CONTINUOS IMPROVEMENT OF YARN QUALITY IN SPINNING MILLS

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Abstract

The main responsibility of any modern quality control system is to improve the status of the organization in which it is responsible. This will enable the organization to go further in the business and maintain a greater portion of the market. The improvement can be made through an institution, pilot plan or on the production line of the factory, without disturbing both quality and productivity. The quality of yarns depends to a great extent on fiber type and machines settings, while labor performance and environmental conditions had lesser effect. Improving the quality by amelioration of labor performance and environmental conditions is performed by training and new installations and not by on line researches. The fiber type is usually chosen depending on the yarn count and selling price; most researches are performed essentially on machines settings. Previous researches indicate that the amount of draft has the greater impact on the yarn quality. Introducing the greater number of factors for improving the yarn quality can tend to optimum quality improvement. To attain such a condition the Constrained Experimental Design was applied. Previous researches focused on studying factors affecting the quality and yarn specifications with no more than five factors.

In this research the factors affecting the quality of yarns in the spinning mill was studied, in order to reach the best operating conditions using the dependent and independent factors experimental design. Drafts are considered as dependent factors while settings, speeds, and twist as independent factors. Thirty six trials for twelve factors were studied at normal operating conditions, to obtain carded yarns of 19.67 Tex. Quality better than 5% Uster level was achieved.

Introduction

The quality and productivity of cotton yarns depends on four categories of factors: fiber types, machine setting, labor performance and environmental condition. Continuous improvement has to be carried out on the factory to attain optimum working condition, which enable the organization to maintain computation. This has to be carried on plant itself with the maximum number of factors and minimum number of experiments. Tens of factors are to be studied and adjusted to attain the best operating conditions. The draft, draft distribution setting and pressure in drafting mechanism are the factors which had maintain a great attention in the literature .Lesser attention was introduced to settings, speeds, labor performance and environmental condition. The application of experimental design in textile industry for detecting the factors affecting yarn quality by Statistical methods was carried out from about half a century by Dudley 1958.

Since that time the Design of Experiment (DOE) were applied in many published papers for determining the effect of different factors on evenness, imperfections, strength and elongation of spinning materials. Barella, Ben Hassen, Dundley, Kumar and Subramaniam applied the experimental designs in their works, with five maximum numbers of factors. The experimental design consist of two or three level factorials, second order rotatable design and central composite rotatable designs. They were also applied on pilot plans or in laboratory, so they need adjusting experiments for implantation on production scale. In all these works only the draft of two mechanisms were varied. This is due to the fact that it is difficult to maintain an acceptable draft for more than two drafting mechanisms. Grishin, Rao and Anderson indicates that the draft has a higher effect on the product evenness and it has either a quadratic or interaction effect while the setting between rollers (ratch) has always a linear effect, also an interaction between draft and ratch sometimes exist

For choosing best draft from blow room to spinning Jack Simpson 1964 carries hundred of experiments on spinning plant, applying one factor at a time procedure. Planned, Sequential and Evolutionary Process can be applied for optimizing or improving Quality. Evolutionary Process (EVOP) was proposed by Box to find the optimum operating condition during normal operation and was applied by Geiheini on textile plant. The EVOP is restricted by five factors increasing the number of factors can increase to a higher degree the number of trails needed. Mixture Design or Constrained Experimental Designs introduced by Scheffe can have an efficient solution for on plant quality improvement. Mixture designs increase the ability of experimental design for blend components in this case the independent factors are proportions of different components of a blend; there must be sum to one. If for some reason, the sum of the component proportions is less than one, the variable proportions can be rewritten as scaled fractions so that the scaled fractions sum to one. The measured response is assumed to depend only on the relative proportions of the ingredients or components in the mixture and not on the amount of the mixture. For that the simplex- lattice designs and simplex - Centroid designs models can be fitted. When mixture components are subject to additional constraints, such as a maximum and/or minimum value for each component, constrained mixture designs or Extreme-Vertices designs, are appropriate. The main distinction between mixture experiments and independent variable experiments is that with the former, the input variables or components are non-negative proportionate amounts of the mixture, and if expressed as fractions of the mixture, they must sum to one. The purpose of mixture experiments is to model the blending surface with some forms of mathematical equation so that:

- Predictions of the response for any mixture or combination of the ingredients can be made empirically.
- Some measure of the influence on the response of each component singly and in combination with other components can be obtained.

The models obtained in mixture experiments are of the form:

For Simplex Lattice Designs

Linear $$E(Y) = \sum_{i=1}^{q} \beta_i X_i \quad \text{……………………………………………………………………} (1)$$

Quadratic $$E(Y) = \sum_{i=1}^{q} \beta_i X_i + \sum_{i=1}^{q} \sum_{i<j}^{q} \beta_i X_i X_j \quad \text{…………………………………………………} (2)$$

For Simplex- Centroid Designs

$$E(Y) = \sum_{i=1}^{q} \beta_i X_i + \sum_{i=1}^{q} \sum_{i<j}^{q} \beta_{ij} X_i X_j + \sum_{k=1}^{q} \sum_{j<k}^{q} \sum_{i<j}^{q} \beta_{ijk} X_i X_j X_k + \ldots + [\beta_{12\ldots q} X_i X_j \ldots X_q] \quad \text{……………………} (3)$$

Salaman applied the mixture design for optimizing the processing of carded yarn and open-end cotton yarns respectively by using the Extreme Vertices Experimental. The factors under study consist of draft from drawing to spinning. The total draft applied will be equal to

$$E_T = \pi_{i=1}^{s} E_i \quad \text{…………………………………………………………………………} (4)$$

Where: E_T = total draft, E_i = draft at the i^{th} (machine)

While the reduction in size is equal to

$$S = N_y / N_L = \pi_{i=1}^{s} (E_i / d_i) \quad \text{………………………………………………………} (5)$$

Where: S = the reduction in size, N_y = yarn count, N_L = Card feeding count

d_i = doubling at the i^{th} (machine)

It was possible to Transfer the relation (5) to mixture constrains by rescaling the factors and taking logarithm. The extreme vertices design was applied for attaining the experimental procedure. The proposed equation is the form

$$\eta = \sum_{i=1}^{5} a_i X_i + \sum_{i=1}^{5} \sum_{i>j}^{5} a_{ij} X_i X_j \quad \text{…………………………………………………………………} (6)$$

Where: η- is the response under study.

Cornell demonstrates who to treat q mixture components and k process variables.

