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ANALYSIS OF BLENDED YARN STRENGTH

BY

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ANALYSIS OF BLENDED YARN STRENGTH

BY

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ABSTRACT:

A comparsion between the theoretical and actual yarn strength produced from different cotton/polyester blends. The predicted values verfies by experimental results are set in the paper. A non cooperation degree Ø for cotton/polyester blends is measured and through which a new method may be used for estimating the blended yarn strength.

1. INTRODUCTION:

Blending of two or more types of fibres is used to produce yarns with qualities that could not be obtained by using one type of fibre. One of the principle qualities of yarn is its strength. In this study the aim was devoted to the differentiation between the various methods[1,2,3,4] for determining the blended yarn strength and discussing their practicability. Also, this work reports a method for estimating the blended yarn strength.

2. THEORETICAL ANALYSIS OF YARN STRENGTH:

Theoretical calculation of the strength of blended yarn can be made through one of two methods:

The first method is based on the properties of the two components and their proportions in the blend.

Hamburger[1] assumed segregated of independent action, with complete cooperation of like fibres. He expressed the

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strength of blended yarn as a function of the stress. Strain relation of its component fibres. Figures (1-a,b) depicts the strength of the blended yarn for various compositions of two different types of fibres. If B_1 and B_2 are the proportions of fibres A_1 and A_2 by weight, P_1 and $_1$ are the ultimate tenacity and extensibility of fibre A_1, respectively, and P_2, $_2$ are those of fibre A_2. Also he derived the following mathematical form for the strength of blended yarn.

$$\bar{P}_{\varepsilon 1} = B_1 P_1 + B_2 \left(P_2 \cdot \frac{\varepsilon_1}{\varepsilon_2}\right) \qquad \text{........E.(1)}$$

where:

$\bar{P}_{\varepsilon_1}$ = The strength of blended yarn at the rupture of all fibre A_1, i.e., at the first rupture point.

$P_2 \frac{\varepsilon_1}{\varepsilon_2}$ = The stress supported on fibre A_2 for extension of ε_1

Similarly, the yarn strength predicted for the second rupture point is given by:

$$P\varepsilon_2 = B_2 P_2 \qquad \text{........E.(2)}$$

The analysis shown in Figures (1-a, b) indicates that: If the breaking elongation of fibre A_1 in creases then the stress supported by fibre A_2 at the breaking point of fibre A_1 ($P_2 \varepsilon_1/\varepsilon_2$) increases, i.e., the strength of the blended yarn increases. Further more, when ($P_2 \varepsilon_1/\varepsilon_2$) becomes greater than P_1 for all values of the proportion of B_1 component, the strength of the blended yarn becomes greater than the yarn made from 100% of weaker component.

If $P_2 \frac{\varepsilon_1}{\varepsilon_2} = P_1$, the strength of the blended yarn becomes equal to the yarn made from 100% of weaker component, and If $P_2 \varepsilon_1/\varepsilon_2 < P_1$, the strength of the blended yarn becomes lower than the yarn strength produced from 100% of weaker component.

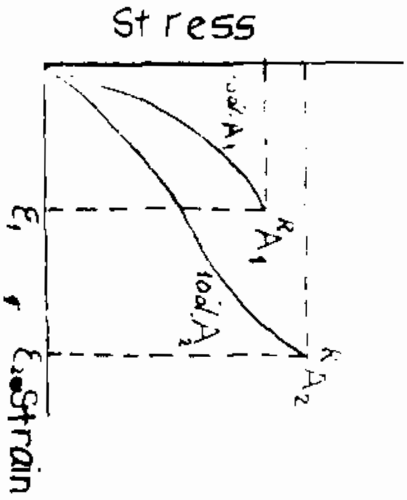
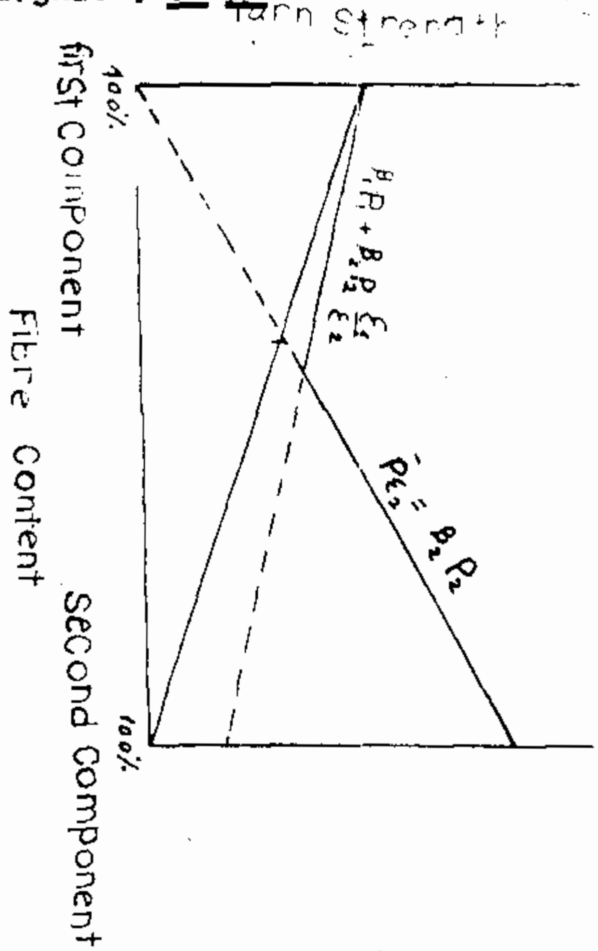


