OPTIMIZATION OF BLEND RATIO AND TWIST MULTIPLIER FOR RING SPUN POLYESTER/COTTON YARNS
PART I: TENSILE PROPERTIES

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Abstract

The study reported in this paper concerns the influence of polyester ratio on the tensile properties of ring spun polyester/cotton yarns of various twist multiplier. For polyester percentage ranging between 33% and 67% and twist multiplier ranging between 3.2 and 4.2, it was found that the twist multiplier has insignificant effect on tenacity, extension, work of rupture and quality index. Also that yarn irregularity is not greatly affected by the polyester ratio in the blend. And for all values of twist multiplier the yarn quality index increases with the increase of the polyester ratio. For the count strength product (CS) it was found to be greatly affected by the polyester ratio but very slightly affected by the twist multiplier.

For 15 tex polyester/cotton yarn (combed cotton-20% noil) the best quality index is obtained for the ratio 67% polyester and at any twist multiplier within the range 3.2-4.2, while for the best CS-product the optimum polyester ratio and twist multiplier are 67% and 3.7 respectively.

1. INTRODUCTION

The blend ratio and twist multiplier are some of the most important factors for yarn quality, as they affect to great extent the tensile properties and irregularity of the produced yarn. The importance of the present work is the logical usage of the expensive Egyptian cottons with other cheaper synthetic fibres to produce high quality yarns that could be used for producing knitted under wear, and apparel fabrics. Blending of two or more types of fibres is widely used to produce yarns of different qualities, that can not be obtained by using one type of fibre alone. One of the basic directions is the blending of polyester fibre with cotton, with a percentage of at least 33% for the former.

In fact the blending of polyester with cotton does not diminish the properties of cotton yarn that used for knitting or for weft yarn purposes, since the polyester added to the cotton keeps these properties and improve the quality charact eristics. For examole wear resistance and overcoming shrinkage when washed.

Without twist, a strand of fibres has very little strength and in the first instance a cotton/polyester yarn must have sufficient tensile strength to withstand the stresses of preperation and fabric manufacture. Nevertheless , the main function of twist is to give coherence to the yarn. So in order to develop strength in a twisted strand of staple fibres, such as cotton/polyester yarn, and so resist breakage, the individual fibres must grip each other when the strand is stressed. This cohesion arises mainly

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from the twist, which presses the fibres together as the stretching force is applied and so develops friction between the adjacent fibres. The pressure results from stressing the twisted strand and has it's origin in the tension applied to the helixes of the individual fibres. It is important to realise that the lateral pressure has no seperate existance untill the twisted element is stressed.

From the above it is evident that there are two factors to be considered, which can be combined to obtain the best possible qualities; these are the cotton/polyester ratio and the twist multiplier.

In the present study yarns of different blend ratio have been produced from combed Egyptian Giza 75 cotton (common type of cotton in the mills) and polyester fibre, to determine the optimum polyester ratio and twist multiplier.

The experiments involved the use of two variables namely X_1 (the polyester ratio) and X_2 (the twist multiplier) and the responses were the tenacity, extension, count-strength product, work of rupture, irregularity and yarn quality index.

Although the proplem of blending has been examined by many investigators, but in these investigations the influence of both cotton/polyester ratio and twist multiplier has been examined experimentaly, and seperately on tensile strength and irregularity of the produced yarns[1]. However, no published research in this field dealing with the proplem in the manner followed here or previously appeared in the literature of yarn physics.

2. YARNS STUDIED AND EXPERIMENTAL PLAN

The yarns examined in the present investigation are spun from a blend of Giza 75 and polyester staple fibres. From the different blend ratio a 15 tex (N_e = 40.) yarn was produced with three twist multipliers nomely 3.2, 3.7 and 4.2 . All the blending operations have been carried out at the drawing stage. Combed (20%) cotton slivers were blended with polyester slivers at the first drawing frame and the required blend ratio was obtained by altering the sliver weight. The blends were 33/67, 50/50 and 67/33 (polyester/cotton).

Given in Table. 1 the main properties of the components used for producing the blended polyester/cotton yarns.

Table. 1. Main Properties of Giza 75 and Polyester Fibres Used.