In this work we will deal with drafts from carding to roving, these drafts will be treated as dependent factors (mixture design), while settings and speeds as independent factors. Experimental Designs for mixture and process variable will be obtained using Random Balance Design Procedures. The work will be carried on the factory plan without altering the production and maintaining the quality at an acceptable level.

Methodology

The work consist of producing carded yarn 19.57 Tex (N_e 30/1) with a total draft from card to roving equal to 64000 ,with doubling 8 at both draw frames , by varying factors from carding till roving on the production line. In the work plan the total draft, spindle speed and turns per meter at the spinning frame were not changed. The settings and break draft at the speed frame and spinning frame was not altered. Properties of the cotton fiber and the range of factors under study are shown in table (1) and table (2) respectively. The range of draft at logarithm scale is shown in table (3).

Table (1) Properties of cotton fiber under study

Effective Length	Short Fiber%	Uniformity index%	Neps/ gm	Pressley Index	Trash%	Micronaire
33.5 mm	17	68.65	14	8.5	4.2	4.3

Table (2) Range of factors under study

	Total Draft	Break Draft	Setting (mm)		Speed	Twist factor
			Back	Front		
Card	(125- 145)	-	-	-	60 mt./min	N.A
Draw 1	(6.48 – 8.11)	(1.38 – 1.56)	(46.5 – 49.0)	(41 – 44.5)	300 mt/min	N.A
Draw 2	(7.33 – 8.48)	(1.16 – 1.70)	(41.5 - 44.5)	(37 – 41.0)	600 mt/min	N.A
Roving	(8.10 – 10.4)	1.26	39.5	51	(900 – 950) rpm	(1.11 – 1.24)
Spinning	30	1.14	60	43	(14500) rpm	4

- Where: N.A - Not available, * - constant medium setting in roving frame 50 mm

Table (3) Range of Machine Total drafts and there Mixture codes

Main Draft	Transferred range		Logarithm range	
	minimum	maximum	minimum	maximum
Card/10	12.50	14.50	0.395	0.460
Draw 1	6.48	8.11	0.110	0.207
Draw 2	7.33	8.48	0.164	0.227
Roving	8.10	10.40	0.207	0.315

From table (3) it is seen that the logarithm range of the total draft are less than one and greater than zero so the Extreme Vertices Design (EVD) had to be applied. The number of experiment which will be determined through EVD procedure will depends on the number of experiment chosen for the dependent factors, thirty six experiments in our case. Table (4) represents the notations of factors under study.

Table (4) Notations of factors under study

Total Draft	Notation	Drawing Ratch	Notation	Break Draft and Roving	Notation
Card	TDC	First Drawing Front	RDF1	Break Draft First Drawing	BD1
First Drawing	TD1	First Drawing Back	RDB1	Break Draft Second Drawing	BD2
Second Drawing	TD2	Second Drawing Front	RDF2	Roving Spindle Speed	RSS
Roving	TDR	Second Drawing Back	RDB2	Roving Twist Factor	RTF

A numbers of break drafts in drawing frames are chosen in a manner that they are obtained from the drafting gears; there percentages are between 15% and 25% of the total draft, they are demonstrated in table (5) for both draw frames. The mixture levels vary from .998 to 1.0008, while the total draft varies from 63874 to 64281instead of 64000. The third group of factors consists of the independent factors: setting, roving twist factor and roving spindle speed, they are six factors; five at three levels and one factor at two levels the (L_{36}) experimental design was chosen, the values of these factors are shown in table (6).

Table (5) Levels of Break drafts and their percentage from total draft

	Levels of Break draft						Max. % of Total Draft	Min. % of Total Draft
B.D1	1.38	1.42	1.46	1.48	1.52	1.56	22	16
BD2	1.16	1.28	1.41	1.70	-	-	26	14

The random balance design technique was applied to attain the combination between dependent and interdependent factors. The range of variation of the studied factors are determined and shown in table (7). From table (7) it can be concluded that the percentage of variation is from 7% till 40%. The maximum value is at BD2 since the range is wider than BD1, most of factors do not exceed 15% (9 out 12), a case which indicates the possibility of no great deviation in the quality. Both TD2 and RTD are within 23% to attain the roving count. It is clearly that the setting percentage variation, is much smaller than the draft (from 5% to 11%), some do not exceed the recommended settings for the fiber length. Drafts factor levels varies from 4 to 8, the roving frame has the higher number of levels. The experiments were made in a manner that every experiment is worked for not less than two days. The doubling at both first and second drawing was constant and equaled eight.

Table (6) Value and levels of independent factors in Drawing and Roving Machines

Coded Levels	Setting(mm)				Roving	
	First Drawing		Second Drawing			
	Back	Front	Back	Front	Twist factor	Speed(r.p.m)
1	46.5	41	41.5	37	1.19	900
2	47.5	42	43.0	39	1.24	950
3	49.0	44	44.5	41	1.11	-

Table (7) Range of variation of the studied factors

	C	TD1	TD2	TDR	BD1	BD2	RSS	RDF1	RDF2	RDB1	RDB2	RTF
Max	145	8.42	8.11	10.4	1.56	1.7	950	49	44.5	44	41	1.24
Min	125	7.33	6.48	8.1	1.38	1.16	900	46.5	41.5	41	37	1.11
Range	20	1.09	1.63	2.3	0.18	0.54	50	2.5	3	3	4	0.13
Mean	135	7.87	7	8.64	1.47	1.37	925	47.7	43	42.33	39	1.18
%Var.	14.8	13.8	23.3	26.4	12.3	39.6	5.41	5.25	7	7.09	10.3	11
L.N.	5	6	6	8	6	4	2	3	3	3	3	3

Results and Discussion

Trails were carried out in the factory working conditions without affecting the mill's production or quality. Stepwise regression was applied for determining the significant factors and the best operating condition.

Intermediate Material

The ranges of experimental properties from carded slivers till roving are shown in table (8). From which, the evenness of carded sliver decreased effectively after the first drawing while the range, this is due to the change in settings and draft. The percentage variation in roving is lesser since the roving count is maintained constant.