FIG (1b) Stress Strain curve of Blend Component



1b. The Strength OF Blended Yarn

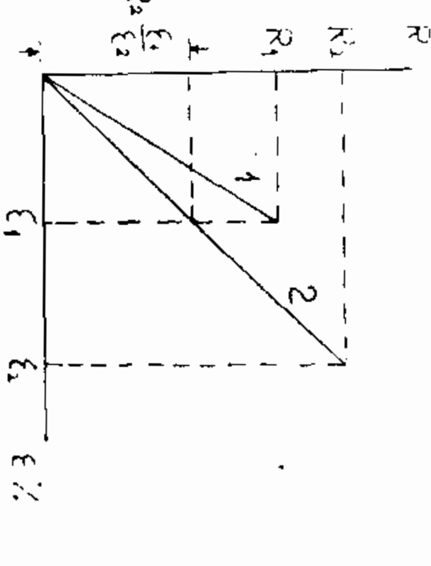


FIG (2) a The Load Extension Diagram

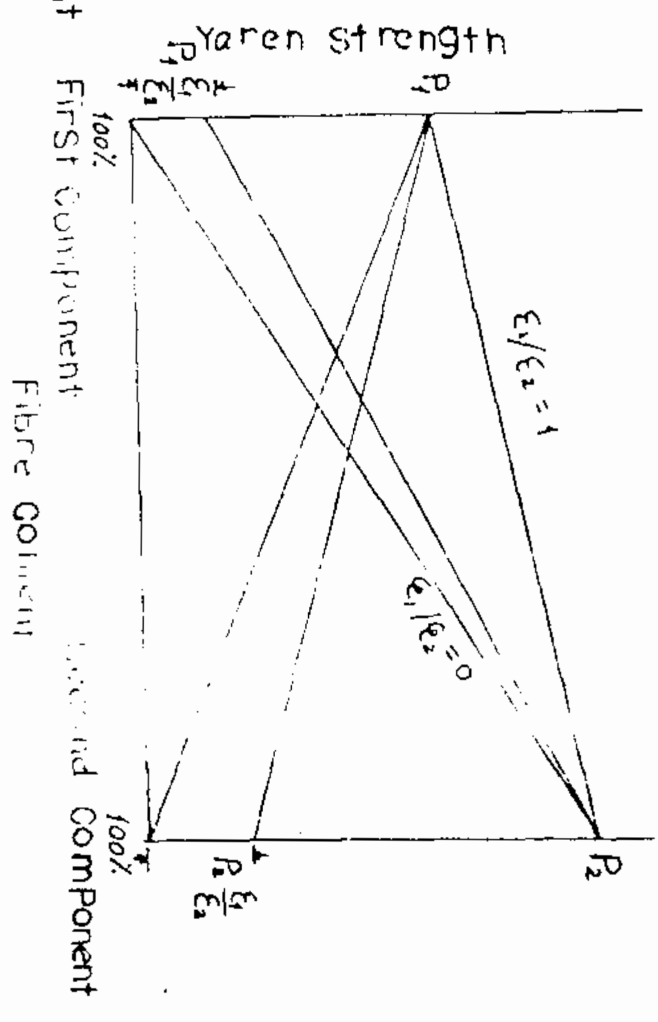


FIG (2) b The Strength Of Blended Yarn

Saksina and Kofman[2] gave a geometrical method which describes the determination of the blended yarn strength from two dissimaller components in relation to the fibre properties and their proportion in blend. They assumed the following:

- The relation between the extension and fibre load is linear,
- At the instant of yarn rupture all fibres in the yarn cross-section were considered to break without any fibre slippage, and,
- The strength and breaking extension are greater in the case of the second component fibre.

They gave, as shown in Figures (2-a, b), the prediction of the strength of blended yarn at:

$$\frac{\varepsilon_1}{\varepsilon_2} = 0 \quad \text{i.e. } \varepsilon_2 \text{ approach to inifinity,}$$

$$\frac{\varepsilon_1}{\varepsilon_2} = 1 \quad \text{and}$$

$$1 > \frac{\varepsilon_1}{\varepsilon_2} > 0$$

Also, they deduced the minimum strength of the blend and the percentage of the strong component B_2 for a yarn by using the following formula:

$$\bar{P} = (P_1 \frac{\varepsilon_1}{\varepsilon_2}) B_1 + B_2 P_2 \qquad \text{........E.(3)}$$

and

$$B_2 = \frac{\bar{P}\,\varepsilon_2 - P_1\,\varepsilon_1}{P_2\,\varepsilon_2 - P_1\,\varepsilon_2} \qquad \text{........E.(4)}$$

The second method:

Is based on strength of yarns having 100% of either component and the strength of one blend.

- The two components would cooperate 100% and then,
- The two components are independent as possible when elongation at breaking is quite different.

Ratnam et al.,[3] determined the strength of the blend yarn in relation to the blend proportion in a parabolic form:

$$\bar{P} = P_1 + B_2 (P_2 - P_1) - 4 \emptyset [B_2(1 - B_2)] \quad .....E.(5)$$

Also, the predicted yarn strength has been given by another expression, which includes trigonometric form by Ewald et al.[4]

$$\bar{P} = P_1 + B_2 (P_2 - P_1) - \emptyset \, Sin \left(\frac{B_2}{50} 90°\right) \quad .....E.(6)$$

Where:

$\bar{P}$ is the predicted yarn strength

P_1, P_2 are yarn strength of 100% of the two components

B_1, B_2 are proportion of the second component

$\emptyset$ is a Non-Cooperation factor equal to $K \left(\frac{P_1 + P_2}{2}\right)$,

where $K = \frac{1}{3}$ at the 50% point of the simple average yarn strength. Also, considering that the values of $\emptyset$ probably governed by three factors: The differences in elongation crimp and surface properties between the fibres.

In the present work,[6] a trial is made for estimation of blended yarn strength in relation to the proportion in the blend for a given yarn number from the strength of the yarns having 100% of either components. As to substantiate this relation considering the two extreme cases are discussed above.[3,4]

- Yarn strength of cooperating blend i.e. $\mathcal{E}_1 = \mathcal{E}_2$, the strength would follow the simple weighed average as shown

$$\bar{P}_1 = P_1 B_1 + P_2 B_2 \qquad \text{........E.(7)}$$

- Yarn strength of non-cooperating blend when extension at breaking is quite different, i.e. $\varepsilon_1 \neq \varepsilon_2$, the strength of independent blend follow a curve given as follows:

$$\bar{P}_2 = P_1 B_1^2 + P_2 B_2^2 \qquad \text{........E.(8)}$$

Thus, the blended yarn strength follows a curve which in between the two curves in form of E.(7) and E.(8) and considering that $\emptyset$ a degree of non-cooperation factor as shown in Fig.(3). The predicted yarn strength is given through the following formula:

$$\bar{P} = P_1 B_1 + P_2 B_2 - \emptyset.4 \left[B_2 (1-B_2)\right] \qquad \text{........E.(9)}$$

where:

$\emptyset$ non-cooperation Degree equal to $K(\frac{P_1 + P_2}{2})$, and The values of K factor varies between 0 and 0.5, i.e. $0.5 > K > 0$

when K = 0, A completely compatible fibres in blend and this resulted in a linear curve E.(7).

K = 0.5 A completely independent fibres in blends, and this resulted in a parabolic function E.(8).

The relationship between K factor and predicted yarn strength at different blend ratio for cotton/polyester blends are given in Table (1) and Figures (4-a, b). It is clear that a linear relation between K factor and blended yarn strength exists. As the values of K increases the predicted strength decreases and when K factor > 0.2 and ranged up to 0.5, the predicted yarn strength of cotton/polyester blends, containing a higher percent of cotton, has lower values than that of 100% of cotton.

