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Effect of Finisher Draw Frame Variables on Combed Cotton Yarn Quality

Vpliv nekaterih dejavnikov raztezanja pramenov na kakovost bombažne česane preje

Short Scientific Article/*Kratki znanstveni prispevek*

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Abstract

This research work is an outcome of a practical problem experienced at a finisher draw frame machine in the spinning preparatory section. Older storage can-spring stiffness decreases due to fatigue loading over the years. Hence, combed sliver characteristics may vary during the storage, transportation and processing on a subsequent machine. The study aims to investigate the influence of the can-spring stiffness factor, sliver deposition rate and sliver coils position on the combed yarn coefficient of variation of mass, imperfections and hairiness. For research design, the three-factor three levels Box-Behnken experimental design was adopted. Moreover, the analysis of variance was performed to check the statistical significance of all observed responses.

Keywords: combed sliver, can-spring stiffness, coils position

Izvleček

Ta raziskava je zasnovana na praktičnem problemu, ki je nastal na raztezalnem stroju v fazi priprave na predenje. Togost starejše vzmeti v loncu se zaradi utrujenosti materiala lahko po večletnih obremenitvah zmanjša, zato se med skladiščenjem, prevozom in pri nadaljnji predelavi lahko spremenijo lastnosti česanega pramena. Namen raziskave je bil ugotoviti vplive togosti vzmeti, hitrosti odlaganja pramena in položaja ovojev pramena na neenakomernost mase, napak in kosmatosti česane bombažne preje. Uporabljena je bila metoda trifaktorskega modela Box-Behnken s tremi nivoji. Poleg tega je bila izvedena analiza variance za preverjanje statistične pomembnosti vseh opaženih odzivov.

Ključne besede: česani pramen, togost vzmeti v loncu, položaj ovojev

1 Introduction

In the ring spinning process of manufacturing combed yarn, sliver cans are the most effective means of storage and transportation of sliver from one machine to another in the spinning preparatory section. Closed coil compression helical springs with a circular cross-section are predominantly used in the storage cans. Thousands of such storage cans are used in the spinning preparatory section as sliver handling systems. The main can-spring function used in a storage can is to absorb the energy due to the force applied by the deposited sliver weight on a draw frame followed by the desired release of this stored energy at the time of a sliver withdrawal on a speed frame machine. Thus, the can-spring is an integral part of the storage can and termed as the heart of the storage can. It has been

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reported that can-spring pressure should be about 80% of the sliver storage capacity for a smoother operation [1]. Can-spring stiffness decreases gradually with time due to fatigue loading [2–3]. Older can-springs fail to perform consistently which can deteriorate the quality of stored combed sliver during the deposition at a finisher draw frame and at the time of withdrawal of sliver from the storage cans on the speed frame creel zone. It has been reported that the condition and adequacy of a can-spring should be carefully monitored for a smoother operation, in order to achieve consistent sliver, roving and yarn quality [4–7].

A finisher draw frame is an imperative stage among the spinning preparatory processes since the inadequacies present in the combed drafted sliver will surely pass into the yarn and the defect in a finished combed sliver could not be rectified on subsequent machines. According to previous studies, the alignment of fibres in the sliver configuration improved the drawing of combed sliver [8–10]. Combed sliver with its low inter-fibre friction is more prone to falsified draft and stretching [11]. The studies reported that the fibre configuration in combed sliver is predominately affected by the draw frame speed [12]. Combed sliver stresses should be appropriately controlled during the sliver deposition and its withdrawal on a speed frame machine as sliver weight is the major source of sliver stress on a draw frame and the magnitude of sliver tension can reach about one-third of the combed sliver strength in a modern high-speed draw frame [13–14].

Combed drawn sliver experiences during the withdrawal at a speed frame stickiness with adjacent sliver layers due to the action of the compressive force applied by the can-spring through the top plate and the compressive force applied by its own weight of deposited sliver from the top, middle and bottom position sliver coils. The reverse force applied by the can-spring through the top plate gradually decreases from the bottom sliver-coil position to the top sliver-coil position.

