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

By

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(Received May. 6, 1987, accepted June 1987)

الخـلاصـه :

في هـذا البحث تم استخدام طريقة بوكسي وهنتر في تصميم التجارب لايجاد تأثير بعض متغيرات الغزل مثل السحب الكلي (أو نمرة الخيط) ، أس البرم ونسـبة خلط البولي استر مع القطن على (سطوح الاستجابه) لخواص الخيوط مثل قوة الشـد والاستطاله والانتظاميه. وقد تم اجراء التحليل الخاص بالنتائج على حاسـب آلـي (آبل ٢) . وقد تم التوصل على عدة علاقات أساسية تحدد مستوى جـودة الخيط مع متغيرات الغزل ومنها تم ايجاد الحـد الامثل لمستوى أس البرم ونسبة الخلـط للنمـر المختلفة للخيوط المخلوطه المنتجه على ماكينات الغزل الحلقـي .

## 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 production 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 $50_c/50_p$ (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 quality. 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 Egyptian 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 quality of combed cotton/polyester blends at different blend levels 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 combination of factors levels resulted in the corresponding value of "y".

$$Y_u = \emptyset\ (X_{1u}, X_{2u}, \ldots, X_{ku})$$

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 funtion (Ø) is called the response surface.

If the functional relation between response "y" and the variables is smooth one, it can be approximated to sufficiently closely by polynomial. The general formula of the response 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:

$$y = bo + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3$$

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.

$$Y_S = b_0 + \tfrac{1}{2}(b_1X_{1S} + b_2X_{2S} + b_3X_{3S})$$

where $X_{1S}$, $X_{2S}$ and $X_{3S}$ 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($\alpha e$) | 3.127 | 3.4 | 3.8 | 4.2 | 4.473 |
| ($\alpha m$) | 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 $x_1$ | $x_2$ | $x_3$ | Uncoded variables $X_1$ Yarn count | $X_2$ Twist factor | $X_3$ Blend ratio | Yarn parameters 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 process 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 rototable central compound design which involves twinty experiments are shown in Table(1) and all combinations distributed as given in figure(1).

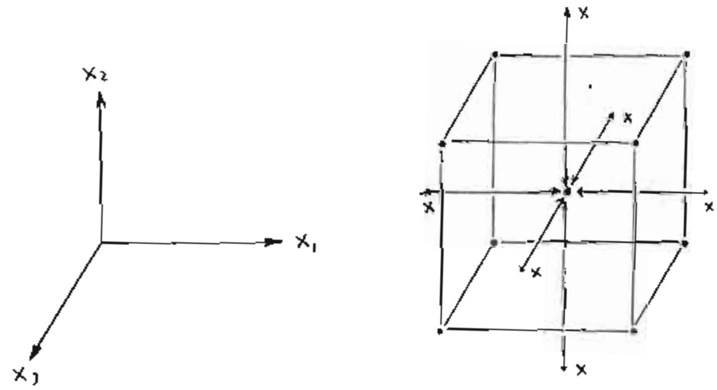


Fig.(1) Central composite Design.

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

where $\alpha$ = 1.682

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

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

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

where $\bar{X}_i$ = uncoded variables; $X_i$ : coded variables and $X_o$ : 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.) | $Y=17.5783-1.0973 X_1+0.2428 X_2-0.8836 X_3$ | $X_{15}=-0.0456$ | |
| | $+0.1418 X_1^2-1.2333 X_2^2-0.3107 X_3^2$ | $X_{25}=0.1374$ | $Y_5=18.2289$ |
| | $+5 X_1 X_2-0.8049 X_1 X_3-0.0699 X_2 X_3$ | $X_{35}=-1.3783$ | |
| Yarn Extension at | $Y=5.1079-0.8444 X_1+0.0695 X_2-0.4564 X_3$ | $X_{15}=-0.7591$ | |
| break (E %) | $+0.2183 X_1^2-0.1352 X_2^2-0.0291 X_3^2$ | $X_{25}=1.1416$ | $Y_5=5.8677$ |
| | $-0.0749 X_1 X_2-0.750 X_1 X_3-0.15 X_2 X_3$ | $X_{35}=-1.7095$ | |
| Yarn Irregularity | $Y=16.9759+1.2146 X_1+0.1 X_2-0.2749 X_3$ | $X_{15}=-2.5705$ | |
| (c.v %) | $+0.1763 X_1^2-0.1507 X_2^2+0.9487 X_3^2$ | $X_{25}=-1.4789$ | $Y_5=15.3562$ |
| | $+0.2175 X_1 X_2-0.12 X_1 X_3-0.12 X_2 X_3$ | $X_{35}=-0.1112$ | |