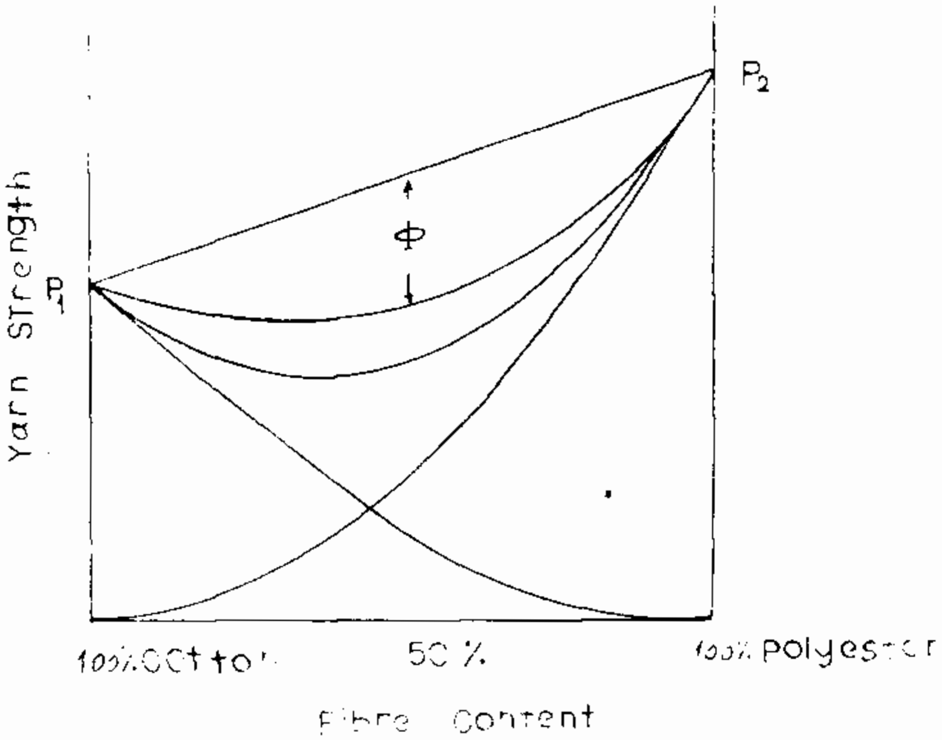


Fig.3. Theoretical Yarn Strength vs Blend Percentage

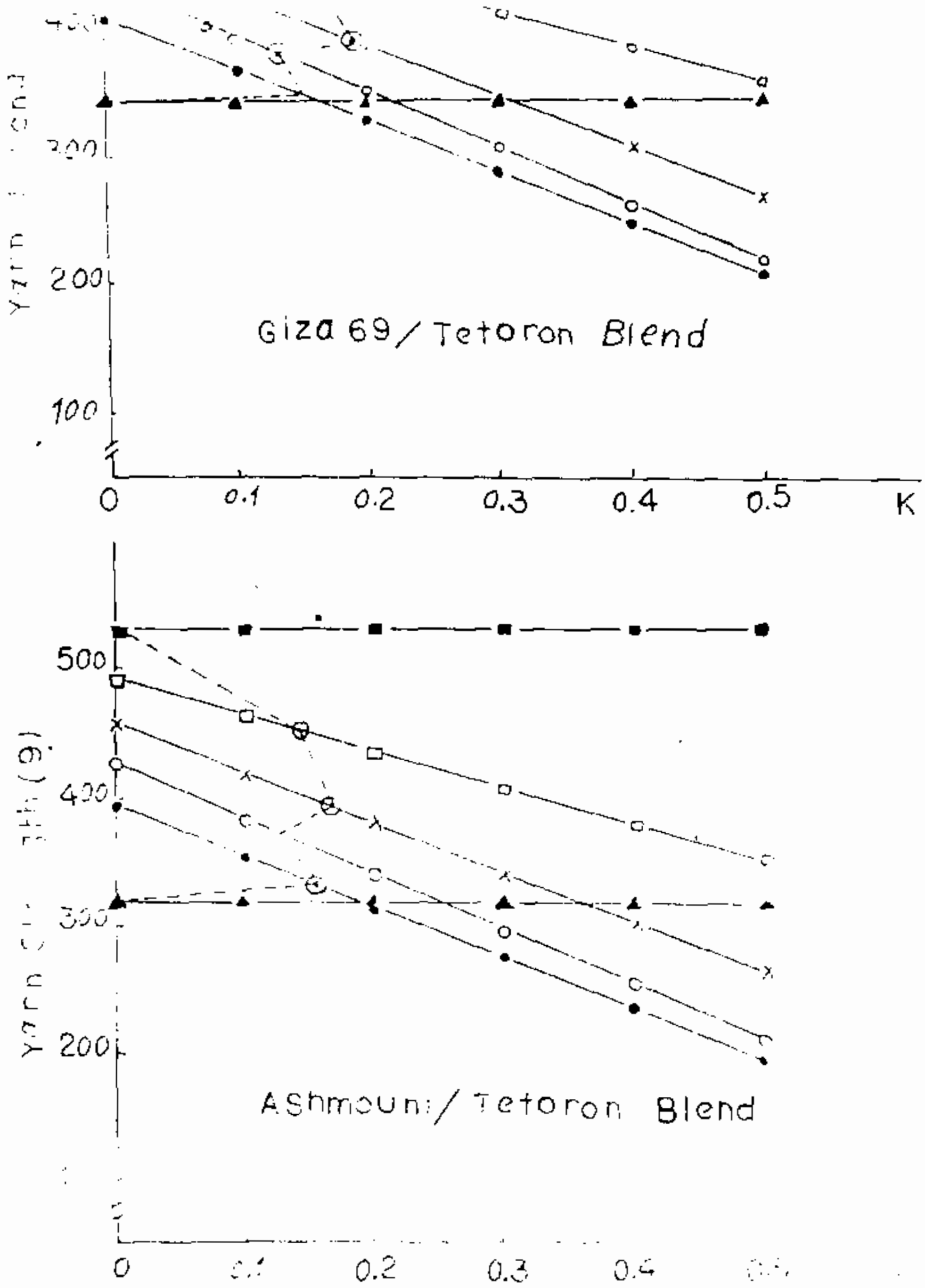


FIG.(4,a,b Relation Between ... Yarn Strength

(■) 100% ... 20/80 ... (▲) 100% ... (•) 65/35 ... (--⊙--) Experimental

The doted lines shown in Figures (4-a, b) expresses the experimental results of blended yarn strength versus K factor. It is abvious that the values of K not constant with different blending ratio and varies between 0 and 0.2. In this study of a non-cooperation degree Ø, the most values of K gives a closer fit with the experimental results ranged from 0.2 to 0.3. Thus, the value of K factor for cotton/polyester blends is equal to ¼ or = ¼ $(P_1 + P_2/2)$.

The predicted yarn strength may be expressed through the following formula:

$$\bar{P} = P_1 B_1 + P_2 B_2 - 0.5 (P_1 + P_2) \left[B_2 (1 - B_2) \right]$$

where

P_1, P_2 are yarn strength of 100% of the two components,

B_1, B_2 are proportion of each component.

