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The Influence of Some Process Parametres on Rotor Spun Yarn Quality Produced from Recycled Cotton Spinning Wastes

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Abstract Rotor spun yarns from recycled cotton spinning wastes were manufactured by means of rotor spinning process and tested for yarn imperfections and strength.Results of studies are examined the effect of cleaning intensity,cylinder speed and combing roller speed of rotor frame by using box and behnken experimental design. Observing the value of co-efficent of determination,it can be said that the properties of yarn imperfections affectedsignificantly by our selected parametres in compared with the incidence of yarn strength. Yarn imperfections (Thick place and Neps) results improve with increasing cylinder speed although higher cylinder speed shows slightly different results in case of yarn neps. Increase of opening roller speed improves yarn imperfections quality at lower cleaning intensitysetting of UNIclean and although further increase of opening roller speed hardly improves the results of yarn neps(+280%) but increases the value of thick place in yarn. Lower cleaning intensity setting gives better rotor yarn strength produced by using 100% recycled cotton wastes. Experiments based on a 60 tex rotor yarn indicate that our selected independent variables influence rotor yarn quality not linearly but quatradically with few exceptions.

Keywords Rotor Spun Yarn, Recycled Waste, Imperfection, Strength, Box and Behnken Design

1. Introduction

The open-end rotor system is the only real alternative to ring spinning for producing coarser yarn counts with the successful processing of fiber at significantly higher speeds [1]. In rotor spinning it is common to spin useful yarns from waste or by adding waste to the normal raw material [2]. It is of interest to note that waste spinning units are being installed. This indicates that profits are better in them, since the raw material, namely wastes from spinning mill, is relatively cheaper to give better returns [3]. It is very common in spinning mill to produce rotor spun yarn using recycled fibers. Since recycled fibres have limitations in aspects of processing, so it can be said that it is necessary to reach a compromise when setting the parametres of process those depend on mainly raw materials, desired yarn quality and machine running conditions.

Beater speed has a positive correlation with fibre quality,that is, fibre rupture and fibre neps [5]. The beater speed is directly proportional to the relative amount of waste viz. grid bar setting & its cleaning intensity [6]. The efficient opening at blow room stage not only improves fiber cleaning but also yarn properties such as yarn tenacity and total imperfections [7]. We had selected the setting of cleaning intensity in UNIclean machine for as one of the process parametres in our investigation to spin yarn from 100% cotton recycled fibre.

The process of carding drastically changes the fibre orientation in sliver. Card cylinder speed is one of the influencing factor of carding machine to perform the better carding action. Fibre individualization,neps removing efficiency and hooked fibre formation has a relation with cylinder speed. Since fibre arrangement in sliver leads to eventually good or bad yarn quality,so card cylinder speed behaviour with recycled wastes in which most of the short fibre are present should be known during spinning of cotton recylced wastes.

In rotor spinning optimum opening is a prerequisite for yarn quality and running behavior. [8] The task of opening roller in rotor frame is to open the carded or drawn sliver fed to the spinning box into individual fibers and at the same time to separate the fibers from the trash. Pinar N. Duru et al reported that the opening roller in the OE rotor spinning system, influences yarn quality and spinning performance [9]. Certain raw materials, especially when using 100% cotton recycled wastes, careful selection of opening roller speed is required. The most suitable speed can be chosen on

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the basis of yarn quality [2].

In textile engineering, strength has been considered to be one of the most important yarn properties [4]. Strength of recycled cotton wastes are related with treatment in blow room, carding and speed of opening roller at spinning box of rotor frame.

On the other hand yarn imperfection (neps, thick and thin places) which is another parameter considered as parameter of yarn quality. Yarn imperfection of rotor spun yarn affects fabric quality significantly.

The present study has aimed at understanding the combined effect of cleaning intensity, cylinder speed and opening roller speed of rotor frame on rotor yarn imperfections (Thick place+50%, Thin place-50% and Neps+280%) and strength produced from 100% cotton recycled wastes using box and behnken experimental design.

2. Materials and Methods

2.1. Producing of Yarn Samples

100% spinning mill wastages have been used to produce 60 tex rotor yarn. Table -1 shows the percentages of different types of wastages used in mixing of blow room for our investigations. These fibres were processed through blow room, carding, and two passages of draw frame. The blow room lines of Rieter Company have been used. The settings of cleaning intensity of UNIclean (B-12) have been changed to change the beater speed. The production rate of carding machine(C-60) was 90 kilograms per hour. The finisher slivers of linear density 5.52ktex were fed to the OE-spinning machine (Rieter BT_923). The rotor speed was kept at 70000 rpm for all samples and rotor diameter was 41 mm. All the yarn samples were spun with TPI of 17.30. Studies based on box and behnken 3-variable and 3-level experimental design had been performed. Three independent variable used were cleaning intensity setting of UNIclean (X_1), cylinder speed of carding machine ((X_2) and combing roller speed of rotor spinning frame (X_3) in three different levels (Table-2). The coded level of 3-variable and 3-level box and behnken experimental design and the sample specifications of 15 experiments are shown in Table-3.

2.2. Testing of Yarn Samples

All the yarns were tested for imperfections/km (Thick +50%, Thin -50% and Neps +280%) on USTER TESTER-5. Testing speed was 400 m/min. The test results were averaged for 10 observations of each sample made according to box and behnken experimental design.