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

(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- Meaurements: The following yarn parameter were investigated: 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. Results and Computer Analysis:

The experimental results of combed cotton/polyester blended 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, analysis 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 elongation at break and the last three to yarn Regularity.

## 5. DISCUSSIONS;

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- Yarn Tenacity:

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 /50 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 $X_2X_3$(twist and 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.

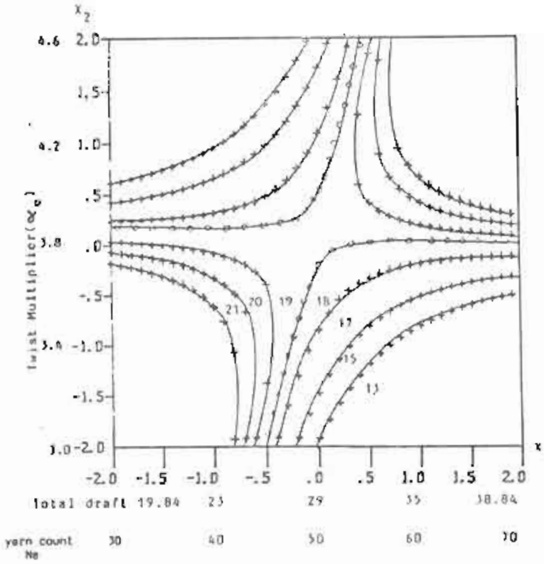


Fig.(2) Contours for Tenacity
(blend level X3 = -1)
(35% Cotton/ 65% PES)

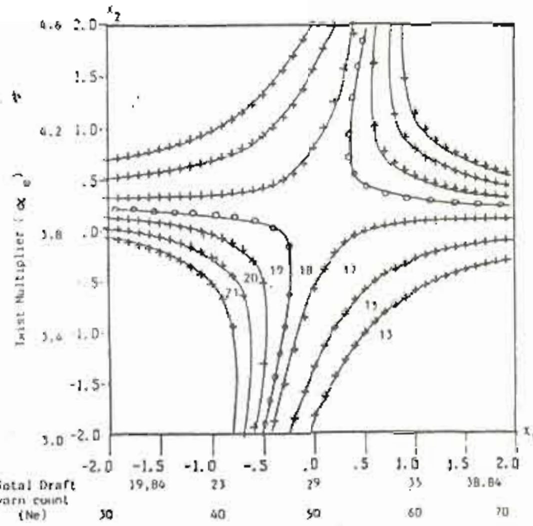


Fig.(3) Contours for Tenacity
(blend level X3 = 0)
(50% Cotton/ 50% PES)

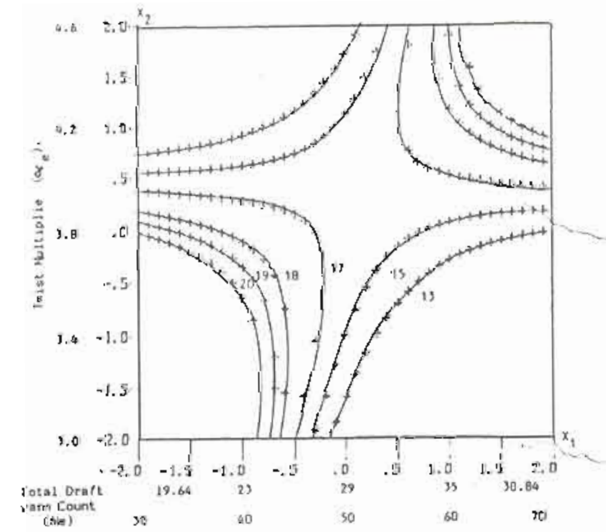


Fig.(4) Contours for Tenacity
(blend level X3 = +1)
(65% Cotton/35% PES)