Table (1)

Blend %	Ashmouni/Tetoron blend					Giza 69/Tetoron blend			
	100_c	65_c 35_p	50_c 50_p	35_c 65_p	100_p	35_c 65_p	50_c 50_p	65_c 35_p	100_c
K factor	The Observed Yarn Strength								
0	318	393.25	425.50	457.75	533	463.25	437.50	408.85	342
0.1	318	354.53	382.95	419.04	533	423.43	393.75	369.03	342
0.2	318	315.81	340.40	380.31	533	383.62	350.00	329.22	342
0.3	318	277.09	298.85	341.59	533	343.81	306.20	289.41	342
0.4	318	238.37	255.30	302.87	533	304.00	262.50	249.60	342
0.5	318	199.65	212.75	264.15	533	267.09	218.75	209.79	342

3. EXPERIMENTAL DESIGN AND PROCEDURE:

3.1. Material:

An analysis of the strength of blended yarns with various blend levels produced from Egyptian cotton (Giza 69, Ashmouni) and polyester staple fibre (Tetoron). The characteristics of the fibres used are set out in Table (2).

Table (2): Fibre property

Material	Fibre fineness			Fibre length		Fibre strength & elongation	
	Meteric count $\times 10^{-3}$	Tex.	µg/ln	U.Q.L (mm)	mean length (mm)	bundle strength g/tex.	% elongation
Egyptian cotton:							
Ashmouni	5.510	0.181	4.61	29.79	24.13	27.1	7.2
Giza/69	6.846	0.146	3.71	32.33	25.73	32.1	6.4
Polyester Fibre:							
Tetoron	4.334	0.231	5.86	36.33	32.56	56.0	17.4

3.2. Blending Ratios:

The yarn processed for the tests were Giza 69/Tetoron and Ashmouni/Tetoron blended yarn, containing 65, 50, and 35 oercent cotton. Also the yarn having 100% of each component, 100% Giza 69, 100% Ashmouni and 100% Tetoron, were processed. All yarns were produced at a nominal count Ne 30 (50 meteric count) and optimum Twist Multiplier.

3.3. Measurments:

All tests on fibres and yarns were made according to the procedure stuted in A.S.T.M. Standard. Fibre Length was evaluted by using the sutter webb, Fibre Fineness in terms of µg/inch by sheffild micronaire and Fibre Strength measurments of cotton and polyester staple fibre are determined by the stelometer tester ($\frac{1}{8}$ inch gauge) expressed in terms of grams per tex and on the pressley flat bundle strength tester (zero gauge) expressed in terms of strength weight ratio. Fibre elongation measurments are obtained from the stelometer ($\frac{1}{8}$ inch gauge).

The testing was carried out on an Uster Tensomatt II (Automatic yarn strength tester) and 200 test/yarn were performed to determine the yarn strength, in grams, strength variability and extension at break, %. Also, Apendulum type tester was used for testing skein strength of yarns.

4. RESULTS AND DISCUSSIONS:

The main fibre properties are given in Table (2). The mechanical properties of cotton/polyester blended yarn with different blending ratios, at optimum T.M was given in Table (3).

The theoretical values of yarn strength were obtained by the various methods comparing with the experimental results as shown in Figures (5-a), (6-a), (7-a) for Giza 69/ Tetoron and Figures (5-b), (6-b) and (7-b) for Ashmouni/ Tetoron blends.

A comparison of actual yarn strength and that calculated by various methods on blends is given in Table (5) and Table (6).

In Both Figures (5-a), (5-b) the curve 1 shows the theoretical prediction of yarn strength according to the method of Hamburger.(1) Also, in Figures (6-a), (6-b), the curve 1 experesses the theoretical values of yarn strength according to Saksina.(2)

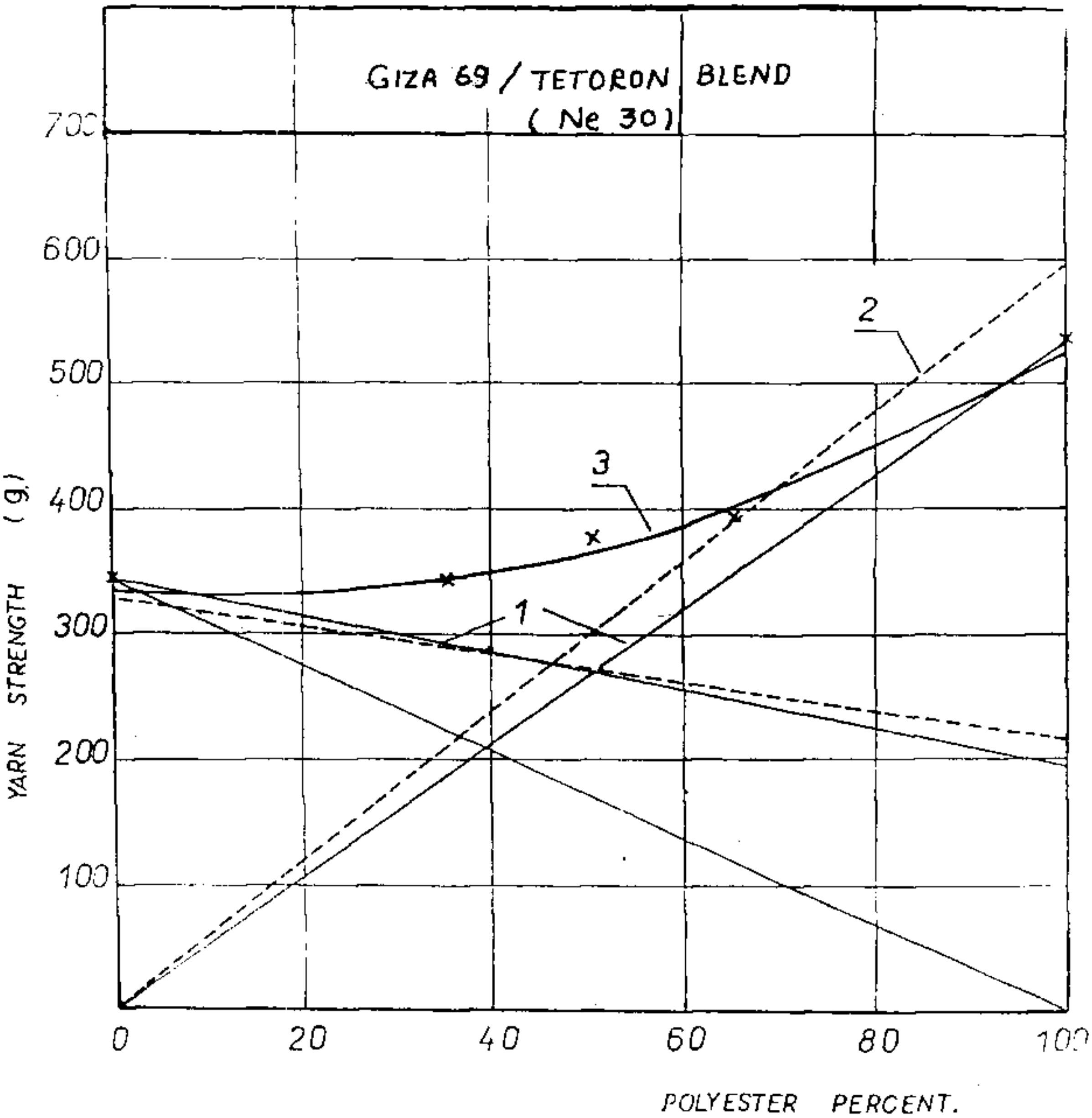


FIG. (5a) THE STRENGTH OF COTTON / POLYESTER YARN

1. PRETICTED ANALYTICALLY FROM THE MEASURED STRENGTH OF COTTON AND POLYESTER YARNS. (HAMBURGER, 1)

2. PRETICTED ANALYTICALLY FROM THE YARN STRENGTH CALCULATED FROM /5/

3. CURVE PLOTTED FROM EQUATION E. (10)

(x) EXPERMENTIAL RESULTS.

