Fractional Factorial Treatment of Ring Spun Yarn Quality

تأثير عوامل التشغيل بطريقة تصميم التجارب الجزئية على جودة خيوط الغزل الحلقي

By

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ملخص البحث

يهدف هذا البحث الى دراسة بعض العوامل الخاصة بماكينة الغزل الحلقي والمؤثرة على جودة الخيوط الممشطة من قطن جيزة ٧٧ . ولقد تم بحث العوامل التالية: نمرة الخيوط الناتجة ، سرعة المردن لفة/دقيقة ، وزن الدبلة ، الضغط على السلندرات العلوية ، المسافة بين منطلونات السحب على سطح الاستجابه لخواص الخيوط مثل قوة الشد والاستطالة ودرجة الانتظامية والعيوب الغزلية /١٠٠٠ متر وقد تم اجراء التحليل الخاص بالنتائج على الحاسب الآلي باستخدام طريقة تصميم التجارب الجزئية (٩) وقد تم التوصل الى علاقات توضح مستوى جودة الخيوط مع متغيرات الغزل

Abstract

In the present work a study was made about the effect of the following five parameters: "yarn linear density , spindle speed, traveller size, top roller pressure and cradle opening" on the quality of ring spun yarn.

The experiments were carried out by varying each parameter at two levels using the fractional factorial technique (9). The experimental design treatment with the help of mini-computer programming was used to determine the effect of main parameters and two factor interactions. A statistical analysis for the study of the significance of main variables and interactions between two parameters were carried out by the method of variance analysis.

1- Introduction:

It is well known that spinning performance and yarn quality at ring spinning frame are governed by many factors, such as, roller eccentrecity, spindle speed, traveller weight, top roller loading, cradle spacing, break draft, drafting roller setting, feeding conditions and twist of the input roving (14,16,17,5,8)

R. Audivert et al. (13) studied the effect of apron spacing on yarn quality using four values of spacing and stated that : increase in apron spacing was turned into decreasing in both tenacity and uniformity of ring spun yarns. End breaks also have been shown to increase as apron spacing increases (12,17).

Yablonskii (11) studied the effect of roller weighting on yarn quality and end breakage rate and found that, there was a high negative correlation between weighing of the delivery rollers and the average number of end breaks. However no significant correlation was found between delivery rollers weighing and yarn properties.

Audivert et. al (7) studied the effect of drafting speed on yarn irregularity . It was found that , increasing the drafting speed in terms of spindle speed increases

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yarn irregularity when fibres of high extensibility and low modulus were employed. Conversely, increasing drafting speed improves regularity of yarns spun from fibres of low extensibility and high modulus.

Earlier working on high draft ring frames equipped with casablanca apron cradles; Simpson et. al.(2,3 ,4) found that, spinning draft has more effect upon yarn strength and yarn uniformity than other parameters. The optimum draft value was found to vary with yarn count and cotton fibre parameters.

An earlier study(14) indicated that the hank of the input roving and ring frame draft can be varied over a wide range in top arm loading without affecting yarn quality in coarse and medium varieties of cotton.

Simpson et. al.(1) studied the effect of doubling at ring frame, they found that , the benefits of doubling depend upon the count spun as well as the total draft. Also Rantnam (16) concluded that, there is a little difference between the quality of yarn when using single and double feeds in counts 40s and above .

Earlier work on top arm drafting Salasubramanian .(14) have shown that, yarn quality is also affected by the input hank and feeding conditions (single or double). Further studies indicated a high degree of interaction between the different processing variables, and the optimum with respect to each of them is found dependent upon the value of the parameters.

El-Bealy et. al. (18) studied the influence of drafting zone parameters, such as : break draft, distance clips, total draft, drafting speed and blend properties at the ring frame on the quality of two-component blended yarn. The investigation was carried out by varying each two variables at different levels while the others were kept constant.

El-Behery (15) carried out methodolgy studies to determine the effects of machine parameters, break draft, spacer stud and total draft on spinning end breakage, strength, elongation and yarn irregularity for two types of cotton spun on the Sacolowell Magna-draft system for both short and long cradle types.

Thus the present study was aimed to investigate the effect of yarn linear density,, spindle speed, traveller number, top roller pressure and cradle spacing using fractional factorial design technique to get a proper understanding of their effect as individuals or interactions on yarn tenacity, uniformiy and yarn imperfections .

2- Experimental work:

2-1 Material used:

Egyptian cotton fibres G_{77} of 32 mm mean length, 3.81 Micronair reading and pressely index 11.1 (lb/mg) and trash content 3.64% was used in the present study.

2-2 Yarn production

The machine sequence was adopted for cotton fibre as shown in Fig.(1) (all items were put through).

