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Optimization of spinning parameters influencing the tensile properties of polyester/cotton vortex yarn

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The influence of vortex spinning parameters on the tensile properties of polyester/cotton vortex yarn has been studied. Polyester/cotton yarn of 50:50 blend ratio have been produced in two different counts (Ne 20s and Ne 40s) each with four different spinning parameters (delivery speed, spindle size, feed ratio and nozzle pressure). Experiments are designed with the aid of response surface method. Accordingly different samples are produced with three levels of each parameter. The tenacity and elongation-at-break have been evaluated from the samples produced with these combinations. It is found that the tenacity of coarser count vortex yarn is influenced by feed ratio and the medium count vortex yarn is influenced by all the spinning parameters considered for this study. Elongation-at-break of coarser count vortex yarn is influenced by the feed ratio and nozzle pressure while that of the medium count vortex yarn is influenced by the spindle size, feed ratio and nozzle pressure. The interactions of spinning parameters have significant influence on the tenacity and elongation-at-break of medium count vortex yarn. On the other hand the interactions have significant influence on the coarser count vortex yarn elongation-at-break, but they do not have any influence on its tenacity.

Keywords: Delivery speed, Feed ratio, Polyester/cotton yarn, MVS yarn, Nozzle pressure, Spindle size, Yarn elongation, Yarn tenacity

1 Introduction

A yarn must have a certain minimum tensile strength and a minimum elongation in order to stand up to the processes subsequent to spinning without being damaged. The required tensile strength and elongation depend primarily on the type of processing. For instance, yarns require a considerable strength to survive the load applied on the yarn on a modern weaving machine. Yarns, which are processed on the warp or weft knitting machines, are not subjected to high tensile force; they however have good elongation properties. The breaking force is found to be the highest force registered while carrying out a tensile test and the breaking elongation is the elongation at this breaking force. In order to simplify a comparison between various raw materials, various spinning processes, various finishing methods and various yarn counts, it is more practical to study the combine effect of breaking force and yarn count. In this way, a value which is practically independent of yarn count is the 'tenacity'.

Basal and Oxenham[1] studied the influence of spinning parameters on the vortex yarn properties and reported that the increase in spinning speed, decrease in nozzle pressure and increase in spindle diameter result in increase in hairiness. Their findings revealed that the tenacity of vortex yarn reduces while attempting to increase the hairiness. They also reported that the tenacity of vortex yarn is dependent on both the ratio of wrapper and core fibres and the wrapping length of the sheath fibres. Compared to yarn produced by the air jet spinning, in vortex spinning the higher number of wrapper fibres and decrease in unwrapped sections have significantly improved the characteristics such as better tensile properties, better evenness and lower hairiness. Basal[2] reported that when the nozzle pressure of vortex spinning machine increases, both the axial and tangential velocity also increases. As a result, the fibre bundle receives more twist and yarn becomes stronger.

The effects of various spinning parameters, such as delivery speed, nozzle air pressure, nozzle angle, spindle diameter, distance between front roller nip point and spindle size on the structure of the vortex yarn have been studied by Tyagi *et al.*[3] to prepare a process – structure - property model for vortex spun yarns. Erdumlu *et al.*[4,5] found that higher delivery speed deteriorates the physical properties of the vortex yarn in terms of yarn evenness, thin places and

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tenacity. The results of Erdumlu *et al*[6] showed that the coarser yarns tend to have a higher tenacity. However, they found that the difference between the sample means is statistically insignificant. Since the values were very close to each other, they concluded that the tenacity of vortex spun yarn remains almost unchanged as the yarn becomes finer. The regression analysis revealed that the tensile properties of the vortex spun yarn are related to the yarn count (Ne) and the yarn structural properties. This result contradicted with the findings of Tyagi *et al.*[4,5] , who showed that the coarser yarns posses higher tenacity. They explained this behavior considering the fact that, as the finer yarns contain more proportion of wrapper fibres or less load bearing fibres (core fibres) these yarns have lesser tenacity in comparison to the coarser ones.

Zou *et al.*[7] studied the numerical computation of a flow field affected by the process parameters of Murata vortex spinning. According to them, wrapper fibres are produced by the twist effect of tangential velocity. Enhancing the tangential velocity can increase the efficiency of twisting. As a result, the vortex yan can gain better tensile properties. However, when the nozzle pressure is too high, the separated fibres are easily taken out of the fibre bundle by the high speed air flow, which produces more wild and waste fibres and leads to deterioration in uniformity of vortex yarn. They also stated that, improving the axial velocity easily makes the open trail end fibres to twine over the hallow spindle, thereby the twisting efficiency is improved. Zou *et al*.[8] discovered that the fibre spatial configuration in vortex spun yarn consists of core fibre, migration wrapper fibre and regular wrapper fibre. Zou *et al*.[9] also investigated the twisted strength acting on the vortex spun yarn from the whirled air flow.

A change in air flow velocity will lead to a change in air flow entrainment effect[10]. The bigger the air flow entrainment effect, the higher the negative pressure at the inlet of the nozzle block. According to swirl-jet theory, the relationship among air flow entrainment effect (dm/dx), air flow thrust (Gt), and the degree of swirl (*S*) of the jet flow is

$$dm/dx = f\,[(P{*}Gt)^{1/2}\,S^q] = f\,[(P{*}Gt)^{1/2}\,(Ut/Ua)^q]$$

where *Ut* and *Ua* are the tangential and axial velocity; and q, the constant.

