Indian Journal of Fibre & Textile Research
Vol. 37, December 2012, pp. 337-342

# Performance characteristics of viscose ring and air-jet spun yarns as a consequence of draw frame speed and its preparatory process

G K Tyagi[a] & S Shaw
The Technological Institute of Textile & Sciences, Bhiwani 127 021, India

***Received 9 August 2011; revised received and accepted 8 December 2011***

The influence of high speed draw frame and its preparatory process variables on the performance potential of viscose ring and MJS yarns has been studied. The data indicate marked differences in the performance of the yarns produced with different card drafts and the yarns made with high card draft display poor structural integrity, low abrasion resistance and more hairiness than the yarns spun under identical conditions but with lower card draft. Increasing second nozzle pressure greatly enhances structural integrity, compressional resilience and abrasion resistance, but reduces compressional energy and hairiness. The magnitude of change in these characteristics, however, is highly dependent on the yarn linear density and card draft. High draw frame speed is imperative for air- jet spinning if adequate wrapper fibres are to be produced, and the best one will, in practice, depend on the spinning parameters used. The behaviour of MJS yarns is noticeably better in many respects.

**Keywords**: Air-jet spinning, Card draft, Compressional resilience, Ring-spun yarn, Second nozzle pressure, Wrapper fibres

## 1 Introduction

In past many years, a great number of studies, of both fundamental and applied nature, have been carried out in order to establish the effect of changes in preparatory process variables on spinning performance and yarn properties. Detailed attention has, for instance, been directed to the draw frame speed with specific reference to its impact on fibre configuration in drawn sliver[1-4]. Additionally, Huh and Kim[5] also pointed out that the fibre configuration in feed card sliver also alters the ultimate fibre layout at the draw frame sliver. Research conducted so far on ring spinning mainly deals with yarn regularity and related characteristics[6-7]. There are occasional references to the response of fibre orientation in drawn sliver to high speed draw frame and its preparatory[8]. However, information regarding role of preparatory processes in air-jet spinning is scanty. This paper reports the results of experiments undertaken to establish a more in depth understanding of the performance characteristics of viscose ring-and air-jet spun yarns as a consequence of card draft, draw frame speed and second nozzle pressure.

## 2 Materials and Methods

### 2.1 Preparation of Yarn Samples

Two sets of yarns of 17.3 and 24.6 tex were spun from viscose staple (length, 51mm; fineness, 1.66 dtex; tenacity, 19.8 g/tex; and breaking extension, 18.5%) on ring- and air- jet spinning machines with different second nozzle pressures ranging from 3.5 kg/cm$^2$ to 4.5 kg/cm$^2$. Lap was made on Lakshmi Rieters' blow room line and carded on MMC card with 80, 100 and 120 card drafts using a doffer speed of 26 rpm. The conversion to drawn sliver was carried out by using Trutzschlers' draw frame TD 03, the linear density of finished sliver being adjusted to 3.5 and 4.9 kex. Two drawing passages were given to carded sliver using three breaker draw frame speeds, viz. 300, 500 and 700m/min. The drawn slivers were spun into yarns on Murata air jet spinner 802 MJS. The process parameters used to produce these yarns are given in Table 1. For ring yarns, the drawn slivers were converted into 1.2 and 1.7 Ne roves using an O K K fly frame, which were used to produce 17.3 and 24.6 tex yarns on Rieters' G 5/1 ring frame using a spindle speed of 15000 rpm.

### 2.2 Test Methods

All the yarns were tested for tensile properties and structural integrity on Instron tensile tester using 200 mm gauge length and 20mm/min cross-head

---

[a] To whom all the correspondence should be addressed.
Present address: M L V Textile & Engineering College, Bhilwara 311 001, India
E-mail: drgktyagi@rediffmail.com