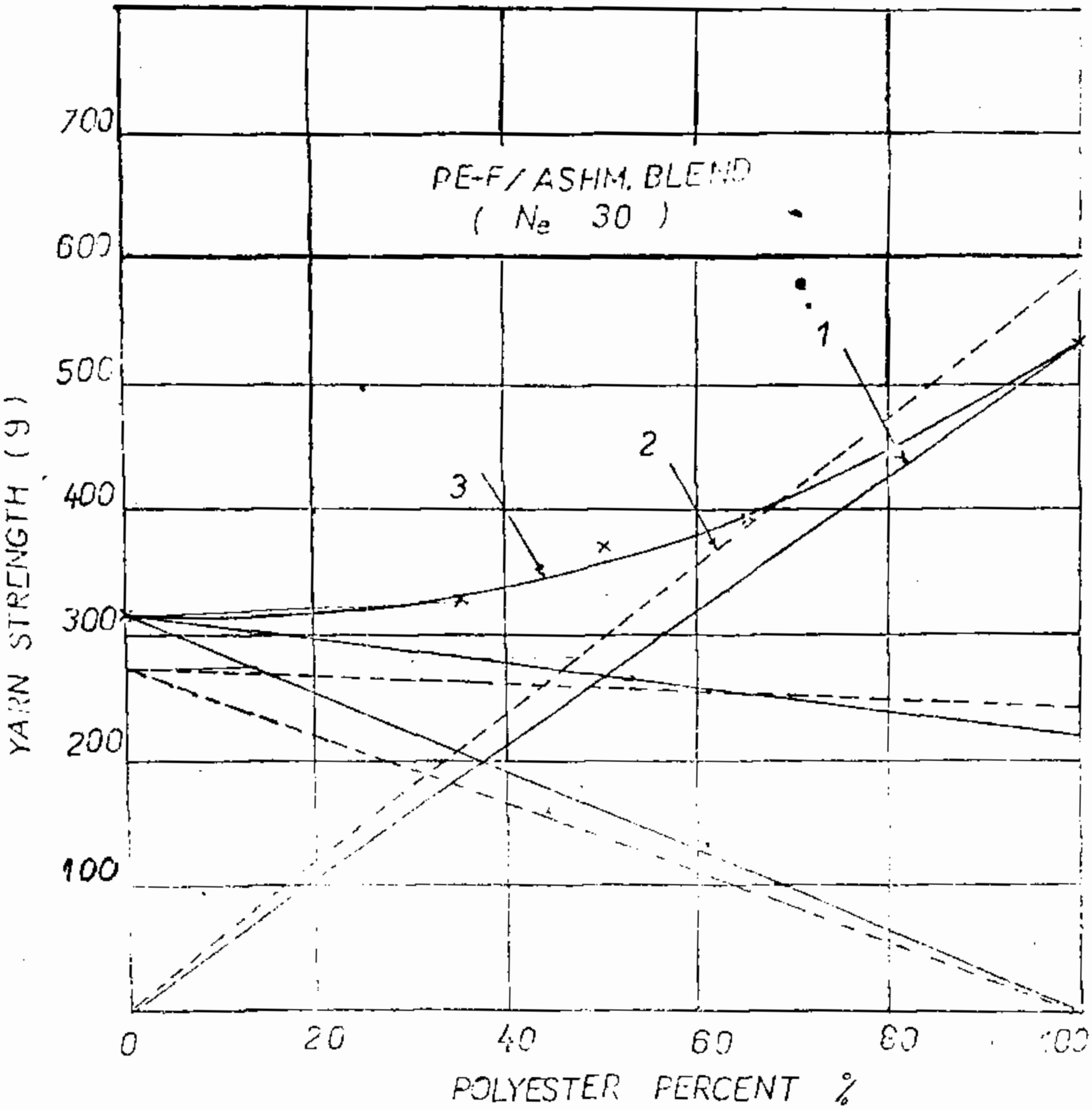


FIG.(5b) THE STRENGTH OF COTTON / POLYESTER YARN

1. Predicted analytically from the measured Strength of Cotton and polyester yarn (hamburger 1)
2. Predicted analytically from the yarn strength Calculated From /5/
3. Curve plotted from equation E.(11)

(x) experimental results.

