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Part I: Blends of Untreated Wool and Polyester Fibres in Plain Weaves

by

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STUDIES OF SOME WOOL/POLYESTER WOVEN FABRICS:

PART I: BLENDS OF UNTREATED WOOL AND POLYESTER FIBRES IN PLAIN WEAVES

*by MIRIAM SHILOH and R.I. SLINGER**

ABSTRACT

Plain weave, light weight suiting fabrics were constructed from blends of wool and three types of polyester fibres at various levels of composition. The fabrics were finished by four different procedures. The mechanical properties, and in particular, the wrinkle resistance of these fabrics, were measured and compared.

KEY WORDS

Wool, polyester, blends, mechanical properties, strength efficiency, mass loss, wrinkling, bending, autoclave-decatising.

INTRODUCTION

The purpose of the present study was to establish the effect of the polyester fibre component in wool/polyester blends on some mechanical properties with special emphasis on the wrinkle resistance of wool-rich blends. In the first part of this study the effect of yarn and fabric structural variables on the properties tested was eliminated by producing plain weave fabrics of similar structure. In the second part of this study structural variables were also investigated.

The first factor which had to be analysed was the effect of the percentage of the polyester component. The utilization of polyester fibres as blend components with wool is widely known to be advantageous in respect of a number of properties, particularly the wash-and-wear performance of such fabrics. In practice the percentage of polyester used in wool/polyester fabrics is very often based on previous experience and economic considerations rather than on the outcome of systematic laboratory tests. In some cases, therefore, the particular blend ratio chosen may not be the best one for utilizing the beneficial properties of each fibre component.

It is very difficult to predict the percentage of polyester required for ensuring successful performance and whether, by exceeding this percentage, it would be possible to obtain further improvements or whether at higher percentages certain properties may begin to deteriorate. A knowledge of the behaviour of each fibre component is not sufficient for predicting the behaviour of the blend. Even

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* Deceased.

though theoretical values can be calculated for average properties of the two component blends, actual experimental results very often deviate in a positive or negative direction from such predicted values. The deviations are due to fibre, yarn, and fabric structural parameters interacting with the mechanical properties. By testing blends containing various amounts of polyester fibre, therefore, some further information can be obtained which facilitates the selection of fabrics, the properties of which reflect the better characteristic features of both wool and polyester.

Another object of the present study was to compare different polyester types in respect of their contribution towards the properties of the blend fabrics. The first type of polyester used was a 'normal' type, the second was a 'low pilling' type and the third a 'high-bulk' type. The latter two types were recently introduced as they had been found to have beneficial effects on certain end commodities. Multilobal filaments and staple fibres with reduced pilling propensities have been developed(1) and introduced to the market as 'low pilling' fibres. These fibres are physically modified with built-in 'weak-spots' which are responsible for the breakage of the fibres once they are pulled out of the fabric. Normal fibres, on the other hand, usually produce pills when they migrate to the surface of the fabric.

'High bulk' polyester fibres shrink more rapidly than do normal polyester fibres, both in hot air and in boiling water. Their shrinkage is due to a more moderate and controlled crystallinity in the fibres which make them particularly suitable for fabrics which are bulked during finishing. The 'high-bulk' polyester fibres offer increasing possibilities for styling and colour effects in light weight apparel fabrics.

Finally, it seemed of interest to study the response of wool/polyester blend fabrics to heat setting, decatising and autoclave-decatising under various conditions. The poor wet wrinkle resistance which is usually associated with the lighter weight fabrics, especially with the pure wool fabrics, makes them more sensitive to the effect of the introduction of polyester fibres which serve to improve their wrinkle resistance. It is claimed by Looney and Handy(2) that the better wrinkle resistance of the heavier fabrics can be attributed to the use of coarse yarns rather than to their increased mass and fabric tightness.

EXPERIMENTAL

1. MATERIALS

Fibres:

Wool tops of 64's quality were blended with 75 mm undyed fibres of Trevira type 220 (N = normal), Trevira type 350 (LP = low pilling) and Trevira type 550 (HB = high bulk) respectively. Specifications for these appear in Table I.

TABLE I.

PROPERTIES OF FIBRES

Fibre	Fineness				Tenacity* (gf/tex)	Extension at break* (%)	Calculated Toughness (gf-cm/tex.cm)
	Diameter (Microns)	Denier	dTex	C.V. (%)			
Wool (64's)	21	4,1	4,6	22,6	14,0 ± 3,4	34,0 ± 4,5	2,4
N = Normal Polyester, Trevira Type 220	18	3,2	3,6	6,6	35,2 ± 3,2	23,1 ± 1,8	4,1
LP = Low Pilling Polyester, Trevira Type 350	21	4,1	4,6	6,2	26,5 ± 2,2	14,0 ± 0,8	1,9
HB = High Bulk Polyester, Trevira Type 550	18	3,2	3,6	9,5	23,6 ± 2,0	25,1 ± 3,1	2,5

*Results of 25 tests and their limits at a 95% confidence level.