Table 1—Spinning parameters for air-jet spun yarns

| Yarn ref. no. | Yarn linear density, tex | Lap weight g/m | Card draft | Card sliver linear density, k/tex | Draw frame speed m/min | Draw frame draft | Second nozzle pressure, kg/cm$^2$ |
|---|---|---|---|---|---|---|---|
| S1 | 17.3 | 277.7 | 80 | 3.5 | 300 | 8 | 3.5/4/4.5 |
| S2 | 17.3 | 277.7 | 80 | 3.5 | 500 | 8 | 3.5/4/4.5 |
| S3 | 17.3 | 277.7 | 80 | 3.5 | 700 | 8 | 3.5/4/4.5 |
| S4 | 17.3 | 347.0 | 100 | 3.5 | 300 | 8 | 3.5/4/4.5 |
| S5 | 17.3 | 347.0 | 100 | 3.5 | 500 | 8 | 3.5/4/4.5 |
| S6 | 17.3 | 3470 | 100 | 3.5 | 700 | 8 | 3.5/4/4.5 |
| S7 | 17.3 | 416.5 | 120 | 3.5 | 300 | 8 | 3.5/4/4.5 |
| S8 | 17.3 | 416.5 | 120 | 3.5 | 500 | 8 | 3.5/4/4.5 |
| S9 | 17.3 | 416.5 | 120 | 3.5 | 700 | 8 | 3.5/4/4.5 |
| S10 | 24.6 | 393.4 | 80 | 4.9 | 300 | 8 | 3.5/4/4.5 |
| S11 | 24.6 | 393.4 | 80 | 4.9 | 500 | 8 | 3.5/4/4.5 |
| S12 | 24.6 | 393.4 | 80 | 4.9 | 700 | 8 | 3.5/4/4.5 |
| S13 | 24.6 | 492.0 | 100 | 4.9 | 300 | 8 | 3.5/4/4.5 |
| S14 | 24.6 | 4920 | 100 | 4.9 | 500 | 8 | 3.5/4/4.5 |
| S15 | 24.6 | 492.0 | 100 | 4.9 | 700 | 8 | 3.5/4/4.5 |
| S16 | 24.6 | 590.0 | 120 | 4.9 | 300 | 8 | 3.5/4/4.5 |
| S17 | 24.6 | 590.0 | 120 | 4.9 | 500 | 8 | 3.5/4/4.5 |
| S18 | 24.6 | 590.0 | 120 | 4.9 | 700 | 8 | 3.5/4/4.5 |

Table 2—ANOVA test results

| Process parameters | Yarn characteristics | | | | |
|---|---|---|---|---|---|
| | Structural integrity | Compressional energy | Compressional resiliency | Abrasion resistance | Hairiness |
| Yarn linear density | s | s | s | s | s |
| Card draft | s | s | s | s | s |
| Draw frame speed | s | s | s | s | s |
| Second nozzle pressure | s | s | s | s | s |
| Spinning mode | s | s | s | s | s |

s— Significant at 99% confidence level.

speed. The upper limit was fixed at 2% strain and twenty cycles were fixed on Instron universal tester. The yarn performance was assessed in terms of percentage decay using the following expression:

$$\% \text{ decay} = \{(\boldsymbol{A}_1-\boldsymbol{A}_{20})/\boldsymbol{A}_1\} \times 100$$

where $\boldsymbol{A}_1$ and $\boldsymbol{A}_{20}$ are the areas under the curve for first and twentieth cycle respectively.

Yarn hairiness was measured by Zweigles hairiness meter (Model G 565). Fifty observations were made for each yarn. The yarns were tested for compressional energy on the Instron universal tester according to the method described by Basu and Chellamani[9]. A parallel array of yarn was compressed between two parallel compression plates to a pressure of 2.5 kg/cm$^2$ with the anvil and foot diameter as 120mm and 40mm respectively. The compressional resiliency was calculated by expressing unloading curve area as a percentage of loading curve area. The abrasion resistance was measured in terms of abrasion cycles required to rupture the specimen by Universal wear tester. Twenty readings were recorded for each yarn sample.

## 3 Results and Discussion

The significance of five experimental factors, viz yarn linear density, card draft, breaker draw frame speed, second nozzle pressure and spinning mode, on the yarn performance properties was assessed with the help of ANOVA analysis (Table 2), the confidence level used was 99%.