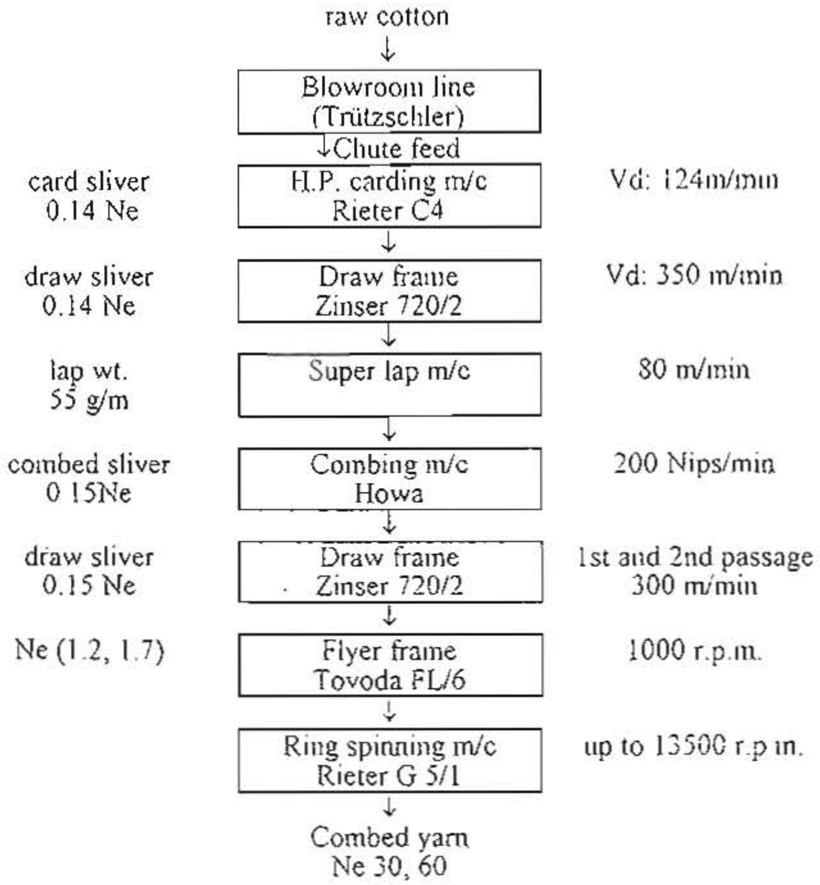

Fig. (1) Machine Sequence

Vd : delivery speed

2-3 Measurements:

Yarn Evenness: for each test 10 bobbins were presented to Uster Evenness Tester II. Material speed was 200 m./min, with testing time 2.5 min. The yarn nep counts, thin places and thick places were tested under the same conditions.

Yarn strength: Tests were performed on Uster Tensomat.Batches of 10 bobbins were tested with 20 individual tests / bobbin.

The count, and count variation of the final ring yarn in C.V% was tested using Uster Autosorter.

Fibre parameters were examined for length characteristics on Digital Fibrograph, trash content on shirley analyser and fineness on Shiefeld Micronair.

2-4. Statistical Design:

The general method of analysis of the present study which is drawn from the previous literature of experimental design (9) will be described here. The fractional factorial experiments was set up in order to investigate the quality of ring spun yarn and to optimize the yarn linear density, spindle speed (r.p.m), traveller weight (number), loading the top arm (Kp) and cradle spacing (mm).

The investigation of ring variables each at two levels will entail 32 observation (2^5), but the aim of the present investigation is to obtain information on main effect and interaction with the technique of "five factors in sixteen observation" than is required by the complete design as shown in Table (2).

Table (1) Levels of Variables

Levels	Variables				
	X1	X2	X3	X4	X5
	Ne	r.p.m	tr. no.	kp	mm
Lower level (-)	30	9000	2/0	15	2.5
Upper level (+)	60	13500	5/0	18	4.0

Table (2) Plan of Experiments

Combination No.	Level of Variables					Response
	X1	X2	X3	X4	X5	
1	-	-	-	-	-	y1
2	+	-	-	-	+	y2
3	-	+	-	-	+	y3
4	+	+	-	-	-	y4
5	-	-	+	-	+	y5
6	+	-	+	-	-	y6
7	-	+	+	-	-	y7
8	+	+	+	-	+	y8
9	-	-	-	+	+	y9
10	+	-	-	+	-	y10
11	-	+	-	+	-	y11
12	+	+	-	+	+	y12
13	-	-	+	+	-	y13
14	+	-	+	+	+	y14
15	-	+	+	+	+	y15
16	+	+	+	+	-	y16

Table (3) Yarn properties

Yarn Properties							
Combination No.	Strength g.	Tenacity g./tex	Elangation %	Irregularity C.V%	Imperfections/ 1000m		
					thin	thick	neps
1	450.74	22.88	5.42	9 10	0	2.3	9.5
2	205.47	20.86	3.77	13 63	12.7	34.5	60.6
3	436.55	22.16	4.6	9.40	0	2.2	14
4	207.44	21.06	2.15	13.49	15.1	24.7	61.4
5	430.25	21.84	5 36	9.11	0	2.2	12
6	210.30	21.35	3 93	12.48	3 4	16.9	51.5
7	434 98	22.08	4.57	9.09	0	1.7	9.8
8	204.58	20 77	3.40	13.30	16 8	23 3	72.8
9	465 31	23.62	5.62	8 92	0	2 2	12.1
10	200.84	20 39	3.59	12.25	4.3	12.3	51.9
11	456.45	23.17	4.74	8.82	0.1	2.5	12.0
12	190.89	19 38	2.49	14.05	24.1	26.6	70.0
13	471.03	23.91	5 35	8.94	0.2	2.4	13.2
14	213 55	21.68	4.18	12.97	10.1	19 6	55
15	436.75	22.17	4 64	9.19	0 1	2.3	14.8
16	208.03	21.12	3.57	12.44	7.9	16.7	56.4

