Factorial Treatment of the Effect of Spinning Variables on the Quality of Cotton/Polyester Yarns.

Rizk El-Bealy
Assistant Professor., Textile Engineering Department., Faculty of Engineering., El-Mansoura University., Mansoura., Egypt., rizk@mans.edu.eg

S. Ibrahim
Textile Engineering Department., Faculty of Engineering., El-Mansoura University., Mansoura., Egypt.

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FACTORIAL TREATMENT OF THE EFFECT OF SPINNING VARIABLES ON THE QUALITY OF COTTON/POLYESTER YARNS.

By

R. El-Bealy' and S. Ibrahim**

الخــلاصــه :

فى هــذا البحث تم استخدام طريقة بوكسى وهنتر فى تصميم التجارب لايجاد
تأثير بعض متغيرات الغزل مثل السحب الكلى (أو نمرة الخيط) ، أس البرم ونســـبة
خلط البولى استر مع القطن على (سطوح الاستجابه) لخواص الخيوط مثل قوة الشــد
والاستطاله والانطاميه · وقد تم اجراء التحليل الخاص بالنتائج على حاسب آلـــى
(آبل ٢) · وقد تم التوصل على عدة علاقات أساسية تحدد مستوى جـودة الخيط
مع متغيرات الغزل ومنها تم ايجاد الحــد الامثل لمستوى أس البرم ونسبة الخلـــط
للنمـر المختلفة للخيوط المخلوطه المنتجه على ماكينات الغزل الحلقــى ·

ABSTRACT:

The application of rotatable central compound design of
Box and Hunter(1,2) combined with the use of computer (Apple
II) to study the influence of spinning variables ,Total draft
(or yarn linear density), twist multiplier and blend levels
at Ring Spinning frame on the Tenacity, elongation at break
and the irregularity of combed cotton/Misr polyestr blended
yarn.

1- INTRODUCTION:

Most of Egyptian Textile Mills concerned with the pro-
duction of Misr-polyester staple fibers at Kafr El-Dawaar
 (RAYON) mill. Consequently several textile institution and
industrial laboratories began experiments to determine the
spinning performance of cotton/polyester blends and the best
operating conditions.

The cohesion phenomenon for Egyptian cotton/polyester
blends in roving and sliver have been studied (3). The
effect of cotton fiber properties on the quality of $50_c/So_p$
(carded cotton/polyester) blended yarns have been previously
reported (4).

Recently the authers (5) studied and discussed how Misr
polyester fibers perform in blends with most of all egyptian
cotton Variaties considering some factors such as carding and
combing phase for cotton fibers, yarn counts and blend levels.

In practical,fiber Blend spinning, the major problem
occurs is adjusting several factors to give a good yarn qua-
lity. The optimum values of some factors when considering
a certain yarn parameter are not necessarily the same as
would give for other parameters. In the earlier Sudies, the
author (6) investigated the spinning performance of Egypt-
ian cotton fibers (Giza 69 and Ashmouni) with Tetoron fibers.
The general method of getting the best response, when all but
one variable is held constant, and then the best response is
found as a function of this one variable. Another variable
is studied while the rest are kept constant. Also, the values
of the factors to get the best results have usually been set
by a combination of experience and guidance from machinery
manufacturs.

Thus, the present study was aimed to detect the best qua-
lity of combed cotton/polyester blends at different blend lev-
els with the interaction of some other variables such as total
draft and twist multiplier by using the experimental design
Technique, optimizing the spinning variables (Total draft,
Twist and blend levels). This Technique leads to reduce the
total experimentations and find the levels of these variable
which give an optimum response.

2- The Statistical Design of Experiments:

The technique of experimental designs have been used for
a long time in many fields of industrial processes and there is
a little amount of litterature on Textile industry (7,8,9).

The mathematical basis of the present study, which is
drawn from the previous literature of experimental design(1,2)
will be described here as follows:

Suppose there are "k" variables or factors whose levels
are denoted by X_{iu} . The value of which for any given combina-
tion of factors levels resulted in the corresponding value of
"y".

$$Y_u = \emptyset \ (X1u, \ ^X2u, \cdots, ^Xku)$$

where:

　　　u = 1, 2,... N represents the (N) observations in the
　　　　　factorial experiment and X_{iu} represents the level
　　　　　of ith.factor in the uth.Observation,and the funt-
ion (∅) is called the response surface.