Table 1. Name of wastages and their percentage in input raw materials

Serial No.	Type of wastage	Quantity in blend (%)
1.	Flat strips	60%
2.	Comber Noil	15%
3.	Roving	10%
4.	Filter waste	15%

Table 2. Actual values corresponding to coded levels of variables

Variable	Level in box and behnken design		
	-1	0	1
Cleaning Intensity (X_1)	0.3	0..4	0.5
Cylinder Speed (rpm) (X_2)	800	825	850
Opening Roller Speed(rpm) (X_3)	8000	8500	9000

Table 3. Coded levels of variables as per box and behnken 3 –variables and 3-levels experiment

Exp. No.	Coded level of variables			Actual level of variables		
	(X_1)	(X_2)	(X_3)	Cleaning Intensity (X_1)	Cylinder Speed (rpm) (X_2)	Opening Roller Speed (rpm) (X_3)
1.	-1	-1	0	0.3	800	8500
2.	-1	1	0	0.3	850	8500
3.	1	-1	0	0.5	800	8500
4.	1	1	0	0.5	850	8500
5.	-1	0	-1	0.3	825	9000
6.	-1	0	1	0.3	825	9000
7.	1	0	-1	0.5	825	8000
8.	1	0	1	0.5	825	9000
9.	0	-1	-1	0.4	800	8000
10.	0	-1	1	0.4	800	9000
11.	0	1	-1	0.4	850	8000
12.	0	1	1	0.4	850	9000
13.	0	0	0	0.4	825	8500
14.	0	0	0	0.4	825	8500
15.	0	0	0	0.4	825	8500

3. Results and Discussions

Table-4 shows the test results of all dependant variables for 15 experimental results. For every sample, average result of 10 observations has been calculated. Response surface equations (Table-5) were formed with the help of MATLAB software.

The ANOVA tables have been given bellow:

A. Yarn Thick Place:

The results of yarn quality in consideration of yarn thick place (+50%) at our three selected opening roller speed shown in Fig- 1 are distinguishable. By comparing the Fig-1(a), Fig-1(b) and Fig-1(c), it is clear that the result of yarn thick place (+50%) improves with the increase of opening roller speed up to a certain limit when cleaning intensity setting is low. But with high cleaning intensity setting, increasing opening roller speed results in increasing yarn thick place. This may be explained in such a way that when cleaning intensity setting is low that means beater speed is also low. Lower beater speed will not gives good fiber openness. So, at low cleaning intensity, higher opening roller gives better fiber opening in spinning box of rotor frame and also better removal of trash particles. Ultimately yarn imperfection viz. yarn thick place will be decreased. But when cleaning intensity setting is high, then stresses on fiber will be more due to higher beater speed. As a result percentage of fibers having poor strength will be increased in finished sliver. Ultimately higher opening roller speed will break the fiber and eventually create short fibers. Increasing short fibers mean increasing wrapper fibers in rotor during yarn formation. Wrapper fibers will form thick place in yarn. Hooking tendency of fibers increase with the increase of opening roller speed that may be resulted in yarn thick place. Figure-1 also reveals that increasing cylinder speed corresponds to improving results of yarn thick place. This may be happened because of better individualization of fibers lead to better quality of yarn for the incidence of thick place. Higher cylinder speed results in higher carding force. High carding force will improve fiber individualization and parallelization as well. Fiber individualization influences the drafting process and ultimately improves yarn quality.

Table 4. Experimental results of dependant variablesas per box and behnken design

Exp. No.	Thick place (+50%)	Thin place (+50%)	Neps (+280%)	Strength (g/tex)
1.	116.5	2.5	162.0	10.69
2.	104.2	2.5	154.3	10.37
3.	111.9	0	176.7	10.74
4.	93.7	0	170.5	11.05
5.	109.6	0	158.2	10.25
6.	100.5	5.0	143.7	10.83
7.	88.2	0	169.0	9.96
8.	114.0	10.0	155.1	9.79
9.	121.3	7.5	180.5	10.59
10.	106.0	0	173.0	10.71
11.	97.7	0	187.8	10.29
12.	88.0	0	167.5	10.17
13.	96.5	0	152.6	10.47
14.	101.3	0	157.0	10.55
15.	95.5	0	149.1	10.53

Table 5. Response surface equations for dependant variables

Dependant variable	Response surface equation	Co-efficient of Determination (R^2)
Thick place (+50%)	$97.766 - 2.8750x_1 - 9.0125x_2 - 1.0375x_3 - 1.4750x_1x_2 + 8.7250x_1x_3 + 1.4000x_2x_3 + 4.3167x_1^2 + 4.4917x_2^2 + 0.9917x_3^2$	0.82
Thin place (-50%)	$-0.9375x_2 + 0.9375x_3 + 1.2500\ x_1x_3 + 1.8750x_2x_3 + 1.5625\ x_1^2 - 0.3125x_2^2 + 2.1875x_3^2$	0.42
Neps (+280%)	$152.9000 + 6.6375\ x_1 - 1.5125\ x_2 - 7.0250\ x_3 + 0.3750\ x_1x_2 + 0.1500\ x_1x_3 - 3.2000\ x_2x_3 - 3.8625\ x_1^2 + 16.8375\ x_2^2 + 7.4625x_3^2$	0.96
Strength	$10.5167 - 0.0750\ x_1 - 0.1062\ x_2 + 0.0512\ x_3 + 0.1575\ x_1x_2 - 0.1875\ x_1x_3 - 0.0600\ x_2x_3 - 0.0183\ x_1^2 + 0.2142\ x_2^2 - 0.2908x_3^2$	0.59

Table 6(a). Analysis of variance table for thick place (+50%)