TABLE II

PROPERTIES OF YARNS

Composition			Resultant linear density (Tex)	Singles Twist (t.p.m.) Z	Ply Twist (t.p.m.) S	Breaking Strength		Extension at break (%)	Calculated Data	
% Wool	% Polyester	Type of Polyester				(gf)	(gf/tex)		Mean Fibre Tenacity (gf/tex)	Yarn to Fibre strength Efficiency (%)
100	–	–	37,4	687	435	256	6,8	20,7	14,0	48,6
80	20	N	38,2	680	403	495	13,0	22,9	18,2	71,4
60	40	N	42,3	711	405	828	19,6	24,3	22,5	87,1
40	60	N	44,6	676	412	1147	23,5	24,4	26,7	88,0
80	20	LP	42,8	690	420	456	10,7	14,8	16,5	64,9
60	40	LP	42,3	659	412	588	13,9	15,3	19,0	73,2
40	60	LP	42,4	702	409	744	17,5	15,5	21,5	81,4
80	20	HB	41,2	678	402	361	8,8	21,0	15,9	55,3
60	40	HB	40,5	676	403	457	11,3	23,1	17,8	63,5
Approximate 95% confidence limits			±3,0	±50	±10	±30	±0,7	±2,0	–	–

Yarns:

Blends of 80, 60 and 40 per cent (by mass) of wool with the three types of polyester fibres were prepared. Yarns of approximately R42 tex S400/2 Z 650 were produced. After twist setting, the actual counts and properties of the yarns were determined (Table II).

Fabrics and Finishing:

Plain weave fabrics of about 22 ends and picks per cm were woven, with a density of approximately 200 g/m^2 (6 oz/sq.yd.).

Each fabric was subdivided into two pieces to obtain two lots. Both lots were two-way crabbed for 20 min with a top roller pressure of 1 kg/cm^2. Subsequently one lot was quenched in cold water immediately after crabbing whereas the other lot was cooled on a roller for 16 hours. All fabrics were then scoured on a winch with 0,5 ml/*l* Eriopon HD (Ciba-Geigy A.G.) and 1 ml/*l* ammonia (25%) at 60°C for 30 min. This was followed by a hot (45°C) rinse and a cold rinse, during which the material was treated with 1% acetic acid, and by hydro-extraction and tenter drying at 120°C for 1 min. The fabrics were then left overnight to achieve normal regain.

Except for the pure wool fabrics, all the other fabrics were heatset on a tenter at 180°C for 30 sec, allowing for different overfeeds for the different blends – from 8% overfeed (in length) for the 80/20 wool/N and wool/LP blends, to 16% for the 60/40 wool/HB blend.

All the fabrics were subsequently scoured, at 40°C for 15 min, in a Dolly with no top roller pressure, followed by a hot and cold rinse. This scouring procedure was incorporated to soften the harsh handle of the fabric after heat-setting. After hydro-extraction and tenter drying, the fabrics were steamed, brushed and cropped.

The fabrics were once again subdivided into two – the one lot was decatised twice (3 min steaming and 2 min cooling) and is referred to as the "D"-series. The second lot was autoclave-decatised for 4 min employing a pressure of 2 kgf/cm^2 and is referred to as the "K"-series. Altogether four series were prepared of the 9 different fabric blends: the D series, cooled overnight or cooled in water, and the K series, cooled overnight or cooled in water.

The dimensions and properties of the fabrics are presented in Table III. Since it was later established that for most properties no significant differences were found between the "cooled overnight" or "cooled in water" series, the results of the "cooled overnight" D and K series only are reported on.

TABLE III

PROPERTIES OF FABRICS

Composition			Finishing	Picks and Ends (cm^{-1})	Density (g/m^2)	Cover Factor	Thickness (mm)	Air Permeability*	Bursting Strength (Kgf/cm^2)	Breaking Strength (gf/tex)	Extension at Break (%)	Fabric to Fibre Strength Efficiency (%)	Martindale mass loss** (%)
% Wool	% Polyester	Type of Polyester											
100	—	—	D	22,0 x 20,5	191	20,6	0,43	10,3	9,2	8,0	36,3	57,4	17,1
			K	23,2 x 21,7	192	21,4	0,42	8,7	8,4	7,3	28,9	52,3	4,4
80	20	N	D	22,8 x 22,0	197	21,5	0,48	8,9	13,6	15,5	37,7	79,6	2,0
			K	22,4 x 22,4	200	21,5	0,42	9,7	13,4	13,4	36,6	73,9	3,7
60	40	N	D	22,4 x 21,3	207	21,9	0,49	7,8	17,5	19,3	40,5	85,7	1,5
			K	22,0 x 22,4	205	22,1	0,43	9,2	18,7	19,7	37,2	87,5	2,8
40	60	N	D	21,7 x 22,4	213	22,4	0,53	10,0	23,0	25,7	41,2	96,0	2,1
			K	22,8 x 22,8	216	22,6	0,46	6,9	22,6	25,2	39,8	94,2	2,1
80	20	LP	D	22,4 x 21,3	204	22,0	0,47	7,6	11,8	11,2	26,4	67,8	2,2
			K	22,4 x 22,0	203	22,2	0,44	10,0	11,2	10,8	26,6	65,2	4,3
60	40	LP	D	21,7 x 22,0	199	21,9	0,48	9,1	13,4	15,6	24,5	82,1	2,8
			K	22,0 x 22,4	198	22,1	0,44	12,7	14,2	14,7	25,5	77,5	3,7
40	60	LP	D	21,7 x 21,3	202	21,6	0,48	7,8	18,0	19,6	26,8	91,3	3,2
			K	22,4 x 21,7	206	22,0	0,41	8,5	16,8	18,5	26,3	86,2	2,5
80	20	HB	D	23,2 x 22,0	214	22,2	0,51	7,3	11,0	9,9	42,1	62,3	8,5
			K	24,0 x 22,4	223	22,5	0,49	7,1	10,4	9,0	35,7	56,5	4,7
60	40	HB	D	23,6 x 23,6	231	22,6	0,61	6,9	12,3	12,4	42,1	69,5	6,6
			K	24,8 x 23,6	226	23,0	0,52	5,8	12,0	10,4	40,4	58,2	10,8

