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Impact of Carding Parameters and Draw Frame Speed on Migration Characteristics of Ring Spun Yarns

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ABSTRACT

Fiber migration in ring yarn is found to be affected by the high draw frame delivery speed and associated sliver preparations. Considering the importance of high draw frame delivery speed, and its preparatory (viz., card draft and coiler diameter), earlier work (Ishtiaque et al., 2007) reveals a strong influence on the fiber orientation parameters in the sliver. The effect of the above parameters transmits up to the yarn fiber assembly affecting its structure and properties. In the present study it has been observed that the impact of the three process variables (viz., card draft, coiler diameter of card and delivery speed of draw frame) on the mean fiber position, root mean square deviation and mean migration intensity is very significant as confirmed from higher R^2 values. As draw frame delivery speed and coiler diameter of card increases, mean fiber position, root mean square deviation and mean migration intensity decreases. However, with the increase in card draft, there is marginal increase in mean fiber position and no significant change in the mean migration intensity is observed.

Keywords: ring yarn, carding, fiber migration

1. INTRODUCTION

The tensile behavior of spun yarn is one of the most important parameter of the yarn quality and determines the performance of sequential process as well as the end uses of textile products. The said property is mainly influenced by the characteristics of constituent fibers, the process of formation, and the geometrical arrangement of fibers in yarn. During the process of yarn formation the fibers undergo different level of tension and hence the fiber migrates and occupies different radial position along the length of yarn. Gupta (1970) observed that staple yarn system involves unavoidable geometrical changes in the fiber bundle structure during conversion into a yarn. During drafting process not only longitudinal movement of fibers involved, but also the transverse movement of fibers is accomplished due to combined effects of fiber length variability and the drafting device setting. These expectedly irregular transverse movements may be termed as noise along the helical paths of the individual fiber in the yarn.

Hearle et. al. (1965) stated that in the ring spun yarns, the tension mechanism predominates over twist, and geometry of ribbon twisting to give a rapid migration. Tao (1996) observed that individual fiber in the yarn cross section migrate with a different order in terms of their radial position and also in terms of their position along yarn axis. Huh et. al. (2001) stated that twist constricts the amplitude of the migration behavior of fibers, while promoting fast changes in fiber location. Migration behavior reaches a saturation point between twist multiplier 4 to 5, and one migration occurs when on average, four turns of twist are inserted to yarn. Later, Huh et. al. (2002) found that the ring yarn exhibits the highest fiber migration followed by rotor and friction spun yarn. A high migration factor leads to higher yarn breaking tenacity. Further, yarn hairiness is found to be strongly dependent on the mean fiber position, with an inward shifting of the packing density leading to low yarn hairiness. Oxenham et. al. (2006) observed that higher rate of fiber migration as well as amplitude in compact spun yarns is responsible for higher tenacity.

Fiber migration is also likely to be influenced by the fiber orientation and hooks in the fiber assembly presented to ring spinning machine. Considering the importance of high draw frame delivery speed and accordingly sliver preparations to achieve the objective, Ishtiaque et al. (2007) observed that draw frame delivery speed and its preparatory viz., card draft and coiler diameter can have strong influence on the fiber orientation parameters of the sliver. The effect of the above parameter may transmit up to the yarn fiber assembly affecting its structure and properties. In a very recent study (Ishtiaque et al., 2008); it was found that the fiber extent and spinning in coefficient improves as draw frame delivery speed and coiler diameter of card increases, but decreases as the card draft increases. Consequently fiber migratory behavior is likely to be influenced by the said process variables. In the present study the impact of process variables viz. card draft and coiler diameter of card and delivery speed of draw frame on the migration parameters has been studied.