Table (8) Range of variation in the properties of carded slivers to roving frame

	Carding sliver			First Drawing sliver			Second Drawing sliver			Roving		
	ktex	CV count	Ev	ktex	CV count	Ev	ktex	CV count	Ev	ktex	CV count	Ev
Max	4.7	2.891	5.94	5.1	1.486	5.47	6.3	1.118	4.76	0.61	2.56	6.18
Min	4.1	0.383	5.26	3.9	0.233	3.52	4.8	0.121	3	0.57	0.5	5.11
Range	0.7	2.508	0.68	1.2	1.253	1.95	1.6	0.997	1.76	0.04	2.06	1.07
Mean	4.4	1.595	5.748	4.5	0.751	4.184	5.1	0.412	3.757	0.59	1.695	5.592
% variation	16	157.2	11.83	27	166.9	46.61	31	242.4	46.84	6.98	121.5	19.14

Results of carded yarns

The properties range of the carded yarns obtained from different experiments are shown in table (9). From table (9) we can deduce that the percentage variation of the yarn properties, except imperfection, is within 10%, while this is very high for imperfections and C.V. due to the type of distribution which describes these properties. Also most of the produced yarns attain a properties better than factory results, this indicate that the proposed procedure is of great help when carrying quality improvement strategy.

Figure (1) to Figure (6) demonstrate the comparison between the factory (F), level Uster levels (U) and experimental results of the yarn properties. For yarn Evenness, figure (1), all the experimental results are better than the factory levels about80% within 5% - 25% Uster Statistics. For yarn tenacity figure (2), 22% of results are between 5%-10% Uster Statistics while the factory level attains 10% levels. About 15% of the experimental results exceed that of the factory

Table (9) Range of variation of the properties of carded yarns

	Yarn														
	Tex	**CV count**	**Ev**	**ST (Bf)**	**BW**	**CV BW**	**RKM**	**CV st**	**%El**	**CV El**	**TK**	**TH**	**N**	**TPI**	**CV TPI**
max	20	1.67	16.5	389	548	16.4	19.8	11	5.5	11	230	11	312	22.5	2.9
min	19.2	0.32	14.8	349	473	12.2	17.7	7.3	5.1	6.2	151	2	192	21.6	0.7
Range	0.78	1.35	1.65	40	75	3.95	2.03	3.7	0.4	5	79	9	120	0.9	2.2
mean	19.7	0.84	15.3	365	504	13.8	18.6	8.5	5.3	7.1	200	6.4	261	22	1.8
% var.	3.93	160	10.8	11	15	28.7	10.9	43	8.5	71	40	140	46	4.08	125
Fac.lev	19.9	1.5	17.2	357	475	15.8	16.9	11.0	5.3	10.8	410	22	420	21.8	3.0

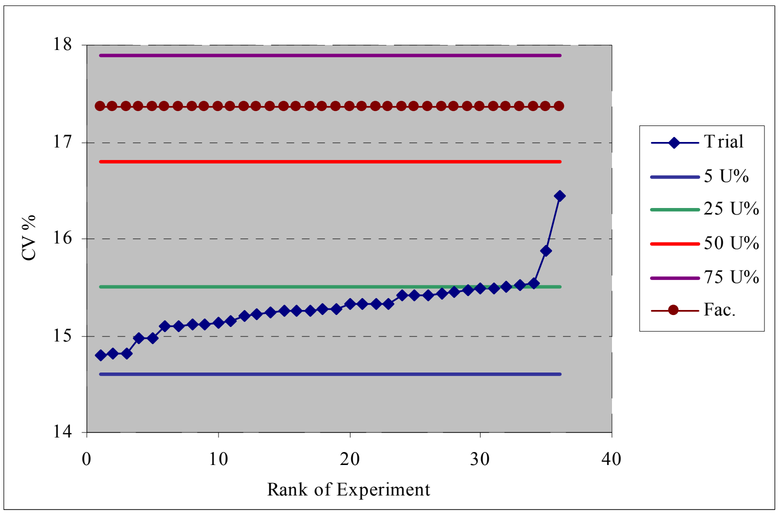

Fig (1) Yarn Evenness

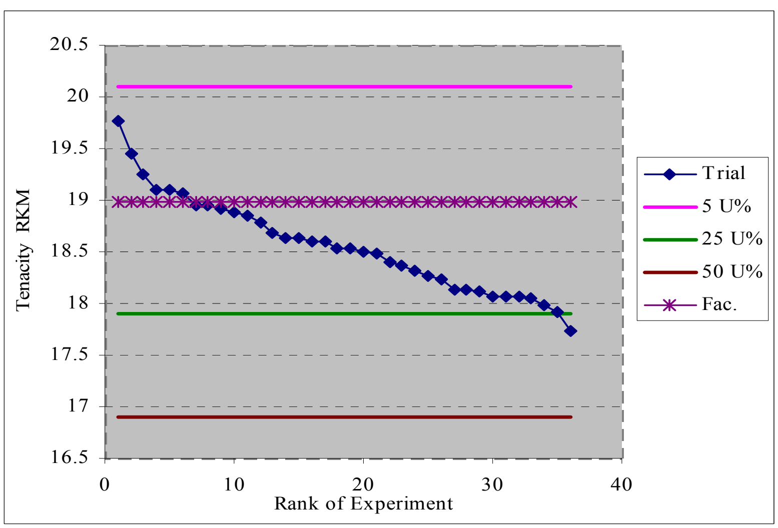

Fig (2) Yarn Tenacity

Egyptian cotton give a lower Elongation at break level compared to Uster Statistics figure (3), the obtained results don't differ significantly then the factory level. In case of Thin places figure (4), experiments are much better than factory level and some results are lower than 5% and don't exceed 25% Uster Statistics

