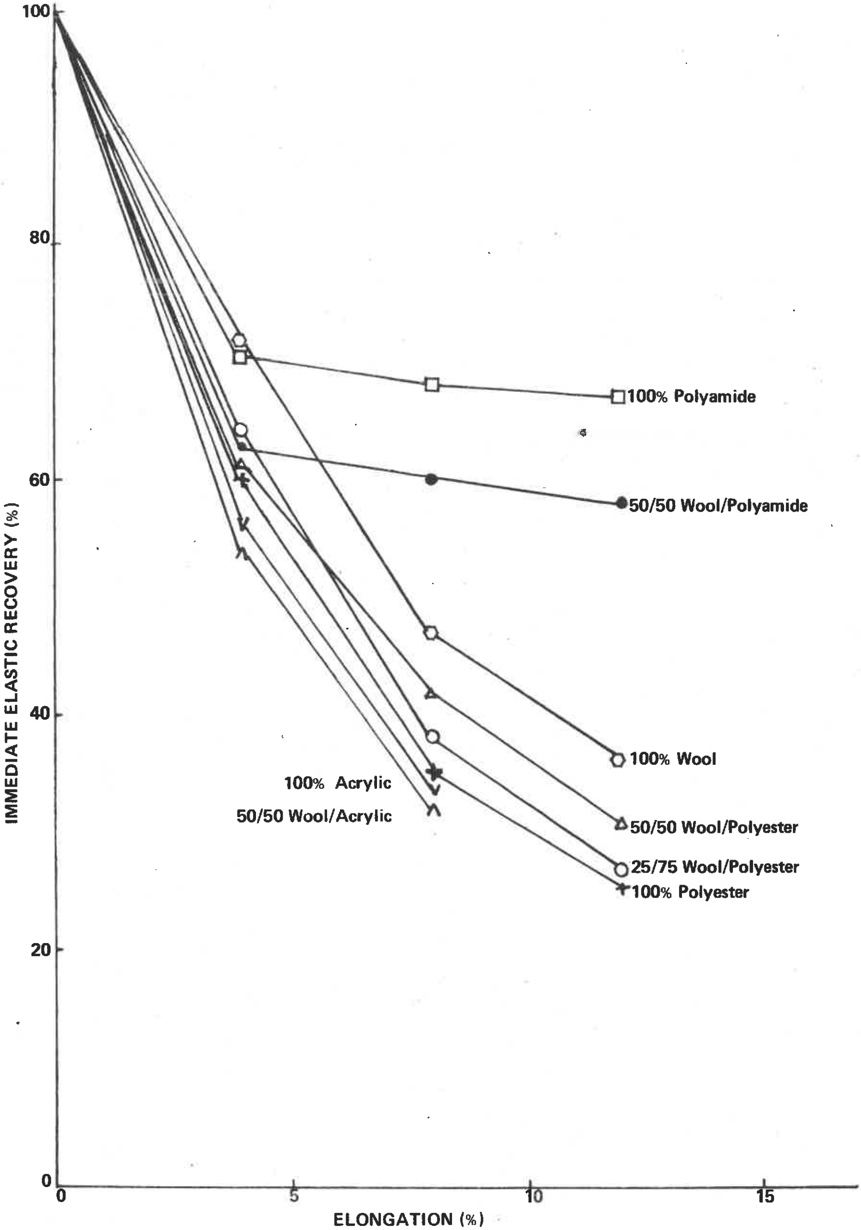

FIGURE 10
Immediate elastic recovery versus elongation for different blends

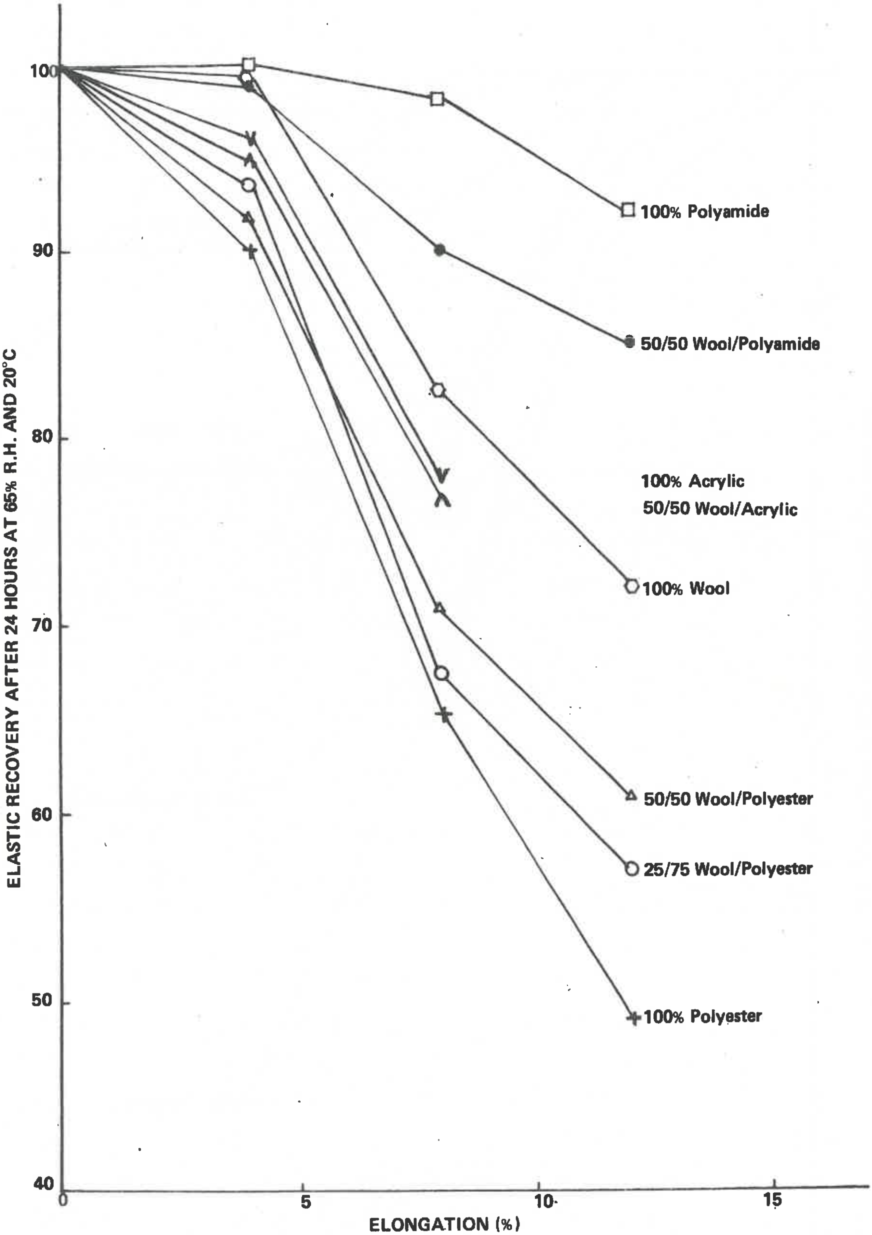

FIGURE 11

Elastic recovery after 24 hours at 65% r.h. and 20°C versus elongation

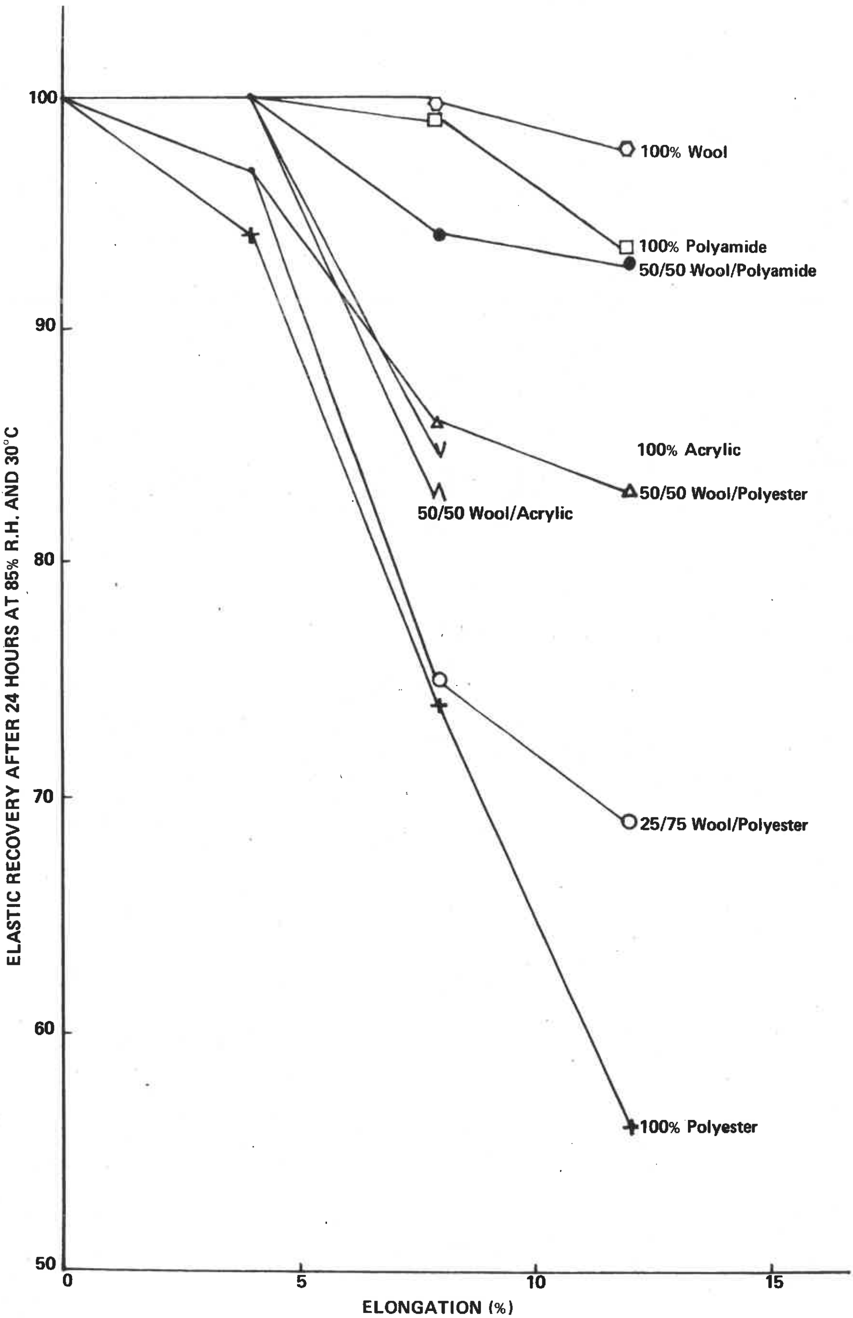

FIGURE 12

Elastic recovery after 24 hours at 85% r.h. and 30°C versus elongation or 50/50 wool/polyamide blends. It is apparent from Figure 12 that pure wool yarns can ultimately recover from almost all original deformation up to elongations as high as 12%. The addition of either polyester and acrylic fibres to wool, however, reduce the elastic recoverability of the yarns and even at elongations as low as 4% considerable residual elongation is apparent.

The tensile recovery properties of the yarns are closely coupled to those of the individual fibres in the yarns which were not investigated. The results quoted here are, however, in close agreement with that of Poller and McDougall[12], who reported on the tensile recovery properties of polypropylene, nylon and polyester filament yarns. The polyester yarns exhibited the poorest total recovery (as low as 40% recovery at 15% elongation). The nylon yarns, however, exhibited excellent consistency of recovery as a function of per cent elongation.