Table (4)
Regression coefficients

Regression coefficient	Responce Parameter						
	Strength g.	Tenacity g/tex	Elangation %	Irregularity C.V%	Imperfections/ 1000m		
					thin	thick	neps
b0	310.33	21.781	4.21	11 07	5.925	12.025	36.063
b1	-108.76	-0 953	-0.804	2002	5.875	9.782	23.887
b2	-6 21	-0.291	0.441	-0.149	2.088	0.475	2.838
b3	0.85	0.088	0.164	-0 134	-0.113	-1.388	-0.375
b4	2.45	0.52	0.061	-0 126	-0 125	-1.45	-0.388
b5	-4.86	0.744	0.048	0.248	-2.05	-2.088	-2.85
b12	2.46	0.047	-0.042	0.95	2.088	0.525	2.363
b13	4.396	0.314	0 221	-0.145	0.188	-1.313	-0.65
b14	-3.83	-0 334	0.012	-0 024	-0.125	-1.588	-1.238
b15	3.23	0.061	-0.028	0.164	-2.075	-2.088	-1.8
b23	-0.92	-0.043	0 109	-0.084	-0.7	-0.113	0.075
b24	-3.52	-0.179	0.029	0.028	0.113	0 975	-0.213
b25	-1.334	0.153	0.034	0.015	1 38	0.988	-1.15
b34	0.915	0.199	-0.001	0.075	-0.163	1.063	-0.45
b35	-1.77	0.031	0.026	-0.045	0 113	0.875	-0.113
b45	-1.046	0.002	0.086	0.088	-0.675	-0.013	0.55

Table (5-a)
Summary of Variance Analysis

Source of Variance	Degree of Freedom	Mean Square (M S)						
		Yarn Properties						
		Strength g	Tenacity g/tex	Elongation %	Irregularity C.V%	Imperfections/ 1000m thin	thick	neps
(!) Main effects								
Yarn count (Ne)X1	1	189279	14.53	10 336	64.12	552.25	1538.6	9129.8
Spindle Speed (r p.m)X2	1	616.9	1.35	3.115	0.35	69.72	3.61	129.39
Traveller number X3	1	11.65	0.1278	0 429	0 29	19.80	30 80	2 25
Top roller pressureX4	1	96 29	0 363	0 060	0 26	0.203	33 64	2.40
Cradle spacing X5	1	377 82	0.74370	0.037	0 97	64.80	69 72	129.96
(ii) Two-Factor Interacions								
X1X2	1	96 77	0 035	0 4360	0 144	69 72	4.41	89.30
X1X3	1	309 32	1.5805	0 7863	0 336	20 70	27.56	0.20
X1X4	1	234 47	1 7891	0.0020	0 009	0.25	40 0	3 34
X1X5	1	167.38	0.0613	0 0125	0 429	68.89	69 72	4 84
X2X3	1	13.59	0 0297	0.1911	0.112	7.84	29 16	6.76
X2X4	1	198.46	0 5149	0 0132	0.013	2.03	15.21	24 50
X2X5	1	28 49	0 3750	0.0187	0.004	0.276	15.60	51.84
X3X4	1	13 41	0 6362	0.00003	0.081	0.423	18 06	0.09
X3X5	1	50.23	0 0149	0 0110	0.032	0.203	12.25	0.723
X4X5	1	17.54	0.0005	0.1198	0 123	7 29	70 64	21.16

(For n = 10) (*) Significance for 99% (**) Significance for 95%
(***)Significance for 90%

The five variables mentioned will be refered to as X1, X2, X3, X4 and X5 respectively. The levels chosen for each variable as shown in Table (1), considering the previous practical experience(9)

3-Results and Discussion

The results of yarn quality tests at different conditions "16 experimental combination" for yarn count , spindle speed , treaveller weight , top roller pressure and cradle spacing are shown in Table (3). Regression coefficients were determined for the measured yarn quality and tested for significance are given in Table (4)

Summary of variance analysis of different yarn characteristics is shown in Table (5-a) and (5-b) . Also two factor interactions which have a significant effect on yarn characteristics are given in Tables(6) .