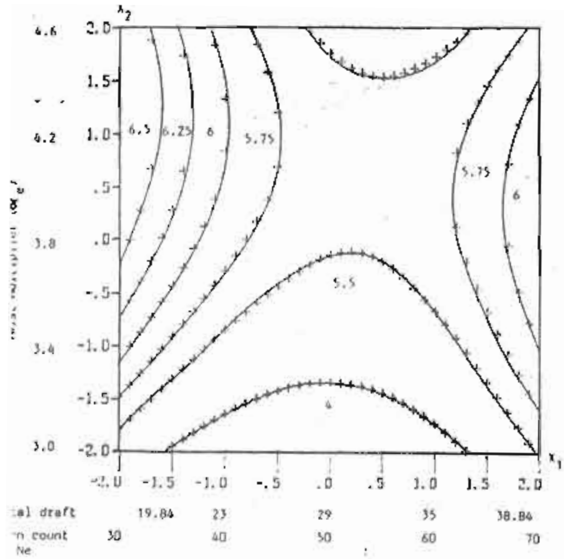

Fig.(5) Contours for Elongation
(blend level X3 = -1)
(35% Cotton/65% PES)

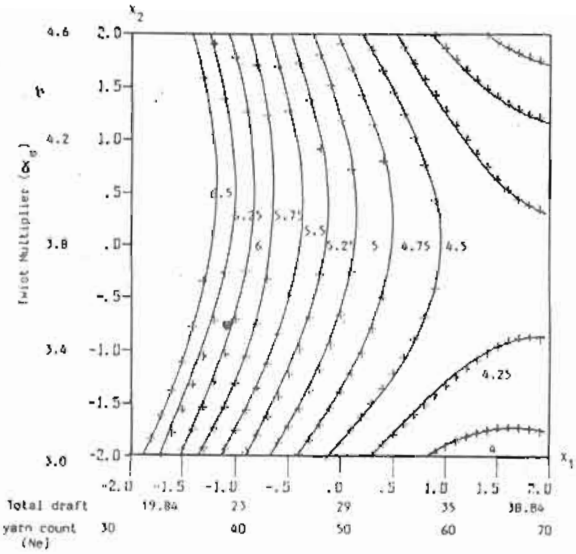

Fig.(6) Contours for Elongation
(blend level X/ = -1)
(50% Cotton/50% PES)

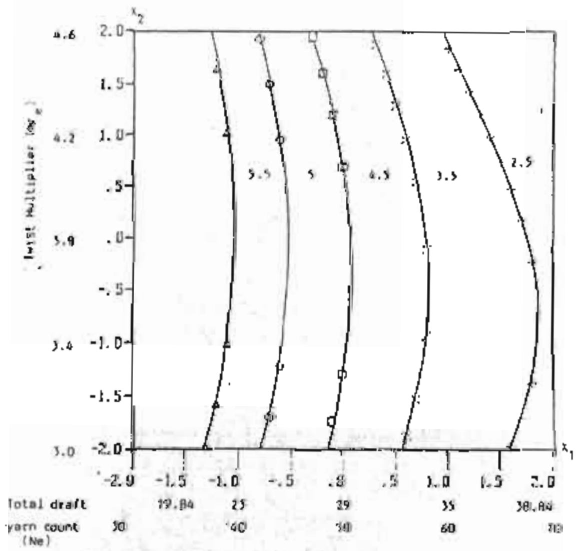

Fig.(7) Contrours for Elongation
(blend level X3 = +1)
(65% Cotton/35% PES)