The recovery behaviour of Dacron (polyester) fibres from 1%, 3%, 5% and 15% elongation was reported to be very similar to that of wool, with that of Orlon (acrylic) fibre slightly lower[13]. The results illustrated in Figure 10 indicate similar trends for pure wool, polyester and acrylic yarns.

CONCLUSIONS

The addition of 50% acrylic staple fibre to wool lowered the elongation at break by 35%, but increased the yarn tenacity by 70% compared to that of a pure wool yarn. Similar wool/polyamide and wool/polyester yarns exhibited increases of up to 200% in tenacity with the wool/polyamide fibre blend also giving an increased elongation at break.

Blends of wool/polyester fibre containing increasing percentages polyester showed no change in elongation at break when compared with pure wool yarns. The addition of either polyamide or acrylic fibre to wool, however, resulted in a significant increase and decrease, respectively in elongation at break. The major increase and decrease in elongation at break occurred when the synthetic fibre component was increased from 0 to 25%.

Within the range investigated, the effect of twist on yarn strength was smaller for a 50/50 wool/acrylic fibre blend than for similar blends of wool/polyamide and wool/polyester fibres, especially at low twist levels. The wool/acrylic and wool/polyester fibre blend exhibited maximum yarn strength at a lower twist than the wool/polyamide fibre blend.

Wool/polyester and wool/acrylic fibre blends showed inferior elastic recovery properties from elongations of 4%, 8% and 12% when compared to pure wool and wool/polyamide fibre blends. Pure wool and to some extent also wool/polyamide yarns could recover from almost all original deformation up to elongations as high as 12%, while wool/polyester and wool/acrylic yarns showed considerable residual elongation, even after elongations as low as 4%.

ACKNOWLEDGEMENTS

The authors wish to thank the following persons who contributed to the investigations: Dr. P. J. Kruger, for valuable advice; Miss Yvonne Mannell, who assisted in yarn testing and Mr. S. G. Marsland, who was responsible for the spinning of the yarns. The authors also wish to thank the S.A. Wool Board for permission to publish this report.

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Published by
The South African Wool and Textile Research Institute
P.O. Box 1124, Port Elizabeth, South Africa,
and printed in the Republic of South Africa
by Nasionale Koerante Beperk, P.O. Box 525, Port Elizabeth.