Table (5-b)
Summary of Variance Analysis

Source of Variance	Degree of Freedom	Mean Square (M.S) Yarn Properties: Strength g	Tenacity g/tex	Elongation %	Irregularity C V%	Imperfections/ 1000m: thin	thick	neps
(I) Main effects								
Yarn count (Ne)X1	1	189279.4	14.53	10.336	64.12	552.25	1538.6	9129.8
Spindle Speed (r.p.m)X2	1	616.9	1.35	3.115	0.35	69.72	3.61	129.39
Traveller number X3	1	11.65	0.1278	0.429	0.29	19.80	30.80	2.25
Top roller pressureX4	1	96.29	0.363	0.060	0.26	0.203	33.64	2.40
Cradle spacing X5	1	377.82	0.74370	0.037	0.97	64.80	69.72	129.96
(ii) Two-Factor Interacions								
X1X2	1	96.77	0.035	0.4360	0.144	69.72	4.41	89.30
X1X3	1	309.32	1.5805	0.7863	0.336	20.70	27.56	0.20
X1X4	1	234.47	1.7891	0.0020	0.009	0.25	40.0	3.34
X1X5	1	167.38	0.0613	0.0125	0.429	68.89	69.72	4.84
X2X3	1	13.59	0.0297	0.1911	0.112	7.84	29.16	6.76
X2X4	1	198.46	0.5149	0.0132	0.013	2.03	15.21	24.50
X2X5	1	28.49	0.3750	0.0187	0.004	0.276	15.60	51.84
X3X4	1	13.41	0.6362	0.00003	0.081	0.423	18.06	0.09
X3X5	1	50.23	0.0149	0.0110	0.032	0.203	12.25	0.723
X4X5	1	17.54	0.0005	0.1198	0.123	7.29	70.64	21.16

(For n = 6) (*) Significance for 99% (**) Significance for 95%
(***) Significance for 90%

3.1 Yarn Strength

The analysis of results are given in Tables (5-a) and (5-b), the main effect of individual five parameters and two-factor interactions while three factor which are regarded as negligible. The significant effects in order of magnitude are X1: yarn count, X2 : spindle speed and X5 : spacer setting. From the variance analysis, it can be noticed that yarn count, spindle speed and cradle spacing have a significant effect

Table (6) Two- Factor Interaction

(i) Yarn Strength

***Single end strength (gm)**

Interaction X_1X_3

X_1	X_3	
	-	+
-	423.2	416.1
+	196.9	207.4

Interaction X_1X_4

X_1	X_4	
	-	+
-	413.4	225.9
+	203.5	200.75

Interaction X_1X_5

X_1	X_5	
	-	+
-	427.8	411.6
÷	203.8	200.5

Interaction X_2X_4

X_2	X_4	
	-	+
-	311.13	323.1
+	305.75	303.6

***Tenacity (g/tex)**

Interaction X_1X_3

X_1	X_3	
	-	+
-	22.96	22.51
+	20.42	21.28

Interaction X_1X_4

X_1	X_4	
	-	+
-	22.25	23.22
+	21.01	20.64

(ii) Yarn Elongation

Interaction X_1X_3

X_1	X_3	
	-	+
-	5.095	4.98
+	3.0	3.77

(iii) Yarn Irregularity

Interaction X_1X_3

X_1	X_3	
	-	+
-	9.06	9.08
+	13.36	12.79

Interaction X_1X_5

X_1	X_5	
	-	+
-	8.99	9.16
+	12.67	13.49

(iv) Yarn Imperfections

*** Neps / 1000m**

Interaction X_1X_2

X_1	X_2	
	-	+
-	11.6	12.70
+	54.8	65.15

Interaction X_1X_4

X_1	X_4	
	-	+
-	11.30	13.03
+	61.58	58.33

Interaction X_1X_5

X_1	X_5	
	-	+
-	11.3	13.03
+	61.58	58.33

Interaction X_2X_5

X_2	X_5	
	-	+
-	31.53	34.43
+	34.9	42.9

***Thin places / 1000 m.**

Interaction X_1X_2

X_1	X_2	
	-	+
-	0.05	0.05
+	7.63	15.98

Interaction X_1X_5

X_1	X_5	
	-	+
-	0.075	0.025
+	7.68	15.93

***Thick places / 1000 m.**

Interaction X_1X_5

X_1	X_5	
	-	+
-	2.23	2.23
+	17.65	26.0

Interaction X_4X_5

X_4	X_5	
	-	+
-	11.4	15.56
+	8.48	12.68

on yarn strength property" single end strength, tenacity and elongation". Yarn tenacity decreases as spindle speed increases from 9000 to 13500 r.p. m as shown in Fig (2-1). These results are in agreement with earlier work (10). This could be explained on the basis of increased drafting speed, increases the average fibre tension which resulting in an increase in the fibres dragging out of the roving into the front roller nip and this helps in reducing yarn strength.

In the present analysis, it is considered that the two factor interactions (10 items) were combined to give an estimate of error variance as shown in table (5-!). Also since the interaction of X1X3, X1X4, X1X5 and X2X4 are large, the six interactons were combined to give an estimate of error variance as shown in Table (5-b). Thus it is clear that from the statistical analysis, the two factor interaction X1X3 yarn count with traveller weight; X1X4 yarn count with loading the top arm affect significantly at 95% level as shown in Table (5-a and 5-b) While the interaction of X1X5 yarn count with cradle spacing and X2X4 spindle speed with pressure have a slight influence on yarn strength.