If the functional relation between response "y" and the
variables is smooth one , it can be approximated to sufficie-
ntly closely by polynomial. The general formula of the res-
ponse at the uth.observation is assumed to be:

$$y = bo + \sum_{i=1}^{k} b_i X_{iu} + \sum_{i=1}^{k} b_{ii} X_{iu}^2 + \sum_{i<j} b_{ij} X_{iu} X_{ju}$$

The regression coefficients (b) are the elements of the matrix:

$$\hat{B} = (X^T \underline{X})^{-1} X^T Y$$

where X^T: is the transposed matrix of $\underline{X}$;

$(X^T \underline{X})$: is the matrix of sum of squares and products of independent variables,

$(X^T \underline{X})^{-1}$: is the inverse matrix of $(X^T \underline{X})$, and

Y: is the response vector.

In the present work, three variables (K = 3) and a second degree model will be considered so that the polynomial to be fitted will take a quadratic surface as following:

$$y = bo + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_{11} X_1^2 + b_{22} X_2^2 + b_{33} X_3^2$$
$$+ b_{12} X_1 X_2 + b_{13} X_1 X_3 + b_{23} X_2 X_3$$

The analysis of this surface can be simplified by reducing it to its canonical form:

$$Y - Y_s = B_{11} X_1^2 + B_{22} X_2^2 + B_{33} X_3^2$$

where:

Y_s: The value of response predicted at the stationary point(S).

The position(S): is the center of the system of contours represented by the following equation.

$$Y_s = b_0 + \tfrac{1}{2} (b_1 X_{15} + b_2 X_{25} + b_3 X_{35})$$

where X_{15}, X_{25} and X_{35} are the coordinates of (S),
B_{11}, B_{22} and B_{33}: are the coefficient,
X_1, X_2 and X_3. The direction of the axes.

3- Experimental work:

3.1- Materials: The experiments were carried out on cotton/ polyester fiber blends, which containing combed cotton fibers (Gza 75, noil 20%), having an effective fiber length 34 mm and micronaire reading 4.5 ug/inch, while Misr polyester fiber having 38.5 mm fiber length and 1.4 denier.

Table (1)

Experimental combination		Levels of Three Variables		
		X_1	X_2	X_3
Factorial 2^3	1	-1	-1	-1
	2	+1	-1	-1
	3	-1	+1	-1
	4	+1	+1	-1
	5	-1	-1	+1
	6	+1	-1	+1
	7	-1	+1	+1
	8	+1	+1	+1
Star.	9	-1.682	0	0
	10	+1.682	0	0
	11	0	-1.682	0
	12	0	+1.682	0
	13	0	0	-1.682
	14	0	0	+1.682
Central replicates	15	0	0	0
	16	0	0	0
	17	0	0	0
	18	0	0	0
	19	0	0	0
	20	0	0	0

Table (2)

	Level				
	-1.682	-1	0	+1	+1.682
x_1: yarn count(Ne)	34.12	40	50	60	66.82
Total Draft	19.84	23	29	35	38.84
x_2: Twist Multiplier(αe)	3.127	3.4	3.8	4.2	4.473
(αm)	94.75	103,02	115;14	127.26	135.53
x_3: Blend ratio(cotton %)	24.77	35	50	65	75.23

Table (3) Experimental Combination Results for Three Variables.