2. MATERIAL AND METHODS

Samples were prepared with the variation of three process variables viz., breaker draw frame delivery speed, coiler diameter and card draft in accordance to Box-Menken design as shown in Table 1 and 2. Cotton fiber [J-34 and S6 in equal proportion] was used as raw material for the preparation of samples. The average length, strength, elongation %, micronaire of the cotton fiber was 28 mm, 29.7 g/tex, 7.55 and 4.2 respectively. Samples were prepared with the variation of three process variables i.e., breaker draw frame delivery speed, coiler diameter of card and card draft in accordance to Box-Behnken design (1960). Table 1 and 2 show the level of process variables in accordance to the experimental design. All the 15 samples from the finisher draw frame were passed through speed frame LF 1400 A and ring frame LR 6 in the actual running condition of the mill. Roving hank 1.20 Ne (492.08 Tex) was used to produce 40^s (14.76 Tex) carded hosiery yarn.

Variables	Coded level		
	-1	0	+1
Breaker draw frame delivery speed (x_1) (m/min)	400	700	1000
Coiler diameter of card (x_2) (inches)	10	12	14
Card draft (x_3)	80	100	120

Table 1: Actual values of variables corresponding to coded levels

To study the migration parameters viz. mean fiber position, root mean square deviation and mean migration intensity in yarn, the classical tracer fiber technique has been used as proposed by Morton et al. (1952) and Hearle et al. (1965).

During lying of fiber mixing, 0.3 % green medium shade fiber taken by weight was added in the mixing for yarn preparation. The formulae used for the calculation of the migration parameters were those provided by Hearle et al. (1965) and are given below.

Mean Fiber Position:

$$(Y) = 1/Z_n \int_0^{Z_n} y.dz = (\sum_{1=1}^{n} y_i)/n$$

Where, n observations of Y, made over a length Z_n and $y_i = (\frac{r_i}{R_i})^2$

RMSD $(T) = [1/Z_n \int_0^{Z_n} (y-Y)^2 dz]^{1/2} = \{\sum_{i=1}^{n} (y_i - Y)^2/n\}^{1/2}$

Mean Migration Intensity:

$$I = [1/Z_n \int_0^{Z_n} (dY/dz)^2 dz]^{1/2} = \{[\sum_{i=2}^{n} (y_i - y_{i-1})^2/(z_i - z_{i-1})^2]/n\}^{1/2}$$

Where, R_i and r_i are i^{th} value of yarn radius and helix radius, z_i corresponding values of length along the yarn (Figure 1).

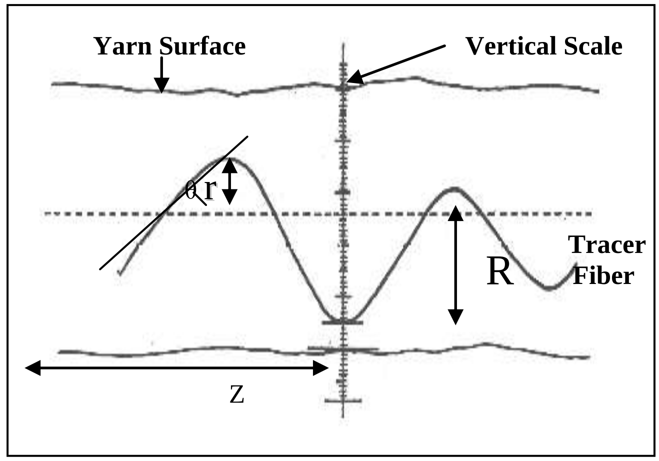


Figure 1: Schematic view of a tracer fiber seen under projection microscope

Table 2: Fiber configuration parameters in yarn and migration parameters at different process variables

Sample No	Delivery speed (x_1)	Coiler diameter (x_2)	Card draft (x_3)	MMI /mm	MPF	RMSD
1	-1	-1	0	0.746	0.510	0.325
2	1	-1	0	0.733	0.485	0.321
3	-1	1	0	0.767	0.496	0.328
4	1	1	0	0.562	0.463	0.309
5	-1	0	-1	0.756	0.504	0.299
6	1	0	-1	0.596	0.456	0.286
7	-1	0	1	0.968	0.524	0.305
8	1	0	1	0.627	0.472	0.291
9	0	-1	-1	0.885	0.501	0.301
10	0	1	-1	0.701	0.488	0.282
11	0	-1	1	0.841	0.510	0.318
12	0	1	1	0.663	0.501	0.305
13	0	0	0	0.667	0.495	0.315
14	0	0	0	0.633	0.505	0.322
15	0	0	0	0.705	0.491	0.309