### 3.1 Structural Integrity

Table 3 shows the decay pattern of various yarns with respect to different spinning parameters. In variably, the structural integrity appears to be progressively better for the MJS yarns, but it substantially reduces as card draft is increased from 80 to 120. Obviously, this reduction in structural integrity could be caused by the decrease in coefficient of relative fibre parallelization and increase in proportion of curved fibre ends and hooked fibres, which, in turn, makes the yarn less compact and hence poor structural integrity. With draw frame speed, structural integrity displays distinct trends. In general, the structural integrity of MJS yarns initially improves with increasing draw frame speed and then deteriorates at a draw frame speed of 700m/min. A high draw frame speed would help produce more wrapper fibres, which exert greater radial pressure on core fibres and thus results in a more compact yarn with better structural integrity. However, a further increase in draw frame speed is observed by the reduced yarn compactness caused by the combined effect of irregular wrappings and reduced transverse pressure due to fewer wrapper fibres, which, in turn, leads to decreased inter-fibre cohesion and hence inferior structural integrity[10]. The second nozzle pressure seems to be a major factor influencing structural integrity of MJS yarns. Raising second nozzle pressure from 3.5kg/cm$^2$ to 4.5 kg/cm$^2$ significantly improves the structural integrity due to higher incidence of wrapper fibres and wrapped-in length[10] which restrict the possibility of fibre slippage during cyclic loading. Increasing yarn linear density enhances the structural integrity of ring-spun yarns but adversely affects the structural integrity of MJS yarns.

### 3.2 Compressional Energy

Table 3 shows that the compresonal energy of ring-spun yarns varies between 1.49% and 1.69%, depending upon the spinning conditions. In the case of MJS yarns produced on Murata air-jet spinner, it varies from 1.24% to 1.51% and from 1.43% to 1.60% for the 17.3 and 24.6 tex yarns respectively, indicating that compresonal energy is sensitive to the spinning system. A large difference in compresonal energy between the MJS and the ring-spun yarns is believed to be the outcome of the greater consolidation brought out by the higher incidence of wrapper fibres binding the core fibres in the former. The influence of card draft on compresonal energy is critical, as these data reveal that the high card draft produces very significant increment in compresonal energy. The compresonal energy, however, shows distinct trends with draw frame speed. For ring-spun yarns, the compresonal energy shows a steady decrease with the increase in draw frame speed. In the case of MJS yarns, the compresonal energy initially decreases when the draw frame speed increases from 300m/min to 500m/min; the latter, however, increases as the draw frame speed is further

Table 3—Effect of draw frame speed and its preparatory process on structural integrity, compressional energy and compressional resiliency of viscose ring- and air-jet spun yarns