Increasing the nozzle pressure first enhances the tenacity of vortex spun yarn, then generates more thin places and deteriorates the yarn quality when the angular velocity of the fibre exceeds the critical angular velocity[11]. Pei and Yu[12] studied the effect of nozzle pressure and the yarn delivery speed on the fibre motion in the nozzle of muratec vortex spinning. According to them, when the rotational amplitude of fibre is the greatest, the wrapping of the fibre is the tightest. The number of helical wrappings will be higher at lower delivery speeds and due to this higher number of helical wrappings the rotational amplitude will be lower. At higher delivery speeds the lower rotational amplitude allows the fibre to have less number of helical wrappings. Also the rotational amplitude will be higher at higher nozzle pressure. Xia *et al*.[13] studied the effect of singeing and stated that breaking elongation and tenacity decreased after singeing effect. As the hairs snarled on the surface of the yarn stem during the breaking process, division of hairs needed extra energy and contributed to longer elongation. Thus, reduction of hairs would result in less elongation and loss of tenacity.

The aim of this investigation is to determine the relationship between the tensile properties of polyester/cotton vortex yarn and the vortex spinning machine parameters, and to design the appropriate models for predicting the tensile properties of polyester/cotton vortex yarn. The major process parameters selected for experimental study have been altered and the experimental results of tensile properties are analyzed by the response surface analysis of Design Expert Software 8.0.7.1.

2 Materials and Methods

2.1 Preparation of Yarn Samples

Polyester/cotton vortex yarn samples of 50:50 blend ratios were produced with two counts (Ne 20/1 and Ne 40/1), which covers both coarser and medium counts. The polyester fibre of 32mm length and 1.0 denier fineness was used for the study. Combed cotton of Sankar-6 variety was selected. The polyester and combed cotton fibres (50:50) were blended at mixing and processed through blow room, carding and three-passage drawing before reaching the vortex spinning machine. The finisher drawing sliver was produced by Rieter auto leveler draw frame at 500 m/min delivery speed, and the linear density of the finished drawing sliver was adjusted at Ne 0.140. The drawn slivers were spun into Ne 20/1 and Ne 40/1 counts polyester/cotton yarn on Murata vortex spinning machine (MVS 861) with three different levels of each of the all four parameters. The process parameters of Vortex spinning machine for both counts are given in Table 1. Here level 2 is the standard spinning parameters recommended by the manufacturer of the vortex spinning machine for the respective counts.

2.2 Test Methods

The yarn samples produced by varying the spinning parameters were tested for their tensile properties. The tenacity and elongation properties were measured using Uster Tensorapid, UTR4. For each test sample, 6 cones were produced. Tensile properties were measured using UTR4 at 5000mm/min. Twenty observations were made for each cone and then averages were calculated in UTR4.

2.3 Statistical Methods

The analysis of variance (ANOVA) was used to study the effect of spinning parameters on the tensile properties. The Design Expert Software 8.0.7.1 was used to study the effect of interactions of spinning parameters on the tensile properties. All the three levels of each parameter were coded by the Design Expert software and the ANOVA analysis was done by the response surface quadratic model. The final equations in terms of actual factors were arrived by the Design Expert software from the equations in terms of coded factors. The information available from the 3D surface contour diagram is found very much useful to explain the interactions of the spinning parameters and to decide the parameters for various count range by the vortex yarn manufacturers. Multiple regression equations were arrived to establish the relationship between the spinning parameters and the tensile properties of vortex yarn.

3 Results and Discussion

3.1 Effect of Spinning Parameters on Tenacity of Vortex Yarn

The ANOVA results of the tenacity of polyester/cotton vortex yarn with different spinning conditions are presented in Table 2. Tenacity of

Table 1 — Spinning parameters of 50/50 polyester/cotton vortex yarn

Parameter	Ne 20			Ne 40		
	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Delivery speed, m/min	360	400	440	310	350	390
Spindle size, mm	1.2	1.3	1.4	1.0	1.1	1.2
Feed ratio	0.95	0.97	0.99	0.95	0.97	0.99
Nozzle pressure, Mpa	0.45	0.50	0.55	0.45	0.50	0.55

Table 2 — ANOVA test results of tensile properties of 50/50 polyester/cotton Vortex yarn

Parameter	Tenacity						Elongation					
	Ne 20			Ne 40			Ne 20			Ne 40		
	F value	p- value	Significance	F value	p-value	Significance	F value	p- value	Significance	F value	p-value	Significance
Delivery speed (A)	3.33	0.0722	ns	19.73	<0.0001	s	0.019	0.8899	ns	0.16	0.6911	ns
Spindle size (B)	2.75	0.1015	ns	31.31	<0.0001	s	0.51	0.4762	ns	18.35	<0.0001	s
Feed ratio (C)	396.23	<0.0001	s	141.79	<0.0001	s	33.08	<0.0001	s	114.89	<0.0001	s
Nozzle pressure (D)	2.98	0.0886	ns	52.45	<0.0001	s	5.79	0.0188	s	33.06	<0.0001	s
A*B	0.41	0.5220	ns	0.37	0.5428	ns	0.86	0.3557	ns	4.64	0.0346	s
A*C	1.77	0.1876	ns	2.94	0.0907	ns	4.50	0.0374	s	14.80	0.0003	s
A*D	0.35	0.5569	ns	5.31	0.0241	s	0.091	0.7642	ns	0.043	0.8355	ns
B*C	1.12	0.2929	ns	1.60	0.2100	ns	2.35	0.1300	ns	0.17	0.6813	ns
B*D	0.33	0.5666	ns	1.16	0.2859	ns	0.39	0.5317	ns	1.91	0.1716	ns
C*D	0.34	0.5601	ns	17.78	<0.0001	s	3.12	0.0814	ns	5.20	0.0256	s
A*B*C	0.026	0.8733	ns	0.21	0.6496	ns	0.093	0.7615	ns	0.050	0.8238	ns
A*B*D	0.10	0.7499	ns	0.10	0.7510	ns	0.074	0.7859	ns	0.32	0.5715	ns
A*C*D	0.013	0.9107	ns	4.38	0.0400	s	0.22	0.6433	ns	2.93	0.0912	ns
B*C*D	0.52	0.4721	ns	2.43	0.1237	ns	2.42	0.1243	ns	2.45	0.1221	ns
A*B*C*D	2.39	0.1266	ns	0.13	0.7211	ns	0.39	0.5317	ns	0.014	0.9077	ns

s – Significant, ns – Non significant.