Property / Type of Fibre	Cotton (Giza75)	Polyester
mean length (mm)	31	38.5
Fineness (millitex)	160	156
Strength (g./tex)	31.8	53.1
% extension	5.62	22

The Uster Tensomat was used to determine the most important properties, i.e. strength, extension at break and work of rupture. And for yarn irregularity measurment, the Uster Evenness tester II was used.

The quality index of the yarn (Q. I) was calculated from the equation;-

$$Q.\,I = \frac{\text{Tenacity (g / tex)} \times \text{Extension (\%)}}{\text{Uster coefficient of variation (\%)}} \qquad \dots (1)$$

This equation was proposed and used by Barrella[2], to assess the quality of open-end yarns when processing parameters are altered.

The experimental plan was orthogonal plan for two variables. The variables were X_1 the polyester ratio, and X_2 the twist multiplier αe. The levels of the variables are given in Table 2.

Table 2. Levels of Variables

Level	Variable	
	% of polyester	twist multiplier αe
	X_1	X_2
+ 1	67	4.2
0	50	3.7
- 1	33	3.2
interval	17	0.5

The yarns were produced with low and medium twist multiplier for knitting and filling purposes in knitting and weaving respectively.

3. RESULTS AND ANALYSIS

The planning matrix and the results of the experiments carried out are given in Table 4.

The investigation was designed from the begining to be suitable for analysis by means of two-variable design 3,4. From the analysis the equations of the response surfaces and other statistical parameters were obtained.

The regression equations for the response surfaces can be represented by the following equation:-

$$\hat{Y} = b_0 + b_1X_1 + b_2X_2 + b_{11}X_1^2 + b_{12}X_1X_2 + b_{22}X_2^2 \qquad \dots (2)$$

The equations of the response surfaces, an analysis of variance, and other statistical parameters were obtained. Table 3 shows the coefficients in the regression equations.

Table 3. Regression Coefficients of the Response Surfaces

$$y = b_o + b_1 X_1 + b_2 X_2 + b_{11} X_1^2 + b_{12} X_1 X_2 + b_{22} X_2^2$$

Parameter \ Coefficient	b_o	b_1	b_2	b_{11}	b_{12}	b_{22}
Tenacity (g/tex)	15.851	1.836	(0.478)	(0.302)	(-0.267)	(-0.679)
Extension (%)	5.905	1.348	(-0.311)	(0.120)	(-0.194)	(0.153)
Work of Rupture(g.cm)	386.03	135.807	(-14.805)	(22.827)	(-22.02)	(4.972)
Irregularity (C.V.)	16.04	(-0.131)	-0.325	(-0.443)	(0.238)	(0.311)
Quality Index (Q.I)	5.815	2.083	(-0.049)	(0.5565)	(-0.3468)	(-0.1575)
Count-strength product (CS)	2819.65	106.67	126.67	(92.2)	- 220	-207.8

(. . . .) denotes insignificant coefficient.

In fact the two equations (3) and (4) concerning the relationship between the count-strength product (C.S.P.) and single end tenacity (g/tex) and blend ratio (X_1) and twist multiplier (X_2), do not show any differences with respect to the effect of blend ratio and twist multiplier, and both have direct effect or by interaction on the two mentioned properties. So there is no any physical difference between the two equations.

$$\text{Tenacity} = 15.851 + 1.836 X_1 + \underline{0.478} X_2 + \underline{0.302} X_1^2 - \underline{0.267} X_1 X_2 - \underline{0.679} X_2^2 \quad .. (3)$$

$$\text{CS} = 2819.65 + 106.67 X_1 + 126.67 X_2 + \underline{92.2} X_1^2 - 220 X_1 X_2 - 207.8 X_2^2 \quad .. (4)$$

In fact the two equations of tenacity (g/tex) and count strength product (C.S.P.) are the same and concides with the general following equation :-

$$y = b_o + b_1 X_1 + b_2 X_2 + b_{11} X_1^2 + b_{12} X_1 X_2 + b_{22} X_2^2$$

But with statistical analysis it was found that the coefficients underlined in equations (3), and (4), are insignificant. Hence these coefficients have been eliminated because of it's lòw effect, and this can be shown from the calculated and measured values. The addition of these coefficients with X_2 give large differences between calculated and measured values.$_2$ Also that the sum of the values from X_2 (i.e.$126.67 X_2 + 92.2X^2 - 220 X_1 X_2 - 2078 X_2^2$) in the equation of CS - product, is not of a weight on the value of the count strength product and does not exceed in average + 5 % from the maximum value of count strength product. And hence the count strength product, showed the very small effect of the twistmultiplier, therefore there is no physical difference between the two forms of the equations (since the tenacity of the single end and the count-strength product of the skein still depend to a large degree on blend ratio). But the effect of twist multiplier was of a less weight because it's range is not wide, the twist multiplier ranges between 3.2 and 4.2 for weft yarn of the present work.

