MECHANICAL PROPERTIES OF AIR-JET YARNS SPUN ON DIFFERENT SYSTEMS

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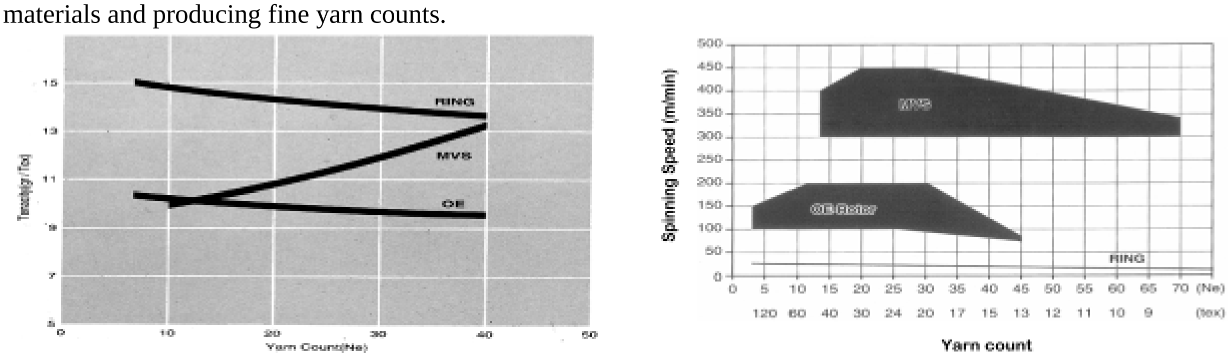
Abstract

In yarn production, the technology of twist insertion is the major factor that affects the structure and ultimately the properties and performance of the produced yarn. Moreover, the differences within the same spinning technique have, to some extent, a similar effect. In this work, we are studying the effect of the design of the nozzles of Murata Vortex Spinning (MVS) and Reiter air-jet spinning (J20) on the resulted yarn structure and properties. The scanning electron microscopy (SEM) images of the yarns are used to show the variations in yarn structures, while the mechanical properties of air-jet yarns (MVS and J20) are studied and compared to rotor spun yarns of similar counts. Sonic modulus as measured by the Dynamic Modulus Tester (DMT) produced by Lawson-Hemphill is compared to the results of the standard mechanical and the cyclic loading tests. The impact of the dynamic modulus is also evaluated.

Introduction

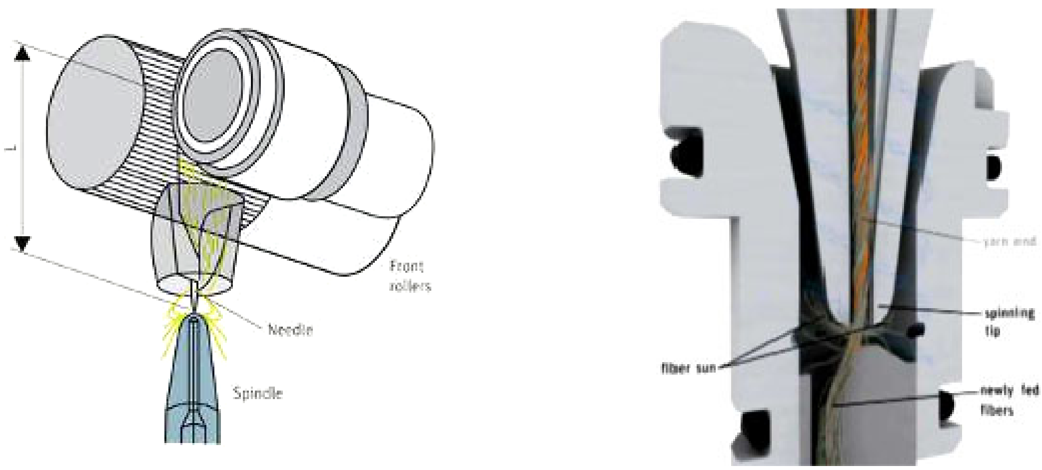
There is a direct relation between yarn processing, structure, properties, and performance. Yarn production technology identifies the "processing" term in this series of relations where ring-spinning, rotor spinning, air-jet spinning, friction spinning, etc found to have different effects on the produced yarns. Each production technology has its own advantages and disadvantages as determined by a certain application window. Air-jet spinning, for instance, was found to be successful in producing yarns with reasonable tenacity (Figure 1-a) at a relatively much higher speed than the ring-spinning and the rotor-spinning (Figure 1-b). The Murata Jet Spinner, MJS 801, was first exhibited at ATME-International in 1982 as a modification of the fasciated spinning system introduced by Du Pont in 1956 [2]. The system at that stage had some constraints on producing yarns of 100% cotton or cotton rich blends which was then solved by introducing the Murata Vortex Spinning (MVS) that allows processing these fibrous materials and producing fine yarn counts.