coarser count vortex yarn is influenced by the feed ratio of the vortex spinning machine. The tenacity of medium count vortex yarn is influenced by all the parameters, such as delivery speed, spindle size, feed ratio and nozzle pressure.

When the delivery speed increases the trailing end of the fibres undergoes less number of wrappings before entering the hallow spindle. As explained by Pei *et al.*[12], at higher delivery speeds the rotational amplitude of the helical rotation is smallest among all the conditions, the wrapping is most untaught. This leads to lowest tenacity in medium count vortex yarn, having less number of fibres in cross-section. Though the same condition is applied to coarser count vortex yarn, due to more number of fibres in cross-section, there is no significant difference in tenacity values with the increase in delivery speed.

The fibre to fibre friction is an important factor for the tenacity of vortex yarn. Due to higher number of fibres in cross-section of coarser count, the fibre to fibre friction does not have any significant change with different spindle size (1.2 - 1.4mm). But in case of medium count of Ne 40, the wrappers become loose by the change in spindle size from 1.0mm to 1.2mm. Due to this reduction in tightness, the friction between the fibres is reduced at bigger spindle size and has a significant reduction in tenacity values of medium count vortex yarn.

The feed ratio directly influences the spinning tension formed over the fibres inside the nozzle zone. As the feed ratio reduces, the spinning tension on each fibre starts reducing inside the spinning chamber. Due to this less tension by keeping other parameters unchanged, the wrapper fibres formed over the core of vortex yarn become less tight at lower feed ratio. The fibres which are loosely rotating inside the nozzle assembly will have more number of contacts with the inside spindle wall and make more number of wrappings[12]. Since the fibres are having tendency to form more numbers of helical wrapping by the less tightness, the rotational amplitude is also reduced. Therefore, the combination of both reduction in tightness and reduction in rotational amplitude reduces the tenacity values of both coarser and medium counts at lower feed ratios. The influence of feed ratio on the tenacity values is found significant for both coarser and medium counts.

The nozzle pressure influences the negative pressure formed at the nozzle inlet. Increase in nozzle pressure increases the negative pressure at the nozzle inlet which strengthens the suction effect. Increase in nozzle pressure beyond the certain optimum level, increases the negative pressure rapidly. This extreme negative pressure allows the fibre bundle to enter the twisting chamber rapidly and make the fibre bundle stay in the twisting chamber shorter. Also the increase in nozzle pressure beyond the optimum level takes out some of the fibres from the fibre strand and form more number of thin places. Due to this reason, the increase in nozzle pressure has a negative effect on the medium count vortex yarn and reduces the tenacity level significantly at higher nozzle pressures. The coarser count vortex yarn does not show any significant difference in tenacity values with change in nozzle pressure.

The interactions of spinning parameters on tenacity of polyester/cotton vortex yarn of both coarser and medium counts are shown in Figs 1 and 2. It is evident from the ANOVA results that the interactions have no influence on the tenacity of coarser count vortex yarn. In case of medium count vortex yarn, the interaction of delivery speed and nozzle pressure has a significant influence on the tenacity. The maximum tenacity is achieved at lower delivery speed and lower nozzle pressure. At this stage when the lower nozzle pressure supports for optimum number of wrappers, it gives optimum twist. In addition to this, the interaction of feed ratio and nozzle pressure also has a significant influence on the tenacity of medium count vortex yarn. The moderate pressure with higher feed ratio has a maximum tenacity. At this stage the higher feed ratio supports for tighter wrapping, and moderate pressure gives optimum twist level. The interaction of delivery speed, feed ratio and nozzle pressure on the medium count vortex yarn have a significant influence on the tenacity of vortex yarn.

3.2 Effect of Spinning Parameters on Elongation of Vortex Yarn

Table 2 shows that the elongation of coarser count vortex yarn is influenced by the feed ratio and nozzle pressure. The elongation of medium count vortex yarn is influenced by the spindle size, feed ratio and nozzle pressure.

As the delivery speed of the vortex spinning machine increases the number of wrapper fibres formed over the vortex yarn reduces. At the same time increase in delivery speed increases the hariness of the vortex yarn due to increase in open trail end fibes. Though the elongation of vortex yarn can be reduced by the less number of wrappers with higher delivery speeds, increase in hairs on the surface