Table 4 . Experimental Conditions and Results of Properties of Polyester / cotton Yarn

Experiment No.	Factors		Linear Density (Tex)	Tenacity (g / tex)		Extension (%)		Work of Rupture (g. Cm)		Irregularity (c.v %)		Q. I		C S	
	X_1	X_2		Exp.	Cal	Exp.	Cal	Exp.	Cal.	Exp.	Cal.	Exp.	Cal.	Exp.	Cal.
1	-	-	14.61	12.86	14.02	4.89	4.56	263.4	250.2	16.89	16.37	3.72	3.73	2160	2158.5
2	+	-	14.72	17.57	17.69	8.18	7.25	597.5	521.8	15.91	16.37	9.00	7.90	2960	2811.9
3	-	+	14.50	14.05	14.02	4.67	4.56	278.2	250.2	15.81	15.72	4.17	3.73	2880	2851.9
4	+	+	15.09	17.69	17.69	7.18	7.25	524.2	521.8	15.78	15.72	8.06	7.90	2800	2625.2
5	-	0	14.67	14.41	14.02	4.87	4.56	293.8	250.2	15.35	16.04	4.75	3.73	3000	2713.0
6	+	0	15.21	17.57	17.69	7.15	7.25	528.6	521.8	15.57	16.04	8.09	7.90	2920	2926.3
7	0	-	14.40	14.48	15.85	6.37	5.90	408.5	386.0	16.58	16.37	5.60	5.82	2560	2485.2
8	0	+	14.98	16.04	15.85	5.72	5.90	378.1	386.0	15.84	15.72	5.81	5.82	2760	2738.5
9	0	0	14.98	15.20	15.85	5.75	5.90	369.6	386.0	15.84	16.04	5.54	5.82	2640	2819.7

Table 5. Best Regression Equations For Yarn Property and the Variables X_1^* and X_2^{**}

Yarn Property	Regression Equation	F_{cal}^{***}	F_{table}^{***}	Level of Significance
Tenacity (g/tex)	Tenacity = $15.851+1.836\ X_1$	0.643	2.35	
Extension (%)	Extension = $5.905+1.348\ X_1$	0.797	2.35	
Work of Rupture (g . cm)	Work of rupture $=386.03+135.81X_1$	0.671	2.35	5 %
Irregularity (uster cv)	c.v = $16.040 - 0.325\ X_2$	1.170	2.35	
Quality index	Q.I. = $5.815 + 2.083\ X_1$	0.803	2.35	
Count - Strergth Product (CS)	$CS=2819.65+106.67X_1+126.67X_2 - 220\ X_1 X_2 - 207.80\ X_2^2$	3.637	2.50	

* X_1 - polyester ratio (%)
** X_2 - twist multiplier (%)
*** F - value

In fact one has to mention that when chosing the type of equation to be used for describing the relation-ships of the quality characteristics of the yarn and the polyester ratio and twist multiplier, it is necessary to study not only the effect of each factor seperately but also their effect together. For this reason the polynomial second order was chosen.

Given in table 5 the regression equations obtained for the various yarn properties, also given $F_{calculated}$ and F_{table} at 5% level of significance. The $F_{cal.}$- values obtained indicated that these equations could be used satisfactorily to describe the relationships and the prediction of these properties from the variables X_1 and X_2.

Plotted in Figs.1 to 8 the various yarn properties versus the polyester ratio (X_1) and the twist multiplier (X_2).

The correlation coefficients between the calculated and the experimental values are 0.915, 0.955, 0.973, 0.582, 0.964 and 0.864 for tenacity, extension, work of rupture. cv%, quality index and count-strength product respectiveley. These values are significant at the 5% level, when the t-test was used.