| Yarn ref. no. | % Decay | | | | Compressional energy, % | | | | Compressional resiliency, % | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ring yarn | Air-jet yarn | | | Ring yarn | Air-jet yarn | | | Ring yarn | Air-jet yarn | | |
| | | 3.5[a] | 4[a] | 4.5[a] | | 3.5[a] | 4[a] | 4.5[a] | | 3.5[a] | 4[a] | 4.5[a] |
| S1 | 54.3 | 38.9 | 39.6 | 40.4 | 1.54 | 1.37 | 1.34 | 1.31 | 48.3 | 67.6 | 68.7 | 69.9 |
| S2 | 47.0 | 33.5 | 34.0 | 34.8 | 1.52 | 1.35 | 1.32 | 1.30 | 49.6 | 68.8 | 70.1 | 71.3 |
| S3 | 40.1 | 35.1 | 35.7 | 36.5 | 1.49 | 1.30 | 1.28 | 1.24 | 50.5 | 66.5 | 67.6 | 68.7 |
| S4 | 55.3 | 43.7 | 44.4 | 45.2 | 1.59 | 1.48 | 1.45 | 1.43 | 44.0 | 62.6 | 63.6 | 64.8 |
| S5 | 48.3 | 34.6 | 35.1 | 35.8 | 1.55 | 1.41 | 1.38 | 1.35 | 46.6 | 63.4 | 64.6 | 65.8 |
| S6 | 45.2 | 38.3 | 38.9 | 39.7 | 1.52 | 1.38 | 1.35 | 1.34 | 48.3 | 61.3 | 62.4 | 63.7 |
| S7 | 64.5 | 45.9 | 46.6 | 47.4 | 1.64 | 1.51 | 1.49 | 1.49 | 41.3 | 60.4 | 61.4 | 62.7 |
| S8 | 54.8 | 36.3 | 36.8 | 37.5 | 1.61 | 1.48 | 1.45 | 1.43 | 43.4 | 62.2 | 63.5 | 64.6 |
| S9 | 48.1 | 40.3 | 40.9 | 41.7 | 1.57 | 1.45 | 1.42 | 1.39 | 44.6 | 59.8 | 60.9 | 62.0 |
| S10 | 47.1 | 43.4 | 44.0 | 44.7 | 1.60 | 1.55 | 1.51 | 1.48 | 44.9 | 60.5 | 61.6 | 62.8 |
| S11 | 41.2 | 36.5 | 37.1 | 37.8 | 1.56 | 1.52 | 1.48 | 1.46 | 45.6 | 62.6 | 63.8 | 64.9 |
| S12 | 37.2 | 41.5 | 42.2 | 43.0 | 1.53 | 1.47 | 1.45 | 1.43 | 46.2 | 59.3 | 60.3 | 61.5 |
| S13 | 53.4 | 48.8 | 49.4 | 51.1 | 1.64 | 1.58 | 1.55 | 1.52 | 42.6 | 58.9 | 60.1 | 61.4 |
| S14 | 44.8 | 37.2 | 37.7 | 38.3 | 1.62 | 1.52 | 1.49 | 1.47 | 43.8 | 60.3 | 61.7 | 62.9 |
| S15 | 39.9 | 45.2 | 45.9 | 46.6 | 1.57 | 1.49 | 1.47 | 1.45 | 44.4 | 57.6 | 58.9 | 62.4 |
| S16 | 60.3 | 56.2 | 56.8 | 57.5 | 1.69 | 1.60 | 1.58 | 1.57 | 40.2 | 58.1 | 59.2 | 60.4 |
| S17 | 49.1 | 39.2 | 39.7 | 40.3 | 1.66 | 1.55 | 1.52 | 1.49 | 41.7 | 59.8 | 61.0 | 61.2 |
| S18 | 45.6 | 56.2 | 56.8 | 57.5 | 1.69 | 1.53 | 1.50 | 1.48 | 43.1 | 56.7 | 57.8 | 59.2 |

[a] Second nozzle pressure, kg/cm$^2$.

increased to 700m/min. The large yarn diameter produced with high draw frame speeds contributes greatly to the compresonal energy of these yarns. The analysis of variances demonstrates that changes in compresonal energy caused by change in spinning system are considerably influenced by the second nozzle pressure, at a 99% confidence level. This is practically evident for the yarns produced with higher second nozzle pressure. Moreover, the values of compresonal energy are appreciably higher for coarse yarns, as expected.

### 3.3 Compressional Resiliency

The compressional resiliency of different yarns is given in Table 3. The MJS yarns, in general, display higher compressional resiliency as compared to the ring yarns spun under identical spinning conditions. The analysis of variance of these yarns suggests that there are noticeable differences in compressional resiliency between ring- and MJS yarns. The higher compressional resiliency of MJS yarns is, most likely, due to the enhanced inter-fibre cohesion through fibre consolidation brought out by binding wrapper fibres. The compressional resiliency significantly decreases with the increase in card draft due to decreased packing density. If one looks on the association of compressional resiliency with draw frame speed, there seems to be a significant relationship for the yarns at various draw frame speeds. When draw frame speed increases from 300m/min to 500m/min, the subsequent result is an increase in compressional resiliency of MJS yarns; the latter, however, decreases as the draw frame speed is further increased to 700m/min. The observed changes are principally associated with the alteration in packing density of the yarn matrix, which would unboubtly govern the compressional resiliency. In the case of ring-spun yarns, on the other hand, compressional resiliency consistently increases as the draw frame speed increases. There is an appreciable decrease in the values of compressional resiliency with increasing yarn linear density, though the changes become small at low card drafts. Increasing second nozzle pressure enhances the compressional resiliency of MJS yarns regardless of the spinning conditions used.