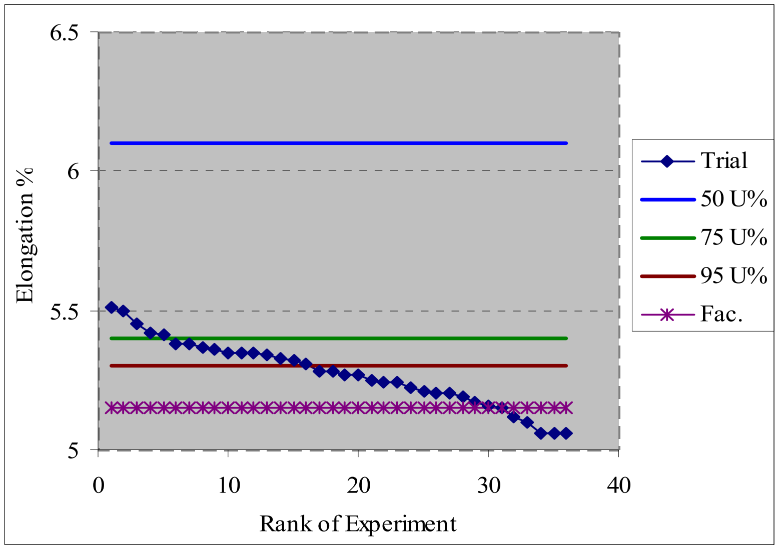

Fig (3) Yarn Percent Elongation at Break

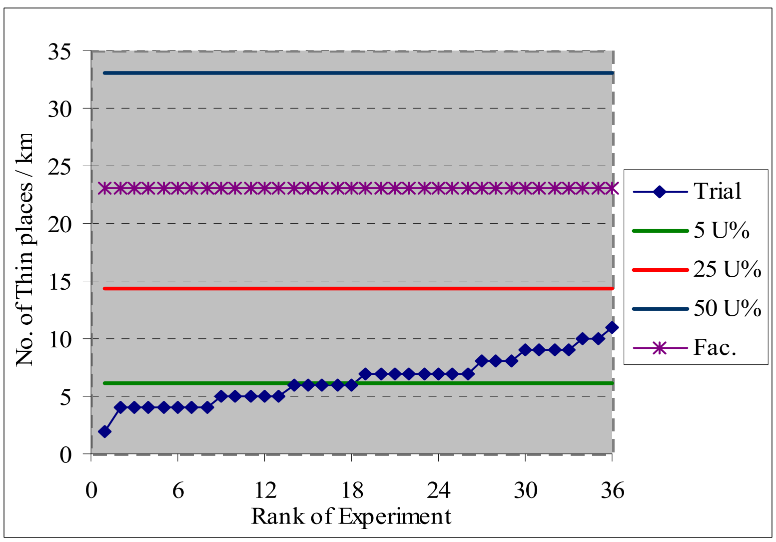

Fig (4) Thin Places in Yarns /1000 meter

The thick places results shown in figure (5) demonstrate that half of them are between 25% - 50% Uster Statistics while the other half is slightly higher than 50% while the routine factory result is over the 75% Uster Statistics levels. The neps results shown in figure (6) are the same of that obtained from the thick places.

From the overall view of the best results obtained as shown in figure (1) to figure (6) it is obvious that all of the experimental results except a portion of the percent elongation at break are better than the factory values, in the mean time the best results attain a 5% uster statistics. The comparison between factory levels, best experimental results and Uster statistics for products evenness at different machine are shown in figure (7). From figure (7) it is seen that there are a continuous improvement of the results in both experiment and factory comparing with Uster Statistics, but the trials demonstrate a better improvement. So the best trail results attain a better Uster Statistics for all the yarn properties which indicate that the proposed procedure is of great help

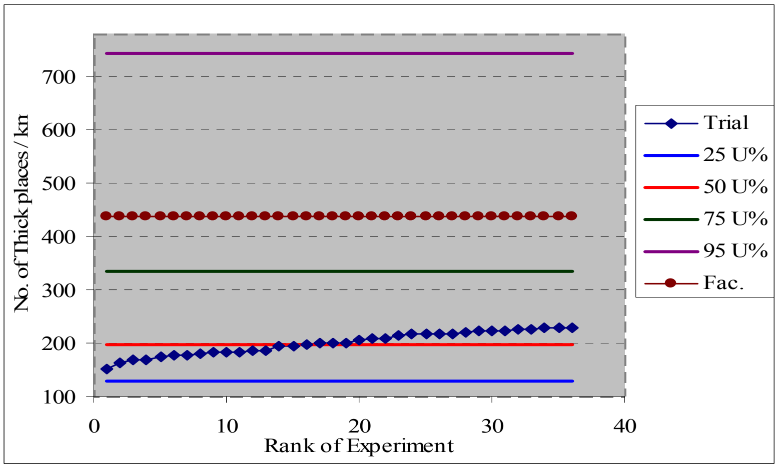

Fig (5) Thick Places in Yarns /1000 meter

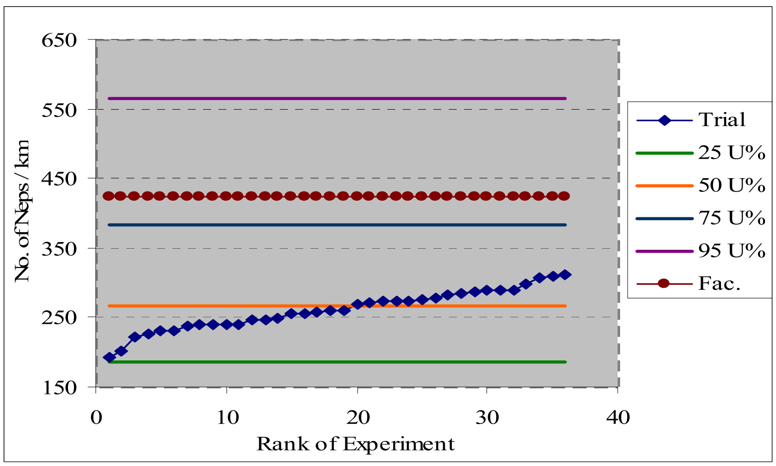

Fig (6) Neps in Yarn /1000 meter

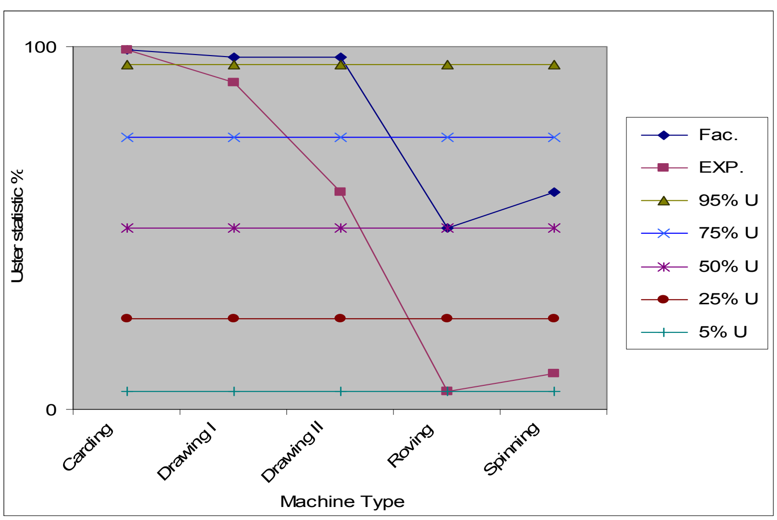

Figure (7) Comparison between factory levels, best experimental results and Uster statistics levels (U) for different machines

Regression Analysis

Linear Regression represents the relation between the tested properties and the factors under study. In case of intermediate product (slivers and roving) the R-Square was between 0.9889and 0.9988 while the F- Statistics was lesser than5E-35, while in case of carded yarn (19.67 Tex), R-Square ranges from 0.908 to 0.9996 and F-Statistics was lesser than2E-19. Table (10) demonstrates the significant regressions coefficients concerning the evenness of the slivers and roving. From table it is obvious that the total draft in card is significant for the product evenness of all machines under study except the second drawing.

