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Fibre migration in compact spun yarns: Part II – Mechanical compact yarn

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Fibre migration of ring and mechanical compact spun combed cotton yarns (40s Ne) has been studied using the tracer fibre technique. It is observed that the migration parameters for compact yarn made from Mechanical Compacting System (MCS)–positive nip are 10-15 % lower than that of the ring yarn and similar to that of pneumatic compact yarn of the same count. However, only a marginal reduction (2-6%) is observed in migration parameter for compact yarn made from MCS–semi-positive nip as compared to ring yarn and it is not significant. Significantly lower degree of migration is observed in mechanical compact yarn spun from MCS–positive nip than in ring yarn due to the significant reduction in size of the spinning triangle in the system and its consequence in the tension gradient. In the case of MCS–semi-positive nip, the base of the spinning triangle remaining the same, its altitude increase causes slight reduction in tension gradient, resulting in marginal change in migration parameters. Yarn diameter of mechanical compact yarn from MCS–positive nip system is found to be significantly lower than that of ring yarn and similar to pneumatic compact yarn, which contributes to increase in strength by 10-15%. The yarn from MCS–semi-positive nip system has shown a marginal reduction in yarn diameter and hence the increase in strength is marginal (3-5%).

Keywords: MCS–positive nip, MCS–semi-positive nip, Mean fibre position, Mean migration intensity, Spinning triangle, Tension mechanism

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1 Introduction

In producing compact yarn, pneumatic compacting system and mechanical compacting system are used in ring spinning frame. Fibre migration in compact spun yarn made from pneumatic compacting system has been reported earlier[1] and the fibre migration of compact spun yarn made from mechanical compacting system is discussed in this paper. In the drafting system of ring spinning the roving of 2-3mm thickness is getting attenuated and hence the fibre strand that comes out of the front roller is widespread to the extent of roving size. The twist being applied is trying to bind most of the fibre and in the process a spinning triangle is formed at the point of yarn formation. The widespread fibres are brought closer through condensation or compacting process in the compact spinning system. The bringing of fibres closer and their twisting could be done sequentially or simultaneously. The various commercially available pneumatic compacting systems in the production of compact spun yarn use extra zone to condense the drafted fibre strands (2-3mm spread) to less than 0.5 mm and they are subsequently twisted and wound by the combined act of ring and traveler. This clearly indicates that this action of condensing and twisting is sequential.

A Mechanical Compacting System (MCS) working on positive nip and semi-positive nip principle has been developed by the first author, wherein the operation of bringing the fibre closer and twisting is being done sequentially in the former and simultaneously in the later. Hence, there are changes in the relative fibre movements at the point of yarn formation and the resultant position of fibres in the yarn structure, which has a decisive influence on yarn properties such as strength, elongation, hairiness and running performance. Morton and Yen[2] termed the relative fibre movement as 'fibre migration'. Huh *et al.*[3] observed that fibre migration characteristic in staple yarns was, to a great extent, influenced by the factors such as spinning system adopted (ring, rotor

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and friction spun yarns), fibre accumulation mechanism and the relative tension of fibres at the point of yarn formation, apart from the fibre characteristics (length, fineness, crimp, cross section). The commercial pneumatic compact yarn is spun with a significantly reduced spinning triangle to less than 20% of the ring yarn and hence a less variation in path distance among fibres of drafted strand is achieved. This results in comparatively less variation in tension among the fibres in pneumatic compact yarn than in ring yarn and hence their migratory characteristic is observed[1] to be 10-25% less. In the MCS-semi-positive nip and MCS-positive nip also there are changes in the size of the spinning triangle and hence the changes in the migration characteristics are expected. The present work was therefore undertaken to study the fibre migration in mechanical compact yarn so as to correlate its structure with properties.

