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Influence of Can-spring Stiffness, Delivery Speed and Sliver Coils Position on Unevenness

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ABSTRACT

The object of this study is to analyze the combed sliver, roving and yarn unevenness caused by the use of older and inadequate can spring for combed sliver handling at finisher drawframe stage. The Can-spring stiffness decreases with time due to fatigue loading which can influence the stored combed sliver quality during sliver deposition and withdrawal. The study aims to investigate the influence of can-spring stiffness, sliver deposition speed and sliver coils position on combed sliver, roving and yarn unevenness. For sample planning, three-factor three levels Box-Behnken experimental design was adopted. Analysis of variance was also performed to check the statistical significance of all the observed responses. The effect of sliver coils position and can-spring stiffness has been found significant on unevenness.

Keywords: Combed sliver, can-spring stiffness, coils position, yarn

Introduction

In combed ring spun yarn manufacturing process, hundreds of storage cans are used for sliver handling at the preparatory section. Can-spring is termed as the heart of storage can, as it allows the desired deformation during sliver deposition and withdrawal against applied load. It has been reported that can-spring pressure should be about 80% of sliver storage capacity for smoother process flow (Ghosh A. *et al.*, 2013). The can-spring stiffness of storage cans decreases gradually with the passage of time due to fatigue loading (Ansel C. Ugural, 2015, James C. Chesley, 2011). Due to this, the older can-springs fail to perform consistently and produce uneven deformation against the applied load during sliver deposition at drawframe and sliver withdrawal at speedframe. It has been reported that condition and adequacy of the can-spring should be examined meticulously for smoother operation, in order to achieve consistent sliver, roving and yarn quality (Arora V. *et al.*, 1998, Kretzschmar S.D. *et al.*, 2012, Kulkarni M.S. *et al.*, 2012, Salhotra K.R., 2004, Singh S. *et al.*, 2018).

The role of finisher drawframe is crucial in spinning preparatory processes because the inadequacies present in the combed drafted sliver will surely pass into the yarn and cannot be rectified on speedframe and ringframe. According to the studies, the fibers orientation in sliver configuration improved on drawing of combed sliver (Bohuslav N. *et al.*, 2012, Das D. *et al.*, 2012, Nowrouzieh, S. *et al.*, 2007). Combed sliver having low inter-fiber friction is more prone to falsified draft and stretching (Klein W., 1987a). The studies showed that the fiber configuration in combed sliver is predominately affected by draw-frame speed (Ishtiaque S.M. *et al.*, 2008). Due to this, the combed sliver stresses should be appropriately controlled during sliver deposition and its withdrawal on speedframe machine because sliver weight is the major source of sliver stress on draw-frame and magnitude of sliver tension can reach about one-third of combed sliver strength in modern high-speed draw-frame (Miao M. *et al.,* 1998, Klein W., 1987b, R. Senthil Kumar, 2014). Hence, the combed sliver will experience more stress when stored and processed in a can having older can spring of decreased spring stiffness due to fatigue loading.

The previous studies showed that the combed sliver should be handled meticulously during deposition, withdrawal, and storage in cans. Moreover, the can-spring stiffness must be chosen precisely, in order to get consistent stored combed sliver quality. It is clear that better yarn demands better sliver and the better sliver demands correct sliver handling system. Incorrect sliver handling cans damage sliver in many ways and the yarn made from it has many more imperfections (Rimtex, 2016, Singh S. *et al.,* 2019). However, the previous studies also lack in detailed explanations for combed yarn quality deterioration due to the use of the older can-spring and the effect of sliver coils position of stored combed sliver unevenness.

Hence, a comprehensive study is required to investigate the effect of finisher drawframe variables on combed yarn quality parameters. This work is an attempt to investigate the influence of can-spring stiffness, finisher drawframe delivery speed and stored combed sliver coils-position on stored sliver and subsequently roving & combed yarn unevenness.