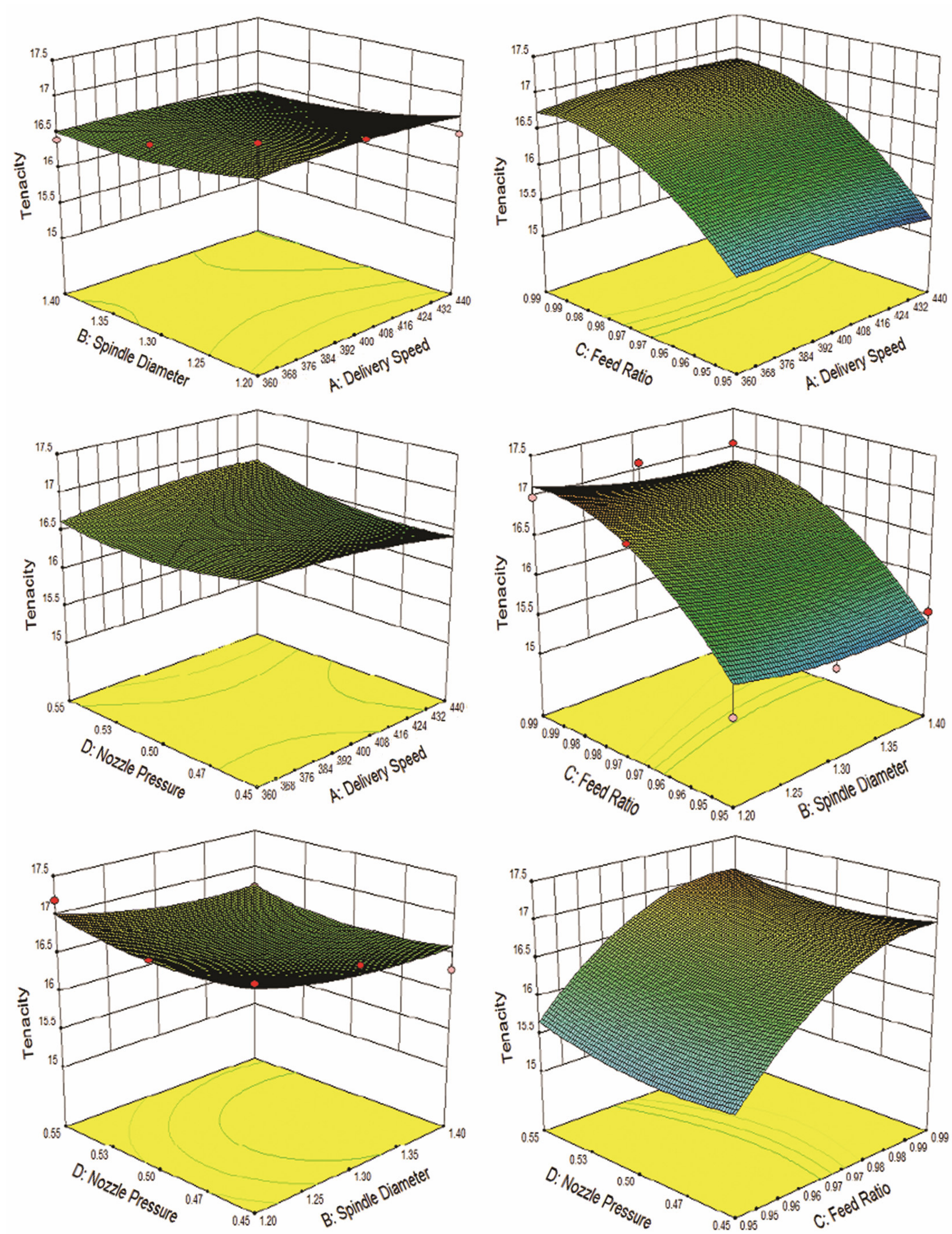

Fig. 1 — Interaction of spinning parameters on tenacity(cN/tex) of Ne 20 polyester/cotton vortex yarn

creates the need of extra energy for the breaking and conrtibute to longer elongation[11]. Due to this opposite effects, the delivery speed of vortex spinning machine does not show any significant difference on the elongation properties of Ne 20 PC and Ne 40 PC counts.

The fibre to fibre friction is an improtant factor for the elongation of vortex yarn. Due to higher number of fibres in coarser count, the friction between the fibres does not change drastically and it has no significant influence on elongation with different spindle sizes (1.2-1.4mm). But in case of medium count, while the spindle size increases from 1.0mm to 1.2mm due to less number of fibres in cross-section, larger spindle diameter allows the fibres to have less friction between other fibres and thereby reduces the