Experimental Combination	Coded variables			Uncoded variables			Yarn parameters		
	X_1	X_2	X_3	X_1 Yarn count	X_2 Twist factor	X_3 Blend ratio	Tenacity g/tex	Ext. E%	Yarn irreg. c.v%
1	-1	-1	-1	40	3.4	35	15.66	4.8	16.35
2	+1	-1	-1	60	3.4	35	15.03	4.1	18.39
3	-1	+1	-1	40	4.2	35	16.47	5.6	16.38
4	+1	+1	-1	60	4.2	35	15.67	5.3	19.38
5	-1	-1	+1	40	3.4	65	17.60	6.5	16.70
6	+1	-1	+1	60	3.4	65	13.56	3.5	18.35
7	-1	+1	+1	40	4.2	65	17.94	7.4	16.34
8	+1	+1	+1	60	4.2	65	14.11	3.4	18.73
9	-1.682	0	0	34.12	3.8	50	20.27	6.9	15.78
10	+1.682	0	0	66.82	3.8	50	16.89	4.8	20.22
11	0	-1.682	0	50	3.127	50	14.40	5.4	16.99
12	0	+1.682	0	50	4.47	50	14.98	4.3	17.16
13	0	0	-1.682	50	3.8	24.77	21.00	7.3	20.20
14	0	0	+1.682	50	3.8	75.23	13.64	3.0	19.17
15	0	0	0	50	3.8	50	17.29	4.9	16.74
16	0	0	0	50	3.8	50	17.31	5.0	17.00
17	0	0	0	50	3.8	50	17.93	5.3	17.47
18	0	0	0	50	3.8	50	17.43	4.8	16.81
19	0	0	0	50	3.8	50	18.00	6.0	16.74
20	0	0	0	50	3.8	50	17.30	4.6	16.90

3.2- Yarn production: The cotton and polyester staple fibers
were processed sepeartly through Blowing room and carding proc-
ess and have been blended at drawing process according to the
construction details of experiments.

3.3- Design of experiments:

The following variables: Total draft or yarn count (X_1),
twist multiplier (X_2) and Blending ratio of cotton/polyester
(X_3) varied according to co composite rotatable central design
of Box and Hunter (1, 2).   The details are shown in Table(1).
The variables were kept within industrial processing zone in
order to obtain good yarn quality.

The rotatable central compound design which involves
twinty experiments are shown in Table(1) and all combinations
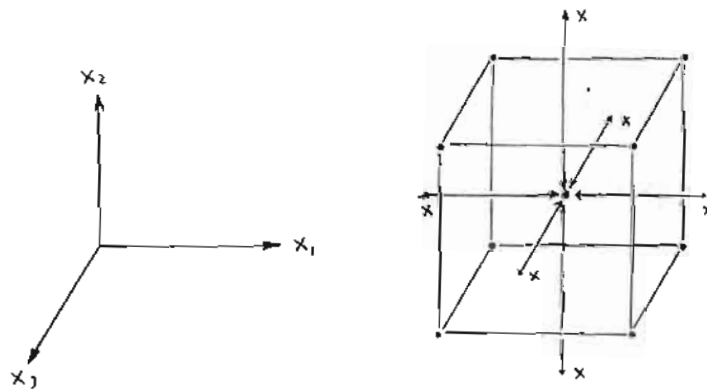distributed as given in figure(1).

Fig.(1) Central composite Design.

(o) points of initial 2^3 factorial (i.e eight combinations)
(x) Additional points added for composite design with coord-
    inates ($\pm \alpha$, 0, 0), (0, $\pm \alpha$, 0) and (0, 0, $\pm \alpha$)

    where α = 1.682

Six replicates at the center with coordinates (0, 0, 0).

The levels of independent variables are calculated by the
following formula:

$$X_i = \frac{\bar{X}_i - X_0}{\frac{1}{2} \text{(Range of X)}}$$

where $\bar{X}_i$ = uncoded variables; X_1 : coded variables and

X_0 : midrange of variables.

Table (4) Equation of Response surface.

Yarn parameters	Equation of Response Surface	Maximum, minimum or Stationary point	Maximum, minimum or Stationary Response
Yarn Tenacity (g/tex.)	$Y=17.5783-1.0973\,X_1 + 0.2428\,X_2 -0.8836\,X_3$ $+0.1418\,X_1^2 -1.2333\,X_2^2 -0.3107\,X_3^2$ $+ 5\,X_1 X_2 -0.8049\,X_1 X_3 -0.0699\,X_2 X_3$	$X_{15} = -0.0456$ $X_{25} = 0.1374$ $X_{35} = -1.3783$	$Y_5 = 18.2289$
Yarn Extension at break (E %)	$Y=5.1079-0.8444\,X_1+0.0695\,X_2-0.4564\,X_3$ $+0.2183\,X_1^2 -0.1352\,X_2^2 -0.0291\,X_3^2$ $-0.0749\,X_1 X_2 -0.750\,X_1 X_3 -0.15\,X_2 X_3$	$X_{15} = -0.7591$ $X_{25} = 1.1416$ $X_{35} = -1.7095$	$Y_5 = 5.8677$
Yarn Irregularity (c.v %)	$Y = 16.9759+1.2146\,X_1+ 0.1\,X_2-0.2749\,X_3$ $+0.1763\,X_1^2 -0.1507\,X_2^2 + 0.9487\,X_3^2$ $+0.2175\,X_1 X_2 -0.12\,X_1 X_3 -0.12\,X_2 X_3$	$X_{15} = -2.5705$ $X_{25} = -1.4789$ $X_{35} = -0.1112$	$Y_5 = 15.3562$