Most previous studies came to the conclusion that combed sliver should be handled meticulously during the deposition, withdrawal and storage in cans. Moreover, can-spring stiffness should be chosen carefully to achieve consistent stored sliver quality, smoother operation and better sliver handling in the spinning preparatory section of a spinning mill. Combed ring spun yarn imperfections once generated during sliver handling cannot be rectified later in the ring spinning process. In line with the thumb rule adopted in the spinning preparatory section, better yarn demands better sliver and better sliver demands a correct sliver handling system. Incorrect sliver handling cans damage sliver in many ways and the yarn made from it has many more imperfections [15]. However, previous studies lack in detailed explanations for combed yarn quality deterioration due to older can-spring and the effect of sliver coils position of yarn quality parameters.

Hence, a comprehensive study is required to examine the effect of finisher draw frame variables on combed yarn quality parameters. This work is an attempt to investigate the influence of can-spring stiffness, finisher draw frame delivery speed and stored combed sliver coils position on the mass coefficient of variation of combed yarn, imperfection and hairiness.

2 Materials and methods

2.1 Materials

Combed cotton sliver samples were produced on a twin delivery finisher draw frame machine. Fibre characteristics were checked using a High volume instrument (HVI). The cotton fibres with on average 29 mm in length and with fibre fineness in micronaire equalling 3.6 were used for the preparation of combed sliver, roving and finally 14.76 tex yarn.

Preparation of yarn samples and experimental plan

In order to investigate the effect of can-spring stiffness, finisher draw frame delivery rate and stored sliver coils position on yarn quality parameters, the Box-Behnken experimental design for three factors and three levels was adopted for sample planning and experimental purpose as indicated in Table 1. The actual values of variables corresponding to the coded levels are shown in Table 2. An appropriate randomisation and replication technique was considered during the sample preparation for an effective statistical analysis and to minimise the chances of error occurrence.

The influential finisher draw frame variables, e.g. can-spring stiffness, delivery and sliver coils position, were shortlisted and taken into account as independent parameters to observe their effect on dependent parameters, e.g. yarn coefficient of variation of mass at 0.01 m cut length, imperfections and hairiness.

Conditioning of samples
Yarn samples were conditioned under standard atmospheric conditions, in a tropical atmosphere of 27±2°C and 65±2% relative humidity, while the number of readings was determined according to the variation in the sample in order to achieve a 95% confidence interval.

2.2 Methods

Design of experiment
Older sliver cans of reduced spring stiffness were tested for spring stiffness using predetermined dead weights and then categorised into different groups of spring stiffness after prolonged scrutiny. Three categories of storage cans with the spring stiffness of 150 N/m, 173 N/m and 196 N/m were considered for evaluation as mentioned in Table 2. These can-springs were used at a finisher draw frame delivery for combed sliver storage and the same cans were fed to speed frame for further processing. Combed drawn sliver samples were produced and stored in the above mentioned storage cans at 250 m/min, 350 m/min and 450 m/min delivery rates at a finisher draw frame and m/min indicating sliver delivery rate in metres per minutes.

Sliver coils position inside the storage can was also considered as a qualitative variable for the study. Therefore, the total length of stored sliver was divided into three segments of equal length representing each sliver coils position, i.e. bottom, middle and top. Afterwards, these sliver segments were by using different can-spring stiffness and different delivery speed processed over speed frame and ring frame to be converted into combed yarn.

Statistical analysis
The effects of the aforementioned independent finisher draw frame variables were statistically investigated using ANOVA at a 95% confidence interval using statistical software. The independent factors taken into account were spring stiffness, delivery rate and sliver coils position to check for any statistical significance.

Yarn testing
Adequate numbers of combed yarn samples were tested taking into account the coefficient of variation. The yarn coefficient of variation of mass at 0.01 metre (CV_m) and total imperfections, including the sum of thick +50%, thin –50% and neps +200% per 1000 metres long yarn, were measured on an USTER® Tester 4-S according to standard ASTM D 1425-96. Yarn hairiness was measured using a ZWEIGLE hairiness tester in accordance with standard ASTM D5647-01. Yarn hairiness, S_3, was considered, i.e. hairs per 100 m with the hair length of 3 mm and above were measured.