Table (10) Coefficients of Significant factors for Evenness of the intermediate materials

		C	T.D1	B.D1	RTD	R Sq.	F-sig.
Card	*Coefficient*	0.042				0.9988	2E-51
	P-value	1E-52					
First Drawing	*Coefficient*	0.022	0.463	-1.642		0.9933	5E-35
	P-value	0.005	0.002	0.049			
Second Drawing	*Coefficient*			2.554		0.9889	5E-35
	P-value			8E-36			
Roving	*Coefficient*	0.024			0.272	0.9976	3E-44
	P-value	3E-07			6E-05		

Table (11) demonstrates the significant regressions coefficients concerning the properties of the carded yarn. From table the total draft in card is not included in the significant regression for the yarn evenness, while this is affected by all the total drafts of other machines. This indicates that finer card sliver which doesn't alter the line production balance can be applied. Table (11) also indicates that finer sliver give better results for thick place and neps, while no effect is detected for both tenacity and elongation. So we can deduce that the finer the card

Table (11) Coefficients of Significant factors in the different regression equations for yarn properties

		Evenness	Thick	Thin	Neps	Tenacity	Elongation	CV_{EL}	CV_T
	Coefficient		**-3.077**		**-2.358**				
C	***P-value***		0.001		0.008				
	Coefficient	**0.754**	**18.5**			**1.317**	**0.195**		
T.D1	***P-value***	5E-07	0.028			1E-09	0.0001		
	Coefficient						**0.655**		
B.D1	***P-value***						0.039		
	Coefficient	**0.628**	**40.1**		**50.91**		**0.152**	**0.724**	**0.898**
TD2	***P-value***	3E-05	3E-05		3E-05		0.002	8E-08	2E-12
	Coefficient	**0.595**					**0.241**	**0.969**	**1.021**
BD2	***P-value***	0.032					0.008	0.08	0.005
	Coefficient	**0.481**	**14.66**	**0.746**	**17.8**	**0.882**	**0.136**		
RTD	***P-value***	3E-05	0.01	1E-19	0.015	8E-07	0.0006		
	Coefficient						**0.076**		**0.337**
RSS	***P-value***						0.059		0.04
	Coefficient						**0.052**		
RDF1	***P-value***						0.036		
	Coefficient		**31.64**		**23.15**			**0.33**	**0.38**
	P-value		0.002		0.027			0.037	0.0003
RDB2									
	Coefficient					**0.284**			**-0.225**
RDF2	***P-value***					0.024			0.029
	Coefficient				**11.7**				
RTF	***P-value***				0.019				
R Square		**0.999**	**0.993**	**0.908**	**0.993**	**0.999**	**0.9996**	**0.989**	**0.997**
F-significance		**9E-51**	**8E-32**	**2E-19**	**5E-32**	**1E-48**	**3E-46**	**7E-32**	**7E-38**

sliver the better will be the produced yarn. The total drafts in drawing and roving frames have positive effects on all tested properties. Due to that we have to maintain the draft to the lower values. The optimum draft ratios for the first drawing, second drawing and roving are 0.65, 0.75 and 1 respectively. The break draft in second drawing has a considerable effect on properties then that of the first drawing, as the sliver is in more straighten condition that working in the first drawing, so it has to be maintained at the lower level. From table it can be deduced that total draft roving affect most of the measured properties, followed by total draft of second drawing frame. Relation between factors and yarn properties are discussed so far.

Evenness

The factors affecting the yarn evenness in significant regression equation as demonstrated in table (11) consist of roving total draft, first drawing machine total draft, second drawing machine total draft and break draft. Fig (8, 9) represents the relation between these factors and yarn evenness. From fig (8), it can be observed that the best yarn evenness is at a total draft in second drawing machine of (7.5) and total draft in roving frame (9.5) While from fig (9), it can be deduced that the best yarn evenness is at a total draft in first drawing machine of (6.5) and total draft in roving frame of (9.5). From figures ,it can be noticed that the best yarn evenness at the total draft in first drawing machine of (6-6.5) and total draft in second drawing machine of (7.5- 8). From these results; it can be stated that the best total draft in first drawing machine (6.5-7), total draft in second drawing machine (7.5-8) and total draft in roving frame (8,9) this value will attain the best yarn evenness.

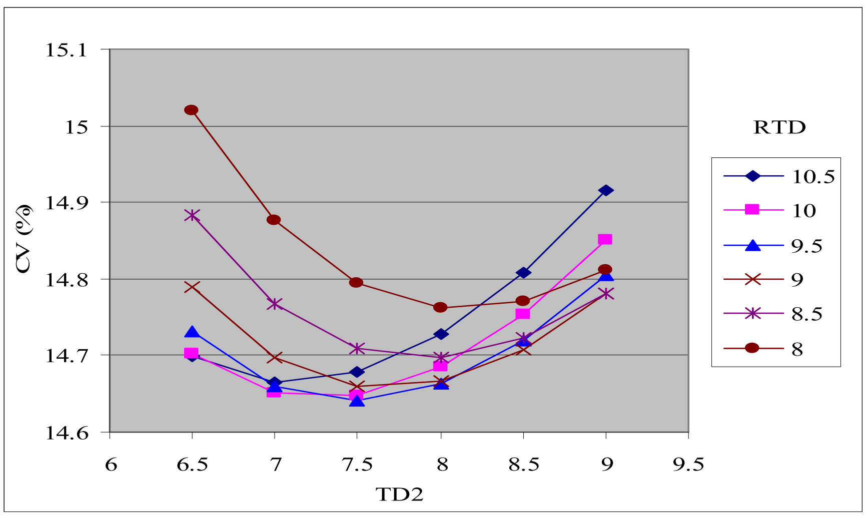

Figure (8) Effects of TD2 & RTD on Evenness Where: BD2=1.16, TD1= (441.4/ RTD*TD2