2 Materials and Methods

2.1 Materials

The same cotton variety H-4 with a 2.5 % span length of 29/30 mm and fineness of 4.0 µg/inch, with combed roving of 1.37 Ne (431 tex), which was used earlier for the production of pneumatic compact yarn, has been used for this study on mechanical compact yarn. A small proportion (1.0% by weight) of the above fibres was dyed black and used as tracer fibres, which were introduced in the carding stage with the remaining un-dyed material. The yarn count 40s Ne (14.8 tex), produced by the mills on Suessen 'Elite Compacting System', working on pneumatic compacting principles, was selected for this study on MCS–semi-positive (MCS-S) nip and MCS–positive (MCS-P) nip. The tracer fibre incorporated roving was used in two spindles to produce mechanical compact yarn in a pilot ring spinning machine. For the production of equivalent count 40s Ne ring yarn, the same spindles without compacting attachment was used, while keeping the process parameters such as spindle speed (16500 rpm), twist factor [$4.2\alpha_e/127\alpha_m$ (1045 tpm)] and traveler weight identical for both ring and mechanical compact yarns. The design concept of MCS- S and MCS- P nip is explained in the following sections.

2.1.1 Design Concept of MCS–Semi-Positive Nip

In the MCS–semi-positive nip[4], a light spring loaded disc is located in front of the front-bottom roller. Guiding the yarn through it helps to converge and condense the drafted strand as shown in the Fig.1. The converging point of condensation will move downwards creating a long spinning triangle based on spinning tension fluctuation, thereby preventing the free flow of twist to a point nearer to the front roller nip. Here also, the creation of long spinning triangle facilitates better integration of fibres due to the reason given earlier. The spring loaded disc is rotated in the direction of yarn movement through frictional contact with the bottom roller.

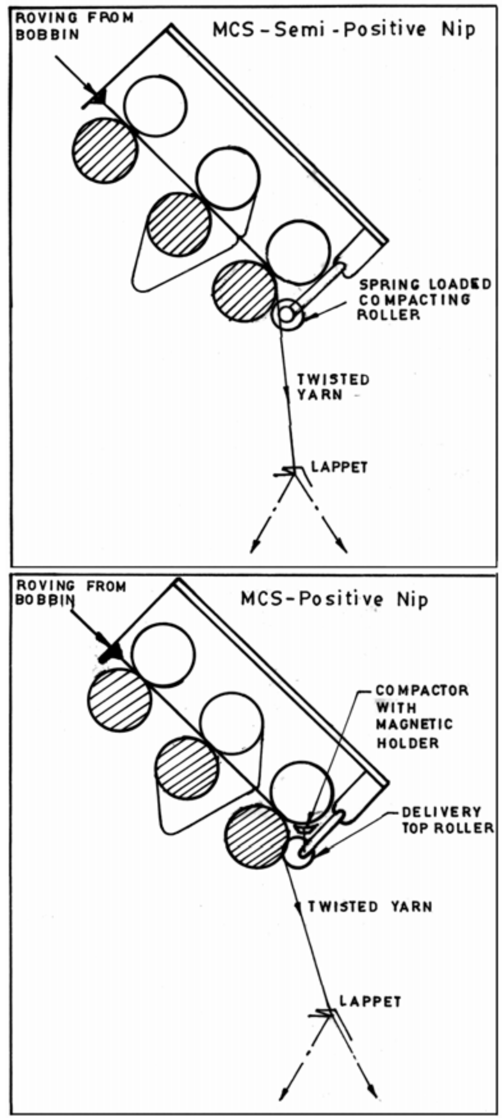

Fig. 1 – Schematic diagram of mechanical compacting system—semi-positive nip and positive nip

2.1.2 Design Concept of MCS-Positive Nip

In the MCS-positive nip, by locating a magnetic floating condenser on the front bottom roller and using an additional small delivery top roller over the existing front bottom roller as shown in the Fig. 1, which is linked to a roving guide bar for giving synchronized traverse to the condenser, the condensation of drafted fibre strand is obtained. This design is conceptually similar to the magnetic compacting system 'RoCoS' of Rotorcraft, Germany, except in the method of holding magnetic condenser so as to facilitate regular roving traverse that helps to obtain normal life to cots and apron.