Material and methods

Material

Cotton variety MCU-5 is processed in a Laxmi-Rieter blowroom line for opening, cleaning, and dust removal at the initial stage. Combed cotton sliver samples were produced on twin delivery finisher drawframe machine. Fiber characteristics were analyzed using a High Volume Instrument. The fiber specifications with average cotton fiber length was 31 mm and fiber fineness in micronaire was 4.1 were used for the preparation of combed sliver (5.32 ktex), roving (0.655 ktex) and finally yarn samples of 14.40 tex.

Preparation of yarn samples and experimental plan

In order to investigate the effect of can-spring stiffness, finisher drawframe delivery speed and stored sliver coils position on yarn quality parameters, Box-Behnken experimental design for three factor and three levels is 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 randomization and replications technique has been considered during sample preparation for an effective statistical analysis and in order to minimize chances of occurrence of any error.

The influential finisher drawframe variables, such as can-spring stiffness, delivery, and sliver coils position were scrutinized and taken into account as independent factors to observe their effect on the responses, such as sliver, roving and yarn unevenness.

Conditioning of sample

The yarn sample was conditioned under standard atmospheric conditions, in a tropical atmosphere of 27°C± 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.

Methods

Design of experiment

The older sliver-cans of decreased spring stiffness were tested for spring stiffness using predetermined dead weights and then categorized into different groups of spring stiffness after prolonged scrutiny.

Spring stiffness is measured in newton per meter and represented by N/m. Three categories of storage cans having spring stiffness 150N/m, 173N/m and 196N/m were considered for evaluation as mentioned in Table 2. Combed drawn sliver samples were produced and stored in above mentioned storage cans at 250 m/min, 350 m/min and 450 m/min delivery speed at finisher draw-frame and m/min indicates sliver delivery speed in meter per minutes. These can-springs were used at finisher draw-frame delivery for combed sliver storage and the same cans were fed to speedframe for further operation. In order to assess the quality of stored combed sliver at different coil positions, sliver samples from top, middle and bottom position were collected.

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
Can-spring stiffness	-1	1	-1	1	-1	1	-1	1	0	0	0	0	0	0	0
Delivery speed	-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

Sliver coils position inside the storage can is also considered as a qualitative variable for the study. In order to convert qualitative factor into quantities terms, the total length of stored sliver is divided in three segments of equal length representing each sliver coils position like bottom, middle and the top position excluding some soft waste from bottommost sliver coils as shown in Table 2.

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

Variables	Corresponding levels of variation		
	-1	0	+1
Can-spring stiffness (N/m)	150	173	196
Delivery Speed (m/min)	250	350	450
Sliver coils position	Bottom	Middle	Top

Statistical analysis

The effect of the aforementioned independent finisher drawframe variables were statistically investigated using an ANOVA at a 95% confidence interval using statistical software. The independent factors taken into account were spring stiffness, delivery speed and sliver coils position to check for any statistically significance.

Yarn testing

Adequate numbers of combed sliver, roving and yarn samples were tested taken into account a coefficient of variation in all the cases. Yarn unevenness is measured on USTER® Tester 4-S according to ASTM D 1425-96 based on capacitive principles. Sliver and roving evenness were also measured on uster evenness tester.

Results and discussion

Effect of the finisher drawframe variables on combed sliver unevenness

It is observed that the combed yarn samples produced from bottom sliver coils positions using older can-springs of reduced spring stiffness 150 N/m were showing higher sliver unevenness compared to rest of the samples as mentioned in Table 3 and can be observed from surface and contour plots as shown in Figure 1. The sliver unevenness remains almost unchanged at different sliver deposition rates. Moreover, it was observed that the combed sliver unevenness is slightly higher at lower sliver deposition speed. At higher sliver deposition speed 450 m/min, combed sliver experience shorter residence time in drafting zone and coiler assembly, result in marginal improvement in the sliver strength compared to the sliver samples produced at 250 m/min delivery speed (Miao M. *et al.*, 1998).