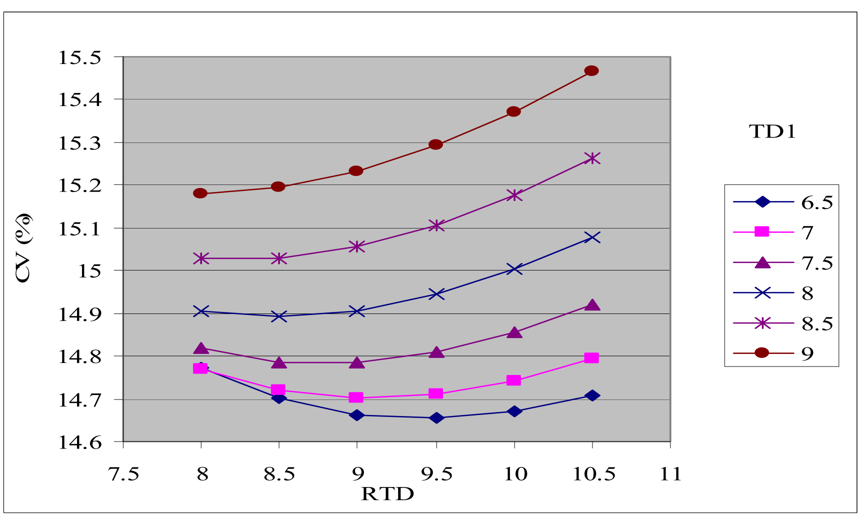

Figure (9) Effects of TD1 & RTD on Evenness Where: BD2=1.16, TD2=441.4/RTD*TD1

Thick Places

In case of thick places the total drafts of the machine under study are effective, also the back setting in second drawing machines shown in table (11). The increase of all these factors except carding total draft increase the number of thick places .Due to that the draft of the carding machine has to be at is maximum permissible value. From this it is better to have a finer sliver from the card the same as attained in case of [18], while the other drafts had to be chosen to attain the lower value of thick places. So that the total drafts in the three other machine can adapt with the conditions needed for evenness, strength and elongation. Also the RDB2 (back ratch in the second draw frame) has the same tendency as in case of C.V. elongation. Figures (10, 11) demonstrates the effect of these draft on the value of thick places at different working conditions, from these figures the best operating condition can be obtained at the following points Card Draft (140-145), first drawing machine Total Draft (6.5-7), second drawing machine Total Draft (7.5-8) and Roving Total Draft (9.5-10.5) which interrelate to a great degree with that of tenacity, elongation and evenness

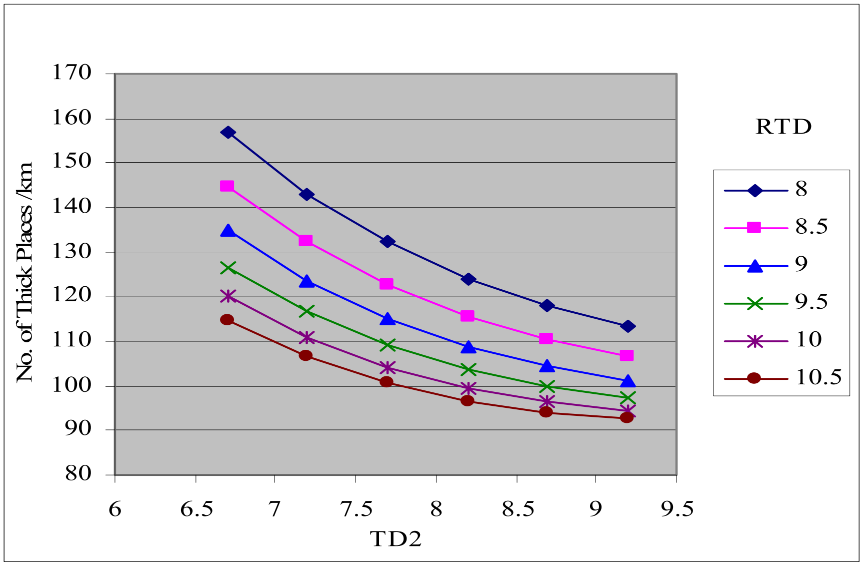

Fig (10) Effects of RTD & TD2 on No. of thick places RDB2= 41.5mm, TDC =145, TD1 = const/RTD*TD2*TDC

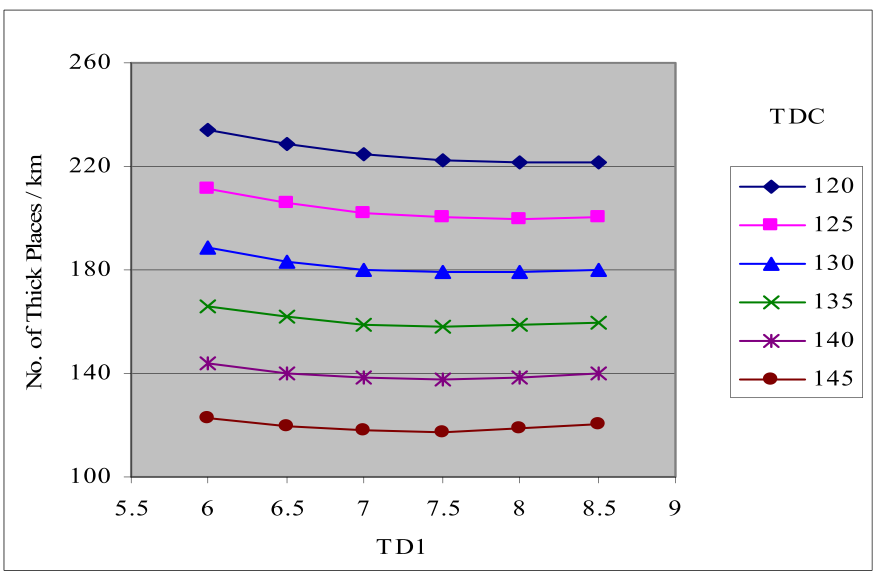

Fig (11) Effects of TD1&TDCon No. of thick places RDB2= 41.5mm, TD2=7.5, RTD= const /TD2*TD1*TDC

Neps

Regarding the number of neps the total drafts of card, second drawing and roving are effective, also the back setting in second drawing machine and the twist factor of roving had a significant effect this can be observed from table (11). The increase of all these factors except carding total draft increase the number of neps .Due to that the draft of the carding machine has to be at is maximum permissible value. Also it indicate that the increase of second drawing total draft affect the drafting force which will extend the fiber and transfer it after relaxation to nep. Also the back second drawing frame setting has the same effect on neps, at approximately the same level and tendency. Also, the twist factor at the roving frame has to be maintained at lower value to decrease the number of neps. Figures from (12,13) demonstrate this relation in a descriptive manner, which aid to understand the relation of the two factors at the constant value of the other three factors, from which the value of neps range from 140 till 350 .