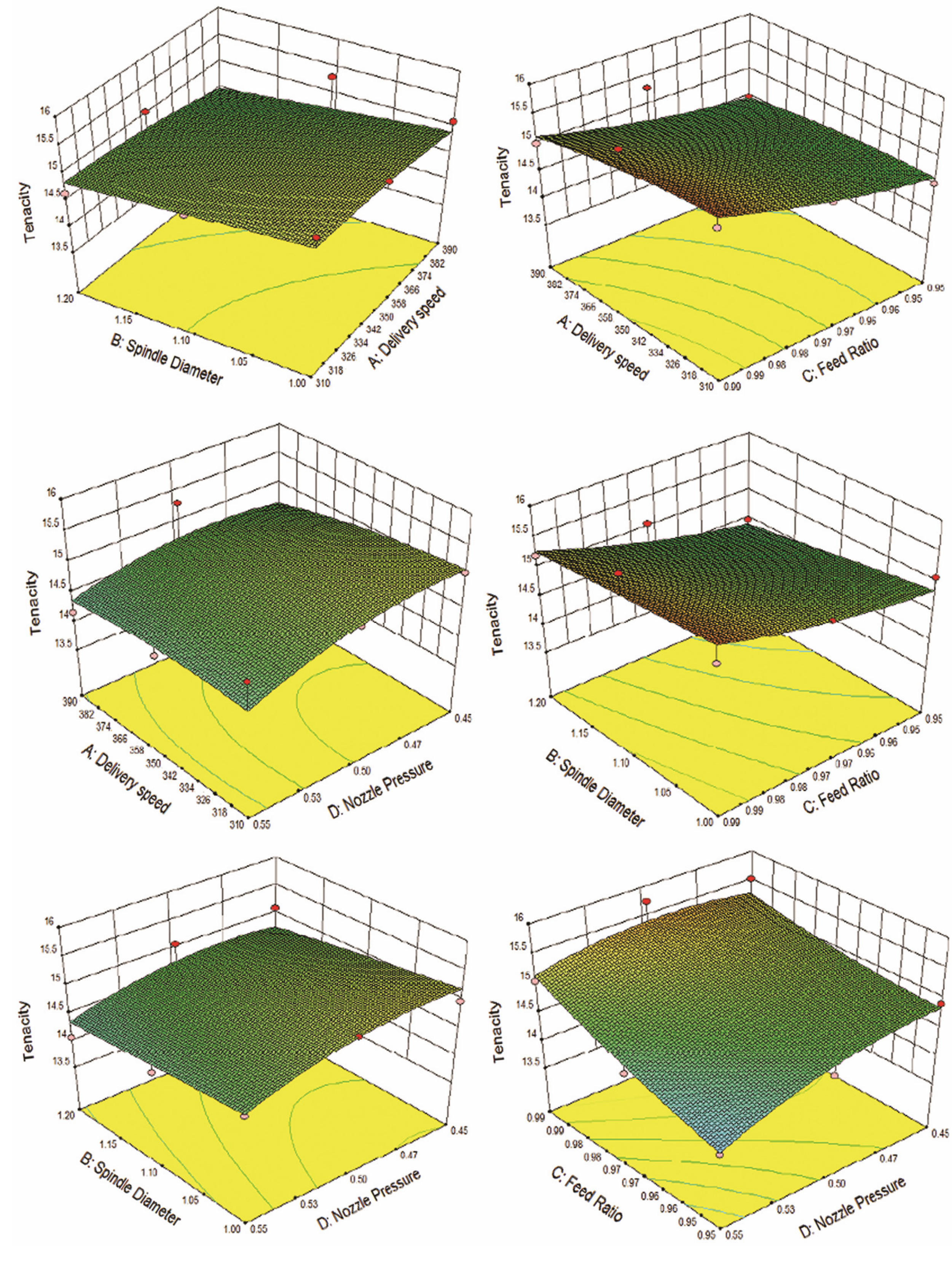

Fig. 2 — Interaction of spinning parameters on tenacity(cN/tex) of Ne 40 polyester/cotton vortex yarn

elongation of Ne 40 polyester/cotton vortex yarn. The influence of spindle size on the elonagtion of medium count (Ne 40 PC) shows a significant change.

The feed ratio directly influences the spinning tension formed at yarn formation zone. As the feed ratio increases the spinning tension on each fibre starts increasing inside the spinning chamber. The fibres are wrapped tightly with less number of helical wrappings. At lower feed ratio due to less tension, the fibres have increased number of helical wrapping but with less tension. At medium level of 0.97 feed ratio, the fibres will have moderate level of helical wrappings with medium tightness. Therefore at higher feed ratio, though the fibres are tightly wrapped due to less number of helical wrapping it slips easliy. Also at lower feed ratio though the wrappings are more due to less friction between fibres, the elongation is lower. Due to this reasons, coarser (Ne 20 PC) vortex yarn shows increase in elongation with moderate level of feed ratio where the yarn is having optimum tightness with more number of helical wrapping. In case of medium (Ne 40 PC) count vortex yarn, the number of helical wrappings reaches beyond the maximum level of requirement at lower feed ratio. This is due to the reason that in addition to increase in helical wrappings by less number of fibres, the number of wrapper fibres is increased by the lower feed ratio. Therefore, the core fibres which hold the yarn become very less which reduces the elongation at lower feed ratio. While the feed ratio increases due to the increase in tightness of the wrapping the elongation of the Ne 40 PC vortex yarn increases. The results show that feed raio has significant influence on the elongation of both coarser and medium counts.

Increase in nozzle presssure beyond a certain optimum level, increases the negative pressure rapidly. This extreme negative pressure allows the fibre bundle to enter the twisting chamber rapidly and make the fibre bundle to stay in the twisting chamber shorter which reduces the twisting effect. Due to this reason, both Ne 20 and Ne 40 PC yarns show little lower elongation with higher nozzle pressure. The reduction in elongation of both counts with increase in nozzle pressure is found to be significant.

The interactions of spinning parameters on the elongation of polyester/cotton vortex yarn of both coarser and medium counts are shown in Figs 3 and 4. It is evident from the ANOVA results that the interaction of delivery speed and feed ratio has a significant influence on the elongation of coarser count vortex yarn. It is observed from the 3D contour diagram that the maximum elonagtion has been achieved with moderate feed ratio and in all range of delivery speeds. At lower feed ratio due to less tension, the wrapper fibres are loosely twisted which reduces the friction between the fibres. Also at higher feed ratio due to high spinning tension the fibres achive the maximum rotational amplitude. Though the maximum rotational amplitude increases the tightness of the wrapping, the numer of helical wrappings are reduced which allows the fibre to slip at higher feed ratio. Therefore, the highest elonagtion which has been achieved at all speed range with moderate feed ratio is significantly different from the elongation at the lower and higher feed ratio combinations as per the ANOVA table.

The interactions of spinning parameters on the elongation properties of medium count have shown significant influence. The interaction of delivery speed and spindle size, delivery speed and feed ratio, feed ratio and nozzle pressure have significant influence on the elongation.