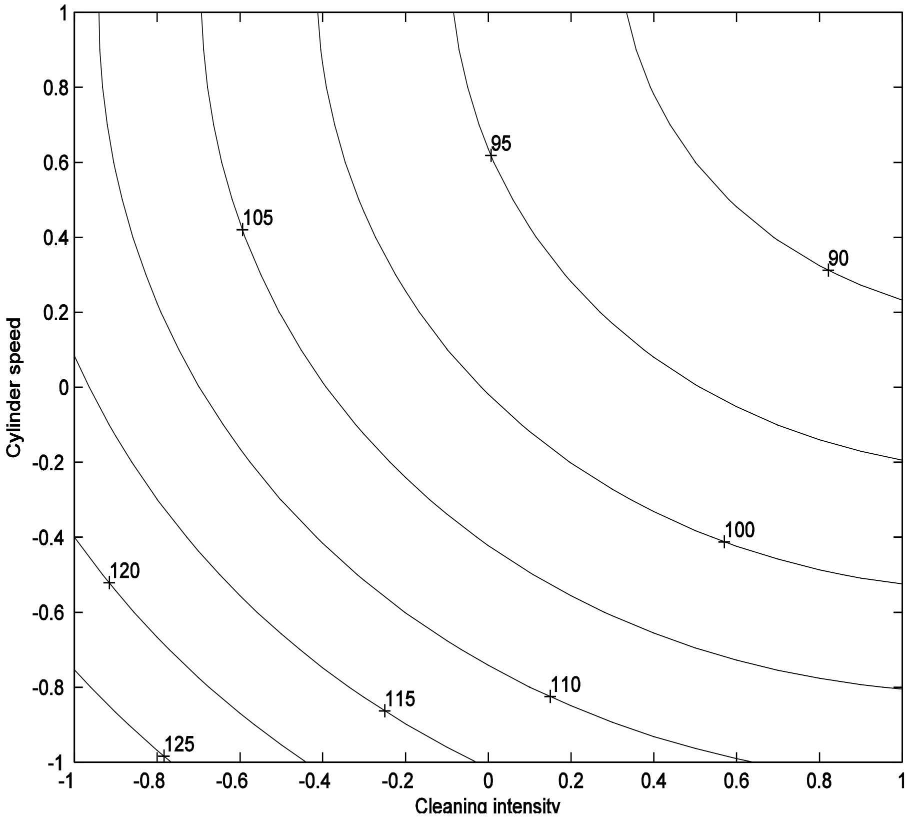
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob> F
Model	985.69	9	109.52	1.21	0.4380
A-Cleaning Intensity	23.81	1	23.81	0.26	0.6297
B-Cylinder Speed	201.00	1	201.00	2.22	0.1961
C-Opening-roll Speed	306.28	1	306.28	3.39	0.1250
AB	8.70	1	8.70	0.096	0.7689
AC	304.50	1	304.50	3.37	0.1259
BC	7.84	1	7.84	0.087	0.7802
A^2	68.80	1	68.80	0.76	0.4229
B^2	74.49	1	74.49	0.82	0.4056
C^2	3.63	1	3.63	0.040	0.8490
Residual	451.92	5	90.38		
Lack of Fit	432.69	3	144.23	15.00	0.0631
Pure Error	19.23	2	9.61		

Table 6(b). Analysis of variance table for Neps (+280%)

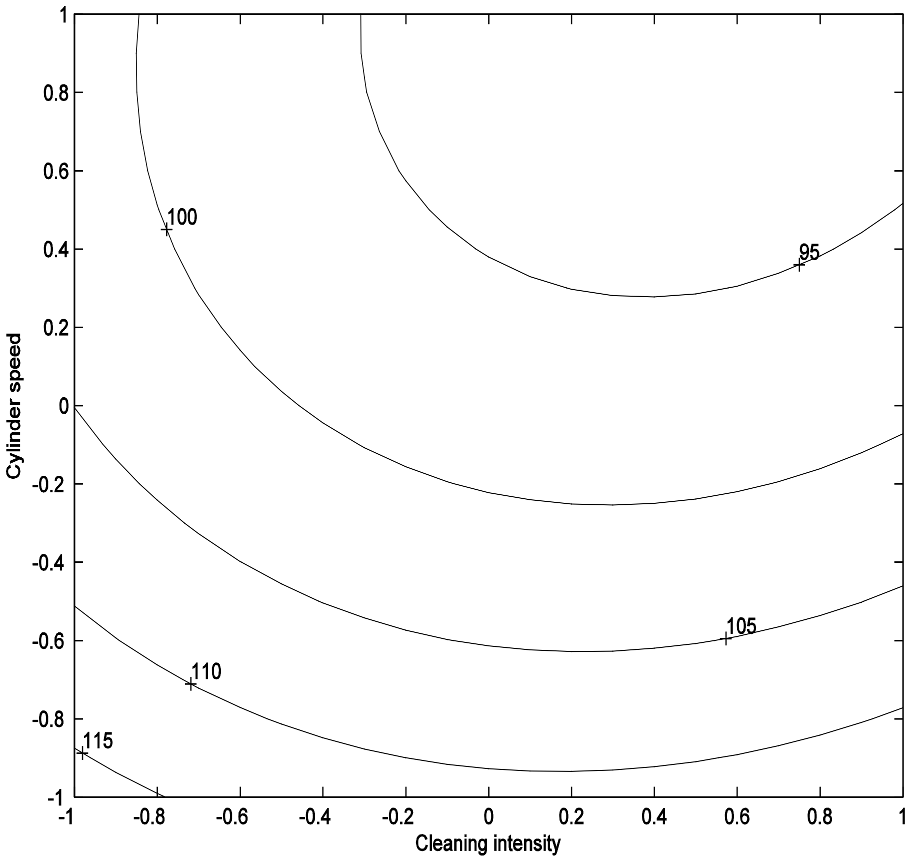
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob> F
Model	1643.53	9	182.61	1.69	0.2924
A-Cleaning Intensity	223.66	1	223.66	2.07	0.2098
B-Cylinder Speed	1.20	1	1.20	0.011	0.9201
C-Opening-roll Speed	72.00	1	72.00	0.67	0.4515
AB	0.56	1	0.56	5.205E-003	0.9453
AC	0.090	1	0.090	8.328E-004	0.9781
BC	40.96	1	40.96	0.38	0.5651
A^2	55.09	1	55.09	0.51	0.5072
B^2	1046.77	1	1046.77	9.69	0.0265
C^2	205.62	1	205.62	1.90	0.2263
Residual	540.35	5	108.07		
Lack of Fit	509.01	3	169.67	10.83	0.0857
Pure Error	31.34	2	15.67		