(i) for total draft or yarn count $(x_1) = \dfrac{\bar{x}_1 - 50}{(Ne) \quad 10}$

(ii) for twist Multiplier ($\propto e$) $(x_2) = \dfrac{x_2 - 3.8}{0.4}$

(iii) for Blend levels (% of cotton)$(x_3) = \dfrac{x_3 - 50}{15}$

This the levels of the variables are shown in Table(2)

3.4- <u>Meaurements</u>: The following yarn parameter were investi-
gated: single-end strength and Elongation at break on Tensomat
strength tester. Yarn count was determined on Autosorter, the
amount of twist was measured by zweigle Twist Tester and yarn-
irregularity measured by Uster evenness Tester.

4. <u>Results and Computer Analysis</u>:

The experimental results of combed cotton/polyester blen-
ded yarn for three parameters: Irregularity (c.v), Tenacity
(g/tex) and elongation at break (E %) and given in Table (3).
The data was fed to an Apple II computer equiped with plotter
(HP) in order to obtain the equation of response surface, ana-
lysis of variances and other statistical data.

The results plotted graphically by the plotter. The first
three graphs relate to yarn tenacity, the next three to elonga-
tion at break and the last three to yarn Regularity.

5. <u>DISCUSSIONS</u>:

Table (4) shows the equations of response surfaces from
the computer, and figures (2) to (10) represents contour lines
from the plotter for each yarn parameter.

5.1- <u>Yarn Tenacity</u>:

Figures (2), (3) and (4) represent contours of the response
surrface of combed cotton/polyester blended yarn tenacity for
$X_3 = -1$, 0 and +1 i.e for three blend levels ($35_c/65_p$: $50_c/50_p$
and $65_c/35_p$). With regard to the influences of X_1 (Total
draft or yarn count) and X_2 (Twist multiplier) on yarn tenacity.
It may be noticed that the tenacity values veries from 13 to 21
g/tex. The higher tenacity can be achieved for meduim counts
(at low draft) and less twisted yarn, also for fine and high
twisted yarn. The influence of blend ration (X_3) on tenacity,
as can be seen, there is a slight change in the centre of their
countour lines on passing from $35_c/65_p$, $50_c/50_p$ to $65_c/35_p$.
The effect of two factor interaction X_2X_3 (^{c}twist and ^{c}Blend
levels) on tenacity, is also observed. At level $X_1 = +1$, the
yarn tenacity = 18 g/tex, for $X_3 = -1$ (i.e $35_c/65_p$) was achived
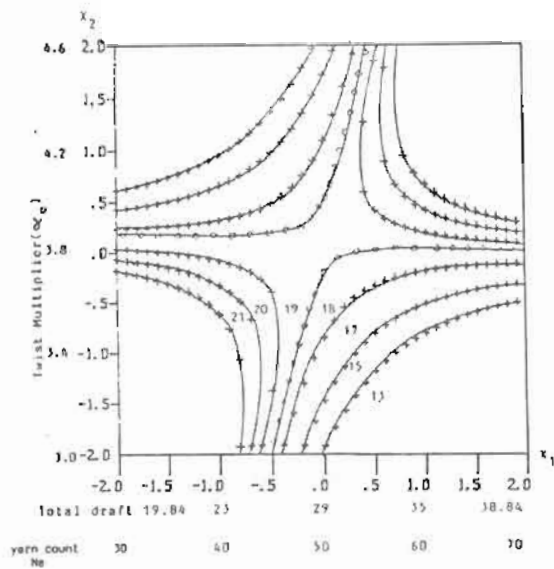at low twist while for $X_3 = +1$ ($65_c/35_p$) the same value obtained
for high twists.