It was thought of a possible relationship between the yarn quality index and the work of rupture. This relationship was examined for the various yarns (9 types.) and it was interesting to find out (as may be seen also from Fig.8) that the Q.I. figure tends to increase with the increase in work of rupture. The correlation coefficient is very high ($r = 0.990$) and highly significant at the 5% level. The best fit equation is in the form of :-

$$Q.I = 0.0153 \; W.R. - 0.12897 \qquad \dots (5)$$

4 . DISCUSSION

The results obtained for the nine types of polyester / cotton yarn used in the present investigation have shown that tenacity, extension, work of rupture and quality index of yarn are greatly affected by the polyester ratio in the blend. Also that these properties increase when the percentage of polyester in the blend increases. This increase corresponds up to a certain point, which in fact is the highest level of polyester ratio used in the experimental design.

Also it was possible, using the regression equations obtained for the various yarn properties, and the variables of the experiment, i.e. the polyester ratio (X_1) and the twist multiplier (X_2), to predict satisfactorily tenacity, extension at break, work of rupture, and quality index. The differences obtained between the calculated and measured values are within the experimental error (Table 4) .

The regression equations obtained have shown that tenacity, extension at break, work of rupture, and quality index could be predicted from the knowledge of the polyester ratio X_1 only, while the count-strength product could be predicted from both the polyester ratio X_1 and the twist multiplier X_2. In addition to this the equations have shown that the c.v. of the yarn depends on the level of twist , though the differences in it's value for the nine types of yarn are within the experimental error.