Table 6(c). Analysis of variance table for Strength

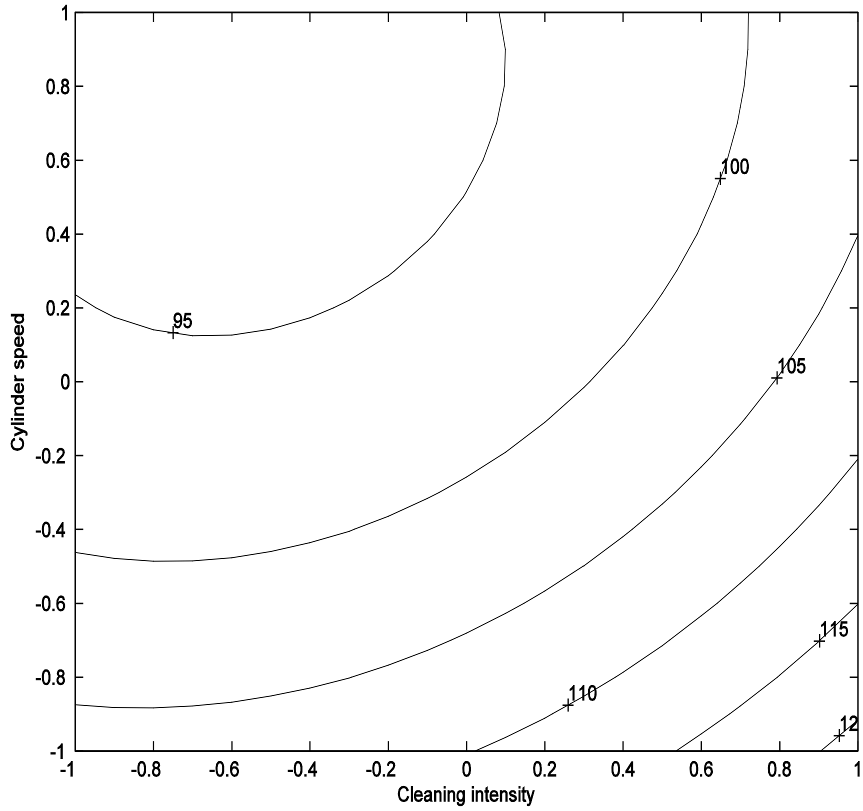
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob> F
Model	1.45	9	0.16	6.60	0.0257
A-Cleaning Intensity	0.020	1	0.020	0.82	0.4070
B-Cylinder Speed	0.067	1	0.067	2.73	0.1596
C-Opening-roll Speed	0.59	1	0.59	24.10	0.0044
AB	0.099	1	0.099	4.06	0.1000
AC	0.14	1	0.14	5.76	0.0617
BC	0.014	1	0.014	0.59	0.4773
A^2	1.241E-003	1	1.241E-003	0.051	0.8306
B^2	0.17	1	0.17	6.93	0.0464
C^2	0.31	1	0.31	12.78	0.0159
Residual	0.12	5	0.024		
Lack of Fit	0.12	3	0.040	22.82	0.0423
Pure Error	3.467E-003	2	1.733E-003		


Cylinder speed
Cleaning intensity
90
95
100
105
110
115
120
125

1(a)


Cylinder speed
Cleaning intensity
95
100
105
110
115

1(b)



1(c)

Figure 1. Effect of cleaning intensity and cylinder speed on 60 tex rotor yarn thick place (+50%) at opening roller speed (a) 8000 rpm (b)8500 rpm (c) 9000 rpm

B. Yarn Neps(+280%)

Figure-2. shows that the value of neps initially reduces distinguishably with the increase of opening roller speed and later hardly improves with further increase of opening roller speed of rotor frame. However, more neps attributed in rotor spun yarn with high cleaning intensity of UNIclean in blow room. It is well known that more beating actions on fiber create more neps. Since we have used 100% recycled cotton wastages, so fibers having poor strength were fed to beater in order to open the tuft. As a result, fibers have been damaged because of more stresses on fibres which then buckle. Ultimately fiber neps have been increased with the increase of cleaning intensity. Bogdan reported that reprocessing increases tangled fibers due to excessive mechanical treatment [11]. Figure-2 also reveals that higher cylinder speed gives better results of yarn neps (+280%). This may be explained in such a way that openness of fibers help during carding action to individualize the fibers and to remove neps because of better carding action. Ghosh and Bhadurihave reported that load on cylinder reduces with an increase in cylinder speed [12]. More opening of fibers in blow room means less loading on card cylinder. When load on card cylinder is low then fiber will be evenly distributed on cylinder surface. As a result better carding action will remove more neps resulting in improvement of yarn quality. The results are similar with the narrations of R.S. Kumar. [13] But at high cleaning intensity (fig.-2), higher cylinder speed shows poor yarn quality in case of neps (+280%). But neps formation due to high cleaning intensity overweighs the effect of neps removing in card cylinder. So neps of rotor yarn had been increased with increasing cylinder speed at high cleaning intensity. From the value of R^2, It is evidently explain that our selected parameters have great influence on yarn neps.

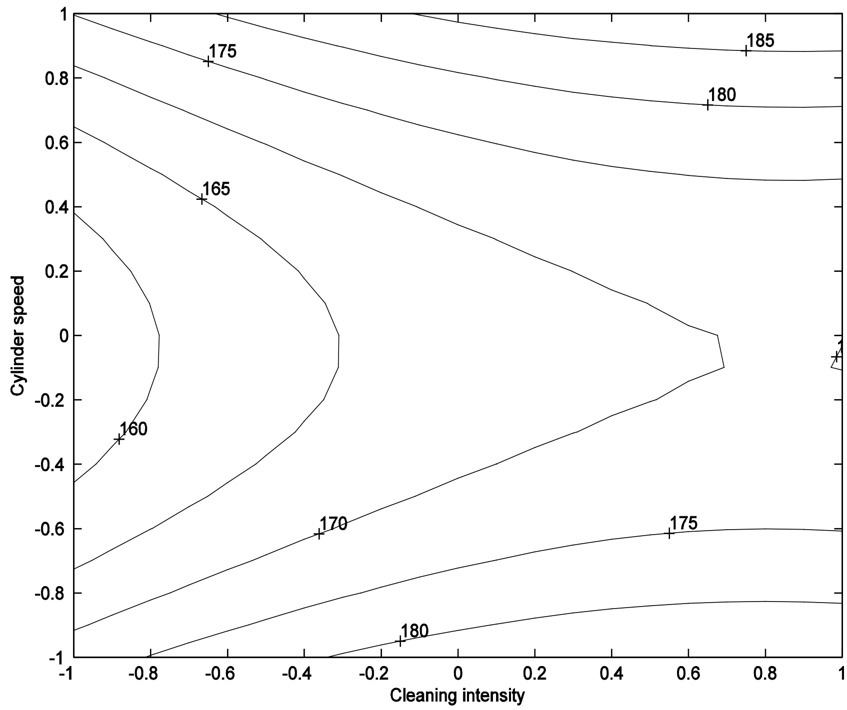
C. Yarn Thin Place

From the value of co-efficient of determination (R^2) and observation of the experimental results, it can be said that our selected parameters are not so significant for thin places in rotor yarn. Results of thin place (-50%) may be varied because of another process parameters.