* cm^3 per sec per cm^2 at 1 cm water Pressure

** Fabric samples after 3 x 10^4 cycles

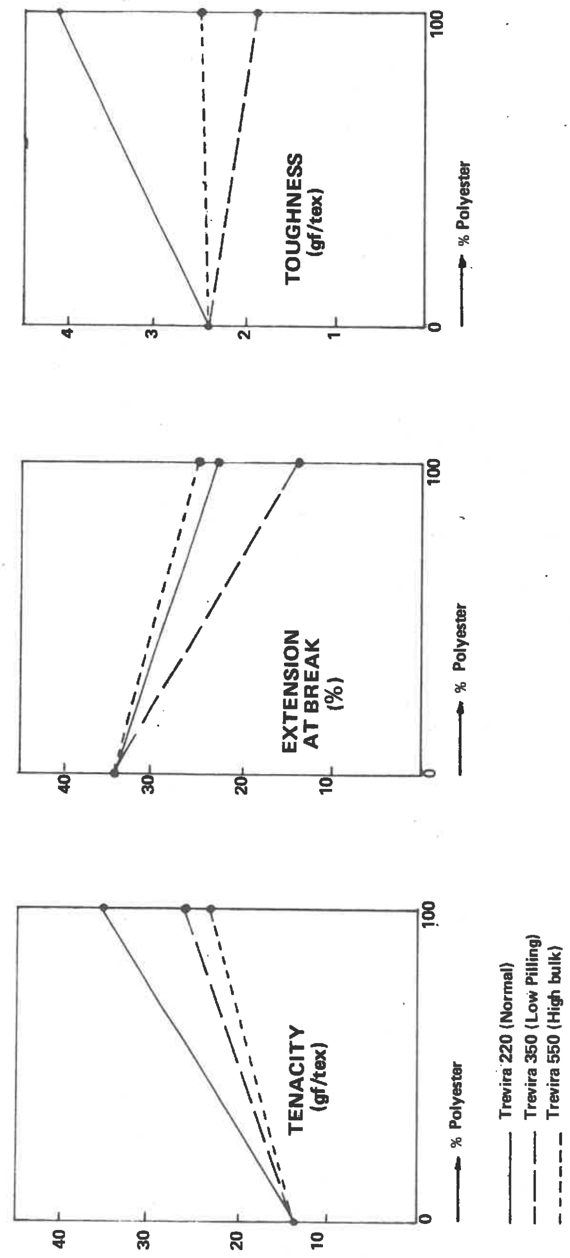

Figure 1: Theoretical lines for average fibre tensile properties in wool/polyester blends.

2. TEST PROCEDURES

Fibre Properties:

The fibre diameters and the tensile properties were measured according to the usual test procedures (IWTO-8-61 test for fibre diameter and 2 cm gauge length tests at a cross-head speed of 2 cm/min on the Instron Tester for the tensile properties).

Yarn Properties:

The breaking strength and elongation of the yarns were measured on the Instron Tester with a test length of 25 cm and a cross-head speed of 10 cm/min. Yarn strength efficiency was calculated as the ratio of the yarn tenacity to the average tenacity of the fibres in each yarn. The latter values were calculated from the percentage of each fibre component as shown in Figure 1.

Fabric Properties:

The thickness of the fabrics was measured (in mm) by the Reynolds and Branson tester under a pressure of a 5 gf/cm^2, and the results represent the means of five determinations. The mass per unit area and the thread counts were determined by standard procedures. Cloth cover factors were calculated(3) thus:

$$Kc = 0{,}04126 \sqrt{Tex} \; (W + F - 0{,}00147 \; W.F. \; \sqrt{Tex})$$

where W and F are the number of ends and picks per inch respectively, the tex counts of warp and weft yarns being equal prior to the finishing.

The breaking strength and elongation tests were carried out on 2" wide samples which were extended on the Instron tester at 10 cm/min with a gauge length of 20 cm. The results of the breaking strengths were divided by the corresponding number of yarns in the 2" sample and the yarn counts in order that they might be expressed in gf/tex. The fabric-to-fibre strength efficiency was then calculated.

The bursting strength of the fabrics was determined on a standard Mullen tester. The air-permeability of the fabrics at 5 cm water pressure was determined on a WIRA Air Permeameter, in litres per min. The results were then calculated as the air flow in cm^3 per second per cm^2 of fabric, per 1 cm of water pressure, and they represent the mean of ten determinations.

Attempts were made to assess the pilling propensity of the fabrics. Each fabric was abraded in the Martindale Tester against a base covered with the same fabric, and using a head weight of about 800 gf. No pills were formed on the fabrics after the initial 100 cycles nor were they formed after subsequent