Table 3. Box-Behnken sample design with variables and their corresponding responses

Runs	Independent variables			Observed responses		
	Can-spring stiffness (N/m)	Delivery speed (m/min)	Sliver coils position	Sliver unevenness (%)	Roving unevenness (%)	Yarn unevenness (%)
1	-1	-1	0	2.38	3.87	11.09
2	1	-1	0	2.20	3.54	10.60
3	-1	1	0	2.26	3.71	10.86
4	1	1	0	2.19	3.56	10.57
5	-1	0	-1	2.41	3.94	11.37
6	1	0	-1	2.32	3.78	11.29
7	-1	0	1	2.27	3.67	10.79
8	1	0	1	2.21	3.53	10.58
9	0	-1	-1	2.37	3.89	11.19
10	0	1	-1	2.25	3.65	10.97
11	0	-1	1	2.18	3.55	10.62
12	0	1	1	2.16	3.52	10.59
13	0	0	0	2.14	3.51	10.61
14	0	0	0	2.21	3.60	10.48
15	0	0	0	2.12	3.57	10.56

In this study, there are two major contributory factors which are responsible for higher sliver unevenness. First one is the decreased can-spring stiffness in case of older can spring due to fatigue and the second is the structural variation in sliver configuration due to variation in compressive forces experienced by the bottom, middle and top position sliver coils because of deposited sliver weight. Combed sliver is more prone to unexpected stretching and older can-spring deform non-uniformly against applied load during sliver deposition and withdrawal. Thus, this can deteriorate combed sliver quality. Not just this but also in case of older springs, outer sliver coils touch and rub against the storage can side wall due to can-spring buckling which again deteriorates stored sliver quality during storage and on subsequent processing over speedframe.

The sliver coils position play a crucial role in the current study. It has been observed that the bottommost position sliver quality deteriorates to a greater extent because of the combined action of the compressive forces applied by the can-spring through the top plate and the force experienced due to its own weight of sliver from middle and top position sliver coils. Thus, combed sliver stickiness improve for bottom position sliver coils due to this and contribute in higher sliver unevenness because of fiber leaking from one layer to adjacent layer.

Experimental result reveals that the can-spring stiffness and sliver coils position significantly influence the combed sliver unevenness whereas the effect of sliver delivery speed has been found insignificant as indicated in ANOVA summary shown in Table 4. The statistical analysis suggested that the insignificant lack of fit (p-value >0.05) implies that the model is valid for the present study. The percentage contribution of sliver coils position is highest followed by the spring stiffness on sliver unevenness.