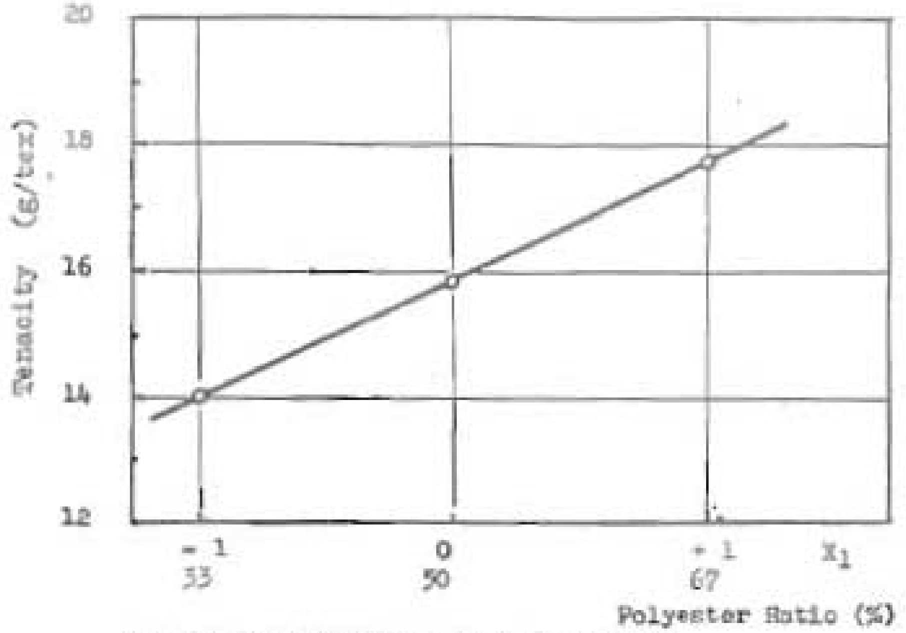

Fig.1 Relationship between polyester ratio and tenacity

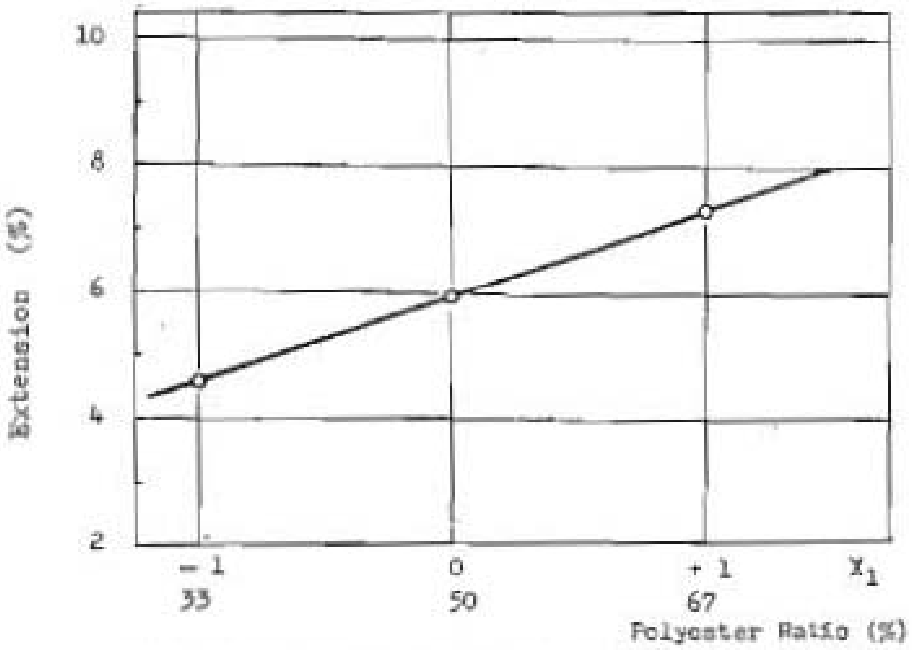

Fig. 2 Relationship between polyester ratio and extension (%)