2.2 Methods

The technique, parameters for the configuration of tracer fibres and measurements are as per the details given in the Part I of the series on pneumatic compact yarn.[1]

2.2.1 Migration Study

The standard tracer-fibre technique has been applied for the study. Microscope with ×40 magnification and fitted with CCD camera has been used along with necessary yarn mounting arrangement to view the tracer. Using CCD camera, around 1.5mm of yarn is photographed at a time and the images are stored using a PC. Then the photographed images are merged sequentially and analyzed using software for configuring the tracer fibre in the yarn body. The number of measured tracer fibres per sample is 10. The number of trough/peak point measured per fibre is between 35-50 and corresponding yarn length is 19-26mm.

2.2.2 Configuration of Tracer Fibre

Parameters, such as mean fibre position ($\bar{y}$), RMS deviation (*D*), mean migration intensity (*I*), equivalent migration frequency defined by Hearle *et al.*[5] and Prementas and Iype[6] and migration factor defined by Huh *et al.*[7] on the basis of Treloar[8] theory, were used for characterizing migration behaviour of the tracer fibre under microscope. This has been explained in the earlier paper[1] on pneumatic compact yarn.

2.2.3 Measurements

Measurements *a, b, c* & *z* were made at successive peak and trough of a tracer fibre image (Fig. 2). The $c_0, c_1, c_2 ... c_n$ and $a_0, a_1, a_2 ... a_n$ points are located at start and end of the body leaving aside the protruding and loosely held fibres. Around 4-5 trough/peak of tracer are appearing in a image of about 1.5 mm yarn length captured at a time and stored in the PC. Using software the images were sequentially merged to track the full length of tracer fibre and measurements were taken subsequent to applying appropriate scale and calibration check. For more details, the paper on pneumatic compact yarn[1] shall be referred.

3 Results and Discussion

Table 1 gives the migration characterization data obtained from measurements taken each on tracer fibres of ring and MCS–S and MCS–P nip yarns of 40s Ne combed cotton. Figure 3 gives the comparative values and percentage change in mean fibre position ($\bar{y}$), RMS deviation (*D*) and mean migration intensity (*I*).

3.1 Mean Fibre Position, RMS Deviation and Mean Migration Intensity

Figure 3 shows reduction in mean fibre position, RMS deviation and mean migration intensity to the extent of 10.2 %, 12.7 % and 15.1 % respectively for the 40s Ne MCS-P nip compact yarn compared to ring yarn. The results are comparable to the findings obtained for pneumatic compact yarn of the same count.[1] Similarly, there are reduction in mean fibre position, RMS deviation and mean migration intensity only to the extent of 1.4%, 3.9% and 5.8% respectively for 40s Ne MCS-S nip yarn compared to ring yarn. The reduction is only marginal for this MCS–S nip yarn compared to other compact yarn. *T*-test values reveal that the quantum of reduction is significant at 95% confidence level for $\bar{y}$, *D* and *I* for MCS–P nip compact yarn and not for MCS–S nip compact yarn. The reason for the reduction and variation among the two MCS is best explained by proper understanding of tension variation among the twisted fibres that are occurring at point of yarn formation due to changes in size of spinning triangle in the compact yarn spinning.

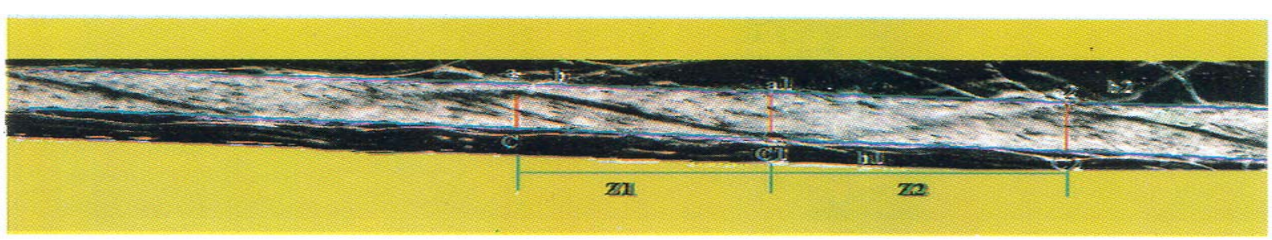

Fig. 2 – Tracer fibre measurement

Table 1– Migration characterization data for MCS–semi-positive nip, MCS–positive nip and ring yarns (40s Ne)