3 Results and discussion

3.1 Effect of spring stiffness on combed yarn quality

As can-spring stiffness decreases with time due to fatigue load and other influential factors, an older can-spring fails to perform its original levelling function effectively during sliver processing at finisher draw frame, storage and withdrawal at speed frame. Combed sliver has very low interfibre cohesion due to a higher degree of fibre parallelisation and straightening of hooked portion. Thus, combed

Table 1: Box-Behnken design for three variables

Standard runs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Spring stiffness [N/m]	–1	1	–1	1	–1	1	–1	1	0	0	0	0	0	0	0
Delivery rate [m/min]	–1	–1	1	1	0	0	0	0	–1	1	–1	1	0	0	0
Sliver coils position	0	0	0	0	–1	–1	1	1	–1	–1	1	1	0	0	0

Table 2: Actual values of variables corresponding to the coded levels

Variables	–1	0	+1
Spring stiffness [N/m]	150	173	196
Delivery rate [m/min]	250	350	450
Sliver coils position	Bottom	Middle	Top

sliver is more susceptible to unexpected stretching as a consequence of the tension generated in the sliver due to its own weight at a higher processing speed. Sliver stretching has been observed at a speed frame creel zone while working with older sliver cans of low spring stiffness. The weight of the sliver in the top sliver layer and lifter roller at the speed frame creel plays a crucial role in the tension generation in combed sliver while working with an older can-spring. An older can-spring will deform more than desired due to the reduced spring stiffness; hence, the length of the sliver in the top sliver coils and lifter roller increases slightly, resulting in an additional contribute in the tension development by increasing combed sliver weight.

It was observed that the yarn samples produced using older can-springs of reduced spring stiffness 150 N/m showed higher hairiness compared to the samples produced using cans with173 N/m and 196 N/m spring stiffness. Moreover, the hairiness value was comparatively higher for the yarn samples produced from the bottom position sliver coils due to increased stickiness of fibres during the sliver withdrawal at the speed frame creel, resulting in fibres protruding from one layer to adjacent layer. These samples therefore contributed to more imperfections in the resultant yarn due to the presence of thick and thin places as indicated in Table 3. The samples produced using a low spring stiffness can-spring from the bottom sliver coils position showed higher imperfections compared to other samples. The analysis of variance confirms that the effect of spring stiffness is significant for CV_m and combed yarn imperfections, which can be seen in Tables 3 and 4.

The experiment results reveal that the combed yarn coefficient of variation of mass is higher for the bottom sliver coils position and for the samples prepared from the low spring stiffness can-spring compared to other samples as shown in the surface and contour plots in Figure 1. The coefficient of determination ($R^2 = 0.9607$) indicates a good fit between the predicted values and experiment data. The statistical analysis suggested that insignificant lack of fit (p-value >0.05) implies that the model is valid for the present study. The relative contribution of spring stiffness was the highest for CV_m, which was 16.86%, followed by the imperfection, which was 15.34%, and the lowest for combed yarn hairiness. The effect

Table 3: Box-Behnken sample design, together with variables and their corresponding responses

Runs	Variables			Responses		
	Spring stiffness [N/m]	Delivery rate [m/min]	Sliver coils position	CV_m [%]	Imperfections	Hairiness, S_3 [hairs/100 m]
1	–1	–1	0	13.87	253	1328
2	1	–1	0	13.47	145	945
3	–1	1	0	13.58	164	1234
4	1	1	0	13.19	110	861
5	–1	0	–1	14.43	280	1592
6	1	0	–1	13.78	205	1667
7	–1	0	1	13.64	189	1164
8	1	0	1	13.44	165	896
9	0	–1	–1	14.30	312	1178
10	0	1	–1	14.14	267	1365
11	0	–1	1	13.49	152	812
12	0	1	1	13.54	157	902
13	0	0	0	13.33	141	780
14	0	0	0	13.38	136	647
15	0	0	0	13.26	119	763

of spring stiffness on yarn CV_m and imperfection was significant whereas the effect of spring stiffness on combed yarn hairiness was found insignificant as mentioned in ANOVA summary shown in Table 4.