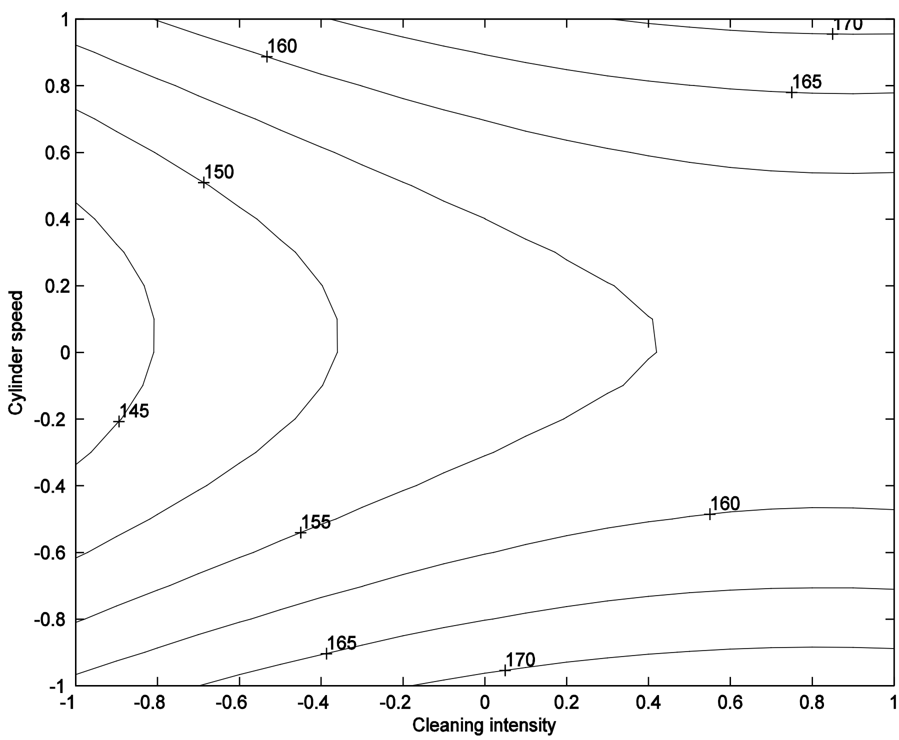
D. Yarn Strength

Figure-4 explains the combined effects of our selected three independent variables on yarn strength. From the results of figure-4 (a), (b) and (c), it is noticeable that fibers treated at lower cleaning intensity setting of UNIclean gives better yarn strength with lower cylinder speed. From figure-4(a) and (b), it is also noticeable that higher cylinder speed along with higher cleaning intensity gives better yarn strength rather than that of higher cylinder speed along with lower cleaning intensity. It may be occurred due to high openness of fibers at high cleaning intensity that will surely assist for better carding action by decreasing the size of the tuft. Better individualization of fiber help to form uniform arrangement of fibers in yarn. Cleanness of fibers will be increased at high cleaning intensity value. Eventually, yarn strength had been increased with higher cylinder speed at higher cleaning intensity. But at lower cleaning intensity, increasing cylinder speed gives poor yarn strength. It may be due to less opening of fiber and high loading on card cylinder. On the other hand, fibers treated with lower Cleaning intensity and lower cylinder speed needs higher opening roller speed to get more strength But if fibers are opened and cleaned very well before entering in spinning box may break due to high opening roller speed. Ultimately yarn strength will be low.

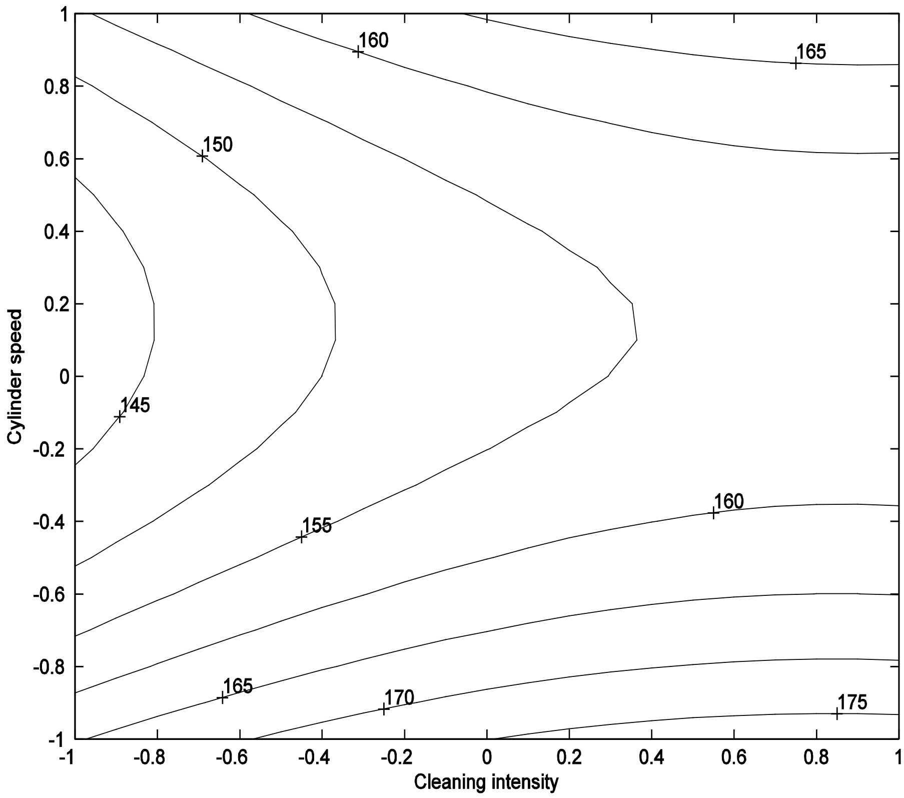
In figure 4 (a), 4 (b) and 4 (c) show the predicted value versus actual value of dependent variables.