Parameter	Yarn diameter, mm			Mean fibre position $(\bar{y})$			RMS deviation (D)			Mean migration intensity (I), cm^{-1}		
	Ring	MCS–S	MCS–P	Ring	MCS–S	MCS–P	Ring	MCS–S	MCS–P	Ring	MCS–S	MCS–P
Overall mean	0.15248	0.14020	0.13341	0.51201	0.50480	0.45962	0.29531	0.28389	0.25787	9.99646	9.41917	8.48955
S D of mean	0.00615	0.00844	0.00584	0.05334	0.05185	0.07038	0.02346	0.01964	0.02770	1.08218	1.41181	1.18767
C V % of mean	4.0323	6.0206	4.3743	10.4183	10.2723	15.3133	7.9453	6.9167	10.7423	10.8256	14.9887	13.9898
$T_{95\%}/F_{95\%}$	T=2.262			T=2.262			F=1.22			T=2.262		
T_{Act}/F_{Act}	Ring ↔ MCS–SP=3.719, Ring ↔ MCS–P=7.111			Ring ↔ MCS –SP=0.307, Ring ↔MCS–P=1.876			Ring ↔ MCS–SP=1.18, Ring ↔ MCS–P=3.262			Ring ↔ MCS–SP=1.026, Ring ↔ MCS–P=2.966		
S D of Individual	0.01249	0.00970	0.01048	0.29980	0.27948	0.26161	—	—	—	—	—	—
C V % Individual	8.1942	6.9176	7.8586	58.5526	56.0625	56.9186	—	—	—	—	—	—
$T_{95\%}$ of Individual	T=1.96			T=1.96			—			—		
T_{Act} of Individual	Ring ↔ MCS–SP=14.53, Ring ↔ MCS–P=21.88			Ring ↔ MCS–SP=0.32, Ring ↔ MCS–P=2.48			—			—		
Equivalent migration frequency, cm^{-1}	—	—	—	—	—	—	—	—	—	4.886	4.789	4.752
Migration factor, cm^{-1}	—	—	—	—	—	—	—	—	—	2.952	2.674	2.189

MCS = Mechanical compacting system; MCS–S = MCS - semi-positive nip compact yarn; and MCS – P = MCS - positive nip compact yarn.
$T_{95\%}$ /$F_{95\%}$ —A statistical term indicating the limiting significance value for T and F derived from statistical tables.
T_{Act} / F_{Act} — Calculated value for the actual values of mean & S D found from the study.
When the calculated value exceeds the limiting values the difference between the two is significant at 95 % confidence level.