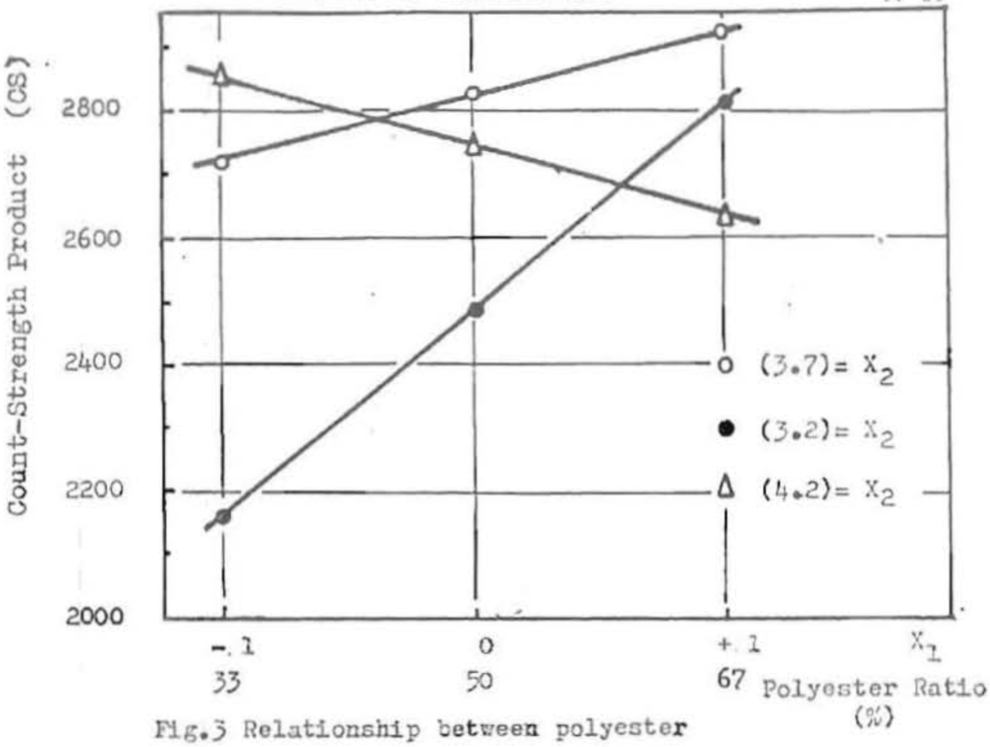

Fig.3 Relationship between polyester ratio and count-strength product

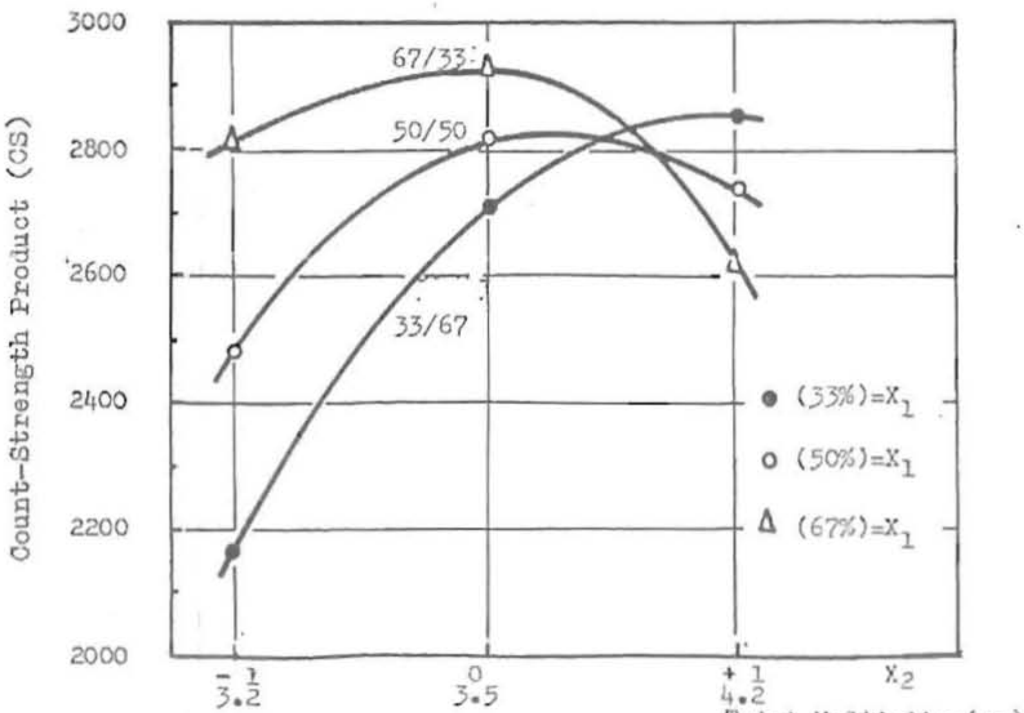

Fig.4 Relationship between count-strength product and twist multiplier

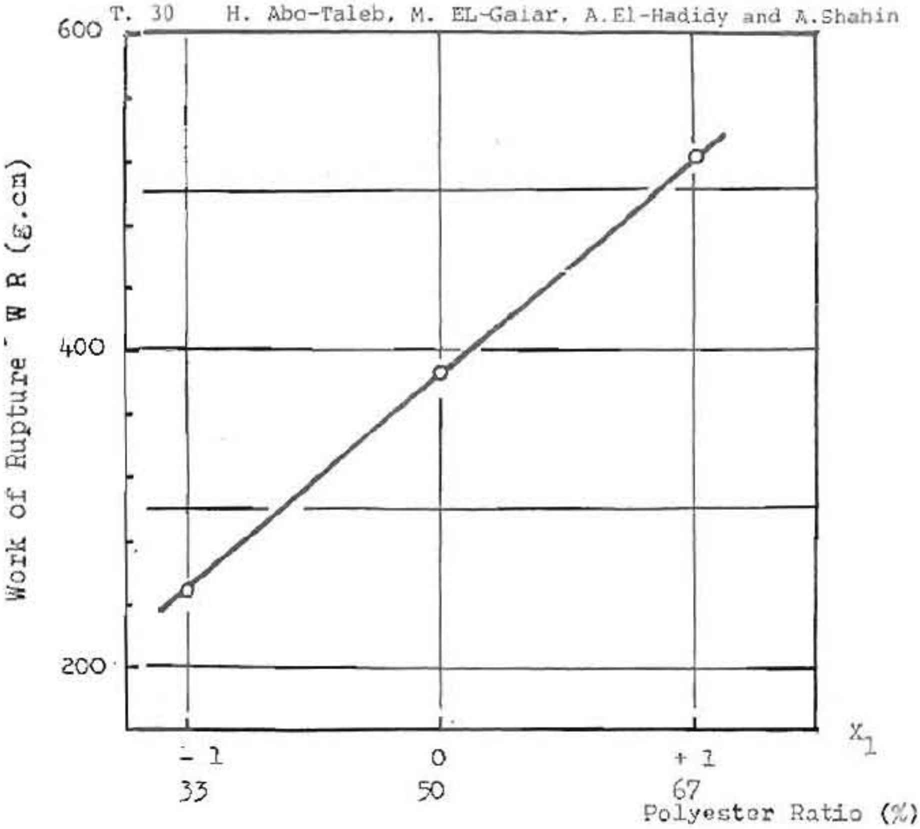

Fig.5 Relationship between work of rupture and polyester ratio

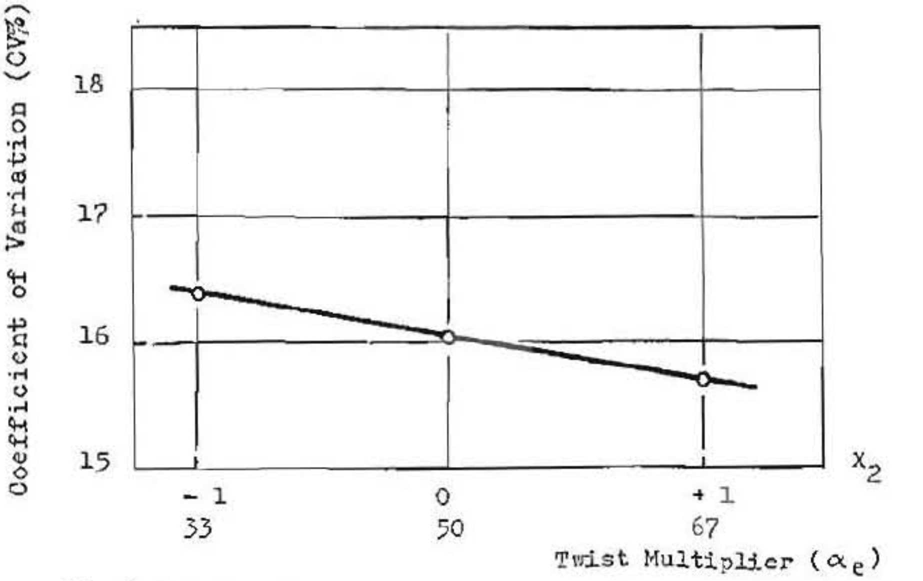

Fig.6 Relationship between coefficient of variation (C.V.) and twist multiplier

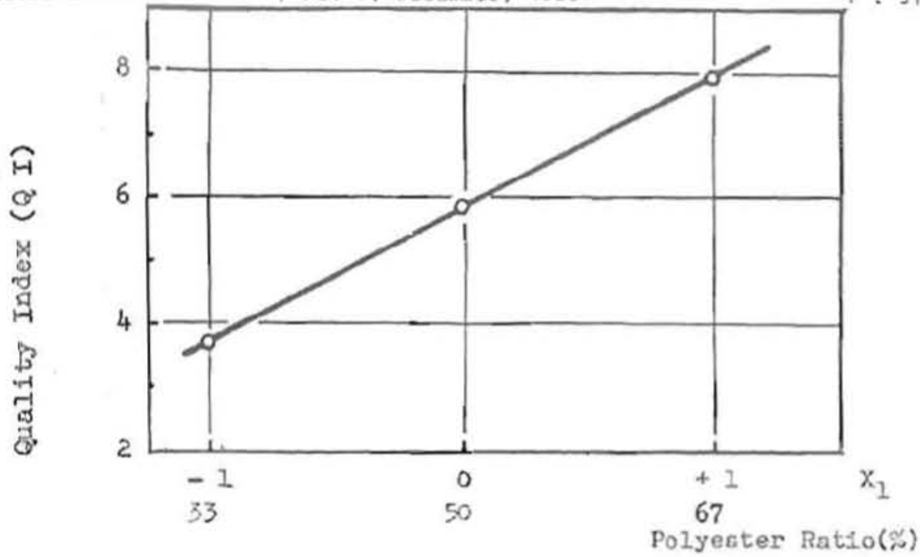

Fig.7 Relationship between yarn quality index (Q.I.) and polyester ratio

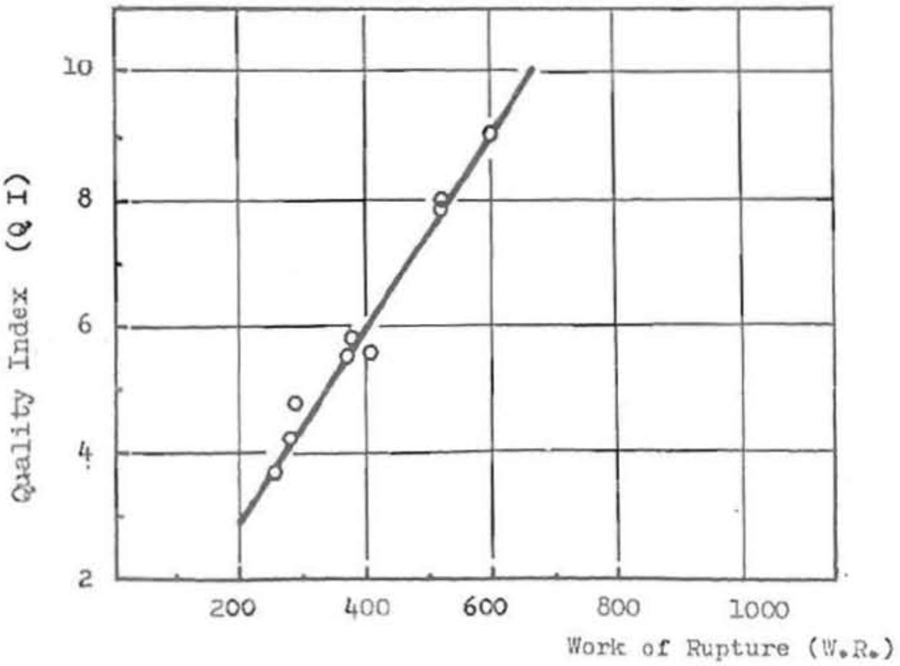

Fig.8 Relationship between work of rupture (W.R.) and quality index (Q.I.)

In fact the slight variation in the c.v. value for the nine types of blended yarn, would have a slight influence on the quality index value as obtained from equ.1.

Since in the routine tests of tensile properties of yarns, the work of rupture is determined automatically, it was thought of studying the relationship between the quality index and the work of rupture of single yarn. The results obtained have shown that there is a strong linear relationship between both. This in fact indicated that both of them could replace each other when judging yarn quality. Yarns of high work of rupture are also of high quality index.

