A COMPARATIVE STUDY OF HOOKS IN THE YARNS PRODUCED BY DIFFERENT SPINNING TECHNOLOGIES

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Abstract:

This article presents a comparative study of hooks' characteristics of ring, rotor, air-jet and open-end friction spun yarns. Hook types and their extent, spinning in-coefficient and mean fibre extent in the yarns produced on different spinning technologies are investigated. The results show that the hook extents for open-end friction spun yarn are the highest followed by rotor, ring and air-jet spun yarns. Ring and air-jet spun yarns have higher percentage and extent of trailing hook as compared with leading hook, whereas, rotor and friction spun yarns show the reverse trend.

Keywords:

Air-jet yarn, Friction spun yarn, Leading hook, Ring spun yarn, Rotor spun yarn, Spinning in-coefficient, Trailing hook

1. Introduction

Staple yarns are constructed from the bundle of fibres, which are twisted together during the spinning process. New spinning technologies of yarn production were developed to increase yarn productivity and impart some new characteristics other than those found in conventional ring spun yarn [1]. Among the modern technologies, rotor, air-jet and friction spinning systems have gained considerable acceptance in the market due to their high productivity, special twist-inserting mechanism and yarn characteristics. The structure of yarn produced by various spinning technologies is different owing to the fundamental difference in the methods of depositing the fibres during yarn formation, twisting mechanism and spinning tension [2-3].

The properties of spun yarns are largely dependent on their internal structure. Basu [4] has critically reviewed the structure-property relationships of ring, rotor, air-jet and friction spun yarn. Over the past 50 years or so, studying spun yarn structure has been the subject of a number of investigations. A critical review of literatures reported on the spun yarn structure reveals that by and large, there are basically two approaches of studying spun yarn structure, viz., cross-sectional and longitudinal behaviours. The cross-sectional behaviour of yarn structure is mainly dealing with yarn diameter, number of fibres in the yarn cross-section and its distribution, packing density and radial packing of fibres. Whereas, fibre migration, helix angle, fibre extent in the yarn and different fibre configuration such as normal, hook, loop, curl, entanglement etc. are the main aspects of longitudinal behaviour of yarn structure.

The migration and radial packing behaviours of fibres for various spun yarns are the two well researched and documented areas on spun yarn structure. The pioneering investigations on fibre migration in the yarns were carried out by Morton and Yen [5],

Morton [6], Hearle et al. [7-10], Treloar [11] and Riding [12-13]. Later on many researchers have analysed the migration behaviours of various spun yarns [14-17]. Ishtiaque et al. [18-22] have made series of publications on the radial packing density of fibres for various spun yarns. Huh et al. [14] have reported a comparative study on the radial packing density of ring, rotor and friction spun yarns structure.

The presence of fibre hooks in a sliver adversely affects the drafting efficiency and material evenness. The features of different types of hooks have obvious influence in determining the average fibre extent in spun yarns. A hooked fibre in the spun yarn may behave like a short fibre. Therefore, a higher percentage of hooks in the yarn leads to the deterioration of yarn quality. Although extensive investigations have been devoted to the fibre migration and radial packing behaviours of spun yarns, limited information is available for the behaviour of different types of hooks in ring, rotor, air-jet and open-end friction spun yarns. Hence, an investigation on the hooks in yarns spun from different spinning technologies and comparing them with ring spun yarns is noteworthy.

Hooks are mainly originating in the carding process. In general, over 50% trailing hooks are generated in the card [23]. The presentation of the fibres in the subsequent machines of the spinning line has considerable influence on the behaviour of hooks in the resultant yarn. The trailing hooks in the card sliver leaving the card, becoming leading hooks as the sliver enters the next machine, i.e., drawframe. As the drawing process principally removes the trailing hooks, the number of drawing passage between card and the final spinning machine has an obvious influence on the behaviour of hooks in the yarn. Most importantly, the new spinning technologies such as rotor, air-jet and friction have a certain influence on the behaviour of hooks in the yarn. For examples, in the case of rotor spinning system,

the reopening of fibres by the opening roller, collision of fibres with the inner wall of transport tube and the deposition of fibres in the rotor groove with respect to the position of yarn peeling point may change the behaviour of hooks [3]. In the case of air-jet spinning system, air current and the frictional resistance encountered by the fibres at the point of entry into the nozzle might have some influence on the hook behaviour [24-25]. The buckling of fibres as they reach the slow moving spinning drum in friction spinning system has a significant influence on the hook generation [26].