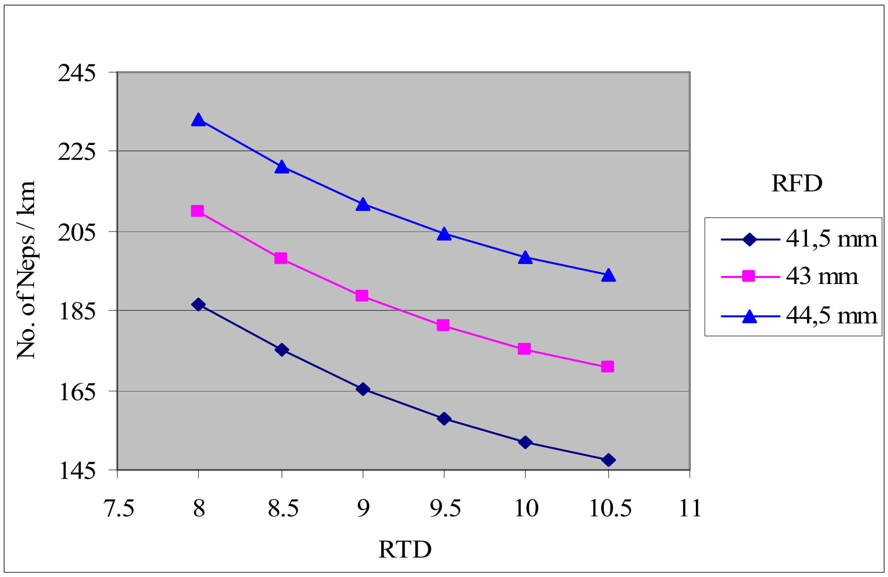

Figure (12) Effects of total RTD & RBD2 on No. of Neps Where: TFR = 1.19, TDC= 145, TD2 =8006/ RTD *TDC

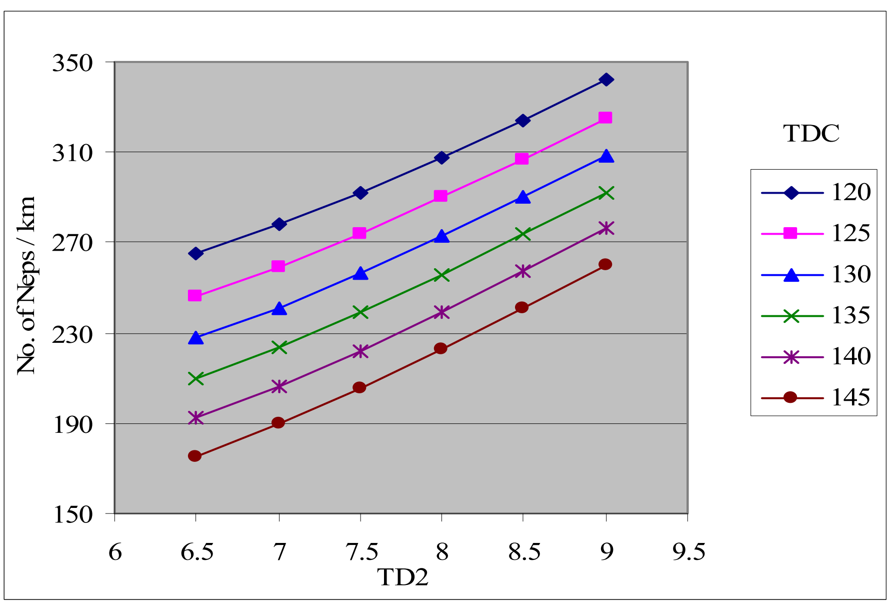

Figure (13) Effects of TD2 & &TDC on No. of Neps Where: RTF =1.19, RDB2 = 41.5, RTD= 8006/ TD2 *TDC

Tenacity

From table (11) total draft first drawing, roving and front second drawing setting are the only factors that affect the yarn tenacity. Figure (14, 15) represents these effects.