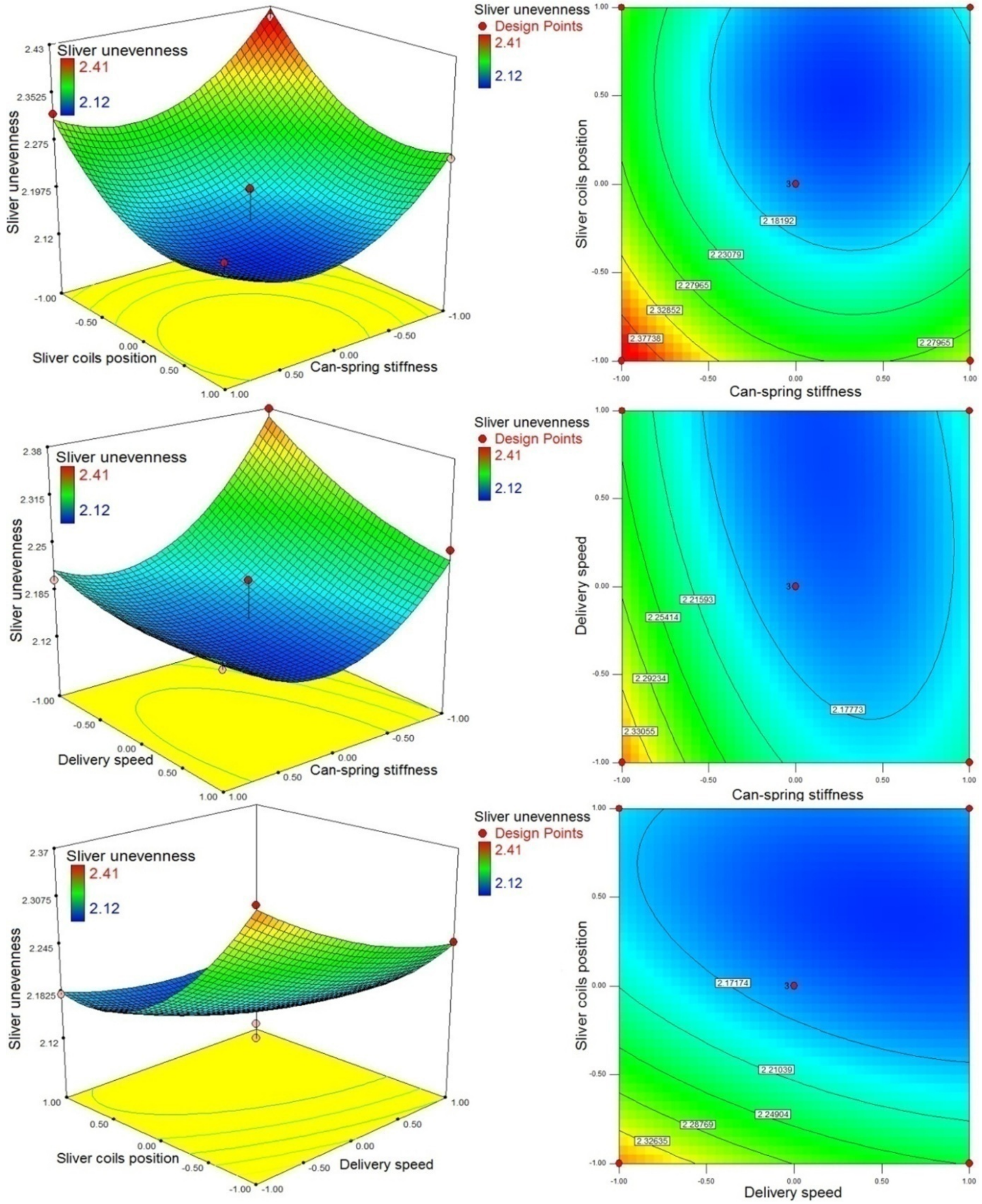


Figure 1. Effect of variables on combed sliver unevenness

Table 4. General linear model ANOVA summary through p-value analysis

Variables	Effects		
	Sliver U%	Roving U%	Yarn U%
Spring stiffness [N/m]	0.00a), s b)	0.00, s	0.00, s
Delivery speed [m/min]	0.07, ns c)	0.11, ns	0.21, ns
Sliver coils position	0.00, s	0.00, s	0.00, s

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

Effect of the finisher drawframe variables on combed roving unevenness

The uniform and even roving structure is a result of even and uniform sliver structure. Better the quality of input sliver, better will be the manufactured roving quality on speedframe. The experimental results showed that the roving unevenness higher for the samples produced from older can-springs stiffness 150 N/m. This is due to poor condition of older cans, can-spring buckling and non-uniform deflection of can-spring as discussed earlier. The roving samples produced from the bottom sliver coils showed highest roving unevenness compared to the roving samples produced from middle and top sliver coils positions as shown in Figure 2. This is because at the time sliver withdrawal from storage cans on speedframe these bottom coils stick with adjacent sliver layers and start climbing with them which contribute to additional stress on the combed sliver. Thus, leads to sliver stretching and even sliver failure either at speedframe creel zone or during drafting operation at speedframe. Also, the roving unevenness is slightly on the higher side at 250 m/min drawframe delivery speed compared to higher delivery speeds. Moreover, the analysis of variance reveals that the effect of sliver coils position and can-spring stiffness is significant but the effect of sliver delivery speed is not significant on combed roving unevenness as shown in ANOVA summary Table 4.