MMI- Mean migration intensity, MPF – Mean fiber position, RMSD – Root mean square deviation

The samples were prepared after randomization for effective statistical analysis and the validity of the inference drawn. A total of 50 tracer fibers from 10 bobbins per sample have been studied on microscope for migration parameter. Finally equation relating to three process variables (delivery speed of breaker draw frame, coiler diameter of card and card draft) with mean fiber position, root mean square deviation and mean migration intensity are obtained through backward elimination regression method. Table 3 shows the relationship between above mentioned process variables with structural characteristics of yarn.

Table 3: Regression equations representing the effect of process parameters on mean fiber position, root mean square deviation and mean migration intensity

Parameters	Regression Equations	R^2	SE	F_{cal}	F_{table}	p
Mean Fiber Position	$0.499-0.020x_1-0.007x_2+0.007x_3-0.010x_1^2$	0.913	0.006	26.19 (4,10)	3.48	0.000
R M S D	$0.315-0.006x_1-0.005x_2+0.006x_3+0.006x_2^2-0.020x_3^2$	0.884	0.006	13.75 (5,9)	3.48	0.001
M M I	$0.688-0.090x_1-0.064x_2+0.067x_3^2$	0.668	0.072	7.39 (3,11)	3.59	0.006

Degree of freedom corresponding to F ratio is given under the parenthesis

In statistical sense, except the above mentioned three variables, other factors are kept as controlled factors. Since the strength of the relationship between the 3 factors and yarn migration characteristics are found to be strong (as R^2 value range from 67 to 91%), it confirms that the impact of the fiber configuration at draw frame sliver transmit up to the ring spun yarn stage. Using ANOVA for regression, F ratio values and p corresponding to each regression equations are provided in the Table 3. It can be seen that F values for the regression is well above the table value; whereas, p values are substantially lower than 0.05. In Box-Behnken design of experiment 3 central point observation was made which takes into account the variability within the materials. The regression equations were evaluated through backward elimination method in which the factors are removed based on F ratio of 0.10. Based on significant test at the level of 90%, all the parameters in regression equations (related to card draft, coiler diameter, and draw frame delivery speed and their interactions), on fiber migration in yarn are quite relevant and important.

3. RESULTS AND DISCUSSIONS

It can be observed from Table 3 that the impact of process variables on the mean fiber position, root mean square deviation and mean migration intensity is significant as confirmed from higher R^2 and F values and lower p values.

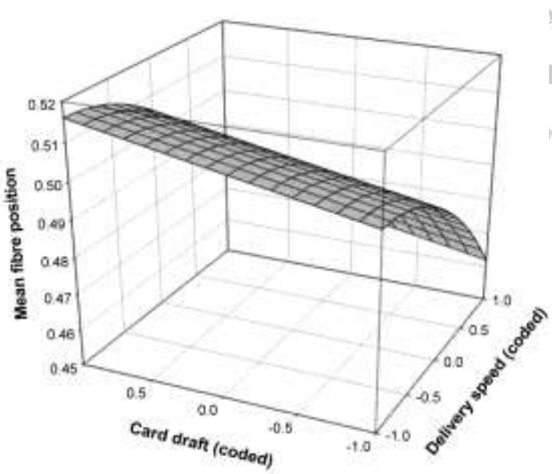
Effect of Process Variables on Mean Fiber Position