### 3.4 Abrasion Resistance

Table 4 shows the influence of processing factors on abrasion resistance of ring- and MJS yarns. In general, MJS yarns exhibit lower abrasion resistance than their ring-spun counterparts. In MJS yarn, the binding wrappers are really not large enough which

Table 4—Effect of draw frame speed and its preparatory process on abrasion resistance and hairiness of viscose ring- and air-jet spun yarns

| Yarn ref. no. | Abrasion resistance, cycles | | | | Hairs/10m | | | |
|---|---|---|---|---|---|---|---|---|
| | Ring yarn | Air-jet yarn | | | Ring yarn | Air-jet yarn | | |
| | | 3.5[a] | 4[a] | 4.5[a] | | 3.5[a] | 4[a] | 4.5[a] |
| S1 | 414 | 270 | 282 | 294 | 202 | 158 | 148 | 140 |
| S2 | 433 | 288 | 300 | 314 | 190 | 123 | 112 | 103 |
| S3 | 447 | 279 | 288 | 301 | 182 | 177 | 167 | 158 |
| S4 | 378 | 266 | 279 | 290 | 258 | 205 | 194 | 186 |
| S5 | 388 | 280 | 292 | 306 | 240 | 190 | 180 | 168 |
| S6 | 408 | 268 | 278 | 289 | 230 | 225 | 215 | 207 |
| S7 | 346 | 248 | 259 | 270 | 296 | 256 | 246 | 235 |
| S8 | 362 | 260 | 271 | 282 | 288 | 233 | 224 | 214 |
| S9 | 385 | 252 | 264 | 275 | 276 | 270 | 262 | 254 |
| S10 | 471 | 228 | 236 | 237 | 282 | 210 | 201 | 190 |
| S11 | 487 | 259 | 268 | 270 | 273 | 143 | 133 | 122 |
| S12 | 496 | 230 | 239 | 250 | 265 | 254 | 245 | 238 |
| S13 | 448 | 210 | 219 | 230 | 306 | 240 | 232 | 225 |
| S14 | 463 | 243 | 254 | 265 | 296 | 195 | 184 | 176 |
| S15 | 482 | 227 | 236 | 247 | 268 | 252 | 248 | 241 |
| S16 | 416 | 180 | 191 | 202 | 365 | 272 | 263 | 257 |
| S17 | 433 | 205 | 216 | 228 | 342 | 248 | 241 | 233 |
| S18 | 456 | 186 | 198 | 210 | 324 | 290 | 278 | 273 |

[a] Second nozzle pressure, kg/cm$^2$.

can protect the core consisting of twist less parallel bundle of fibres during abrasion. The core gets immediately exposed once the binding wrappers are broken and thus the yarn disintegrates immediately and hence lower abrasion resistance. High card draft results in lower abrasion resistance regardless of yarn structure. The lower abrasion resistance results from the decrease in coefficient of relative fibre parallelization and increase in proportion of curved fibre ends and number of hooked fibres which make the yarn less compact and thus increases the abrasion resistance. Besides, the increased hairiness with high card draft also adversely affects the abrasion resistance of these yarns. When one looks on the association of abrasion resistance with draw frame speed, there seems to be a significant and distinct trend for the ring- and MJS yarns. In the case of ring yarns, abrasion resistance is better for higher draw frame speeds due to improved packing coefficient, which, in turn, enhances abrasion resistance. However, for MJS yarns, the abrasion resistance first increases significantly and then decreases with increasing draw frame speed. The increase in abrasion resistance with increase in draw frame speed from 300m/min to 50m/min occurs due to an increase in the number of wrapper fibres which effectively shield the yarn core and thus increases the abrasion resistance. However, at 700m/min draw frame speed, the fibres in the sliver are in more compact form due to the increased tension and higher coiler speed, which, in turn, leads to higher centrifugal force. Consequently, the higher inter-fibre surface cohesion hinders the formation of wrapper fibres needed to effectively shield the core, leading to an early rupture. In regard to yarn linear density, the abrasion resistance reflects different patterns. In the case of ring-spun yarns, abrasion resistance is higher, as expected, for coarse yarns. However, for MJS yarns, the higher abrasion resistance corresponds to 17.3 tex yarns and lower abrasion resistance corresponds to 24.6 tex yarns. In 17.3 tex yarns, the higher incidence of binding wrapper fibres provide effective shield to the core fibres and thus leads to delayed rupture of the substrate. Increasing second nozzle pressure improves abrasion resistance of MJS yarns on account of increased incidence of wrapper fibres and wrapped-in length[11].