From the two way tables (5) and (6) and Fig (4) , it can be seen that the yarn expected count has a significant effect on yarn strength, whatever, the conditions of the other factors (traveller weight, loading the top arm). There is a high value of yarn strength obtained at low level of yarn count (i.e for coarse count). Also the traveller weight effect has been noticed, the high traveller number especially at higher level of yarn count" fine count" resulting in a lower yarn strength than those obtained for coarse count. For the experimental yarn counts (30 to 60 Ne), increasing loading the top arm resulted in a lower yarn strength. Also closer setting with course or fine counts results in a higher strength than that obtained at wide spacer, this is due to better control of fibres by closer cradle setting . On the other hand , the effect of spindle speed with pressure at top roller can be noticed in Table (6) . The results indicate that a higher yarn strength at lower level of spindle speed (for the two levels of top roller pressure) than those obtained for higher level of spindle speed.

3.2 Yarn elognation:

From the experimental results of yarn elongation [Tables (5-a) and (5-b)], it can be seen that , yarn count and spindle speed have a significant effect on yarn elongation. Higher spindle speed has a negative effect on yarn elongation as shown in Fig (2-2).

The influence of two factor interaction on yarn elongation is given in Fig. (5) and Table (6) The interaction between yarn count and traveller weight has a significant influence on elongation at 95% confidence level. Also from two way Tables (6) and Fig (5-2), it is clear that, as yarn gets finer its elongation is largly decreased by using heavy traveller weight.