TABLE IV

BENDING AND WRINKLING

Composition			Finishing	Flexural Rigidity (mgf cm^2 per cm)	Owen's Bending Test			Shirley Crease Recovery Angle (W+F) (°) at RH %			% Area Shrinkage (48 min)	Wrinkle Severity Index H x T (mm x 10^2)	
% Wool	% Polyester	Type of Polyester			Mo (Mgf cm /cm)	B Mgf cm^2/cm	Mo/B (cm^{-1})	65%	75%	100%		Washed	FRL creased
100	—	—	D	78,4	8,5	58,8	0,144	302	259	267	12,1	9,0	7,2
			K	83,1	8,3	49,4	0,172	319	274	282	9,3	7,8	3,4
80	20	N	D	100,1	17,3	70,1	0,247	311	270	251	2,6	1,0	2,4
			K	86,6	9,6	56,9	0,170	311	267	285	1,5	1,4	2,3
60	40	N	D	125,2	22,0	77,8	0,283	310	272	266	1,5	0,5	2,6
			K	93,8	12,1	59,3	0,204	313	272	284	1,5	0,4	2,9
40	60	N	D	130,3	29,5	85,9	0,341	303	265	252	1,5	0,6	2,9
			K	97,0	17,3	65,1	0,262	310	276	276	0,5	0,5	2,8
80	20	LP	D	110,9	15,2	72,6	0,210	310	268	253	2,5	1,5	3,1
			K	103,3	9,2	64,2	0,144	313	273	284	2,0	0,4	2,5
60	40	LP	D	131,3	19,7	76,6	0,255	314	280	272	2,0	0,5	2,4
			K	104,3	11,5	63,2	0,182	309	282	285	0	0,5	2,1
40	60	LP	D	149,5	20,7	86,7	0,238	309	268	262	3,0	0,9	2,1
			K	110,4	15,0	69,5	0,214	310	276	286	1,0	0,4	2,1
80	20	HB	D	124,1	22,2	76,8	0,289	309	266	242	3,5	1,9	2,6
			K	89,6	9,4	55,3	0,171	308	260	275	2,5	0,5	3,3
60	40	HB	D	149,8	29,7	77,9	0,392	298	255	248	1,5	0,6	2,7
			K	112,0	13,5	64,3	0,211	304	261	274	2,0	0,6	2,5

abrasion. The test was continued up to 30 000 cycles after which the mass loss was determined for each specimen.

Bending length was measured by the cantilever method and the flexural rigidity was calculated. Fabric stiffness was also assessed by means of the Owen bending test which provided the frictional couple (Mo), the flexural rigidity (B) and the residual curvature (Mo/B).

Shirley crease recovery angles were determined after exposing the fabric samples to three different conditions: standard atmosphere (65% R.H., 20°C), high-humidity atmosphere (75% R.H., 27°C) and immersed in water (100% R.H., 20°C). The samples were then creased under 2 Kgf pressure for 2 min and the recovery angles determined after 1 min relaxation under standard atmospheric conditions. The area shrinkage was determined after a 48 min Cubex wash(4). The wrinkle severity index(5) was determined after the standard washing cycle(4) and drip drying, and after creasing in the FRL tester at 75% R.H., 27°C.

RESULT AND DISCUSSION

Fibre Properties:

The mean fineness values and the tensile properties of the wool and the three types of polyester fibres appear in Table I. The normal polyester type was stronger and tougher than the other two types, while the high-bulk type had a superior extensibility. The difference in fineness (3 microns) between the fibres was not considered as a variable which could have significantly affected yarn and fabric properties.

Theoretical lines were drawn for the tensile properties of the two component blends from the measured values of the 100% components, from which the average properties of the blends could be predicted, as is shown in Figure 1.

Yarn Properties:

The properties of the yarns are summarized in Table II. It was found that some of the counts of the yarns were lower than the expected count (R42 tex). This parameter was, therefore, taken into account when analysing the properties of the fabrics (Table VI). Both the breaking strength and the extension at break increased with the increasing polyester component, and the normal polyester type was also found to be superior to the other types in its contribution towards the tensile properties of the blends. It was also superior with regard to the yarn to fibre strength efficiency (Figure 2), whereas the high-bulk polyester was the least efficient in utilizing the strength of the fibres in the yarns. It is possible that the high-bulk fibres are less capable of contributing towards the yarn strength not only because of their lower tenacity but due to their crimped configuration. When axial forces are applied to the yarn the stress in the fibres is not in a direction parallel to their