Therefore, it would rekindle our interest about the behaviours of fibre hooks as they are emerging out from the final delivery roller of each spinning system right from the very beginning of carding machine. With this objective in mind, the present work aims to study the features of various types of hooks in ring, rotor, air-jet and open-end (OE) friction spun yarns.

2. Experimental

Viscose fibres of 1.5 denier and 44 mm length were spun to produce yarns on ring, rotor, air-jet and friction spinning systems. Although, cotton is the most common material used in rotor as well as friction spinning systems and polyester-cotton blends are the most common materials for air-jet spinning system, but the choice of viscose fibres facilitates the analysis of tracer fibres, since cotton fibres have length variability and polyester poses great difficulty in choosing the proper immersion liquid for tracer fibre observation. Viscose fibres are a good solution to these problems. The average counts of yarns spun were 18.6, 19.3, 21.0 and 18.1's Ne, respectively,

for ring, rotor, air-jet and OE friction spun yarns. The spinning parameters employed for each yarn were those that are considered appropriate by commercial spinners, based on their experience with each of the spinning systems. The twist multipliers (TM in cotton system) for ring and rotor spun yarns were 3.75 and 4.2, respectively. The tracer fibres were mixed before opening operation in blow-room and tracers of five different colours were used in the mixing.

Lakshmi LG 5/1 ring frame and Rieter M 2/1 machines were used to produce ring and rotor yarns respectively. The air-jet and open-end friction yarns were made on MJS-802 H and Dref-III spinner, respectively. Two draw frame passages followed by a roving frame were used for the production of ring spun yarns. In the case of rotor and OE friction spinning process two draw frame passages were employed. However, three draw frame passages were used for the production of air-jet spun yarns. A flow chart of sample preparation of different yarns is given in Figure 1.

Classical tracer fibre technique [6] was employed to determine the different types of hooks parameters. To visualize the tracer fibres, the yarn was passed through a glass trough containing benzyl alcohol solution as optical diluent. The visible tracer fibres were observed under a Projectina microscope with a magnification of 100. For each type of yarn, 500 different tracer fibres were observed for each yarn. Few observations were also carried out under a Lieca digital microscope with a magnification of 40. The images of the configurations of tracer fibres in the yarn were recorded in a computer and Leica Quin software was used as a tool for image analysis to determine the average fibre extent as well as hook extent. The leading

Figure 1. Process sequence of yarn sample preparation

or trailing direction of a hooked fibre has been distinguished on the basis of the yarn direction as it is emerging out from the final delivery roller of each spinning system.

After measuring the mean fibre extent of each yarn corresponding to different spinning systems, the spinning-in-coefficient (K_F) of different yarns was calculated using the following equation [27]

$$K_F = \frac{\sum_{i=1}^n \frac{L_i}{n}}{L} = \frac{L_0}{L}$$

where L_i = individual fibre extent, L_0 = arithmetic mean of the projected length of individual fibres along the axis of the yarn, n = number of observations, and L = fibre length.

3. Results and Discussion

The hook fibre configurations of different spun yarns are depicted in Figures 2 to 5. Table 1 shows the values of mean fibre extent, spinning-in-coefficient, and different hooks parameters for ring, rotor, air-jet and open-end friction spun yarns.

3.1 Ring Spun Yarn

Table 1 indicates that the percentage and extent of trailing hook is higher than the leading hook for ring spun yarn. Although

the roller drafting process mainly removes the trailing hook but its number is prevailing due to the fact that the trailing hooks are dominantly produced during the carding process. The trailing hooks of card sliver presented at ring frame without the reversal of direction as the odd number of passages are placed in between card and ring frame. It can be inferred from Table 1 that mean fibre extent and spinning in-coefficient of ring yarn is significantly better than rotor and OE friction spun yarn but inferior to air-jet yarn. Figure 2 illustrates a usual configuration of leading and trailing hook in the ring yarn.