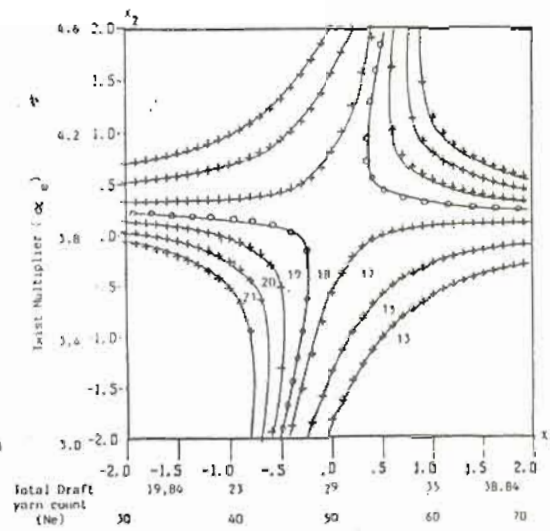Fig.(2) Contours for Tenacity
(blend level X3 = -1)
(35% Cotton/ 65% PES)

Fig.(3) Contours for Tenacity
(blend level X3 = 0)
(50% Cotton/ 50% PES)
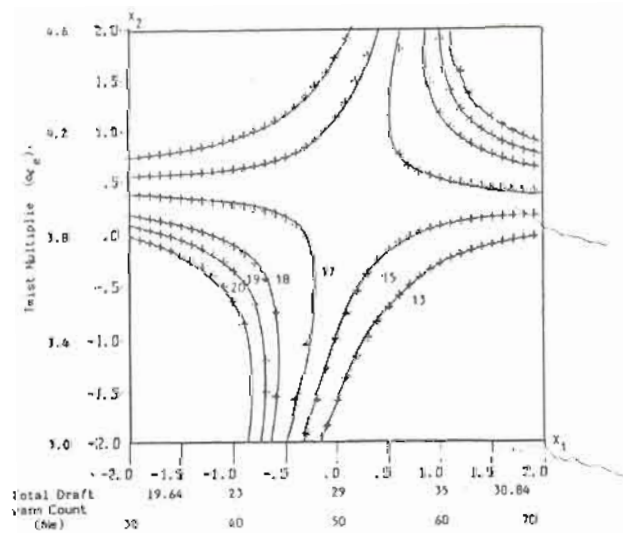
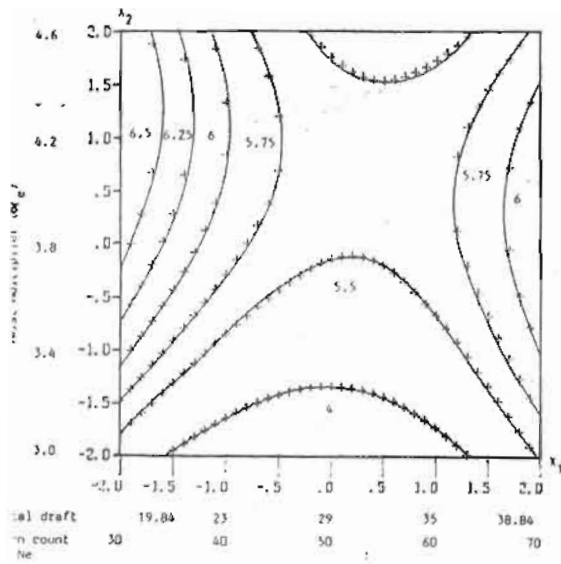Fig.(4) Contours for Tenacity
(blend level X3 = +1)
(65% Cotton/35% PES)

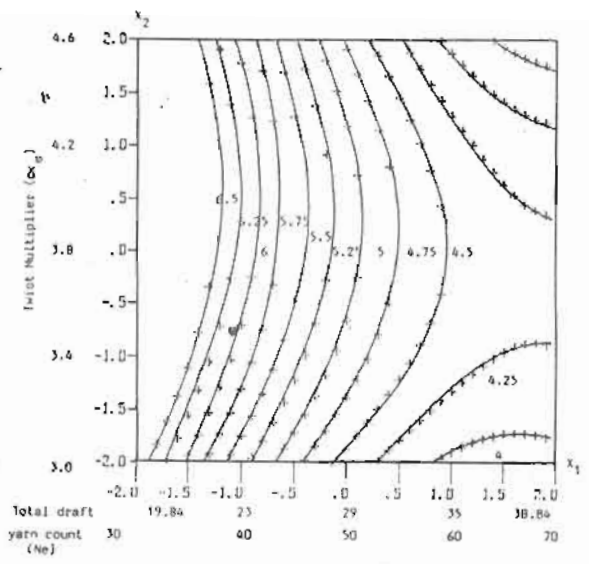Fig.(5) Contours for Elongation
(blend level X3 = -1)
(35% Cotton/65% PES)