### 3.5 Hairiness

The hairiness results for various yarns are given in Table 4. The MJS yarns, in general, are less hairy than the equivalent ring-spun yarns, indicating that wrapper fibres prevent the fibres to protrude from the main body of the yarn. With draw frame speed, hairiness exhibits distinct trends for ring- and MJS yarns. Invariably, the hairiness of MJS yarns initially reduces with increasing draw frame speed and then rises for a draw frame speed of 700m/min. An increase in draw frame speed from 300m/min to 500m/min would help produce more wrapper fibres and thus prevents the fibres to protrude from the yarn structural matrix. However, on further increase in draw frame speed, the hairiness increases considerably on account of the decreased number of wrapper fibres that become insufficient to bind all protruding fibres[12]. The hairiness of ring-spun yarns, on the other hand, consistently reduces with the increase in draw frame speed. The card draft and yarn linear density also have a marked influence on hairiness. For both types of yarns, hairiness increases appreciably when card draft and yarn linear density increase. High second nozzle pressure reduces yarn hairiness according to the data given in Table 4. Yarns spun with 4.5 kg/cm$^2$ second nozzle pressure have the least hairiness and there are meaningful differences between 4.5kg/cm$^2$ second nozzle pressure and the other pressures for hairiness.

## 4 Conclusion

**4.1** The performance characteristics of ring- and MJS yarns alter significantly as a consequence of card draft, draw frame speed and second nozzle pressure. Generally, the yarns made with a high card draft show higher compressional energy, reduced compressional resiliency, more hairiness and poor abrasion resistance for almost all experimental combinations. High second nozzle pressure leads to a marked improvement in abrasion resistance and compressional resiliency, but reduces hairiness and compressional energy. High draw frame speed produces more hairs, reduced compressional energy, and leads to enhanced abrasion resistance with increasing compress ional resiliency of ring spun yarns. However, for MJS yarns, there is an optimum draw frame speed, and too high speed results in deterioration in yarn performance characteristics.

**4.2** The card draft-structural integrity curves for MJS yarns show a maximum that coincides with the maximum for card draft-strength curves, and the maximum is noticeably higher than the corresponding value for ring-spun yarns. The structural integrity of MJS yarns improves when second nozzle pressure increases and, at the same time, when yarn linear density decreases. Additionally, optimums draw frame speed is required for achieving optimum level of yarn structural integrity.

**4.3** The spinning mode itself is a prime factor influencing yarn performance responses. When compared with ring-spun yarns, MJS yarns have better structural integrity and compressional resiliency, but display lower values of compressional energy, abrasion resistance and hairiness.

## References

1 Taylor D S, ***J Text Inst***, 41(1950) T233.
2 Sengupta A K & Kapoor I M, ***Text Res J***, 43(1973)121.
3 Grosberg P, ***J Text Inst***, 52(1961) T91.
4 Cherif Ch, Satlow G & Wulfhorse B, ***Melliand Textilber***, 5(2000) E86.
5 Huh Y & Kim Jong S, ***Fibres Polym***, 7(2006)429.
6 Nerukar S K, ***Indian J Text Res***, 4(1979)63.
7 Miao M, Ning F & How Y, ***J Text Inst***, 89(1998)468.
8 Ishtiaque SM, Mukhopadhyay A & Kumar A, ***J Text Inst***, 98(2007)501.
9 Basu A & Chellamani K P, ***Indian J Fibre Text Res***, 25(2000)163.
10 Tyagi G K & Shaw S, ***Indian J Fibre Text Res,*** 37 (2012) 27.
11 Tyagi G K, Salhotra K R & Kaushik R C D, ***Indian J Fibre Text Res***, 17(1992)219.
12 Shaw S, ***Effect of some preparatory process parameters on the structure and characteristics of viscose ring- and MJS yarns***, M. Tech. thesis, The Technological Institute of Textile & Sciences, Bhiwani, 2009.