2(a)

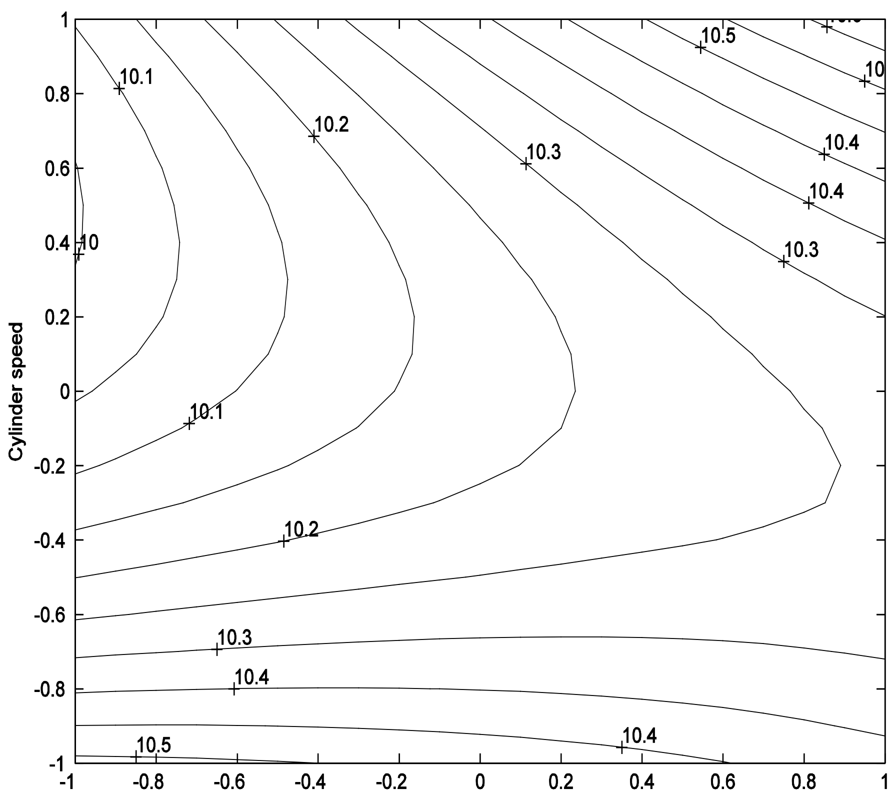


2(b)

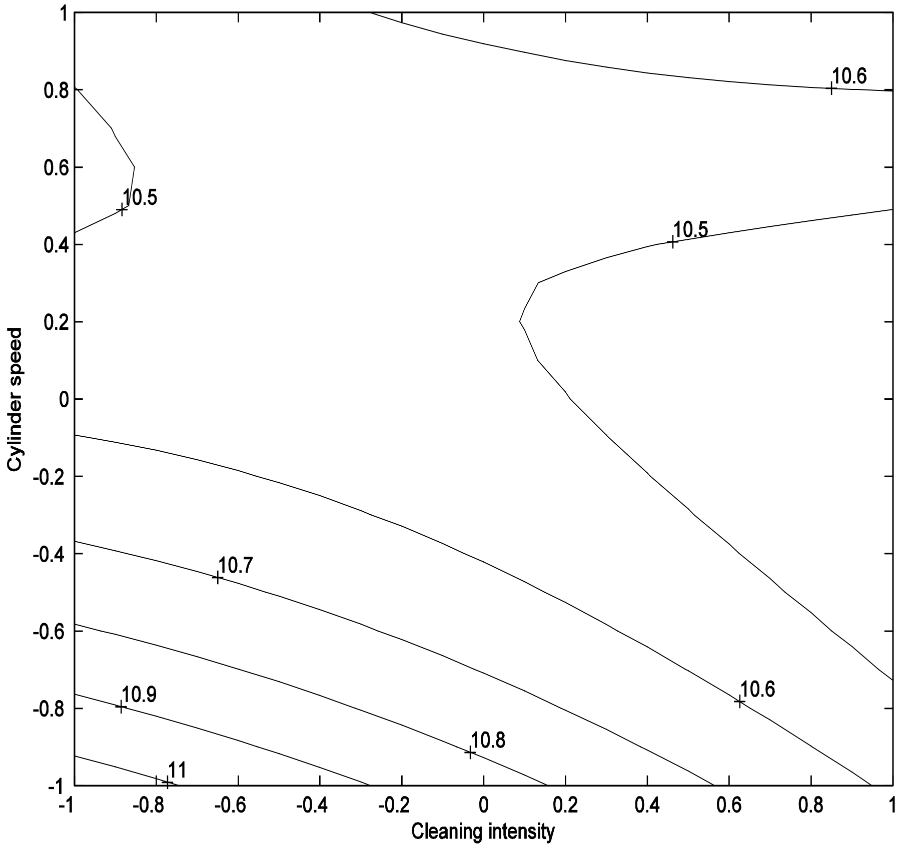


2(c)