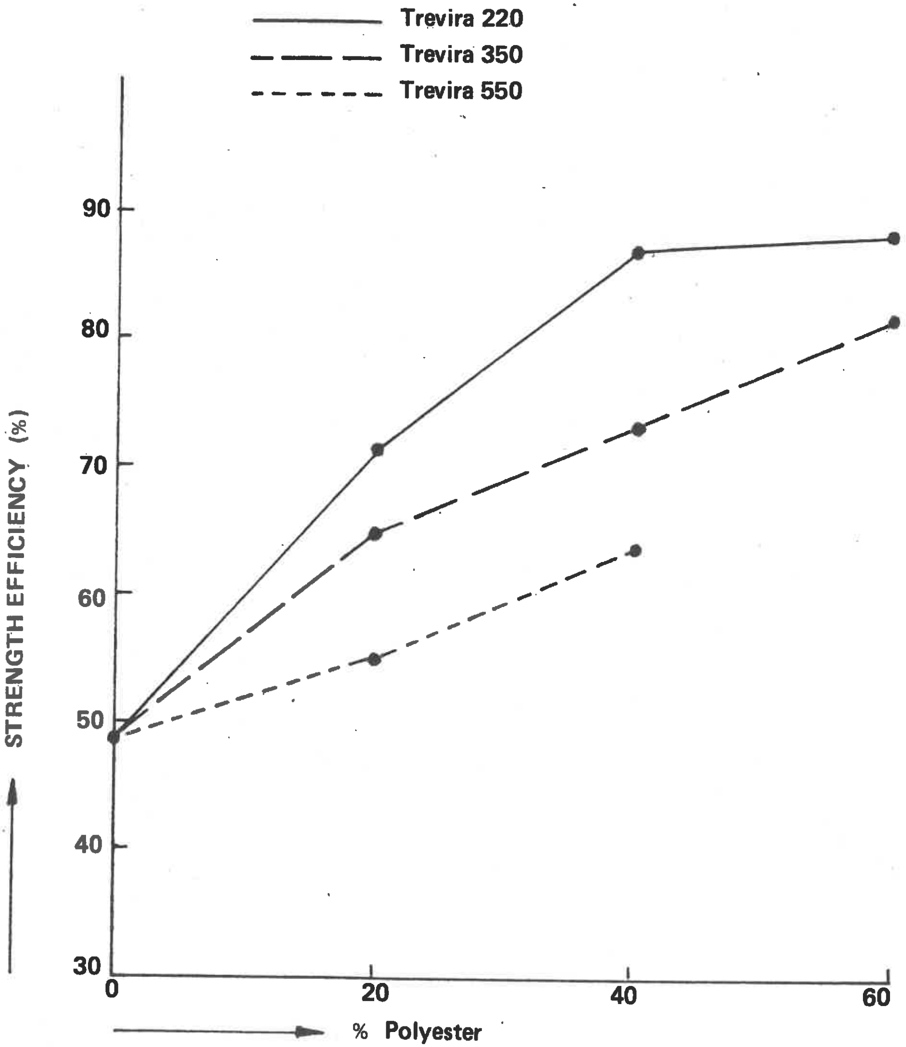

Figure 2: Yarn to fibre strength efficiency

axis, so that their resistance to breakage is lower than what could have been expected. The yarns of the wool and high-bulk polyester have, nevertheless, high extensibilities, so that good performance in weaving, and especially in knitting, can be expected.

TABLE V

SUMMARY OF ANALYSES OF VARIANCE OF SOME FABRIC PROPERTIES ('F' VALUES)

Source of Variance	d.f.	Air Permeability	Bursting Strength	Breaking Strength	Strength efficiency	Martindale % mass loss	Flexural rigidity	M_o	B	Shirley C.R.A. at 75% R.H.	H x T after washing	F.R.L.
Composition	2	3,83	704,72**	294,97**	47,60*	0,84	22,66*	49,27*	13,40	0,97	2,21	0,30
Polyester Type	2	23,21*	336,36**	159,79**	51,02*	3,97	14,31	22,24*	1,05	17,05	0,14	1,30
Finishing	1	0,03	4,08	8,17	9,31	0,24	105,21**	241,21**	86,88*	2,72	2,53	0,00
C X P	4	2,84	18,98	6,31	0,93	0,59	0,78	1,88	0,15	1,67	0,07	1,28
P X F	2	10,20	10,20	1,16	1,56	0,06	4,60	12,52	1,14	0,14	0,91	0,82
F X C	2	8,96	8,95	0,08	0,02	0,40	6,17	1,49	1,12	2,08	0,63	0,06
E.M.S.		1,35	1,11	1,53	28,2	6,70	201,63	7,65	36,92	67,84	0,23	0,13
Means of 16 fabrics		8,5	14,9	15,6	77,1	4,0	113,6	17,1	70,1	269,4	0,8	2,6
95% confidence limits		±0,6	±0,5	±0,7	±2,8	±1,3	±7,1	±1,4	±3,0	±4,1	±0,2	±0,2

* Significant at the 5% level
** Significant at the 1% level
*** Significant at the 0,1% level

Fabric Properties:

A summary of the factorial analyses of the results of the fabric properties is presented in Table V. The experimental design was that of an incomplete three factorial experiment with three composition levels, three polyester types and two finishing treatments. The missing data were for two fabrics which were not available (40/60 composition, HB polyester, "D" and "K" finished). An attempt was made to treat the results by the missing values method$^{(6)}$: Each set of treatments "D" and "K" was taken separately and considered as a two factor design of compositions and *p* polyesters. The missing value could be estimated by the formula:

$$X = \frac{cC + pP - G}{(c-1)(p-1)} = \frac{3(C+P) - G}{4}$$

where C is the total for the composition column with the missing item, P the total for polyester row with the missing item and G the grand total.

The factorial analyses for each property separately, excluding the results of the pure wool fabrics, could then be carried out on the completed 3 factorial design, with the degrees of freedom for both the error and for the total decreased by 2 (namely total d.f. = 15 instead of 17). Multiple regression analyses were also carried out on some of the measured properties with composition and yarn count as independent parameters. The results are summarized in Table VI, where b_1 and b_2 are the regression coefficients for composition and count respectively.

Mechanical Properties:

The mechanical properties of the fabrics are summarized in Table III.

It was originally planned to weave the fabrics in such a way that in their finished state they would all have the same structure and density. The high-bulk polyester fibres did, however, shrink more after finishing than anticipated, so that the density and thickness of the fabrics comprising these fibres were slightly higher than those of the other fabrics. The air-permeability of these fabrics was, accordingly, also lower, due to their increased compactness which restricted the air-flow. The cover factors of the fabrics were calculated from the yarn counts prior to finishing, so that they do not account fully for variations which really exist in the finished fabrics. In spite of this fact a correlation was obtained (at the 5% level) between the air permeability and the cover factor for all 18 fabrics ($r = 0{,}48$, $t = 2{,}18$).

The bursting strength results were found to be correlated with the breaking strength test results ($r = 0{,}99$, $t = 27{,}5$ significant at the 0,1% level) so that similar trends are shown in both tests: the strength increases significantly with the increasing polyester component, the normal polyester type being stronger than the other two types. Fabrics which had been autoclave-decatised had breaking strength values which were approximately 7% lower than those of the decatised fabrics although this difference was non-significant (see Table V).