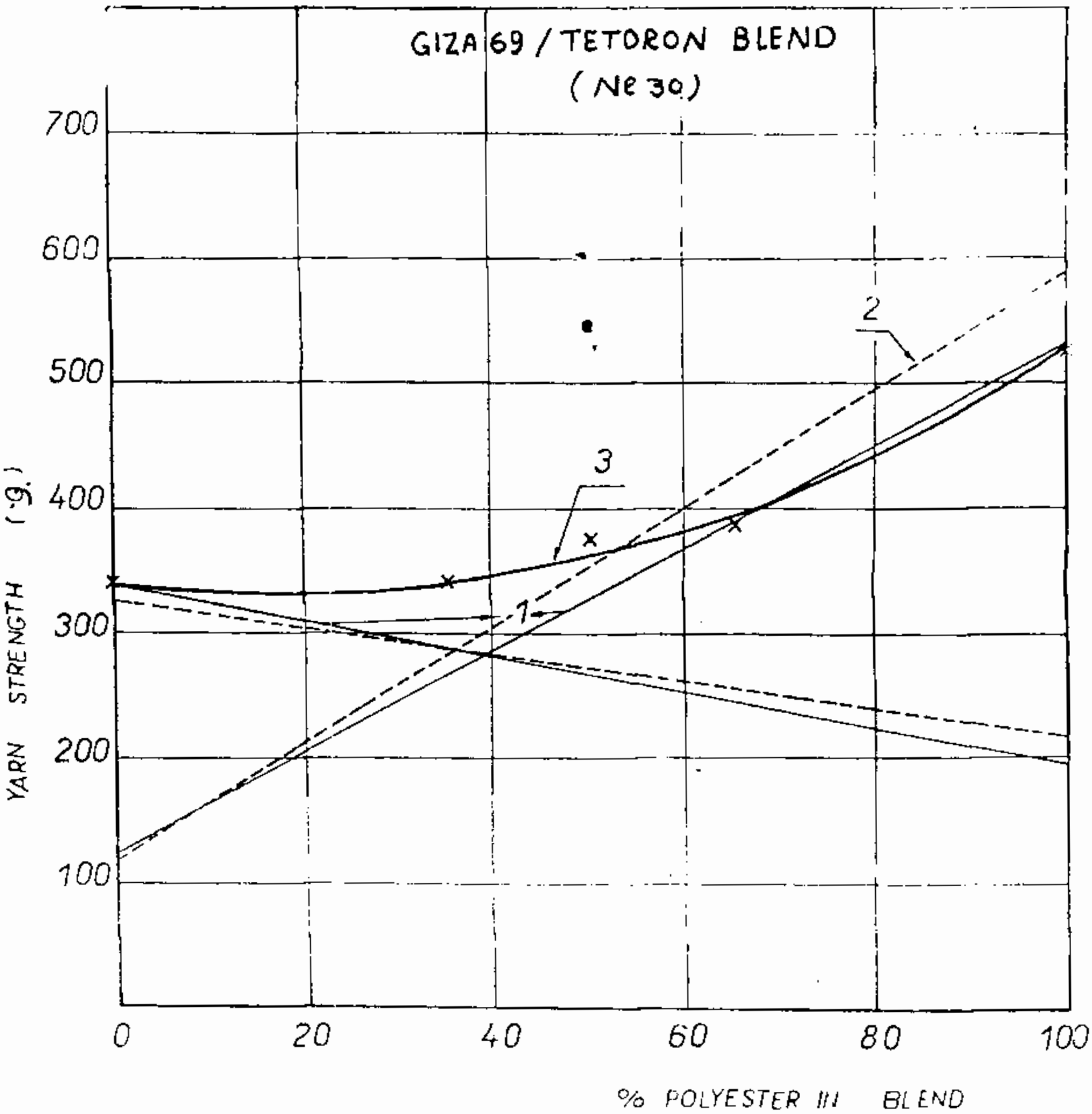


FIG.(6a) THE STRENGTH OF COTTON / POLYESTER YARN

1. PRETICTED ANALYTICALLY FROM THE MEASURED STRENGTH OF COTTON AND POLYESTER YARNS (SARSINA /2/)

2 PRETICTED ANALYTICALLY FROM THE YARN STRENGTH CALCULATED FROM /5/

3. CURVE PLOTTED FROM EQUATION E.(10)

(x) EXPERMENTIAL RESULTS.

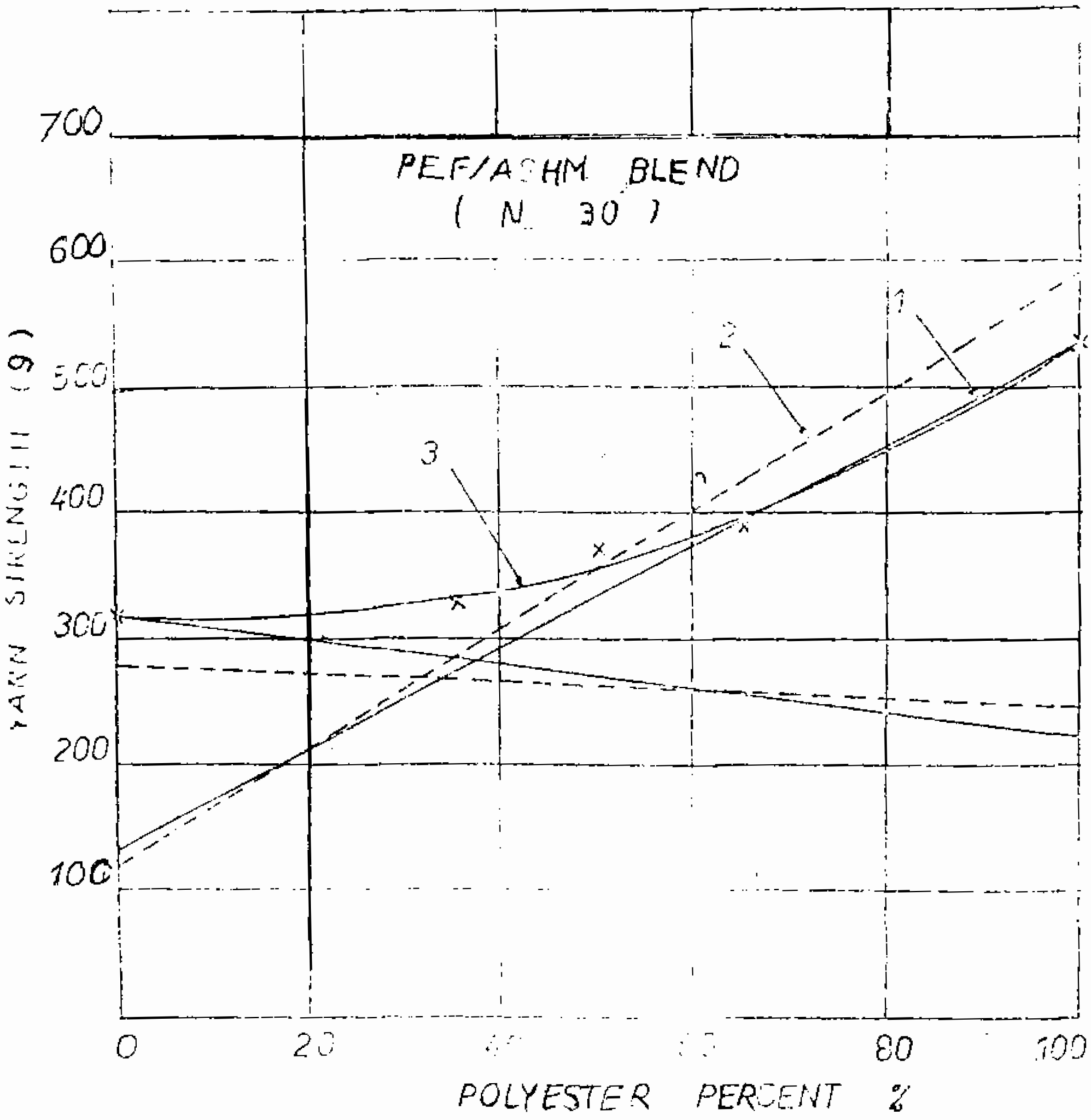


FIG. (6_b) THE STRENGTH OF COTTON/POLYESTER YARN

1. predicted analytically from the measured strength of cotton and polyester yarn Sksina /2/

2. predicted analytically from the yarn strength calculated from /5/.

3. Curve plotted from equation E.(11)

(x) experimental results.