3.2 Rotor Spun Yarn

It is evident from Table 1 that the percentage and extent of leading hook is higher than the trailing hook for rotor spun yarn. This is exactly opposite trend as compared to the ring spun yarn. In addition to the hook formation in the carding machine, the fibres form the leading hook in the rotor spinning machine when they partly emerge into the rotor from the transport tube as the yarn tail sweeps past. In this circumstance, their leading ends lay on the surface of the rotor and their trailing ends within the transport tube; therefore, they are picked up by the yarn tail at some point of their length and consequently leading hooks are formed [3]. Thus, this category of leading hooks is formed by the bridging fibres as they bridge the gap that occurs behind the pick up point. Furthermore, the extent of hook for rotor spun yarn is higher than that of ring spun yarn. Low spinning tension, aerodynamic drafting of fibres, collision of fibres in transport tube and inherent mechanism of wrapper fibre formation are the reasons for poor fibre extent and high incidence of leading

Figure 2. (a) Leading hook and (b) Trailing hook of ring spun yarn

Table 1. Parameters for different spun yarns

Yarns	Mean fibre extent (mm)	Spinning-in coefficient	Leading hook		Trailing hook		Doubled hook	
			%	Extent (mm)	%	Extent (mm)	%	Extent (mm)
Ring	30.2	0.69	9.8	1.3	14.2	1.9	4.0	3.5
Rotor	20.4	0.46	20.1	4.2	10.5	3.1	6.3	7.5
Air-jet	33.3	0.76	7.8	1.2	10.2	1.4	1.6	3.1
Dref II	13.7	0.31	32.3	8.5	25.9	5.6	14.5	13.4

hooks compared to the ring spun yarn. Figures 3(a) and 3(c) depict the typical configuration of leading hook and trailing hook in the rotor yarns. Figure 3(b) illustrates a leading hook formed by the bridging fibre. The tracer fibre technique does not show any evidence of such type of hooks for ring spun yarn.

3.3 Air-Jet Spun Yarn

Table 1 demonstrates that as compared to other yarns, air-jet yarn has the highest mean fibre extent and spinning in-coefficient. It is also ascertained from Table 1 that air-jet yarn not only has least number of hooks but the extent of hooks is

also the shortest. This can be attributed to the fact that the high drafting speed and the higher amount of draft in the process of air-jet spinning help in straightening the fibres. The percentage and extent of trailing hook is higher than the leading hook for this yarn, which are the similar to the trend observed for ring yarn. Trailing hooks of card sliver are presented to air-jet without the change of direction as odd number of passages that is, three draw frame passages are used in between card and air-jet spinner. The configuration of leading hook and trailing hook in the air-jet spun yarns are exemplified in Figures 4 (a) and 4(b), respectively.

Figure 3. (a) Leading hook (b) Leading hook formed by bridging fibre and (c) Trailing hook of rotor spun yarn

Figure 4. (a) Leading hook and (b) Trailing hook of air jet spun yarn

Figure 5. (a) Leading hook and (b) Trailing hook of Dref-II yarn

3.4 OE Friction Spun Yarn

The internal structure of an OE friction spun yarn is characterized by its inferior fibre orientation, looped and buckled fibre configuration. Table 1 illustrates that Dref-II spinning system produces highest percentage as well as longest extent of hooks compared to ring, rotor and air-jet spinning systems. Photographic illustrations of leading and trailing hooks are shown in Figure 5 (a) and 5 (b), respectively. The degree of fibre orientation of this yarn is so poor that the fibres of 44 mm length have a mean fibre extent of only 13.7 mm and spinning in-coefficient value is reduced to as low as 0.31. A vast number of different types of hooks with long hook extent leads to a large reduction in the proportion of straight fibres and average fibre extent in the yarn. The low fibre utilization in this yarn is due to the buckling of fast moving fibres as they reach the slow moving spinning drums.

4. Conclusions

The spinning technologies have a significant influence on the percentage and extent of hooks in the yarns. The percentage and extent of trailing hook is higher than the leading hook for ring and air-jet spun yarns whereas rotor and friction spun yarns show the opposite trend. The hook extents for rotor and friction spun yarns are higher compared to ring and air-jet spun yarns. Air-jet yarn has the least number of fibres having hooks and the extent of hooks is the shortest whereas friction spun yarns has the highest number and extent of hooks. Highest spinning in-coefficient is obtained for air-jet yarn followed by ring, rotor and friction spun yarn.