The extension-at-break was also slightly affected by the treatment, the autoclave decatised fabrics having a slightly lower extensibility. Extension-at-break was

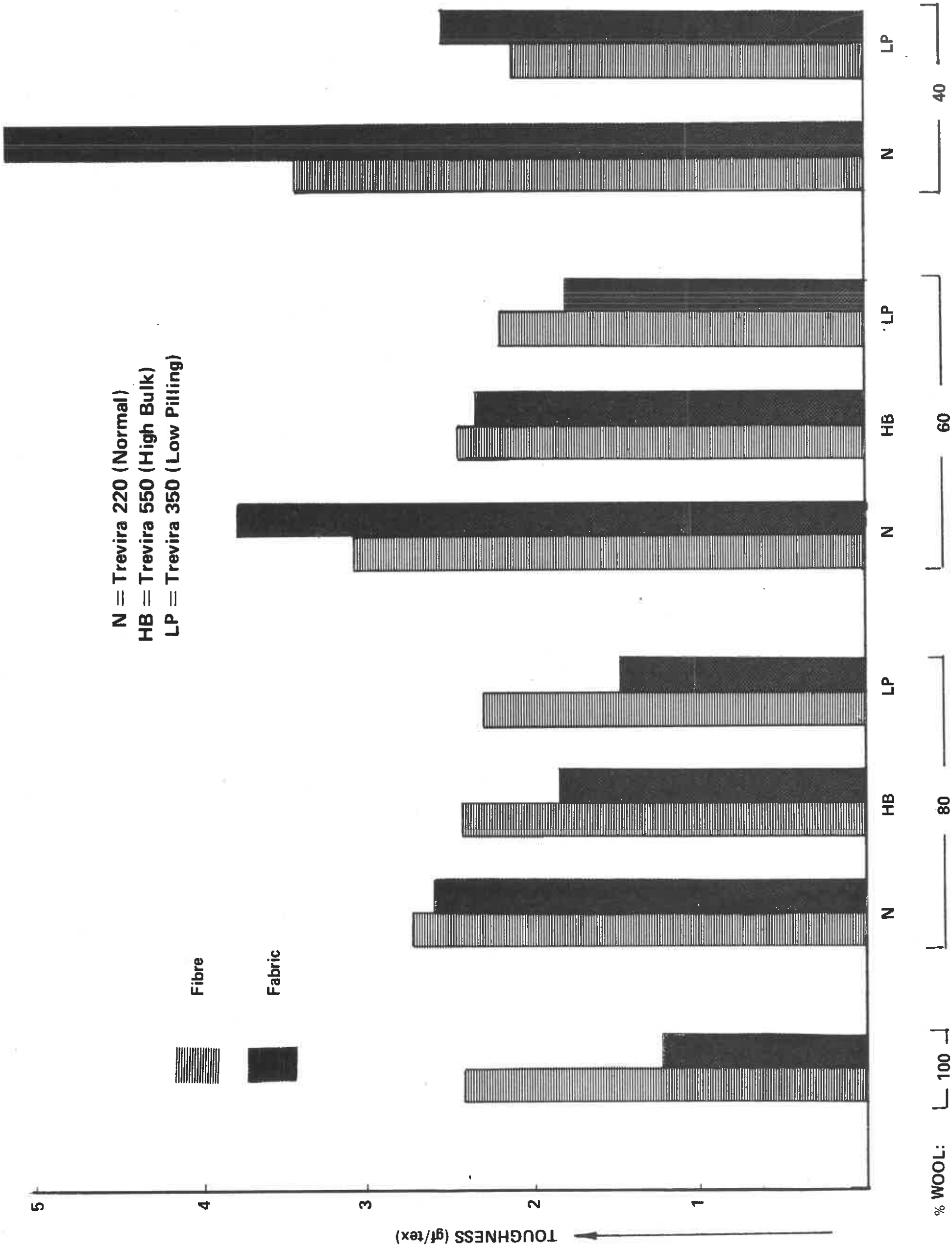

Figure 3: Toughness of Blends

TABLE VI

THE DEPENDENCE OF SOME FABRIC PROPERTIES ON COMPOSITION AND YARN COUNT

y = Dependent Property	$y = bo + b_1 x_1 + b_2 x_2$				n = 18		F	S	Means of 18 Fabrics	C.V. (%)
	x_1 = wool composition		x_2 = yarn linear density							
	b_1	t_1	b_2	t_2	bo	R				
Fabric Density (g/m^2)	-0,166	-0,33	0,697	0,35	189,315	0,397	1,40	11,09	207,0	5,4
Fabric Thickness (mm)	-0,001	-0,69	-0,001	-0,05	0,539	0,253	0,51	0,05	0,47	45,5
Air Permeability	0,018	0,52	0,069	0,22	4,505	0,159	0,20	1,72	8,6	20,0
Bursting Strength (Kgf/cm^2)	-0,163	-3,39***	0,270	0,64	14,033	0,854	20,20***	2,36	14,3	16,5
Breaking Strength (gf/tex)	-0,219	-3,50***	0,280	0,51	17,785	0,854	20,29***	3,07	14,8	20,7
Martindale Mass Loss (%)	0,036	0,672	-1,06	-1,06	30,073	0,528	2,90	3,55	4,6	77,2
Flexural Rigidity (mgf cm^2/cm)	-0,634	-1,70	0,239	0,07	142,377	0,596	4,12*	18,24	110,0	16,6
Wrinkling after washing (H x T, mm x 10^2)	0,051	1,34	-0,433	-1,31	16,111	0,724	8,28**	1,85	1,6	115,6

* denotes significance at the 5% level;
** denotes significance at the 1% level;
*** denotes significance at the 0,1% level.

highest in the blends containing the high-bulk polyester and lowest in the low-pilling polyester blends. In general, the extension at break increased with the increasing percentage of polyester.