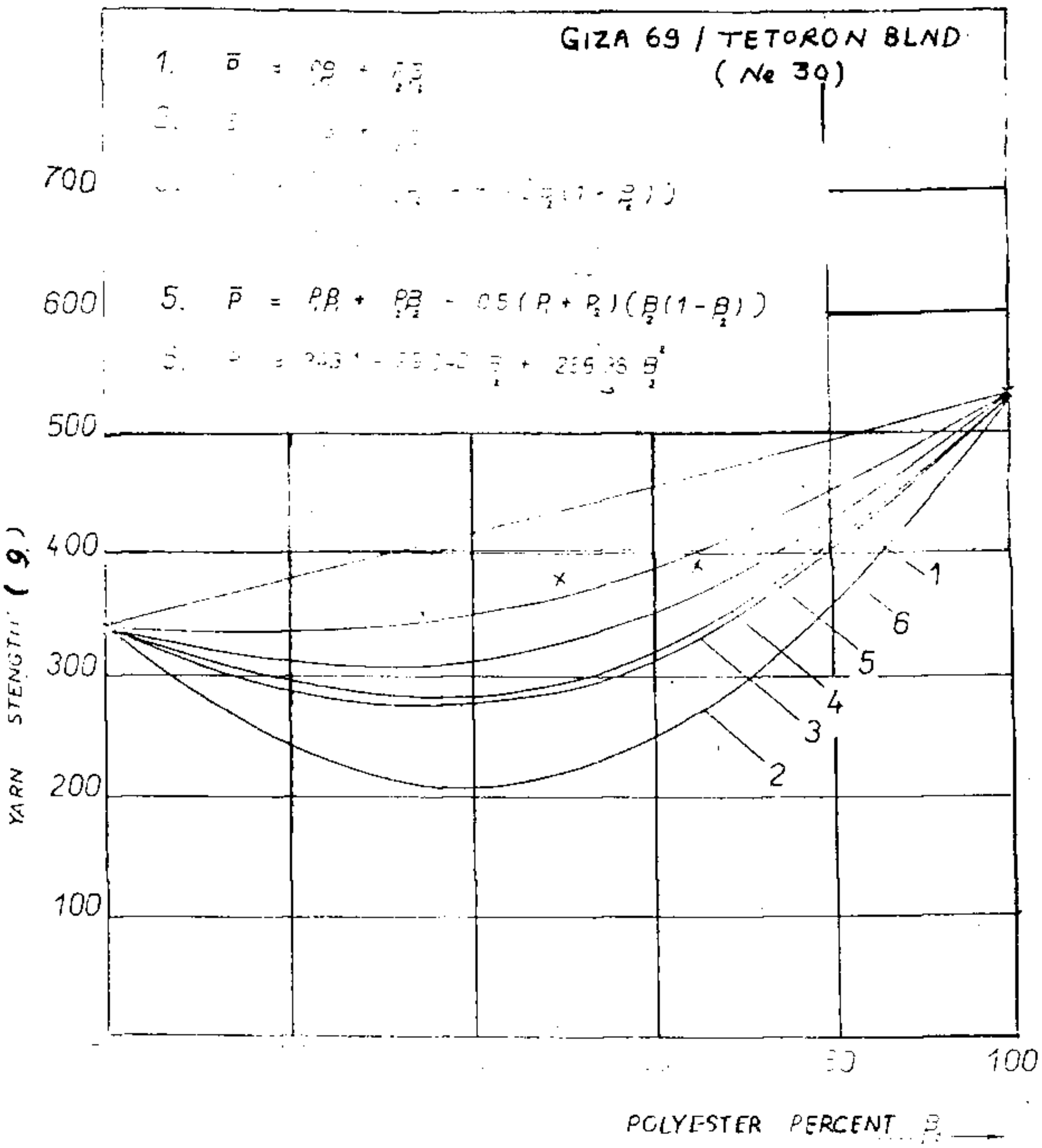


FIG.(7a) THE STENGTH OF COTTON / POLYSTER YAR

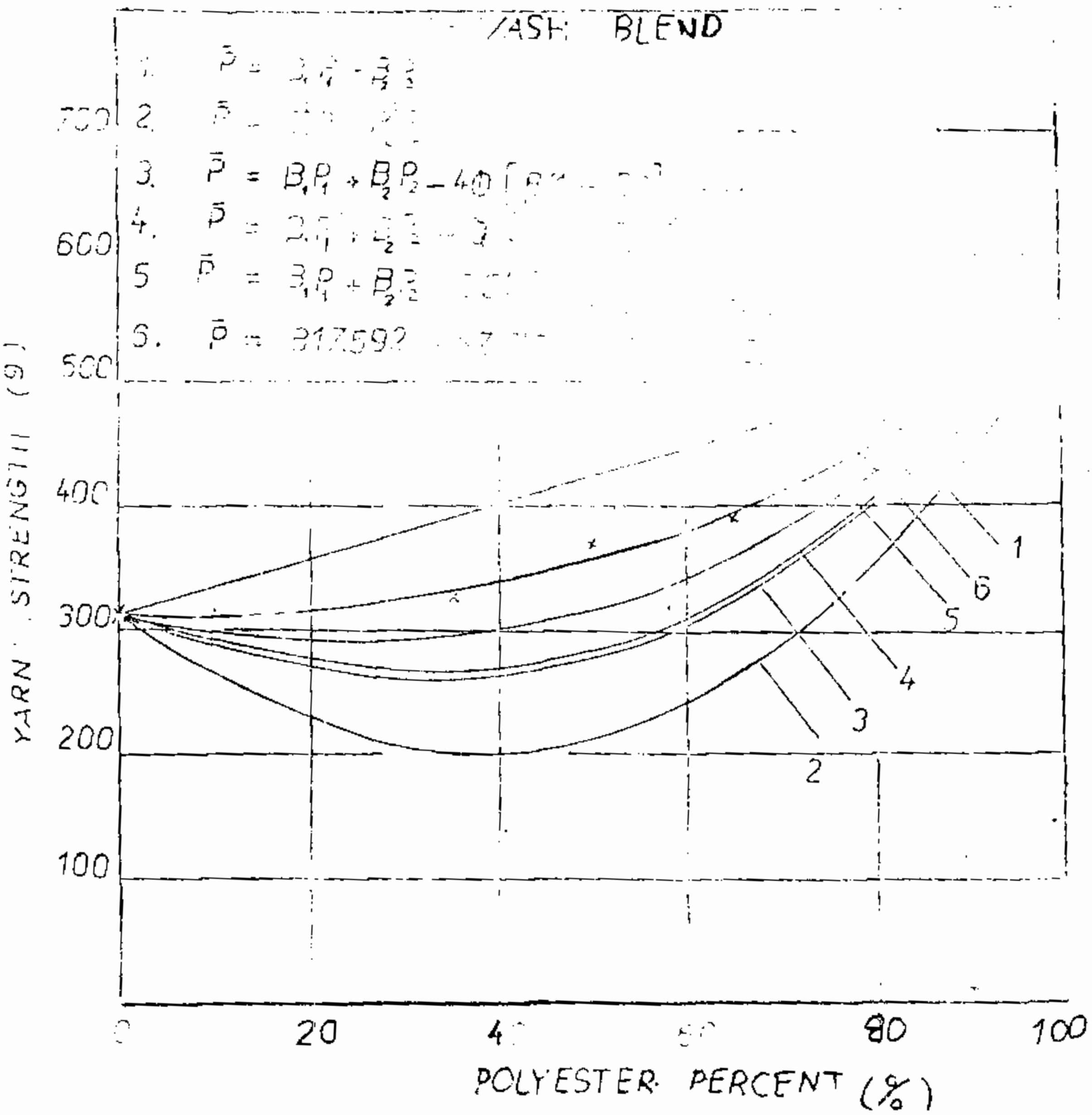


FIG.(7b) THE STRENGTH OF COTTON/ POLYESTER YARN

To determine the strength of blended yarn without producing and tests the yarn from 100% of each blend component, the yarn strength can be calculated from Louis and Fiori[5] equations. According to this equation and for yarn count No 30. The yarn strength of 100% Giza 69 equals 330 gram, for 100% Ashmouni equals 277 gram and that of polyester (Tetoron) yarn 590 gram, these were the strength used for plotting the das Hed line 2 in Figures (5-a), (6-a) for Giza 69/Tetoron and Figures (5-b) and (6-b) for Ashmouni/ Tetoron blend.

Table (3): Physical properties of cotton/polyester blended yarn.

Maleriel	Ne 30, for Optimum T.M.					Optimum Twist Multiplier (O.T.M.)
	Skein break factor C.S.P.	Single end strength (g.)	C.V% of single end strength	Single thread elongation %	C.V% of elongation	
			For Giza 69/Tetoron blend			
100_c	2630	342.0	11.70	6.25	10.50	4.62
$65_c/35_p$	2975	343.9	12.59	6.58	9.28	4.10
$50_c/50_p$	3005	378.0	10.00	6.68	12.17	3.44
$35_c/65_p$	3388	387.9	10.90	7.94	9.71	3.36
100_p	4117	533.0	11.40	11.80	10.80	3.30
			For Ashmouni/Tetoron blend			
100_c	2563	318.0	10.00	6.93	9.00	4.60
$65_c/35_p$	2688	328.0	11.89	7.41	11.50	3.88
$50_c/50_p$	3016	368.5	13.30	7.73	11.54	3.84
$35_c/65_p$	3201	391.4	12.73	8.61	10.95	3.60
100_p	4117	533.0	11.40	11.80	10.85	3.30

c = cotton, p = polyester fibre (Tetoron).

The experimental results in Table (4) was used to drrive the functional relation between the blended yarn strength and proportion of tetoron in the blend.

The assumed relation between blended yarn strength and blend proportion is:

$$Y = a + bx + cx^2 \qquad \text{hence,}$$

for Giza 69/Tetoron blend:

$$\bar{P} = 343.1 - 99.042\ B_2 + 286.38\ B_2^2 \qquad \text{......E.(10)}$$

and for Ashmouni/Tetoron blend:

$$\bar{P} = 317.592 - 47.718\ B_2 + 262.56\ B_2^2 \qquad \text{......E.(11)}$$

where:

$\bar{P}$ is the strength of blended yarn,

B_2 is the proportion of polyester fibre (Tetoron) in blends.

Table (4): Strength of Cotton/Polyester blended yarn.

Yarn Count		Ne 30 (50 meteric count)				
Blend ratio	Cotton%	0	35	50	65	100
	Polyester%	100	65	50	35	0
Giza 69/Tetoron blend		533	388	378	344	342
Ashmouni/Tetoron "		533	392	369	328	318

The curve (3), plotted in Figures (5-a, b) and (6-a, b) expresses the functional relation between yarn strength and blend proportion and given by equation E.(10) and E.(11).