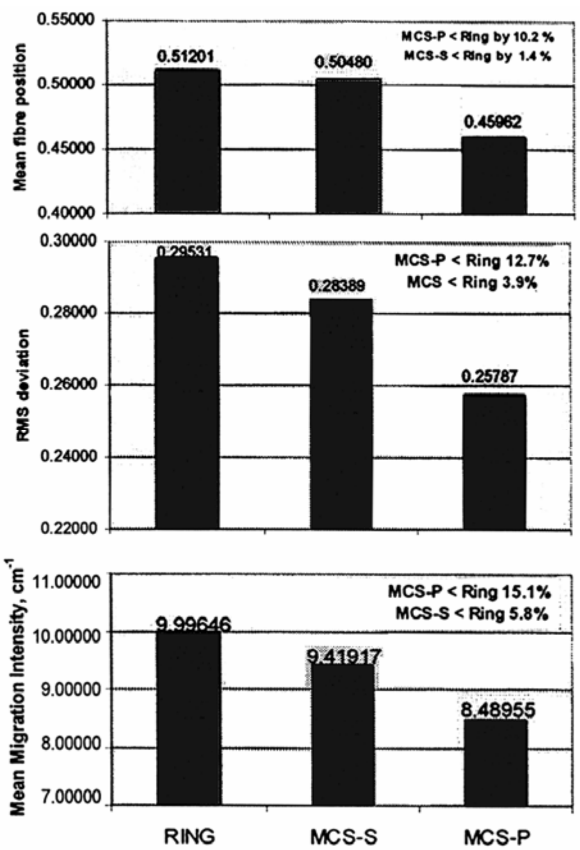

Fig. 3 – Mean fibre position $(\bar{y})$, RMS deviation (D) and mean migration intensity (I) of 40s Ne yarn

3.1.1 Tension Variation due to Changes in Size of Spinning Triangle

Fibres twisting round a long path on the outside of a yarn would develop a high tension, while the fibres following the shorter straight path in the centre would be under low tension as per Morton.[9] In ring spinning, the fibres that emerge from the drafting system are wide spread (2-4 mm) and twisting process to bind those fibres to form yarn creates a spinning triangle. Due to the formation of spinning triangle, the corner fibre of the drafted strand that emerges from the front roller has to travel a longer path than the one at the centre before it reaches the point of yarn formation, which also causes tension gradient. The difference in tension among the fibres would cause an interchange of position of fibres and thus lead to a more or less migration.

In the case of MCS–P nip and the commercially available pneumatic systems, the condensation of widespread drafted and twisting is done sequentially in a separate zone. This causes significant reduction in the size of spinning triangle and the difference in the fibre path distance. But, in the case of MCS–S nip, the condensation and twisting operations are being done simultaneously in the same zone. This results in the increase in altitude of spinning triangle without any change in the size of its base, thereby making fewer changes in the difference of the fibre path distance.

From this, one can understand that the significant reduction in difference of fibre path distance due to near elimination of spinning triangle in MCS–P nip and the commercially available pneumatic systems contributes to significant reduction in migration characteristics ($\bar{y}$, D, I) to the tune of 10-15%, whereas in the case of MCS–S nip due to smaller changes in the difference of fibre path distance the change in migration characteristics ($\bar{y}$, D, I) is only marginal (2-6 %).

3.2 Yarn Diameter and Packing Density

Figure 4 shows that there is an overall reduction in yarn diameter to the extent of 12.5 % for MCS–P nip and 8.1 % for MCS–S nip. This difference is due to the differences in the design concept of the systems. The reduction in yarn diameter and consequent increase in overall packing density apart from better integration of fibre is mainly responsible for the 11.4% increase in strength in MCS–P nip and 3.1% in MCS–S nip[10] yarns (Table 2). This can be visualized from the CCD camera photo (Fig. 5) for the ring yarn and MCS–S and MCS–P nip yarns.

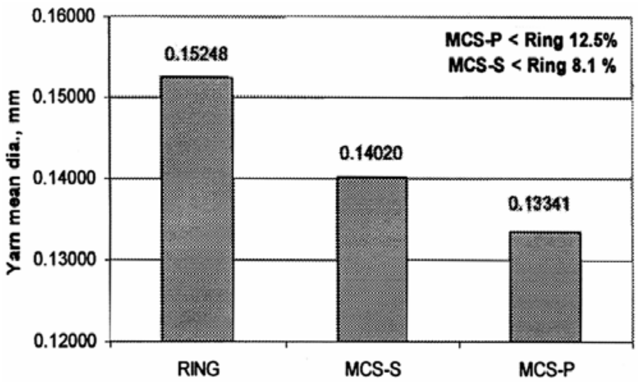

Fig. 4 – Yarn mean diameter

Table 2 – Yarn tensile test results

Characteristic	Ring (1 &2)[a]	MCS-S (1 & 2)[a]	Ring (3 & 4)[a]	MCS-P (3 & 4)[a]
Tenacity, g/tex				
Mean	17.26	17.80	17.35	19.32
CV_b%	8.88	7.52	8.32	8.45
T_{Act} ($T_{95\%}$=1.96)	—	3.75[b]	—	12.78[b]
Breaking elongation, %				
Mean	4.77	5.22	4.72	4.97
CV_b%	12.15	8.05	7.71	7.60
T_{Act} ($T_{95\%}$=1.96)	—	8.89[b]	—	6.74[b]