The overall tensile performance of the fabrics can be expressed by their toughness values (work-to-rupture). The calculated toughness values (in gf.cm per tex. cm) are represented in Figure 3 for the fabrics and for the average fibre values. These results show that whereas toughness increases with increasing amounts of polyester in the blend, the normal polyester type (N) is superior in all cases to the other types, both for the fibre and the fabric state.

The efficiency of strength transfer from fibre to fabric, increases rapidly with the increasing polyester component, and decreases slightly with autoclave-decatising.

In the Martindale test, where samples were exposed to 30 000 rubbing cycles, fluff was removed by brushing and no pills could be observed even in the initial stages of the test. All the fabrics showed a very good resistance in this test, the loss in mass of most fabrics not exceeding 5%. The pure wool fabrics performed worst in this test and the high bulk polyester blends were inferior to the other polyesters in the blends. Finishing had no significant effect on the results. Only when observing the mean values of both "D" and "K" fabrics the differences in polyester types became significant (at the 1% level), the normal type being best and the high-bulk worst in this test of abrasion resistance. It therefore seems as though the normal and low-pilling polyesters are more abrasion resistant than the pure wool, so that with increasing amounts of these fibres in the blends, the loss in mass decreases. On the other hand the increase in mass loss with the increasing high-bulk polyester component indicates that this polyester type is less resistant to abrasion than the wool itself.

Bending and Wrinkling:

The performance of the wool/polyester blend fabrics in the bending and wrinkling tests is summarized in Table IV, and the analyses of some of the test results are included in Tables V and VI.

The flexural rigidity of the "D" and "K" series illustrated in Fig. 4 shows a significant decrease (at the 1% level) in stiffness after autoclave-decatising. A general trend of increasing flexural rigidity with the increasing polyester content is observed (with a 5% level of significance, Table V). This appears to contradict some previous work by Mehta(7) on double jersey fabrics in which he found the bending length and flexural rigidity to decrease with an increase in synthetic fibre content.

The flexural rigidity as determined by Owen's bending test (B) was, as usual, lower than that obtained by the cantilever method, but a very good linear correlation was obtained between these two parameters ($r = 0{,}91$, $t = 8{,}6$, significant at the 0,1% level). The effect of finishing on B was significant, while the differences between the polyester types became non-significant. Again, B increased with increasing amounts of polyester in the blends. The frictional couple (Mo) increased with increasing amounts of polyester (5% level) and it was highest in the high-bulk

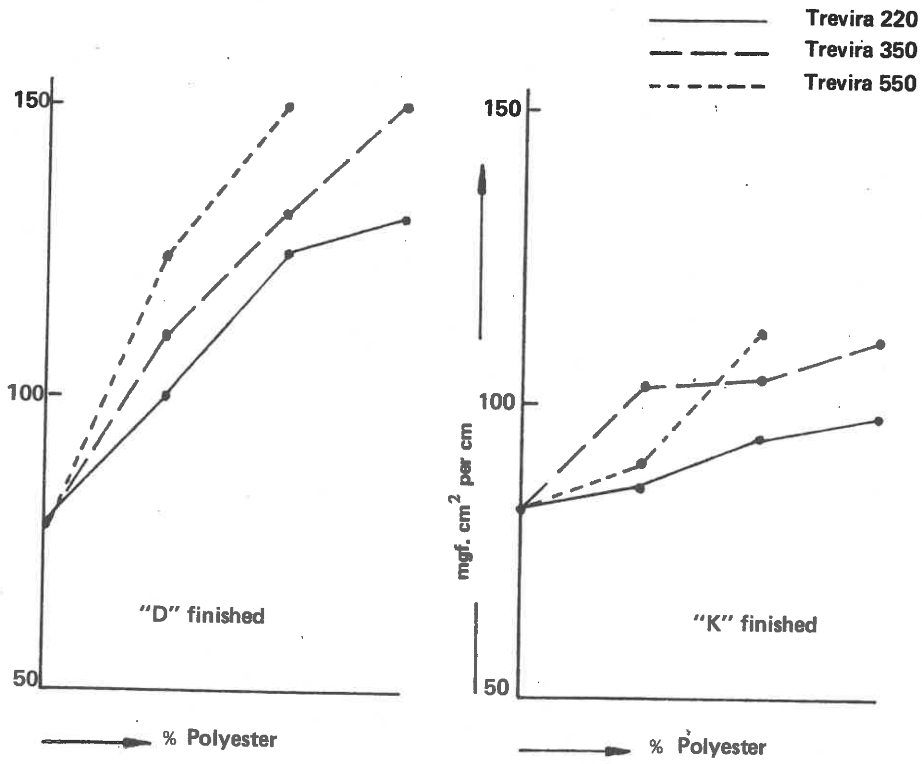

Figure 4: Flexural rigidity of blends

blends. The frictional couple was found to be affected significantly (1% level) by autoclave-decatising which seems to have reduced the internal friction by about 40%. Some contradictory trends were thus found in the Mo results: When the same fabric was finished by different procedures (i.e. "D" or "K"), the decrease in Mo was usually associated with an improvement in the wrinkling performance. This was found to be true under all test conditions, indicating improved rates of recovery from bending after autoclave-decatising. On the other hand the increasing polyester content also brought about considerable improvements in wrinkling performance, but it was associated with increasing frictional couples – the pure wool had the lowest Mo while it wrinkled worse, particularly after washing. It is, however, interesting to note that in spite of the strong effect of composition on Mo and wrinkling, the low pilling polyester blends showed better wrinkling performance than did the other fabrics as well as lower Mo values when similar blend compositions were compared. It therefore seems justified to assume that lower Mo values in similar types of fabrics indicate better wrinkling performance, and that conflicting trends are caused by interacting effects of recovery times and structural parameters.