The interaction of delivery speed and spindle diameter on medium count has shown that the maximum elongation is achieved with the combination of lower spindle size and lower delivery speeds. At this condition, the yarn will have increased tightness with more number of helical wrappings which makes the fibre slippage more difficult. The interaction of delivery speed and feed ratio has shown that the highest elongation has been achieved at higher feed ratio and lower delivery speed. At this stage the wrapper fibres achieve more number of helical wrappings with increased tightness. The interaction of feed ratio and nozzle pressure has shown that the maximum elongation is achieved at lower spindle diameter with higher nozzle pressure. At this stage the medium count vortex yarn, which is having less diameter than coarser count, receives more number of helical wrapping with tighter effect. The interactions of more than two parameters simultaniuosly have no significant influence on the elongation of medium count vortex yarn.

3.3 Regression Analysis

The regression equations of tenacity and elongation for both Ne 20 PC and Ne 40 PC vortex yarns are shown in Table 3. Here T and El are the predicted responses.

The scatter plot of predicted values versus the experimental values and regression line of both coarser and medium count vortex yarn tenacity and

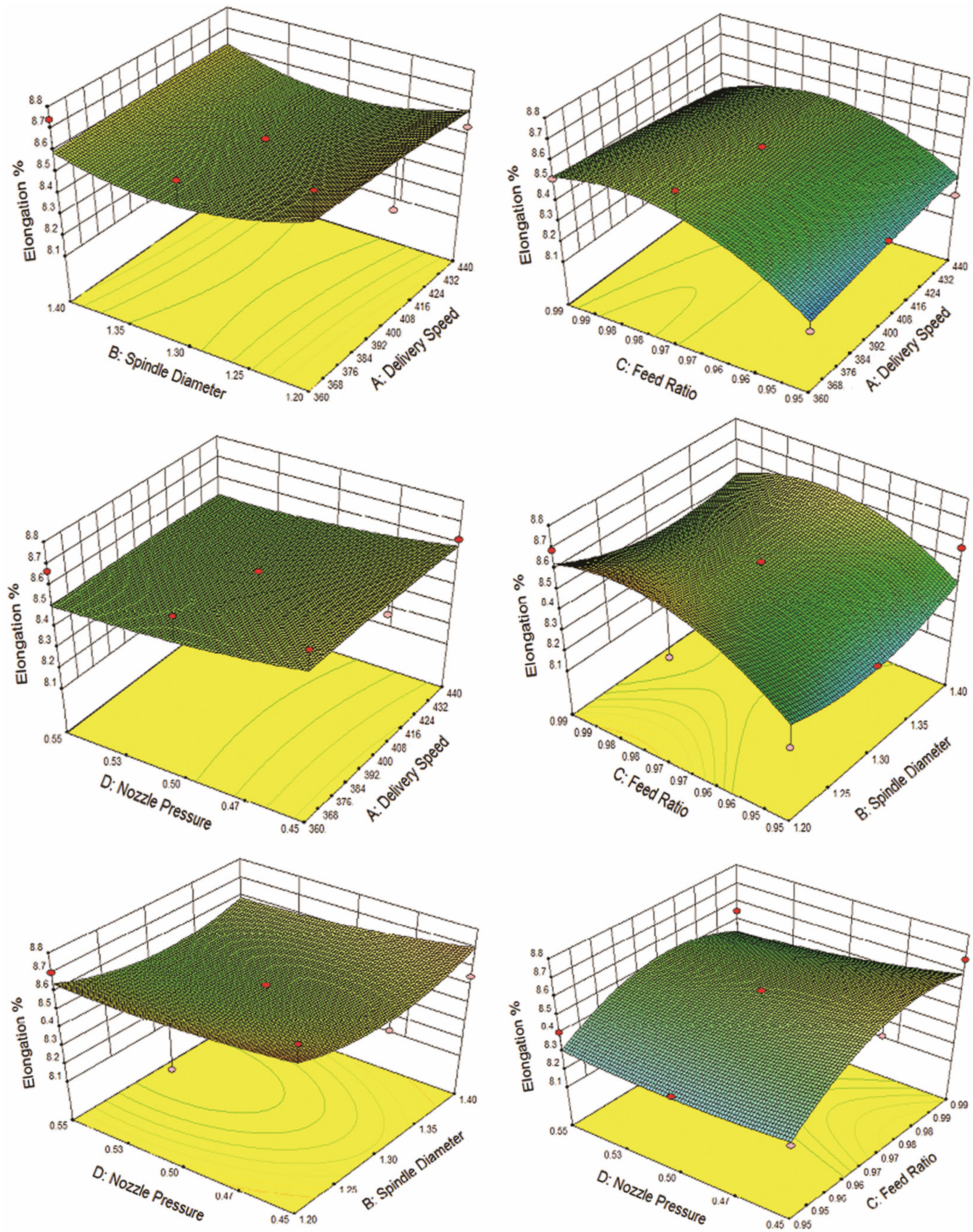

Fig. 3 — Interaction of spinning parameters on elongation of Ne 20 polyester/cotton vortex yarn