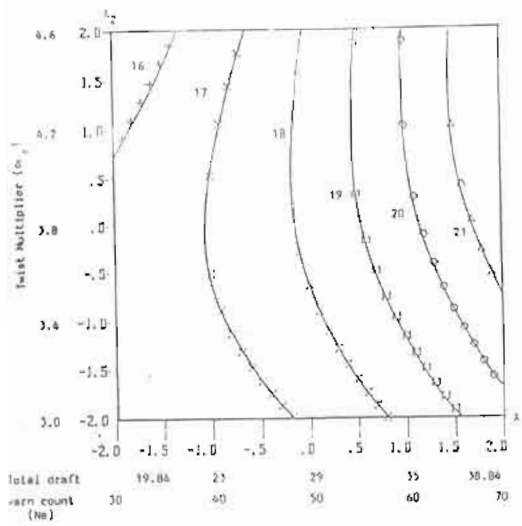


Fig.(8) Contours for Irregularity (blend level X3 = -1) (35% Cotton/65% PES)

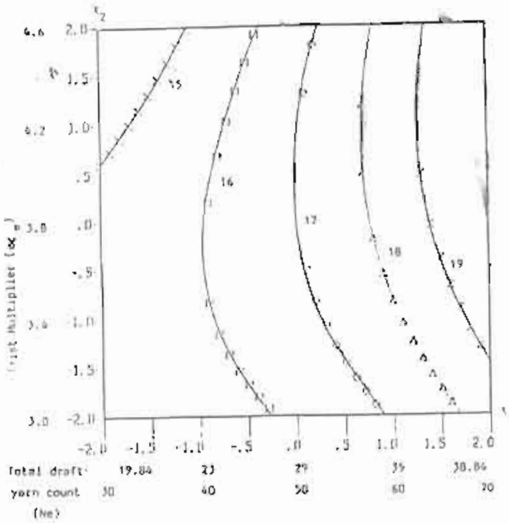


Fig.(9) Contours for Irregularity (blend level X3 = 0) (50% Cotton/50% PES)

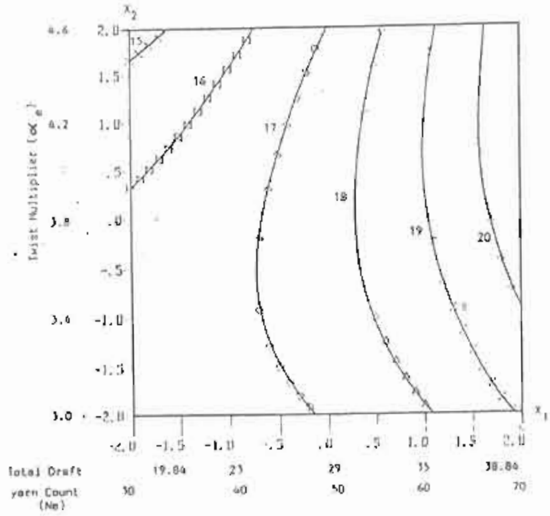


Fig.(10) Contours for Irregularity (blend level X3 = +1) (65% Cotton/35% PES)

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 $X_2$(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 $53_c$/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 multipler $\alpha_e$ 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 | | Yarn extension | | Yarn irregularity | |
|---|---|---|---|---|---|---|---|
| | | s.s | m.s | s.s | m.s | s.s | 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

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

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

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

Table (6) $2^3$ factorial Analysis.

| Factors | d.f | (m.s) mean squares for | | |
|---|---|---|---|---|
| | | yarn Tenacity g/tex. | Yarn extension (E %) | Yarn evenness c.v % |
| Main Effect: | | | | |
| $X_1$: Total draft | 1 | 10.8113** | 8.00 | 10.308** |
| $X_2$: Twist factor | 1 | 0.6844x | 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($\alpha_e$) 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%.

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