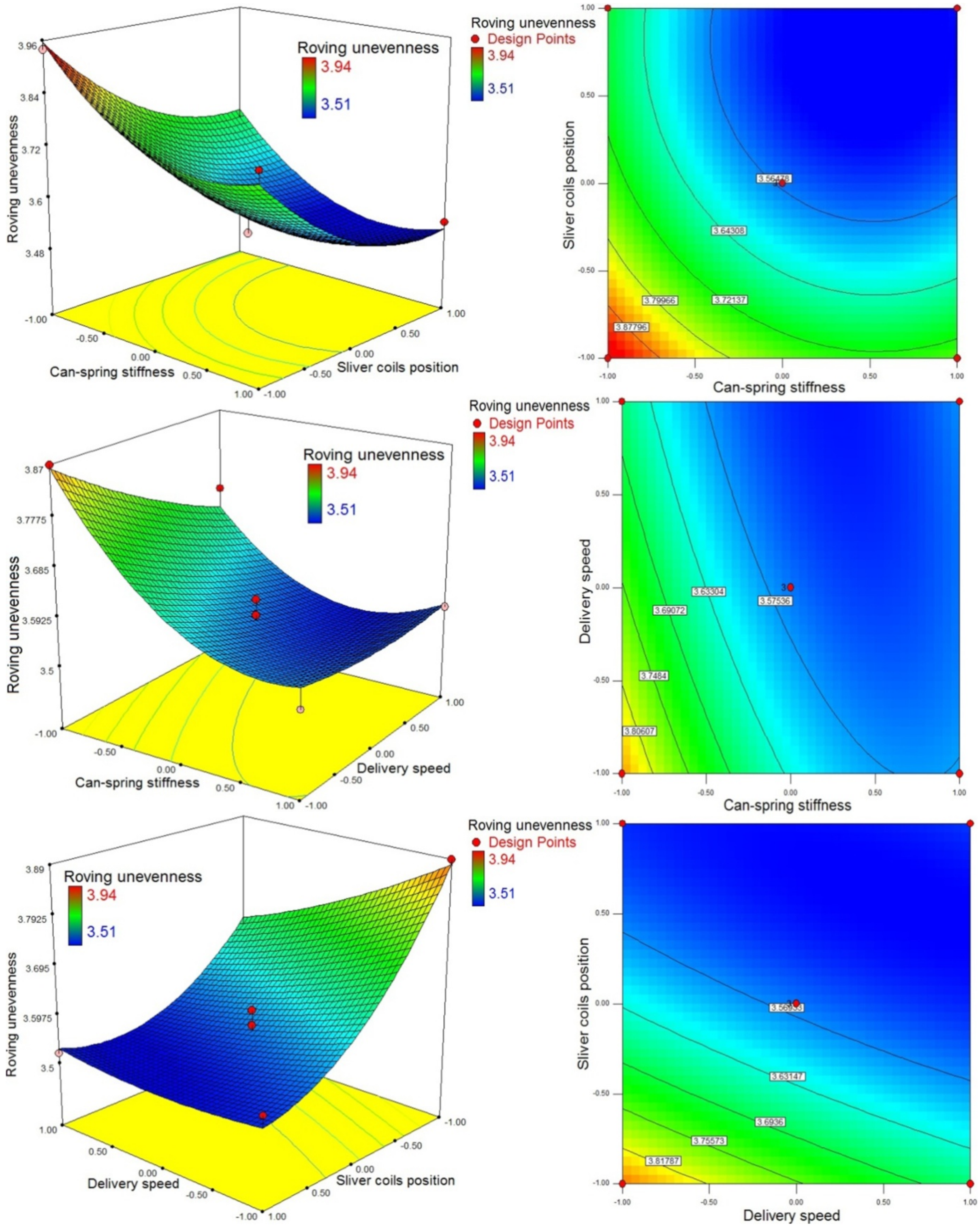


Figure 2. Effect of variables on combed roving unevenness

Effect of the finisher drawframe variables on combed yarn unevenness

Trends observed in the case of yarn unevenness are not different than that of the results obtained in case of the sliver and roving unevenness. As discussed earlier, better yarn demands better sliver and the better sliver demands correct sliver handling system. Thus, confirming that the yarn produced from the poor quality sliver will have less even structure. The experimental results reveal that the combed yarn samples produced from the bottom sliver coils position by using older can-spring of can-spring stiffness 150N/m showed higher yarn unevenness compared to the other samples as shown in Figure 3. It is also observed that samples produced from bottom position sliver coils confront higher sliver failure rate at speedframe and start-up breakage at ringframe compared to other samples. Thus, contributing yarn unevenness by imparting imperfections in resultant combed yarn.