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References

- [1] Klein, W., (1993) "New Spinning Systems, Short Staple Spinning Series," Vol. V, The Textile Institute, Manchester.
- [2] Lord, P. R., (1971). *The Structure of Open-End Spun Yarn*. *Textile Research Journal*, 41, 778-784.
- [3] Nield R., (1975). *Open-End Spinning*, Monograph No. 1, 38-53.
- [4] Basu, A., (2009). *Yarn structure- properties relationship*. *Indian Journal of Fibres and Textile Research*, 34, 287-294.
- [5] Morton, W. E. , and Yen, K. C. , (1952) *The Arrangement of Fibers in Fibro Yarns* , *Journal of Textile Institute*, 43, T60-T60.
- [6] Morton, W. E., (1956). *The Arrangement of Fibres in Single Yarns*, *Textile Research Journal*, 26, 325-331.
- [7] Hearle, J. W. S., Gupta, B. S., and Merchant, V. B., (1965). *Migration of Fibers in Yarns, Part I: Characterization and Idealization of Migration Behavior*, *Textile Research Journal*, 35, 329-334.
- [8] Hearle, J. W. S., and Bose, O. N., (1965). *Migration of Fibers in Yarns, Part II: A Geometrical Explanation of Migration*, *Textile Research Journal*, 35, 693-699.
- [9] Hearle, J. W. S, and Gupta, B. S., (1965). *Migration of Fibers in Yarns, Part III: A Study of Migration in Staple Fiber Rayon Yarns*, *Textile Research Journal*, 35, 788-795.
- [10] Hearle, J. W. S., Grosberg, P., and Backer, S., (1969). *Structural Mechanics of Fibers, Yarns, and Fabrics*, Volume 1, John Wiley & Sons, New York,
- [11] Treloar, L. R. G., (1965). *A Migration Filament Theory of Yarn Properties*, *Journal of Textile Institute*, 56, T359-T380.
- [12] Riding, G., (1959), *An Experimental Study of the Geometrical Structure of Single Yarns*, *Journal of Textile Institute*, 50, T425-T442.
- [13] Riding, G., (1964). *Filament Migration in Single Yarns*, *Journal of Textile Institute*, 55, T9-T17.
- [14] Huh, Y., Kim, Y. R., and Oxenham, W., (2002). *Analyzing Structural and Physical Properties of Ring, Rotor, and Friction Spun Yarns*, *Textile Research Journal*, 72 (2), 156-163.
- [15] Ishtiaque, S. M., Subramani, P., Kumar, A., Das, B., R., (2009). *Structure and tensile properties of ring and compact plied yarns*, *Indian Journal of Fibres and Textile Research*, 34, 213-218.
- [16] Basal, G., Oxenham, W., (2006). *Comparisons of Properties and Structures of Compact And Conventional Spun Yarns*. *Textile Research Journal*, 76(7), 567-575.

- [17] Alagha, M. J., Oxenham, W., Iype, C., (1994). Influence of Production Speed on the Tenacity and Structure of Friction Spun Yarns. *Textile Research Journal*, 64, 185-189.
- [18] Ishtiaque, S. M. and Neckar, B., (1986). New Method to Study the Area of Fibres in Yarn Cross-section, *Indian Journal Fibre & Textile Research*, 11, 26-30.
- [19] Ishtiaque, S. M., (1986). Distribution of Fibres in Cross-section of Rotor and Ring Spun Yarns and Their Strength, *Indian Journal Fibre & Textile Research*, 11, 215-219.
- [20] Neckar, B., Ishtiaque, S. M. and Svehlova, L. (1988). Rotor Yarn Structure by Cross-Sectional Microtomy, *Textile Research Journal*, 11, 625-632.
- [21] Ishtiaque, S. M., and Saxena, A. K., (1998). Rotor Machine Variables and Yarn Structure: Part III- Fibre Distribution in Yarn in Relation to Rotor Machine Variables, *Indian Journal Fibre & Textile Research*, 23, 141-146.
- [22] Punj, S. K., Debnath, S. and Ishtiaque, S. M., (1998). Radial Packing Density of MJS Yarns, *Indian Journal of Fibres and Textile Research*, 23, 229-232.
- [23] Klein, W., (1993). *New Spinning Systems, Short Staple Spinning Series, Vol. II*, The Textile Institute, Manchester.
- [24] Chasmawala, R. J., Hansen, S. M., and Jayaraman, S., (1990). Structure and Properties of Air-Jet Spun Yarns, *Textile Research Journal*, 60, 61-69.
- [25] Tyagi, G.K., Patnaik, A., Goyel, A., Salhotra, K. R., Ishtiaque, S. M., (2002). Structure and properties of polyester MJS plied yarns. *Indian Journal of Fibres and Textile Research*, 27, 236-241.
- [26] Shukla, L., Nishkam, A., (2012). Structural Performance of DREF and Conventional Yarns. *International Journal of Scientific & Technology Research*, 1(8), 152-158.
- [27] Kasperek J. V., (1970). *Spinning in 70's*, Merrow Publishing Co. Ltd. Great Britain, 215-217.