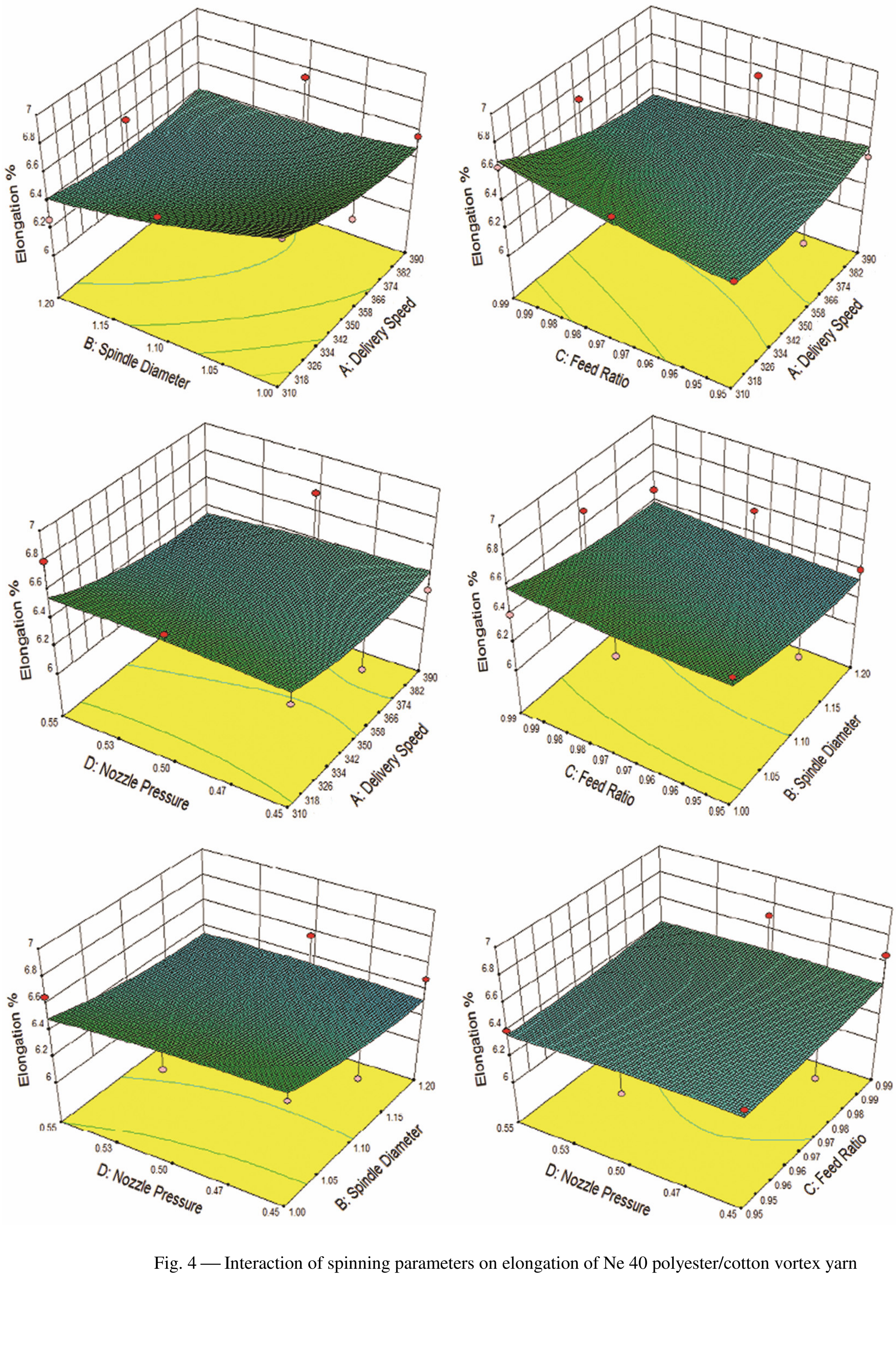

Fig. 4 — Interaction of spinning parameters on elongation of Ne 40 polyester/cotton vortex yarn

Table 3 — Response surface regression equations for tensile properties of 50/50 polyester/cotton vortex yarn

Count	Regression equation	R^2
	Tenacity	
Ne 20	$T = -971.5582 -0.0734*(A) -14.1443*(B) +2073.5478*(C) - 42.3571*(D) +8.1250*(AB) +0.0931*(AC) +0.0529*(AD) -11.2500*(BC) +0.0333*(BD) -37.5000*(CD) -4.1859*(A^2) +10.3025*(B^2) -1052.1605*(C^2) +58.5432*(D^2)$	0.9137
Ne 40	$T = 265.0044 +0.09639*(A) -26.8954*(B) -475.2954*(C) -112.6129*(D) -0.0006*(AB) -0.0847*(AC) +0.04556*(AD) +25.0000*(BC) +8.5000*(BD) +166.6667*(CD) -4.8472*(A^2) -0.5889*(B^2) +213.0556*(C^2) -79.0222(D^2)$	0.8305
	Elongation	
Ne 20	$El = -388.8136 +0.0499*(A) -9.7775*(B) +793.4194*(C) +27.1676*(D) +4.9306*(AB) -0.0563*(AC) +3.1944*(AD) -16.2500*(BC) -2.6667*(BD) -37.5000*(CD) -4.3287*(A^2) +9.5296*(B^2) -374.2593*(C^2) +10.5629*(D^2)$	0.6942
Ne 40	$El = 20.2019 +0.0649*(A) -18.7859*(B) -33.9216*(C) +7.3267*(D) +0.00165*(AB) -0.1125*(AC) 1-0.0149*(AD) +0.4167*(BC) +4.1111*(BD) -0.5556*(CD) +4.5363*(A^2) +4.3691*(B^2) +38.3951*(C^2) -6.3012(D^2)$	0.5625

A - Delivery speed in mpm, B - Spindle size in mm, C – Feed ratio & D – Nozzle pressure in Mpa.