One of the important relationships for the textile yarn is the count-strength product-twist multiplier relationship. This relationship has been examined in details for the variety of blended yarns of the present work. It was interesting to find out that for all blends the count-strength product reaches a maximum value at optimum twist and then falls. This in fact could be explained in the light of the traditional view of effect of twist on strength of staple fibre yarn. 3 - 7 . The rising portion can be interpreted as a region in which the resistance to slippage increases and the proportion of fibres which slip rather than break gradually decreases as the gripping due to twist increases. While the falling portion at high twists is clearly due to fibre obliquity in the yarn and is similar to the behaviour of filament yarn. For the variety of yarns used the optimum twist is around 3.7 for the blends 67/33 and 50/50 and around 4.2 for the blend 33/67.

The CS-product curves show two different trends between the levels of twist (3.2-3.7) and (3.7-4.2), while the 67/33 blended yarn shows the highest CS-Product compared to that of the 50/50 and 33/67 blended yarns, the situation differs completely at the latter level of twist. At the twist multiplier 3.9 the 67/33 blended yarn shows lower strength than that of 50/50 blended yarn. It is propable that at twists above this value the fibres of the 67/33 yarn becomes more oblique, hence the strength decreases.

In fact the CS-product curves for blended yarns could be used for the selection of yarns of equal strength, but with different polyester / cotton ratios. This will be governed by the cost factor and comfort properties when the yarn is to be used for making woven or knitted apparel fabrics, which is the aim of producing the yarns of the present work.

* CONCLUSIONS

1 - For ring spun polyester/cotton yarn, it was found that higher tenacity, extension at break, work of rupture and quality index are obtained for the blend ratio 67 /33 and twist multiplier of 3.2-4.2.

2 - For 67/33 polyester/cotton yarn, the optimum count-strength product is achieved at twist multiplier 3.7.

3 - Yarn irregularity was found to be less affected by the blend ratio, and generally slightly decrease with the increase of twist multiplier.

4 - The optimization equation ;

$$Y = b_o + b_1 X_1 + b_2 X_2 + b_{11} X_2^2 + b_{12} X_1 X_2 + b_{22} X_2^2$$

could be used satisfactorily to predict the various tensile properties, irregularity, quality index and CS-Product of polyester/cotton yarn made from any blend ratio and twist multiplier within the ranges used.

5 - The quality index parameter proposed by Barrella for assessing the quality of open-end yarns, proved it's validity for blended polyester/cotton ringspun yarns. It's value for polyester/cotton yarns ranging between 3.7 and 9.

6 - The quality index of the yarn is well correlated to yarn work of rupture and the best fit equation is in the form of ;

$$Q.I. = 0.0153\ W.R - 0.12897$$

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