It is also difficult to draw conclusions about the relationship between wrinkling and flexural rigidity. Although stiffer fabrics tend to have a better resistance to wrinkling, their recovery is poor, so that only this residual effect should be correlated with the crease recovery angle or wrinkle severity index. The crease recovery angles of the fabrics did not differ significantly, so that only the H x T results after washing were compared with the flexural rigidity results, and a correlation (at the 5% level) was found between these results ($r = 0{,}45$, $t = 2{,}2$) which confirms the trend for stiffer fabrics to wrinkle less, or, that the ability to resist wrinkling by being stiffer is a more dominant factor than the ability of such fabrics to recover from wrinkling. This trend may however be reversed in different types of structures and cannot be considered as a general trend.

The area shrinkage decreased with the introduction of the polyester fibres, even in the 80/20 blends, and it also decreased significantly in the "K" series. The H x T results after washing were correlated (at the 0,1% level) with the area shrinkage results ($r = 0{,}97$, $t = 16{,}4$), showing that a satisfactory dimensional stability is a pre-requisite for durable press performance.

Crease recovery angles under standard atmospheric conditions were found to be approximately 40° higher than those obtained under the two higher humidity conditions, both of them not having been found to yield significantly different results. Introducing the polyester fibres in the blend hardly affected the crease recovery angle test results, as they were not improved significantly in comparison with the pure wool fabric, even when tested under high humidity conditions.

The wrinkle severity index, after FRL creasing under high humidity conditions (75% R.H., 27°C), shows that after autoclave-decatising, the pure wool fabric recovers from creasing to an extent which is comparable to that of some of the blend fabrics. The low pilling polyester performed best in this test as well as in the washing test, and increasing the amount of polyester to above 20% effected no further improvement. In the H x T results, after washing, the 60/40 wool/polyester blends showed a significant improvement over the 80/20 blends. If both tests therefore, which account for wet and dry wrinkling, are taken into account, it may be concluded that the percentage polyester in the blend does not have to exceed the 40% level for maintaining a good overall performance.

The general effect of composition and yarn count:

A summary of some of the regression analyses carried out is presented in Table VI. The dependent variable was the property tested, and the independent variables were the composition (% of wool) and the yarn count. The analyses were made in order that the variation in the property due to these parameters might be explained. The table gives the *t* values of the regression coefficients b_1 and b_2 of the bi-variate regression analyses, as well as the total correlation coefficient (R), the 'F' values and their significance levels, the square root of the residual variance (S in the same dimensions as the property), the overall mean of the fabrics and the coefficient of variation between fabrics (C.V.). For all the analyses there were 18 sets of results.

The only *t* values which were significant were those for composition in the analyses, with bursting strength and breaking strength as dependent variables. The increase in bursting and breaking strength with decreasing amounts of wool was most pronounced, whereas the increase in flexural rigidity and the improvements in wrinkling after washing with increasing amounts of polyester were only indicated by less significant R values.

A trend of the coarser yarns being associated with a better wrinkle resistance was observed (R significant at the 1% level), in agreement with Looney and Handy(2). The differences in yarn count were apparently too small to contribute significantly to the wrinkling and other properties of the fabrics.

The effect of composition and yarn count on fabric density was negligible (C.V. = 5,4%), while the thickness of the fabrics varied much more, due to the high-bulk polyester fibres. The highest variation (C.V. = 115,6%) due to composition and count was observed in the wrinkling-after-washing results, where the introduction of the polyester component had drastically reduced the H x T values even in the 80/20 wool/polyester blends.

CONCLUSIONS

Increasing amounts of polyester improved the mechanical performance of yarns and fabrics.

The breaking strength and the efficiency of transfer of fibre properties to the yarns and the fabrics was best for the fabrics made from normal polyester fibres, and worst for the high-bulk polyester fibres.

The high-bulk polyester fibres produced thicker and less porous fabrics, having high extensibilities, low tenacities, low mass retention in abrasion tests, increased flexural rigidity and inferior wrinkling performance when compared with those from the other two polyester types.

The advantage of using the low pilling polyester fibres on account of their lower pilling propensity was not substantiated, as neither of the blends with the other polyester types showed any significant tendency to pill formation. It was found, however, that the fabrics made of these low pilling fibres were superior in their wrinkling performance to the other polyesters, when comparing fabrics of the same composition levels, and the 60% wool and 40% low pilling polyester blend fabric was very satisfactory in all tests.

The flexural rigidity and frictional couple increased with increasing polyester content with the decatised fabrics showing a greater increase than the autoclave-decatised ones. The normal polyester type produced the lowest values for stiffness, and the low pilling polyester yielded the lowest frictional couples.

When the fabrics were autoclave-decatised it was found that 40% polyester was sufficient for obtaining satisfactory durable press performance with untreated wool blends. On the other hand if decatised only, the fabrics were less efficiently set and the amount of polyester required for obtaining a similar performance should be 20% higher.

The cooling procedures which were applied, in which the fabrics were either quenched in water or left to cool on a roller, did not result in any noticeable differences in the measured properties.

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