Table 4: ANOVA summary through p-value analysis

Spinning variables	Effects		
	CV_m [%]	Imperfections	Hairiness, S_3 [hairs/100 m]
Spring stiffness [N/m]	0.00 [a], s [b]	0.02, s	0.05, ns
Delivery rate [m/min]	0.05, ns [c]	0.9, ns	0.80, ns
Sliver coils position	0.00, s	0.00, s	0.00, s

[a] p-value, [b] s – significant (if $p < 0.05$ at 95% confidence interval), [c] ns – not significant (if $p > 0.05$)

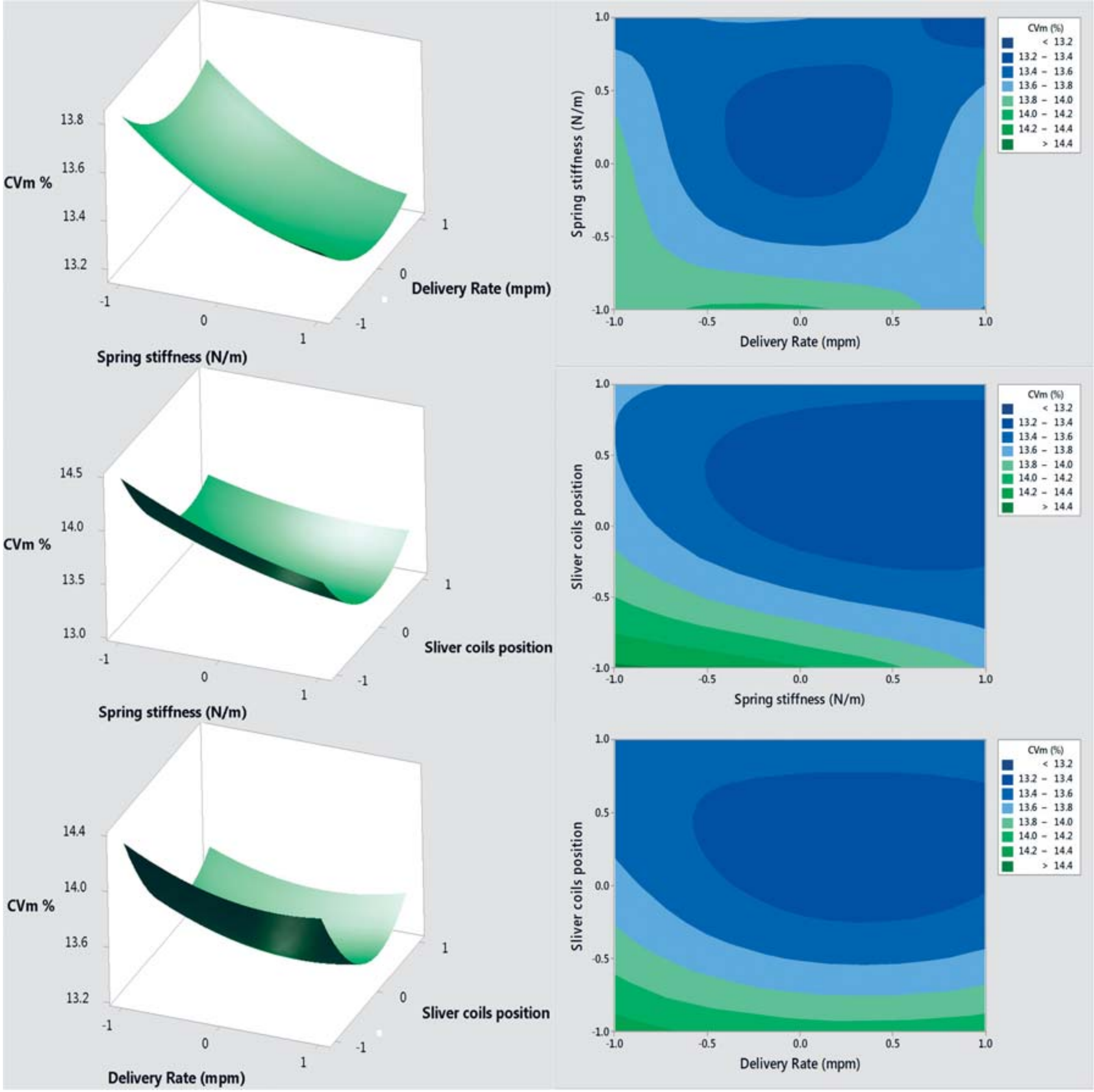

Figure 1: Effect of finisher draw frame variables on combed yarn imperfections

3.2 Effect of delivery rate on combed yarn quality

The higher the finisher draw frame delivery rate, the shorter is the sliver residence time in the drafting zone resulting in less effective straightening of hooked fibres. At a higher delivery rate, sliver experiences more centrifugal force inside the coiler. The aforementioned factors contributed to improved combed sliver strength and enabled fewer chances of sliver failure at the speed frame. It could be observed from the surface and contour plots that combed yarn imperfections were rarer at a higher delivery rate compared to other samples. The statistical analysis of variance revealed that the effect of delivery rate on combed yarn quality parameters was not significant as shown in Table 4. The yarn CV_m and hairiness remained almost unchanged with a variation in the finisher draw frame delivery rate from 250 m/min to 450 m/min as shown in Figures 1 and 3, respectively.

3.3 Effect of sliver coils position on combed yarn quality

The intensity of the force applied by the can-spring through the top plate was gradually reducing from the bottom to the top as shown in Figure 4; hence, the bottom sliver coils experienced more force of compression compared to that of the middle and