In Both Figures (7-a) and (7-b), the curne (3) shows the relation between strength of blended yarn and blend proportion in the form of parabolic function E.(5). Also, the curve (4) expresses the predicted yarn strength in a sin form E.(6), and the curve (6) corresponds to equation (10) and (11).

The yarn strength in relation to the proportion in the blend may be determined through a simple expression given by equation E.(9) as follows:

$$\bar{P} = P_1B_1 + P_2B_2 - 0.5(P_1 + P_2)\left[B_2(1-B_2)\right] \quad ......E.(9)$$

The curve (5) corresponds to the equation E.(9) and shown in Figures (7-a) and (7-b).

The experimental results of yarn strength, marked with (x), were plotted against the theoretical values of yarn strength which were obtained by the various methods.

Table (5): Actual and Calculated Yarn Strength.

Polyester percent	Experimental results	First Method		Second Method		Porabolic Form E.(9)
		Humburger[1]	Saksina[2]	Ratham[3]	Ewald[4]	
		For Ashmouni/Tetoron blend				
0	318	318	318	318.0	318.0	318.0
20[a]	-	296	300	270.2	277.6	292.9
35	328	283	285	264.2	266.9	296.5
50	369	267	335	283.7	283.7	319.1
65	392	345	395	328.7	331.4	360.9
80[a]	-	428	455	399.2	406.6	421.9
100	533	533	533	533.0	533.0	533.0
		For Giza 69/Tetoron blend				
0	342	342	342	342.0	342.0	342.0
20[a]	-	315	315	286.9	294.5	310.0
35	344	290	290	276.1	276.9	309.3
50	378	270	325	291.5	291.7	328.1
65	388	345	390	332.5	333.3	366.6
80[a]	-	425	455	401.5	409.1	424.8
100	533	533	533	533.0	533.0	533.0

(a) Yarn strength read from a smooth curve through the data in Fig.(7-a,b).

Table (6): The differences between measured and predicted yarn strength.

	First Method		Second Method		Perabolic
	Humburger[1]	Saksina[2]	Ratnam[3]	Ewald[4]	Form E.(9)
For Ashmouni/Tetoron blend					
Mean Deviation	39.8	14.6	41.85	41.42	22.71
% mean deviation	0.1067	0.0446	0.1174	0.1144	0.0621
For Giza 69/Tetoron blend.					
Mean deviation	53.7	28.5	64.84	61.38	44.87
% mean deviation	0.1426	0.078	0.1716	0.1634	0.082

5. CONCLUSIONS:

From the study of different methods for prediction of blended yarn strength, the following can be concluded:

- There is no significant differences between the experimental results and the theortical values of yarn strength by all methods mentioned in previous work.
- Aporabolic function is recommended for eastimating the strength of blended yarn from a two component blend having 100% of each component.
- Mon-cooperation factor Ø is determined for cotton/polyester blend, through which the developed equation gives the closest values to the experimental results.

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