[a]Spindle No. #. Same spindle numbers are used on the ring frame in producing ring & MCS–S and ring & MCS–P yarns that are being compared for quality characteristics.

T_{Act} – Calculated '*t*' value for the actual values of mean and S D found from the study.

$T_{95\%}$ – Table value at 95 % confidence level.

[b] Statistically significant difference at 95 % confidence level when $T_{Act} > T_{95\%}$.

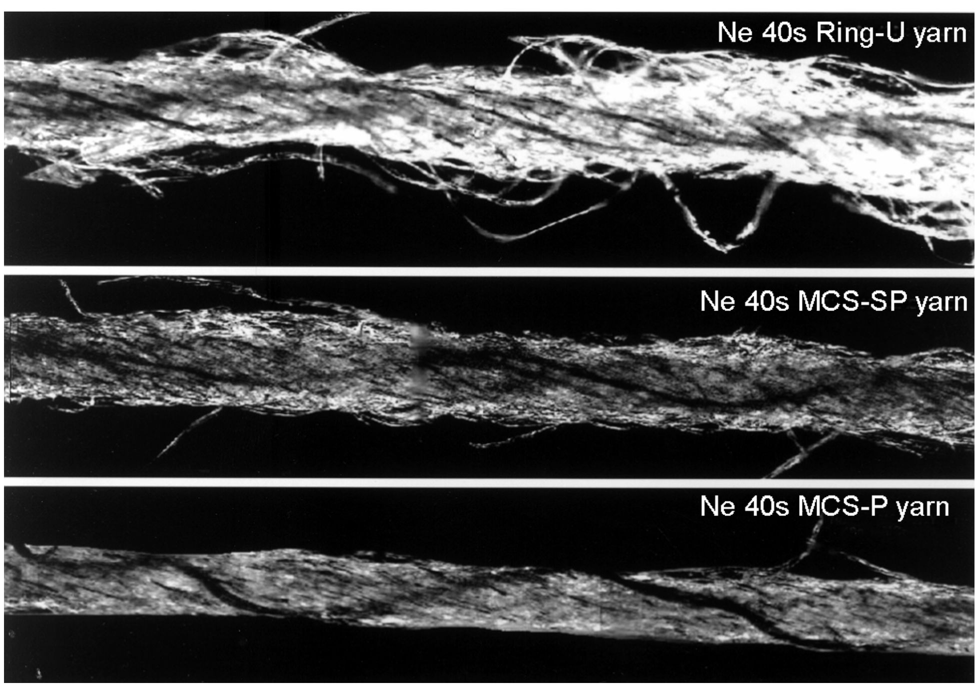

Fig. 5 – Ring, MCS–S and MCS—P yarns with tracer fibre

4 Conclusions

4.1 The near elimination of spinning triangle in MCS–positive nip shows reduction in the migration parameters, such as mean fibre position, RMS deviation and mean migration intensity to the extent of 10-15% only and it is found similar to that of pneumatic compact yarn of the same count.

4.2 In the case of MCS–semi-positive nip, when the base of the spinning triangle remains the same, its altitude only gets increased causing only a slight reduction in tension gradient, resulting in marginal change in migration parameters only.

4.3 Yarn diameter of mechanical compact yarn from MCS–positive nip system is found to be significantly lower than that of ring yarn and similar to pneumatic compact yarn, which contributes to increase in strength (11.4%). The yarn from MCS–semi-positive nip system has shown a marginal reduction in yarn diameter and hence the increase in strength is marginal (3.1%).

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