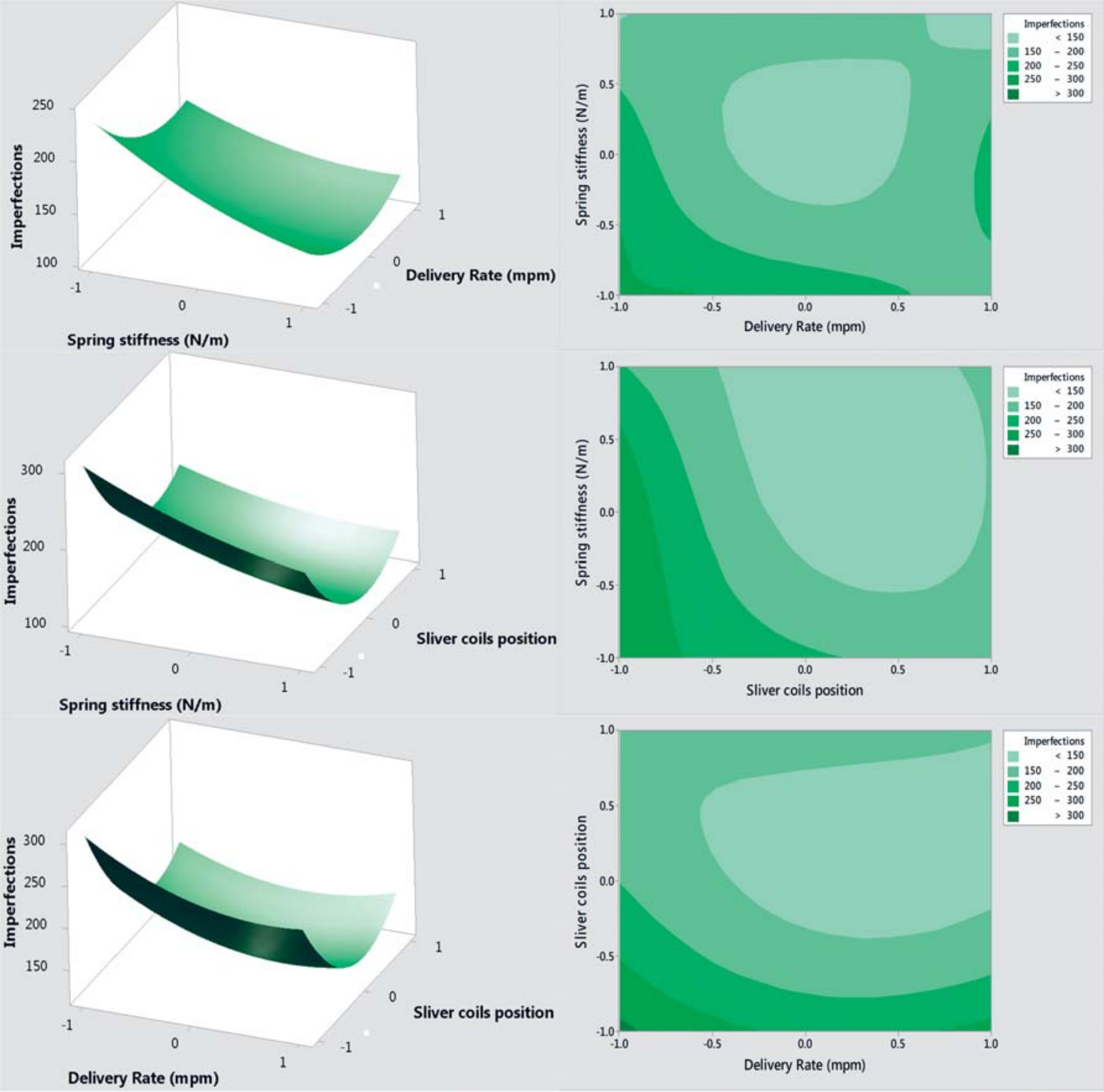

Figure 2: Effect of finisher draw frame variables on combed yarn imperfections

top layer sliver coils. The force experienced at the bottom, middle and top sliver coils position was not equal but variable in nature. Moreover, due to the force applied to its own weight of sliver from the middle and top sliver coils, the bottom sliver coils got sandwiched as shown in Figure 4. Due to this difference in the compression force and force applied by the middle and top sliver coils, the bottom sliver quality deteriorated to a higher extent. The condition of the bottom sliver coils was severely affected due to the increase in adhesion with adjacent sliver layers. A higher number of sliver failures at the speed frame were observed in the case of the samples produced from the bottom sliver coils position. Hence, the resultant yarn showed a higher coefficient of variation of the mass, CV_m, more imperfections and a high level of hairiness in combed yarn shown in Figures 1, 2 and 3.

The coefficient of determination ($R^2 = 0.9321$) indicates a good fit between the predicted values and experimental data. The statistical analysis suggests that the insignificant lack of fit (p-value >0.05) implies that the model is valid for the present study. The statistical analysis suggests that the percentage contribution of sliver coils positioned at 40.44% for the coefficient of variation of mass, 37.5% for hairiness and 36.2% for imperfections. It can be concluded that the effect of sliver coils position was found