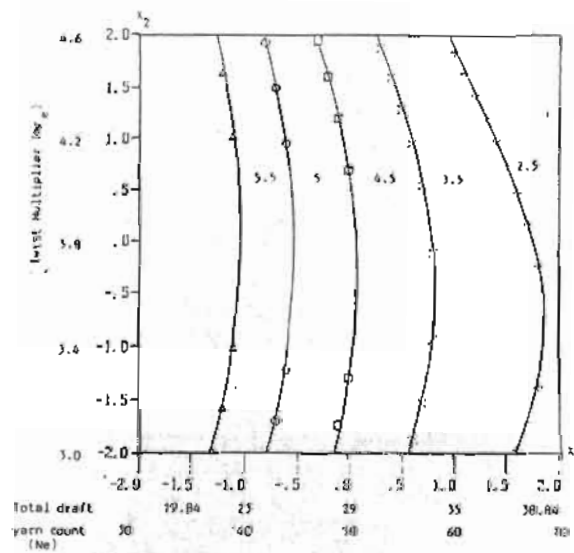Fig.(6) Contours for Elongation
(blend level X/ = -1)
(50% Cotton/50% PES)

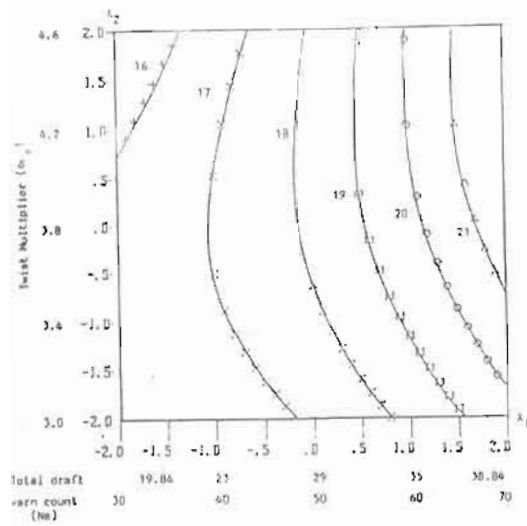Fig.(7) Contrours for Elongation
(blend level X3 = +1)
(65% Cotton/35% PES)

Fig.(8) Contours for Irregularity
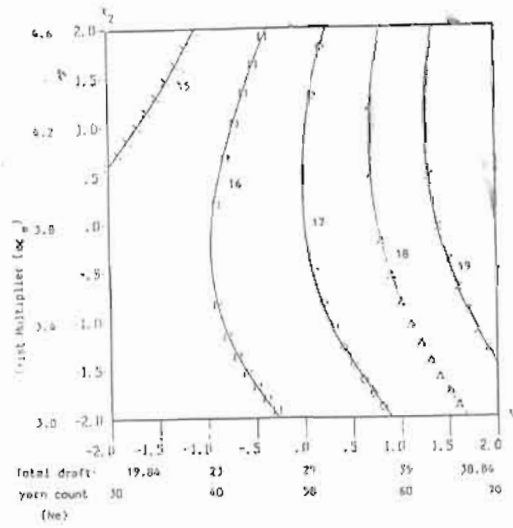(blend level X3 = -1)
(35% Cotton/65% PES)