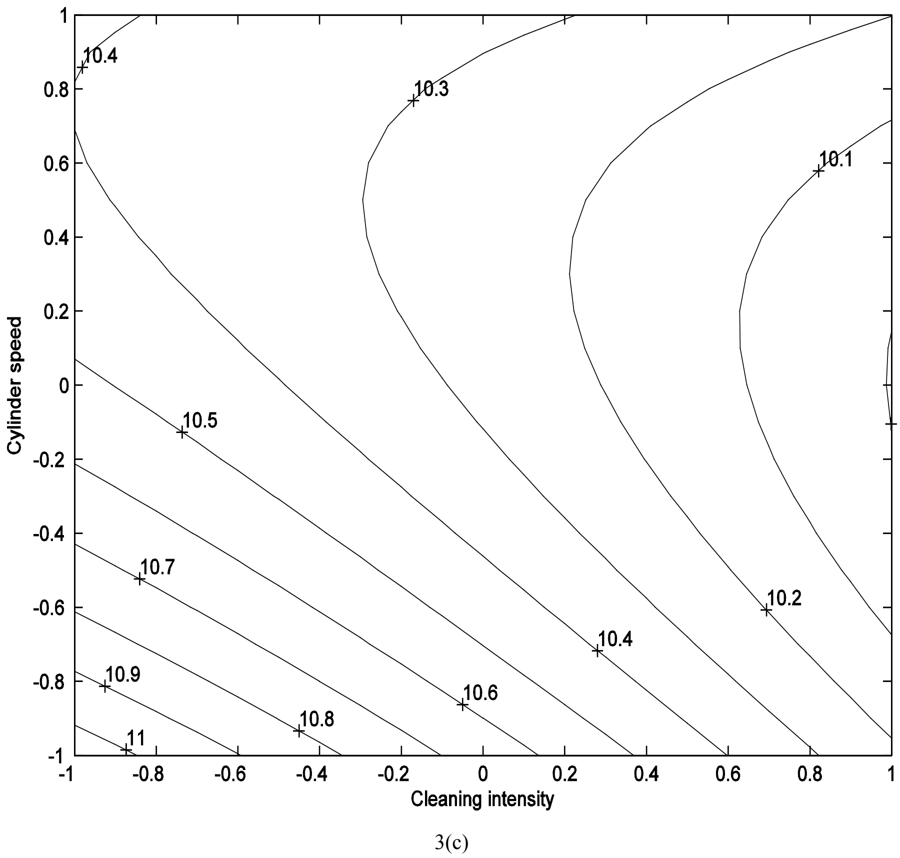
Figure 2. Effect of cleaning intensity and cylinder speed on rotor yarn neps (+280%) at opening roller speed (i) 8000 rpm (ii) 8500 rpm (iii)9000 rpm



3(a)



3(b)



3(c)

Figure 3. Effect of cleaning intensity and cylinder speed on rotor yarn strength at opening roller speed (a) 8000 rpm (b)8500 rpm (c) 9000 rpm

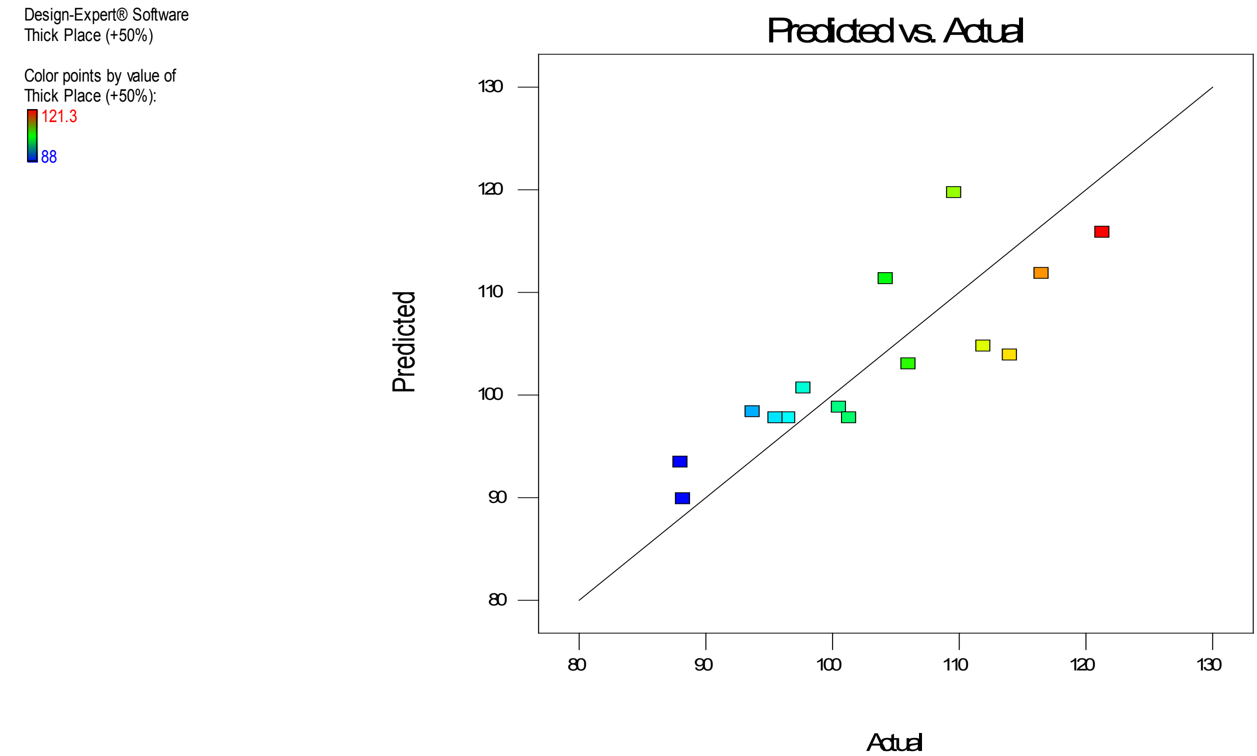


Figure 4(a). Predicted versus actual value (thick place)