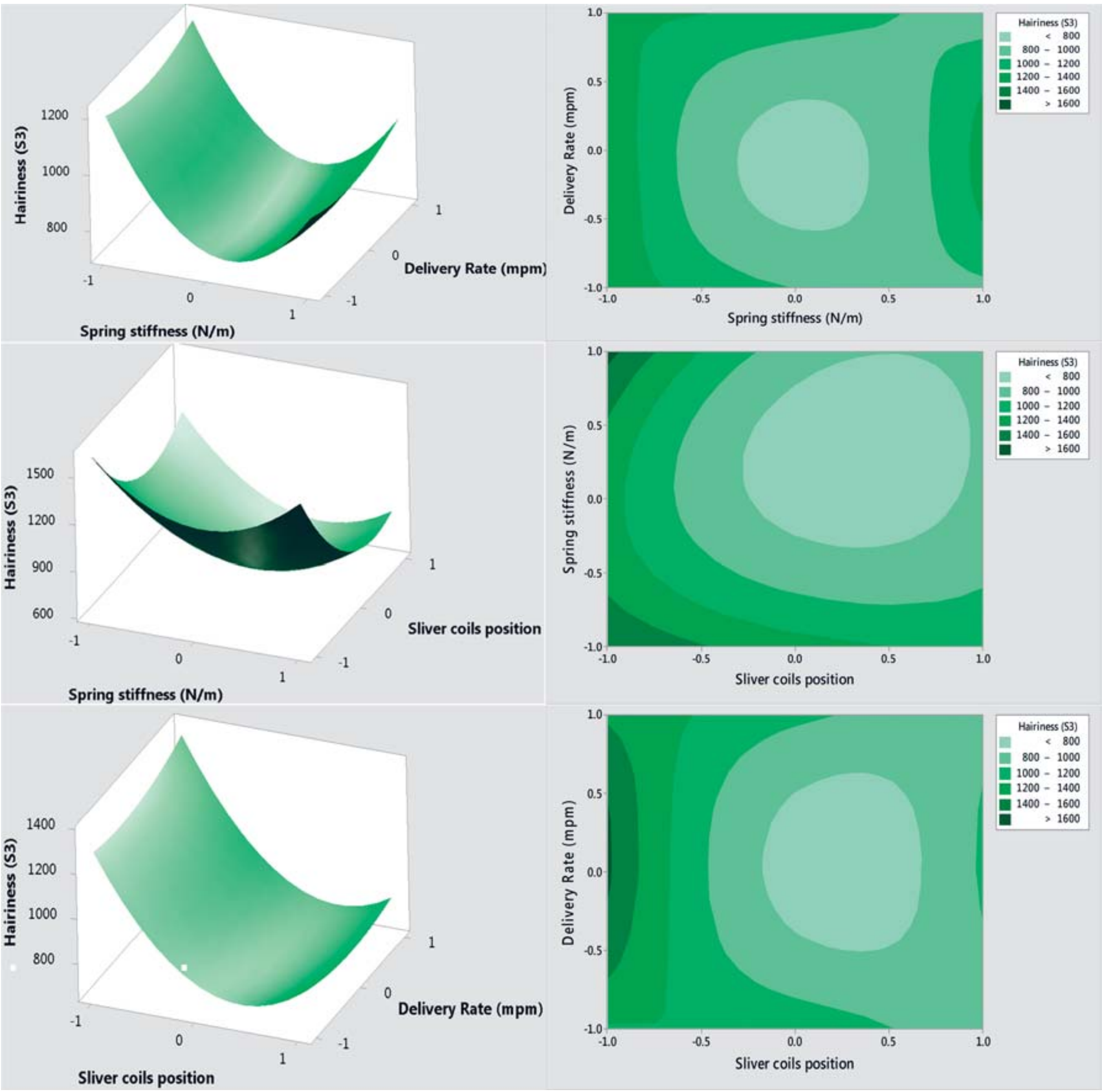

Figure 3: Effect of finisher draw frame variables on combed yarn hairiness

strongly significant in deciding combed yarn CV_m, imperfections and hairiness. The analysis of variance revealed the same as shown in Table 4.

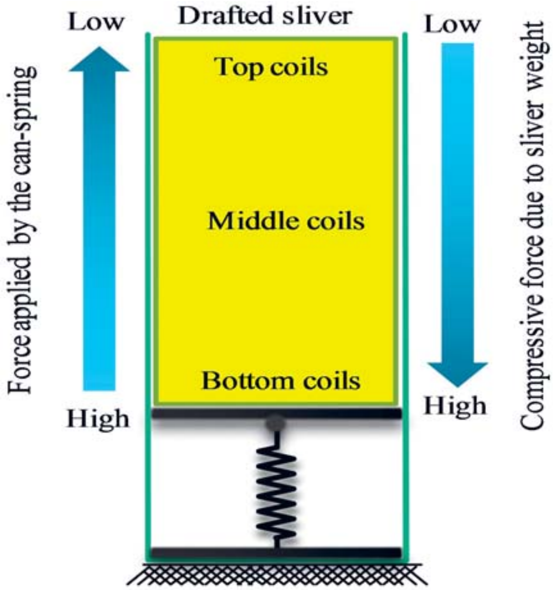

Figure 4: Force applied by can-spring through top plate on different sliver coils positions