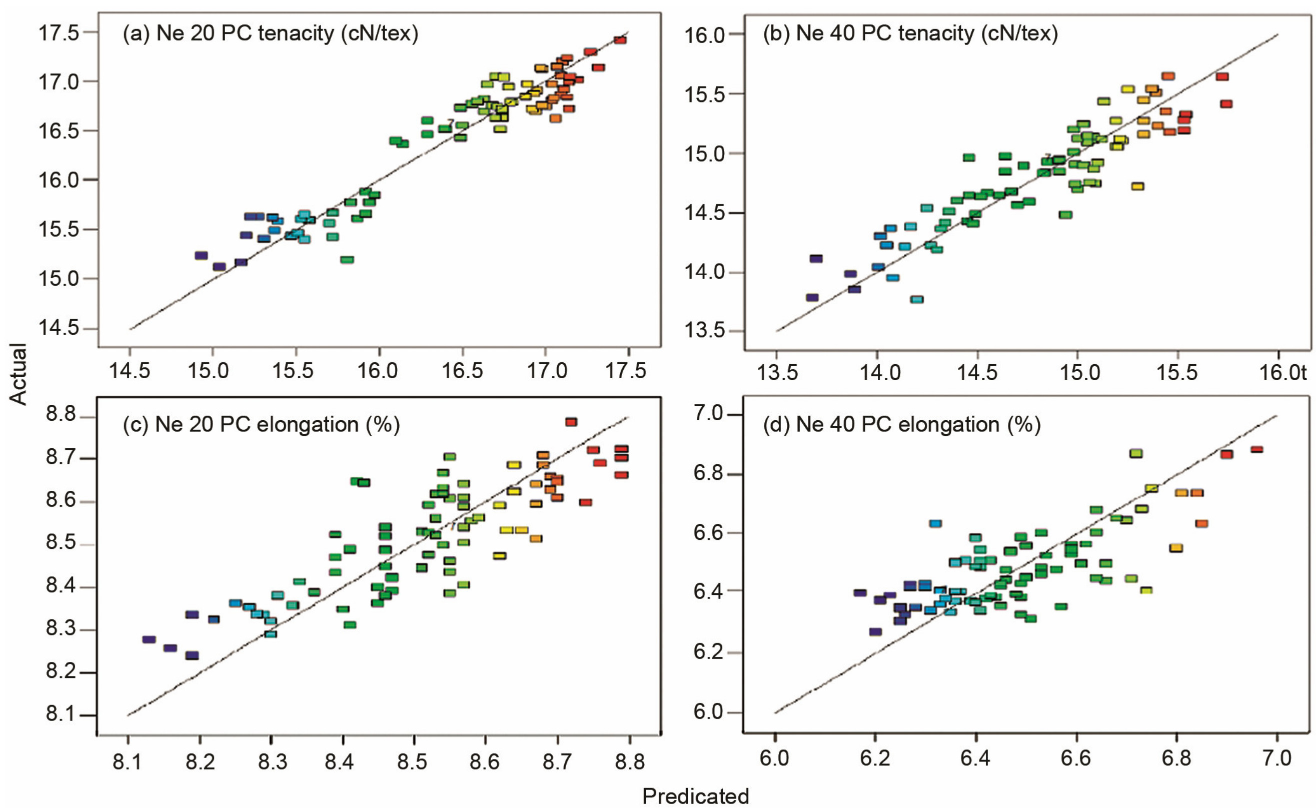

Fig. 5 — Predicted versus observed values of tenacity and elongation of polyester/cotton vortex yarn

elongation are shown in Fig. 5. Here, X axis shows the actual experimental values and Y axis shows the predicted values. The multiple correlation coefficient (R^2 value) of tenacity of Ne 20 polyester/cotton vortex yarn is 0.9137, which gives very high predictive power of this regression model. The values are scattered very near to the regression line. In case of Ne 40 polyester/cotton vortex yarn the predicted values are little widely scattered around the regression line. The predictive power of this Ne 40s PC regression model is also on higher side with the R^2 values of 0.8305. The R^2 values of elongation of Ne 20 polyester/cotton vortex yarn is 0.6942 which shows the average predictive power of this regression model. The values are scattered around near and throughout the regression line. In case of Ne 40 PC vortex yarn the values are scattered horizondally and little far from the regression line. The predictive power of this Ne 40 PC regression model is less with the R^2 values of 0.5625.

4 Conclusion

4.1 The tenacity of coarser (Ne 20 PC) vortex yarn is significantly influenced by the feed ratio of the vortex spinning machine. The delivery speed, spindle size and nozzle pressure do not have significant influence on the tenacity of Ne 20 PC vortex yarn. The tenacity of medium (Ne 40 PC) count vortex yarn is influenced by delivery speed, spindle size, feed ratio and nozzle pressure.

4.2 The interactions of the spinning parameters have no significant influence on the tenacity of coarser count vortex yarn. The interactions between delivery speed and nozzle pressure and between feed ratio and nozzle pressure have a significant influence on the medium count vortex yarn.

4.3 The elongation of coarser count vortex yarn is significantly influenced by the feed ratio and nozzle pressure of the vortex spinning machine. The elongation of medium count vortex yarn is influenced by the spindle size, feed ratio and nozzle pressure.

4.4 The interaction of delivery speed and feed ratio have significant influence on the elongation of coarser count vortex yarn. The interaction of delivery speed and spindle size, delivery speed and feed ratio and feed ratio and the nozzle pressure have significant influence on the elongation of medium count vortex yarn.

4.5 The R^2 value of Ne 20 PC vortex yarn tenacity is 0.9137 and for Ne 40 PC the R^2 value is 0.8305. The regression model have good predictive power for the tenacity of both coarser and medium counts vortex yarns. The R^2 value of Ne 20 PC vortex yarn elongation is 0.6942 and for Ne 40 PC the R^2 value is 0.5625. The regression model have moderate predictive power for the elongation of both coarser and medium counts vortex yarns.

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