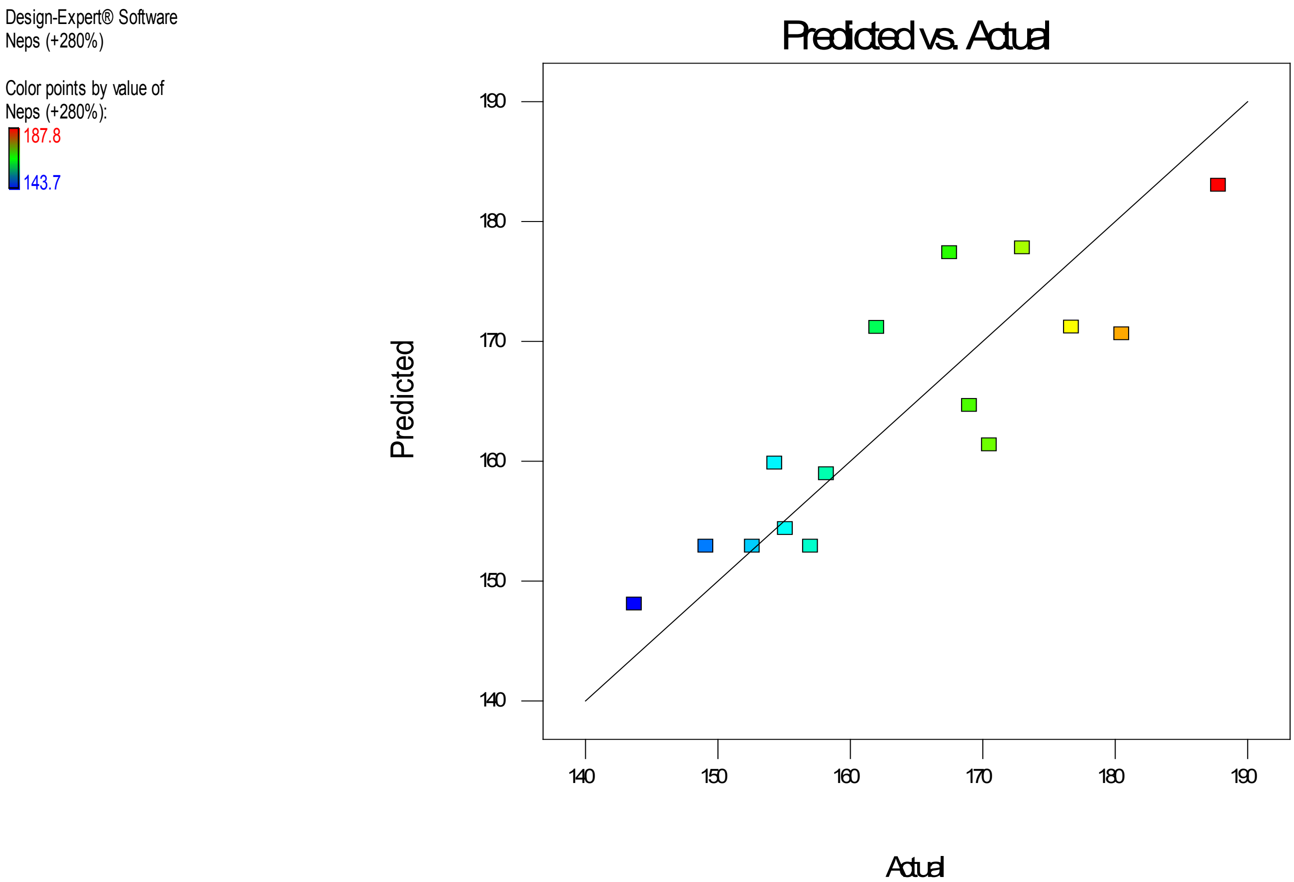


Figure 4(b). Predicted versus actual value (Neps)

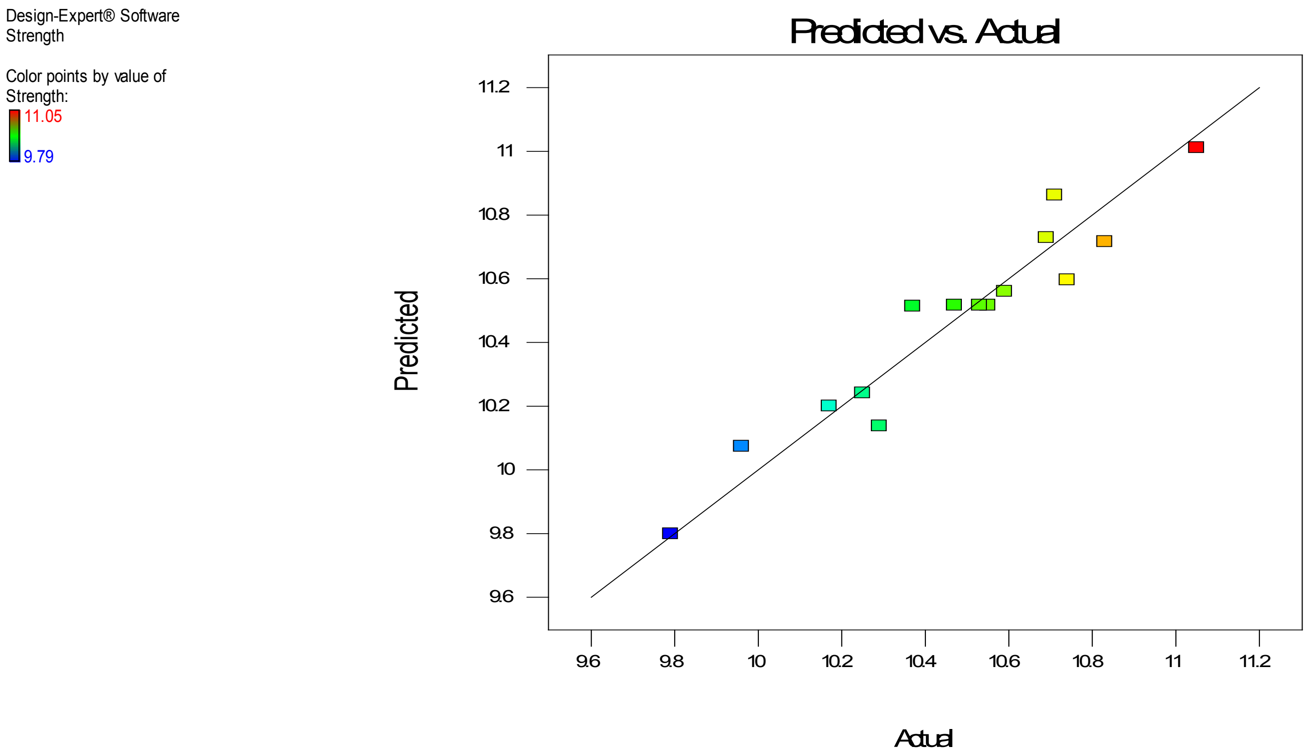


Figure 4(c). Predicted versus actual value (strength)

4. Conclusions

1. Fibers treated with high cleaning intensity gives better result for the incidence of yarn thick place at low opening roller. On the other hand fibers treated with low cleaning intensity need high opening roller.

2. Better result of rotor yarn neps (+280%) has been found for cylinder speed 825 RPM as compared to lower speed (800 RPM) and higher speed (850 RPM) of cylinder.

3. For better rotor yarn strength, cleaning trash particles is very important. When fibres are not cleaned in blow room properly then comparatively high opening roller is recommended to get better strength.

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