It can be observed from Table 2 and Figure 2 a, 2 b that as delivery speed of draw frame and coiler diameter of card increases, mean fiber position decreases. On the other hand as card draft increases there is marginal increase in the mean fiber position. One of the major objectives of draw frame is to removal of hooks and improves fiber parallelization through drafting of fiber assemblies. In this regard inter-fiber friction plays an important role. In an earlier paper [Ishtiaque et al. (2007)], using pair t test, it has been observed that proportion of curved fiber ends decreases whereas coefficient of relative fiber parallelization increases after draw frame passage. With the increase in draw frame delivery speed (400-1000 m/min) proportion of curved fiber ends decreases by a large extent (29 to 44 %) and coefficient of relative fiber parallelization of sliver increases. Decrease in card draft also leads to reduction in proportion of curved fiber ends up to a certain extent. Hence, depending on the draw frame delivery speed and its preparatory, bulk of the sliver and consequently roving material will reduce substantially. It may be added that in a strand of fiber assembly, nonaligned fiber processing greater hook always leads to higher bulk. It is further added that as delivery speed of draw frame increases, tension in the fibers during drafting makes the sliver more compact. Further at high delivery speed, the sliver centrifugal force in the coiler becomes high, causing the fiber to fiber pressure in sliver to increase which makes the sliver more compact and subsequently compact roving. Compactness of the roving reduces the width of spinning triangle at ring frame influencing the migratory behavior of fiber in yarn. Thus along with the reduction in fiber hook and alignment, roving transverse dimension will have important role in structure and properties of yarn.

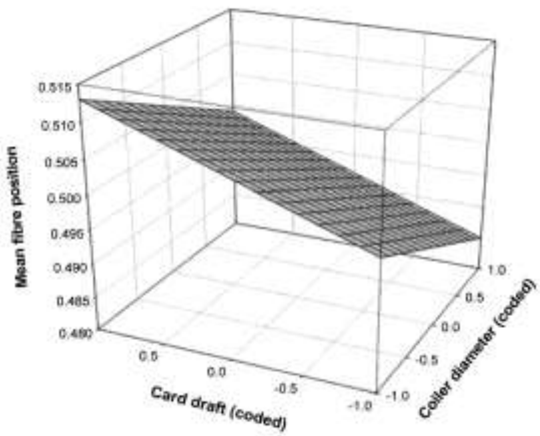
In the earlier investigation (Ishtiaque et al., 2008), it was found that the fiber extent and spinning in coefficient improves as delivery speed and coiler diameter increases, but decreases as the card draft increases. All these factors ultimately lead to improvement in fiber extent in the sliver and roving material. In the spinning triangle, in case of higher fiber extent, there will be more positive control over fiber which reduces the fiber deviation from mean position. The mean fiber position will also be influenced by narrower spinning triangle due to compact roving produced at high delivery speed and while using higher coiler diameter. This in turn is responsible for the less fiber tension at the edge fiber of spinning triangle. This will ultimately lead to low fiber migration i.e. lower mean fiber position.

Effect of Process Variables on Root Mean Square Deviation

It can be observed from Table 3 and Figure 3a, 3b that as the delivery speed and coiler diameter increases there is a decrease in root mean square deviation (RMSD), but as card draft increases RMSD first increases then decreases. The impact of draw frame delivery speed and card coiler diameter on RMSD can be explained in the following manner. As coiler diameter and delivery speed increases fiber extent increases with consequent increase in sliver compactness. Further, with the increase in roving compactness, fibers are subjected to lesser stress at the spinning triangle leading to less deviation from the central position of the yarn. In the earlier investigation, [Ishtiaque et. al. (2007)], it was observed that proportion of curved fiber ends in draw frame sliver first decrease and then increase with the increase in card draft. The effect of the above may transmit up to the ring frame partially affecting the RMSD value in yarn.

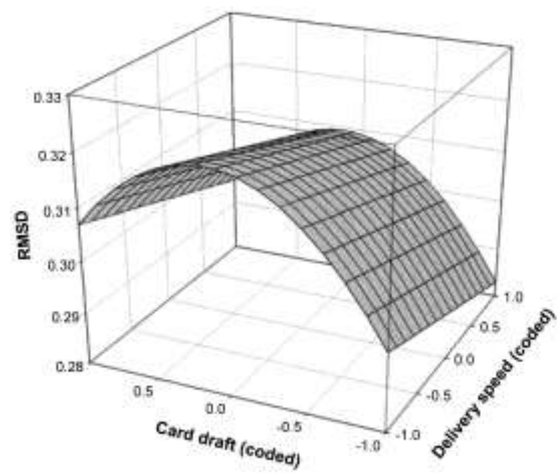


(a)