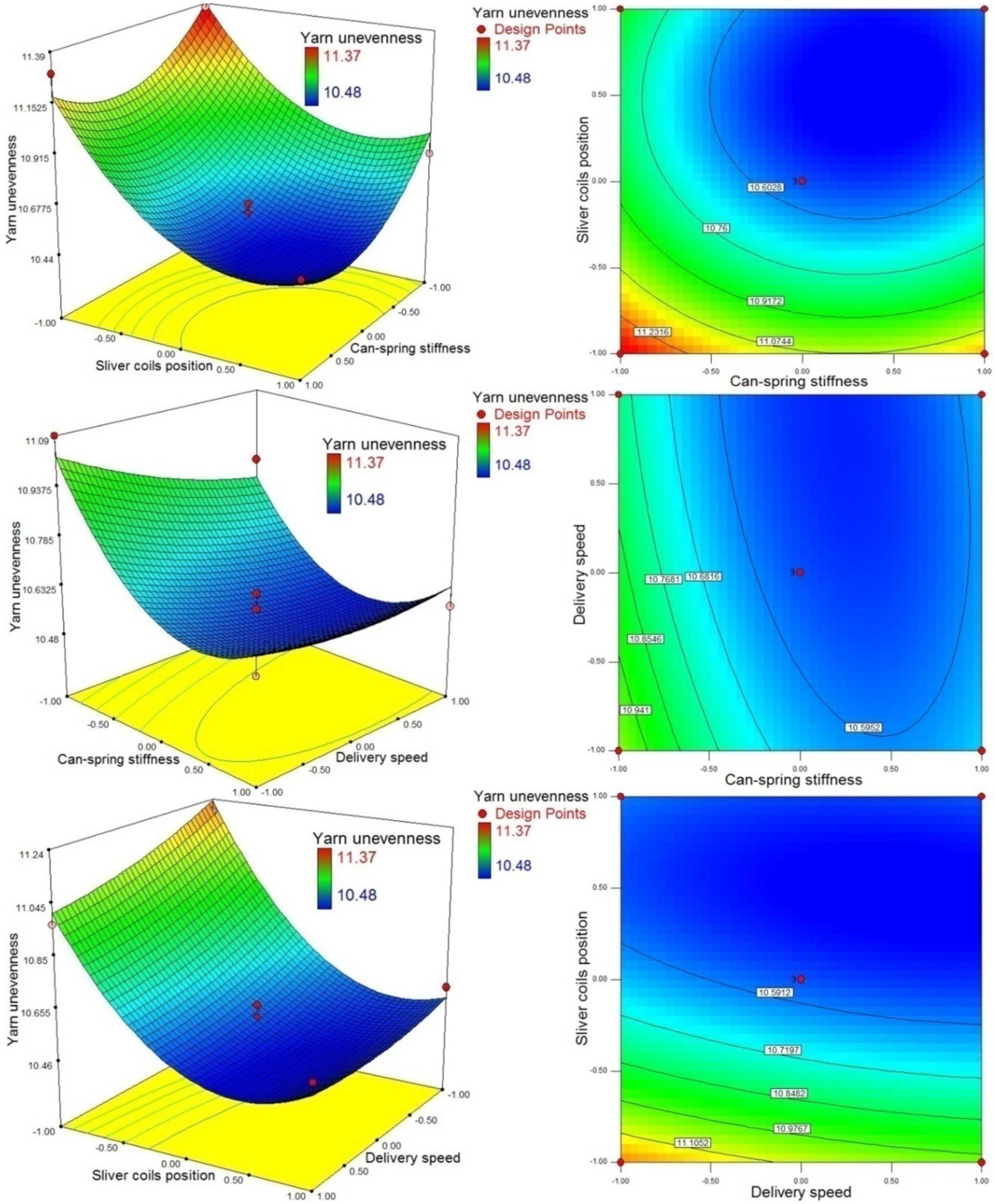


Figure 3. Effect of variables on combed yarn unevenness

The older cans results in poor sliver handling on drawframe and speedframe due to uneven top plate movement. Also, combed sliver rubbing against side wall was observed as a result of can-spring buckling in case of older can spring of reduced spring stiffness 150 N/m as shown in figure 4.