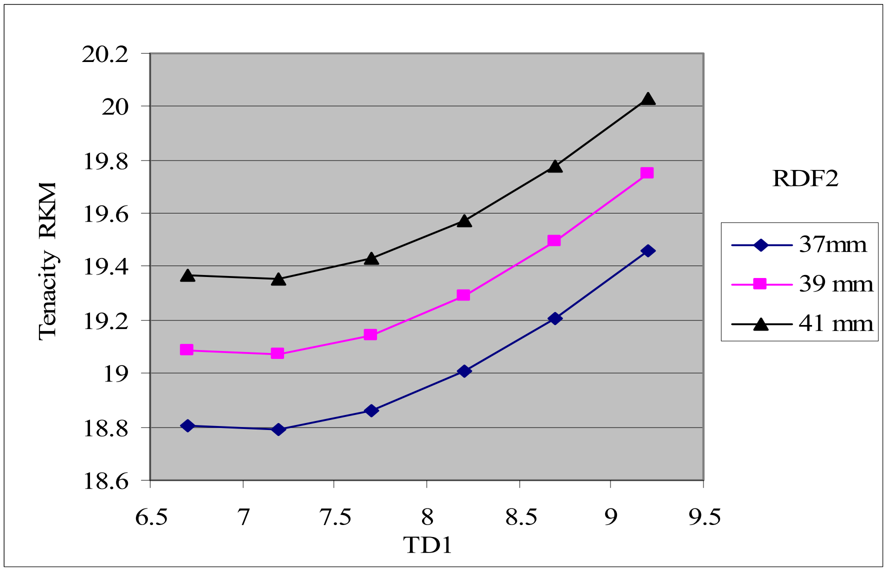

Figure (14) Effects of TD1 & RDF2 on Yarn Tenacity Where: RTD= 73.66/ TD1

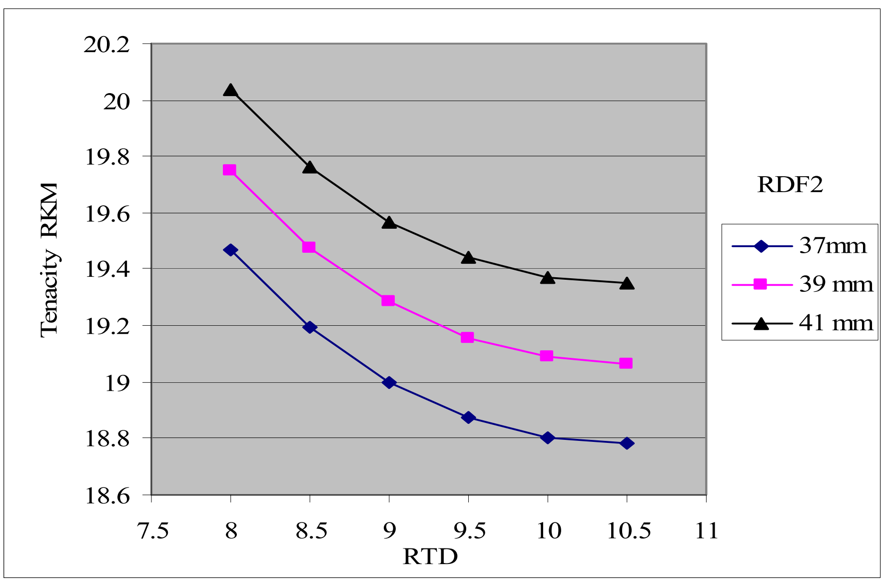

Figure (15) Effects of RTD & RDF2 on Yarn Tenacity Where: TD1= 73.66/ RTD, TD1

Percent Elongation at break

The significant regression equation for percent yarn elongation at break presented in table (11) shows, that the front setting of the first drawing , speed of roving frame and all the draft factor are represented except the card,. The effect of the total draft is the same within three machines. The effect of roving speed and setting is respectively low and is about third of the other effect. Figures (16, 17) represent these relations

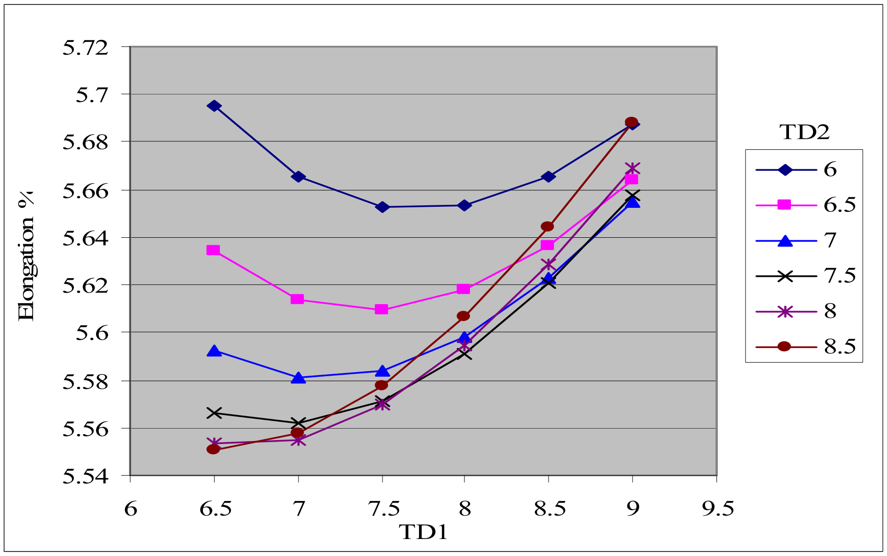

Figure (16) Effects of TD2 & TD1 on yarn Elongation. Where: BD1=1.562, BD2=1.7, RSS=950rpm, RDF1=44mm, RTD= 512/ TD2 *TD1

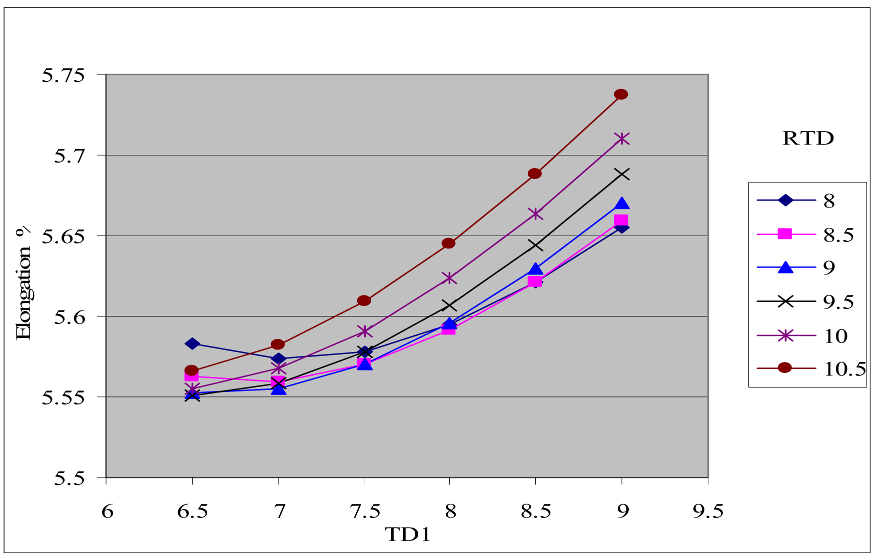

Figure (17) Effects of RTD & TD1 on yarn Elongation. Where: BD1=1.562, BD2=1.7, RSS =950rpm, RDF1=44mm, TD2= 512/ TD1 *RTD

Conclusions

1- The Constrained Experimental Designs was applied in spinning industry which enables to combine dependent factors and independent factors in the same experiment.

2-Twelve factors four dependents, total draft of four machines, and eight independents were studied with thirty six experiments. The R-squares for the regression equations are between 0.851and 0.9997.

3- All the experimental results don't exceed the quality levels of the factory. While the best operating conditions attained are as low as 5% Uster.

4- This technique can be applied for continuous improving of yarn quality.

5- The drafts distributions are one of the main factors affecting the yarn quality; as stated in the literature. This enables the lesser variation in settings for the same class of fiber, for improving or attaining the best operating condition.

6- The roving draft and the first drawing drafts are the most affecting factors among all the twelve studied factors.

7- The best operating condition is attained with finer card sliver, while the needed draft to be distributed to ratio 1, 0.65, and 0.75 for roving, first drawing and second drawing respectively.

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