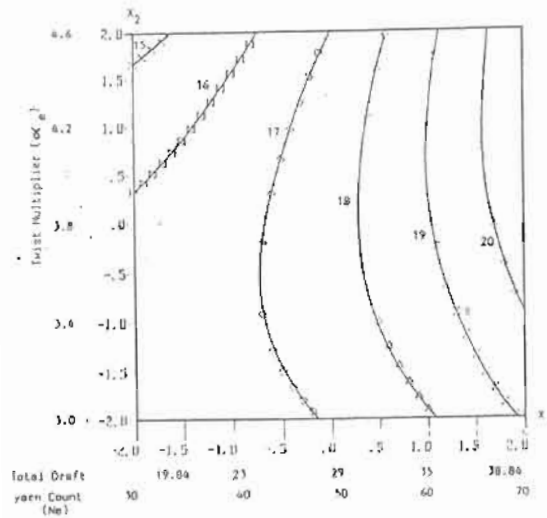Fig.(9) Contours for Irregularity
(blend level X3 = 0)
(50% Cotton/50% PES)

Fig.(10) Contours for Irregularity
(blend level X3 = +1)
(65% Cotton/35% PES)

5.2- Yarn Elongation-at-break:

Figures (5), (6) and (7),clearly show the trends for yarn elongation as a function of X_1: Total draft, X_2: Twist multiplier and X_3 blend levels of cotton/polyster.fibers. As can be seen the configuration of contour lines for yarn elongation (E%) is a saddle shape with a center inside the experimental field (at X_3 = -1). At X_3 = 0 and X_3 = -1, there is a displacement of their center to the outside the experimental field. It will be observed that the increase in elongation is observed for high twist level and polyester content. In other respects, the reduction in elongation associated with the increase of cotton content in blend (i.e at X_3 = +1).

5.3- Yarn Irregularity:

Contours of yarn irregularity for three levels of blend ratios X_3= -1,0, and +1 are shown in figures (8),(9) and (10) with a minimum falling outside the experimental field. As shown in figures, for all blend levels (X_3), in terms of Y_2(Total draft), the regularity deteroirates when the ring spinning draft increases, while the twist does not show effect on yarn irregularity.

On the other hand, there is a noticable variation has been observed on yarn irregularity for blend levels $53/65p$, $50_c/50p$ and $65_c/35p$. The yarn irregularity improved when combed cotton ratio increased in blends.

5.4- Determination of Optimum Values:

From figures (2) to (10), the results clearly indicate the trends for the different parameters, tenacity, elongation at break and irregularity as a function of the chosen variables, total draft, twist multiplier and blend levels. The maximum, minimum or stationary Response for all yarn parameters correspond to the variables are given in Table (4). The optimum values of blended yarn parameter corresponding to values of total draft 20 to 38, twist multiplier $\propto_e$ from 3.55 to 4.25 and blend levels from $48_c/52p$ to $25_c/75p$.

5.5- Statistical Analysis:

(i) Significance of parameters: Table (5) show the analysis for the variables studied. The first order terms are statistically significant at the level of 1% for all yarn parameters (Tenacity, extension and yarn irregularity). Also, the second order terms are significant at the level 1% for yarn tenacity and Regularity, while for yarn extension is significant at level 5%.

(ii) The correlation coefficients: that relate the model represented by regression equations to the experimental values were also studied. The coefficients were 0.99 for yarn tenacity, (0.982) for yarn Regularity and (0.973) for yarn extension at break. All there values being highly significant.

Table (5) Analysis of Variance.

Source	Degree of freedom	Yarn Tenasity s.s	Yarn Tenasity m.s	Yarn extension s.s	Yarn extension m.s	Yarn irregularity s.s	Yarn irregularity m.s
First order terms($S_{1.0}$)	3	27.9097	9.3032**	12.6486	4.2163**	21.3174	7.1058**
Second order terms($S_{2.10}$)	6	28.5947	4.7658*	5.7680	0.9613*	14.3563	2.3927**
Residual R=($S-S_{0.12}$)	10	7.76973	7.7697	28.5895	2.8589	40.2747	4.0274
Experimental Error S_E	5	0.5410	0.1082	1.2400	0.2480	0.3829	0.0765
Lack of fit (R-SE)	5	.7.1563	15.4313	7.3495	5.4699	39.8918	7.9783

where: s.s: Sum of squares; m.s: mean sum of squares

$$S_o = (0y)^2/N; \quad S_{1.0} = \sum_{i=1}^{k} b_i(iy);$$

$$S_{2.10} = b_o (0y) + \sum_{i=1}^{k} \sum_{j=1}^{k} b_{ij}(ijy) - (0y)^2/N$$

$$SE = \sum_{u=1}^{no} (y_{uo} - \bar{y}_o)^2$$

Table (6) 2^3 factorial Analysis.