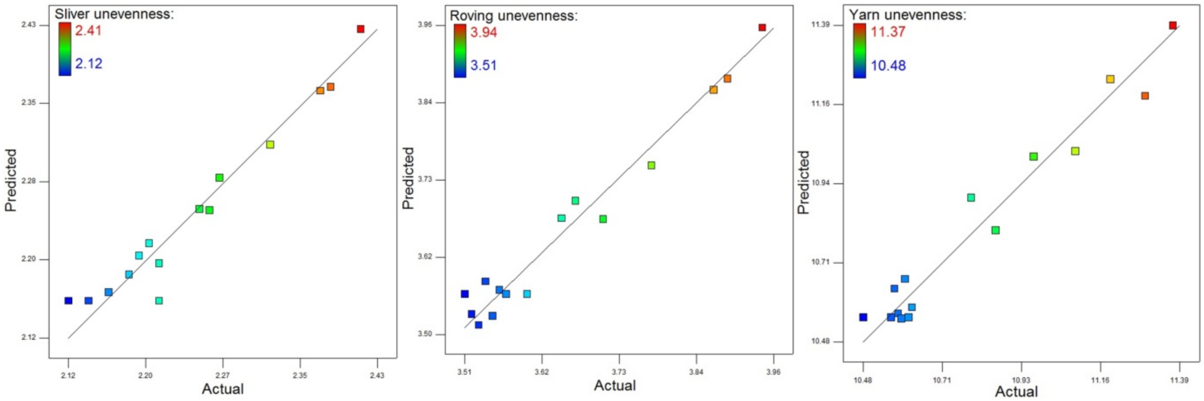
Figure 4. Stored combed sliver touching side wall due to spring buckling in an older can

The condition of bottommost sliver coils is deteriorated to a greater extent as these sliver coils experiences equal and opposite forces as shown in figure 5. Due to this, a higher degree of sliver flattening occur and result in improved stickiness with adjacent sliver coils and increased sliver stresses during sliver withdrawal subsequently at speedframe. This finally results in sliver stretching or failure during processing.

Figure 5. Flattened sliver coils at the end of the batch at speedframe creel zone.

Due to this the quality of the yarn produced from such sliver samples shows higher unevenness as compared to the middle and top sliver coil position. The statistical analysis reveals that the effect of sliver coils position and can-spring stiffness is significant on yarn unevenness whereas the effect of delivery speed is not significant as shown in Table 4.

Analysis of predicted versus actual values responses



The predicted versus actual value plots are graphical interpretation of the analysis of variance for clear understanding. It is proved that for a good fit, the actual points should be located near to the fitted line. It was found that the actual values are in a better alignment with respect to the predicted values in case of sliver unevenness compared to that of roving and yarn unevenness. At the same time it is also observed that most of the yarn unevenness values concentrated in between 10.5% to 10.65%. Also, the roving unevenness trends are similar to that of yarn unevenness, as most of the values concentrated between 3.5% to 3.6% unevenness.

Conclusions

This work demonstrated the effect of can-spring stiffness, finisher drawframe delivery speed and sliver coils position on sliver, roving and yarn unevenness. The experimental results and statistical analysis suggested that the use of older can-spring deteriorates combed sliver quality significantly during storage and processing. It is revealed that the sliver, roving and yarn samples produced from the bottom position sliver coils confront slightly higher unevenness as compared to that of the middle and top sliver coils. In the current study, the contribution of sliver coils position is highest followed by the can-spring stiffness on the sliver, roving, and combed yarn unevenness. The results indicate that the effect of the sliver coils position and can-spring stiffness is significant on sliver, roving and yarn unevenness whereas the effect of sliver delivery speed is found insignificant in this study. Thus, condition and adequacy of can-spring should be meticulously investigated periodically in order to get consistent combed sliver, roving and combed yarn quality. Moreover, the use of correct can-spring system will also contribute in optimizing soft waste in spinning preparatory section by reducing frequency of sliver and roving failures at speedframe.

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