3.4 Analysis of predicted versus actual values

It is believed that for a good fit, the points should be close to the fitted line. The predicted versus actual plots are a graphical interpretation of ANOVA (analysis of variance). It was established that the actual values are in a better alignment with respect to predicted values in the case of CV_m, imperfections and hairiness as shown in Figure 5. Most of the yarn CV_m value came under the gamut of 13.19 to 13.78, hence a non-uniform pattern along the prediction line. Similar trends can be observed in the case of imperfections as well.

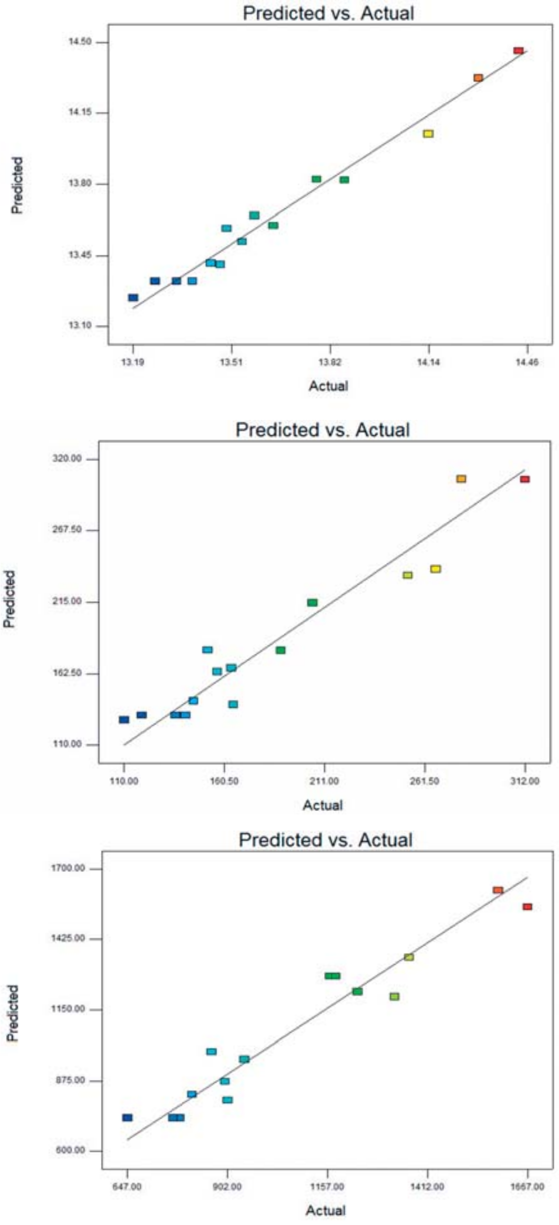

Figure 5: Predicted versus actual curves for CV_m, imperfections and hairiness

4 Conclusion

The experiment results and statistical analysis suggest that the use of an older can-spring results in a higher coefficient of variation of mass and a higher number of imperfections in combed yarn. The effect of spring stiffness on the combed yarn CV_m and imperfections was found significant, whereas it was insignificant for combed yarn hairiness. The effect of the sliver delivery rate was also found insignificant on all observed responses. The results indicate that the effect of sliver coils position is significant for CV_m, imperfections and hairiness. Especially the samples produced from older storage cans with low spring stiffness of 150 N/m and the samples produced from the bottom sliver coils position showed quality deterioration. These samples resulted in higher combed yarn CV_m, a higher number of imperfections and hairy yarn surface compared to other samples. In conclusion, the effect of the sliver coils position and spring stiffness was found significant on the observed yarn quality parameters.

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