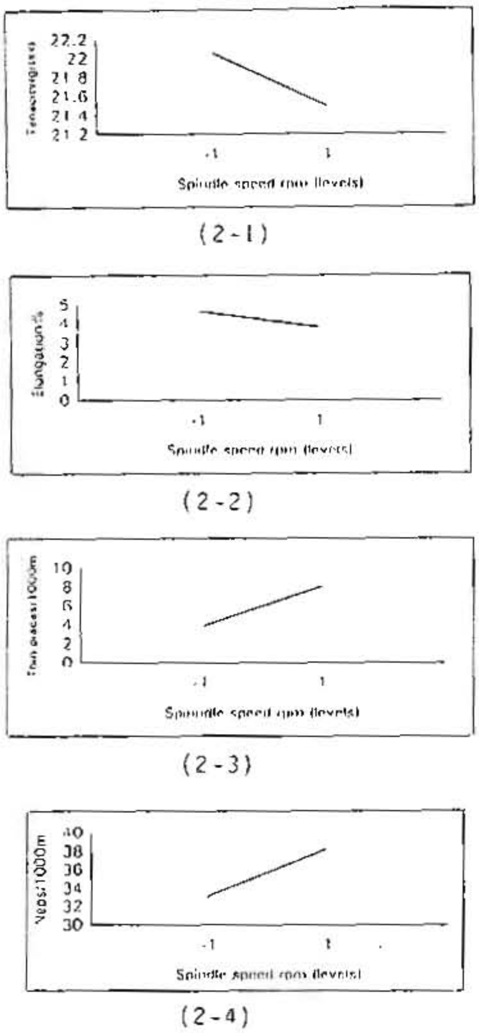

Fig.(2)
Relation Between Spindle Speed and Yarn Properties

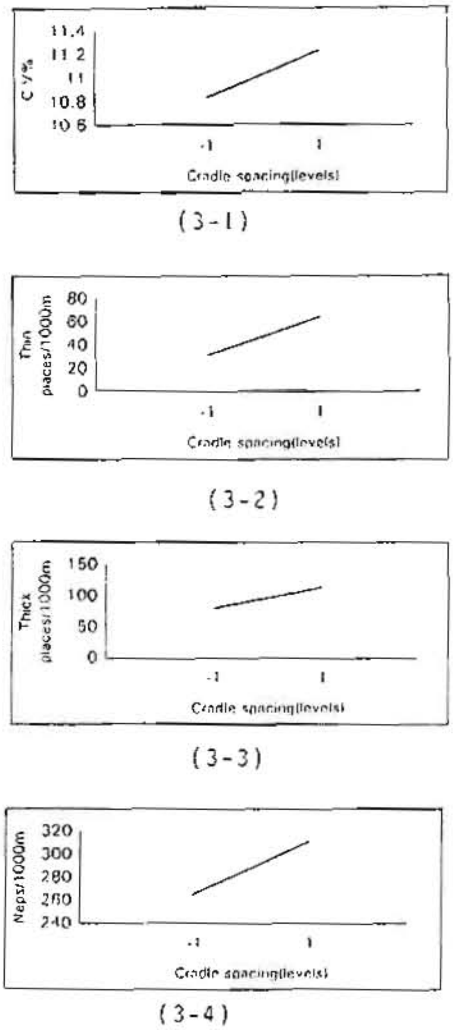

Fig.(3)
Relation Between Cradle Spacing and Yarn Properties

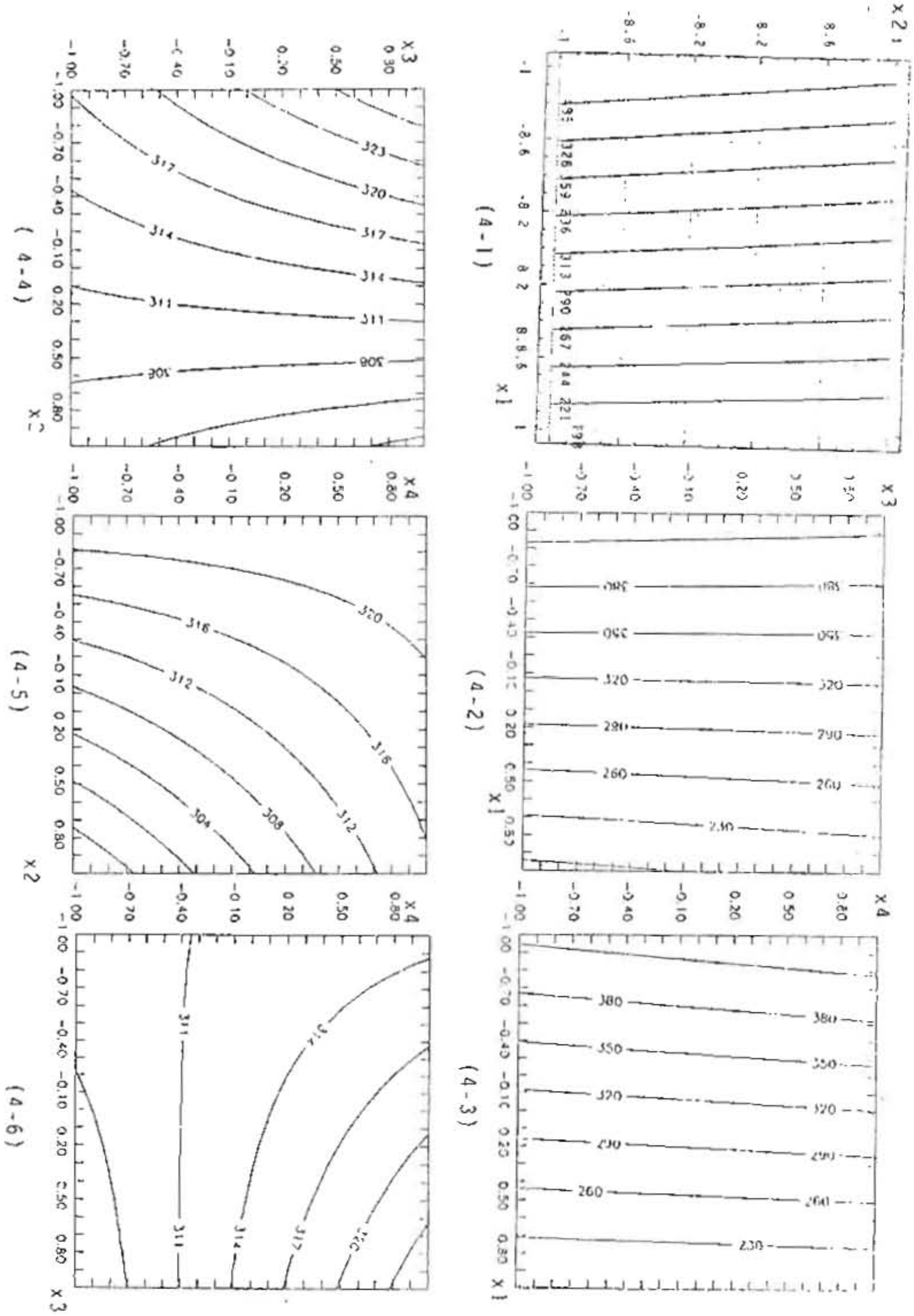

Fig.(4) Contours For Yarn Strength

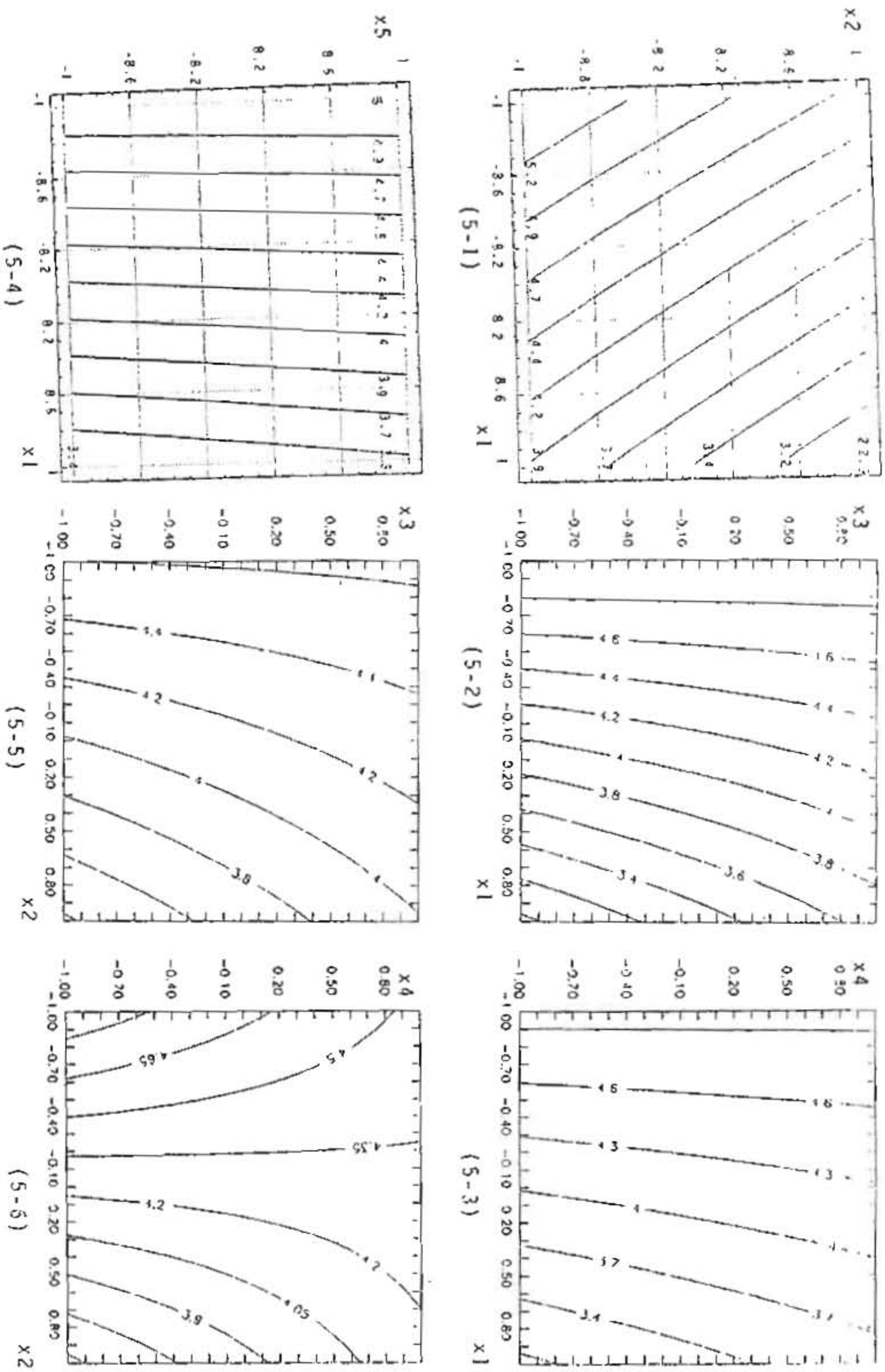

Fig.(5) Contours for Yarn Elongation

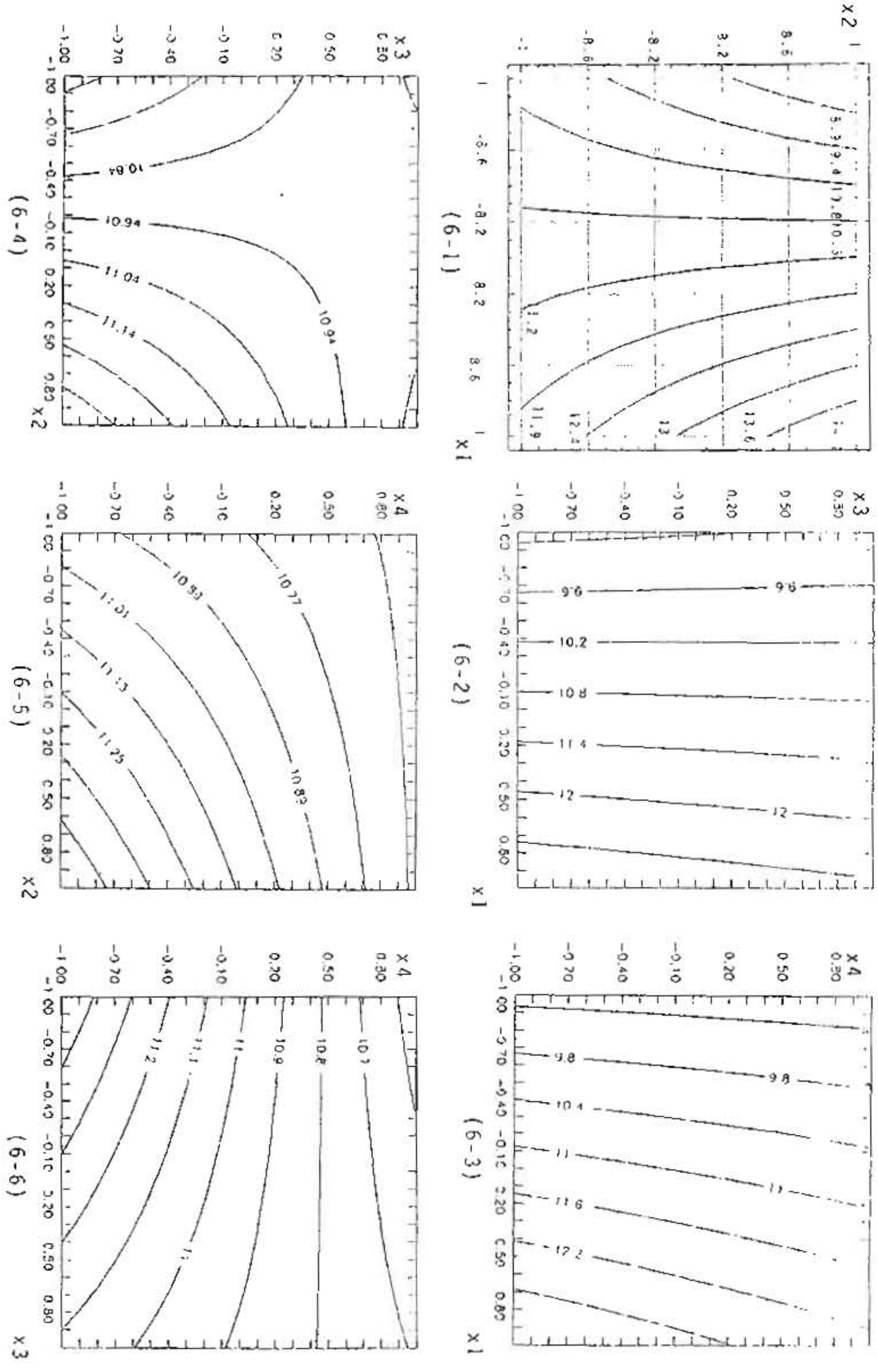

Fig.(6) Contours for Yarn Irregularity

3.3 Yarn Irregularity

It can be noticed from the variance analysis that the main effect of yarn count, cradle spacing on yarn irregulartity is heighly significant (at 99% confidence level). As shown in Fig (3-1) using wide cradle spacing increases yarn irregularity (C.V%) than that obtained with the closer one . This, may be attributed to a wide cradle spacing that will help in increasing the number of floating fibres which results in a high irregularity.

The curves in Fig (6) show that, yarn regularity deteriorates with finer count than these with coarser count. The values of yarn irregularity C.V% ranged between 9.5% to 12% at lower spindle speed while it varies from 9% to 14% at higher spindle speed.

3.4 Yarn Imperfections:

From the statistieal analysis given in Tables (5-a) and (5-b), it can be seen that, yarn count has a significant influence on yarn imperfections " neps, thick places and thin places at 99% " whatever the condition of other four parameters. Also , the spindle speed affects significantly on neps and thin places at the levels of 99% and 90% respectively. In additon to the influence of the earlier parameters, yarn imperfections were affected by apron spacing as shown in Fig. (3). Upper level of cradle spacing increased yarn imperfections , this may be due to the incidence of slippage at wider apron spacing.

The two factor interactions, such as, yarn count with spindle speed, yarn count with top roller pressure and yarn count with cradle spacing affect significntly neps count. as shown in Table (5-a), (5-b) and (6), as well as the interaction between spindle speed and cradle spacing . Also there are another two factor interactions, are given in table (5-1), (5-b) and (6), which have a significant effect on number of thin and thick places.

4- Conclusion:

The present study permits the following conclusions to be drawn:

I) It has been found that the parameters: yarn linear density , spindle speed, traveller size, loading the top arm and cradle opening have a significant effect on yarn quality . Also, the interaction between the effects of two parameters is significant in the majority of the cases.

ii) Yarn strength:

Ring spun yarn strength is influenced by spindle speed and cradle opening:
The two factor interaction such as X1X3, X2X4 and X1X4 affect significantly on yarn strength..
A higher yarn strength is obtained by close setting of cradle for fine and coarse yarns.

For both fine and coarse yarns as loading the top arm increased yarn strength decreased.

For both levels of loading the top arm as the spindle speed increased, the yarn strength decreased.

(iii) Yarn elongation :

The experiments clearly show that;

Higher spindle speed and yarn linear density affect significantly on yarn elongation.

Improper choice of traveller size for the linear density of required yarn will reduce yarn elongation.

(iv) Yarn uniformity:

A better rign spun yarn uniformity was obtained with closer cradle opening.

For higher linear density a better uniformity was achieved as the spindle speed increased. Whereas for lower linear density increasing spindle speed causes deterioration in yarn evenness.

(v) Yarn Imperfections (thin, thick places and neps/1000m):

A constant relationship existed between yarn imperfections (thick, thin places and neps) and yarn linear density at various spindle speed and cradle opening .

Under the reported spinning conditions it has been found that lower linear density , higher spindle speed and as cradle opening is increased yarn irregularity and imperfections increased

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