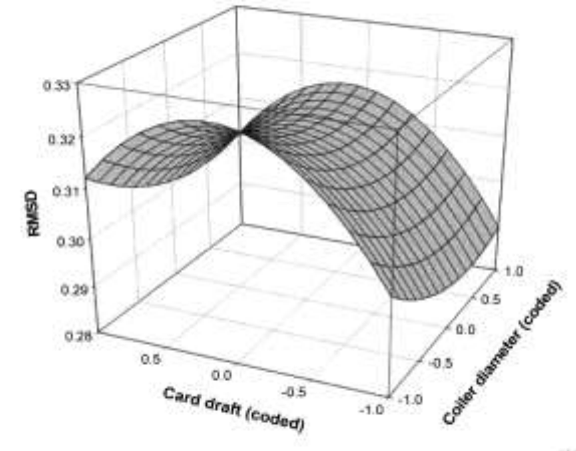


(b)

Figure 2: Effect of process variables on mean fiber position
(a) effect of delivery speed and card draft
(b) effect of coiler diameter and card draft



(a)

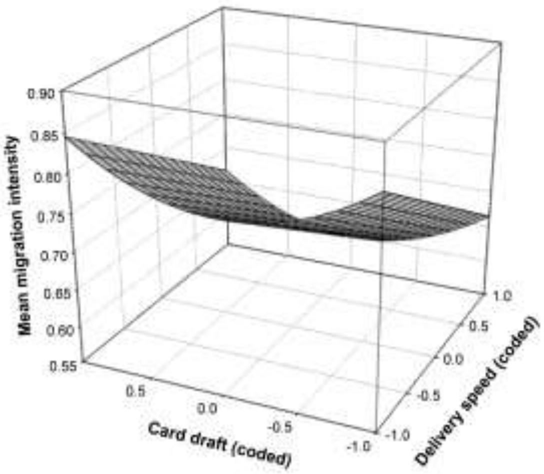


(b)

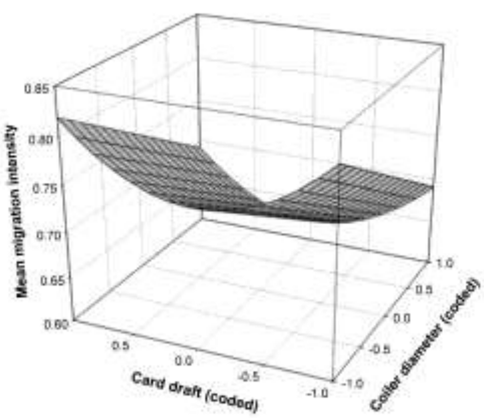
Figure 3: Effect of process variables on RMSD
(a) effect of delivery speed and card draft
(b) effect of coiler diameter and card draft

Effect of Process Variables on Mean Migration Intensity

It can be again observed from Table 2 and Figure 4 a, 4 b that with the increase in delivery speed and coiler diameter, mean migration intensity (MMI) decreases and as the card draft increases, MMI shows marginal increase. MMI is influenced by the tension differences among the fibers, i.e., smaller the tension differences, less will be the mean migration intensity. Higher draw frame delivery speed and coiler diameter result in more compact roving which in turn results smaller width spinning triangle at ring frame. The above factor leads to the reduction in tension differences and lower value of MMI. The above migration characteristics will be also affected by effective fiber length which is improved at higher draw frame deliver speed and coiler diameter. With the increase in fiber extent, there will be greater positive control over fiber at spinning triangle which reduces the mean migration intensity.



(a)



(b)

Figure 4: Effect of process variables on mean migration intensity/mm
(a) effect of delivery speed and card draft
(b) effect of coiler diameter and card draft

4. CONCLUSIONS

Fiber migration in ring yarn, which is one of the major determinants of yarn properties, found to be affected by the high draw frame delivery speed and associated sliver preparations. The migration parameters such as mean fiber position, root mean square deviation and mean migration intensity decreases as draw frame delivery speed and coiler diameter of card increases. On the other hand, with the increase in card draft there is marginal increase in mean fiber position whereas no significant change in the mean migration intensity is observed. However, with the increase in card draft root mean square deviation first increases then decreases.

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