Factors	d.f	(m.s) mean squares for yarn Tenacity g/tev.	(m.s) mean squares for Yarn extension (E %)	(m.s) mean squares for Yarn evenness c.v %
Main Effect:				
X_1: Total draft	1	10.8113**	8.00	10.308**
X_2: Twist factor	1	0.6844 x	0.980	0.135
X_3: Blend levels	1	0.0180	0.125	0.018
Two factor interaction:				
X_1X_2	1	0.0002	0.045	0.447
X_1X_3	1	5.1842*	4.500	0.281
X_2X_3	1	0.0392	0.180	0.125
Three factor interaction:				
$X_1X_2X_3$	1	0.0181	0.245	0.028

(iii) Analysis of variances: The investigation of the main effects of total draft (X_1), Twist multiplier (X_2) and Blend levels (X_3) give the following treatment as shown in Tables (6) and(7).

From Table (6) it was observed that the variable X_1 (total draft) is significant at 1% level for yarn tenacity and irregularity. Also it can be seen that, the variable X_2 (twist multiplier) is significant at level 10% for yarn tenacity. On the other hand, the two factor interaction X_1X_3 (between Total draft and Blend levels) affects on yarn tenacity and is significant at level 5%.

As shown in Table (7), by taking all interactions to demonstrate the main effects of the variables. The factor X_1 (Total draft or yarn count) affect the yarn tenacity and is significant at 5%.Also influences yarn extension and is significant (at 10% level),and highly significant (at 1% level) for yarn irregularity.

6. CONCLUSIONS:

The present study permits the following conclusions to be drawn:-

i) The application of experimental design technique in conjunction with computer analysis enables the determination of the best operating conditions of Ring spinning machine, for processing fiber blends, to be achieved with little experimental work.

ii) The experiments clearly indicate the influence of the three variables, total draft, twist multiplier and blend levels on the tenacity, elongation at break and Regularity of yarns. Also, it justify some of the results obtained from the previous studies (5) relating to the influence of cotton combed phase on the properties of blended yarn.

iii) An increase in total draft causes the quality of blended yarn, tenacity, elongation and regularity to fall. The optimum values for any per-determined count of the feed roving dependent on the final yarn count to be spun.

iv) The optimum twist multiplier(α_e) is ranged from 3.85 to 4.2 for blend yarns and depends on the % age of fiber blend compositions.

v) For combed cotton/polyester blends, it has been found that the best quality corresponding to combed blend containing % age of polyester,are between 52% to 75%.

Table (7) 2^3 Factorial Analysis

Factors	(d.f) degree of freedom	(m.s) mean squares for		
		Yarn Tenacity (g/tex.)	Yarn Extension (E %)	Yarn evenness c.v %
Main Effect:				
X_1: Total Draft	1	10.8115*	8.000ˣ	10.308**
X_2: Twist factor	1	0.6844	0.980	0.135
X_3: Blend levels	1	0.0180	0.125	0.018
Residual	4	1.3104	1.243	0.220

** Significant at level 1%

 * Significant at level 5%

 x Significant at level 10%.

REFERENCES:

1. J.E.P. Box and J.S. Hunter. "Ann. Math. Stat., 1957, 28.

2. O.L. Davies, "The Design and analysis of industrial experiments". Publ. Oliver and Boyd Ltd, London 1954, Chapter 10, M, p 440, 495.

3. S. Ibrahim, R. El-Bealy and M. El-Messiery, Alexandria Bulletin Vol. XXIV, 1985.

4. M. El-Messiery, S. Mansour and S. Ibrahim; Alexandria Bulletin Vol. XXIV, 1985.

5. R. El-Bealy, S. Ibrahim, and M. El-Messier; paper accepted for publication in Mansoura Bulletin.

6. R. El-Bealy, M.Sc. Thesis, 1978. Mansoura University.

7. A Barella, et al., Text. Inst. 1976, 67, 253, 325, 421.

8. A. Barella and J.P. Vigo, J. Textile Inst., 1977, 68(12),407; 1978, 69, (11), 336.

9. R. El-Bealy, Ph.D. Thesis, 1984, Strathclyde University.