(a) (b)

Figure 1. a) Relationship between the tenacity and the yarn counts for ring-spun, Murata Vortex Spinning (MVS), and Open End (OE) yarns. b) Comparative production speeds for different yarn counts that produced on ring-spinning, Murata Vortex Spinning (MVS), and Open End (OE) systems, (Cotton Incorporated, 2004).

In 2003, the Rieter Group introduced its own J10 air-jet spinning technology and updated the system with J20 in 2008. The jets used in Murata and Rieter are different in design and construction but are producing jet yarns based on the same principle. In the Murata Vortex Spinning (MVS) system, fibers leave the front roller of the drafting device and drawn into the fiber bundle passage by air suction created by the nozzle. The fiber bundle passage consists of a nozzle block and a needle holder. The needle holder has a substantially central, longitudinal axis and a guide surface that twists relative to the longitudinal axis, as illustrated in Figure 2-a. A pin-like guide member associated with the needle holder protrudes toward the inlet of the spindle. Rieter jet spinning, on the other hand, uses a fixed spindle with a fiber path in the shape of an arc as shown in Figure 2-b.



(a) (b)

Figure 2. Illustrations for the MVS system (a) [3], and the Rieter jet spinning (b) [4]

This work tries to shed light on the new air-jet system developed by Rieter and compare its properties to other systems of the same family (Murata Vortex Spinning) as well as other systems Rotor spinning. The study begins with the structure of the yarns as observed using a Scanning Electron Microscopy (SEM) and proceeds with physical properties of the studied yarns. Mechanical testing of the yarns was performed using the commonly used single-end strength tests at constant rate of extension (CRE) as well as cyclic loading/unloading. Sonic modulus of the yarns was measured using the Dynamic Modulus Tester (DMT) produced by Lawson-Hemphill.

Materials and Methods

Three yarns of similar counts (20 tex) made from 100% viscose (38 mm and 1.3 dtex) were produced on different systems. Murata vortex spinning (MVS) and Reiter (J20) yarns were produced at production speed of 375 m/min. The rotor-spun yarn was prepared using a similar sliver as the one used with the other systems. Yarn samples were analyzed for their structure using Scanning Electron Microscope (SEM). The mechanical properties were studied using three tests; 1) the common load/elongation response was performed on a universal testing machine of Labortech Tiratest instrument. 2) The same instrument was also used for applying a cyclic loading-unloading on the yarn. Yarn samples were loaded for 20 cycles at levels between 0.2 N and 1 N followed by a continuous extension till the yarn breakage. All yarn samples were tested with a gauge length of 250 mm and under a pre-tension of 0.5 cN/tex. 3) The Dynamic Modulus Tester by Lawson-Hemphill was used to measure the velocity of the sonic pulses at 5MHz in the yarns. The sonic speed can then be used to calculate the sonic modulus of the yarn according to the relation:

$$E = \rho . C^2$$

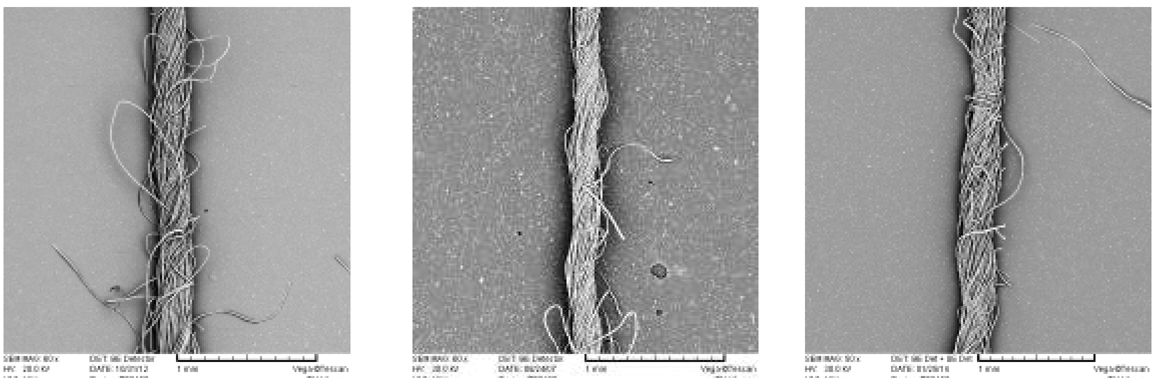
Where E is the sonic modulus in GPa, C is the sonic speed in the material in km/sec, ρ is the material density in (g/cm^3).
or the relation:

$$\mathrm{E} = \mathrm{k}. C^2$$

Where E is the sonic modulus in g/denier, *C* is the sonic speed in the material in km/sec, k is a constant conversion factor we calculated for all yarns to be 12.15 regardless of yarn material or linear density.

Results and Discussion

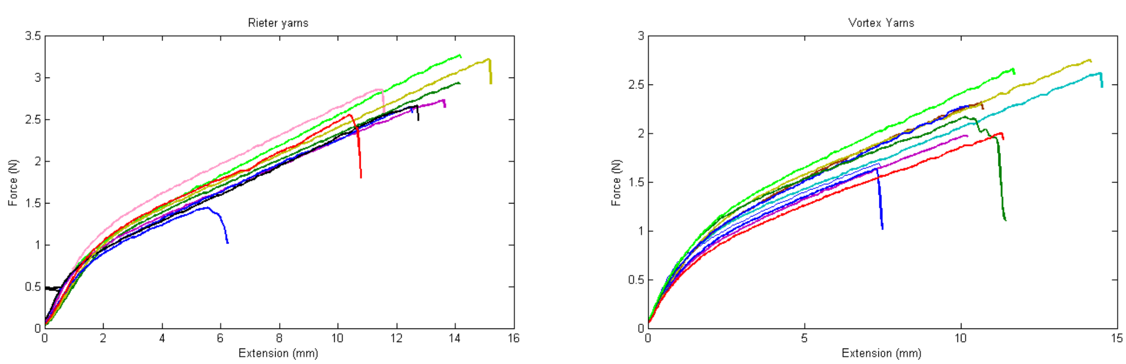
The yarns produced on the three different systems were examined under the scanning electron microscope (SEM) for their structures. As indicated in Figure 3, air-jet yarns (both Rieter and Murata) show a structure where the strand of the input fibers is divided in two groups with relatively parallel fibers in the core and wrapping fibers at the sheath. The amount of the wrapping fibers is affected by the air-pressure in the nozzle, the spindle diameter, and the delivery speed. Rotor yarns, on the other hand, show wildly entangled wrapping fibers which do not behave in a helical shape as the sheath fibers of the air-jet yarns. Yarns produced on Rieter show hairiness and fuzziness that are relatively higher than that for Murata spun yarns as shown in Figure 3. Although the twist factor and its measurement are questionable for air-jet yarns, the pitch of the twists and the twist angle are qualitatively higher in the case of Murata yarns compared to Rieter yarns. Rotor spun yarns show the belt fibers that wrap the other twisted fibers as they are considered a characteristic feature of rotor spinning.



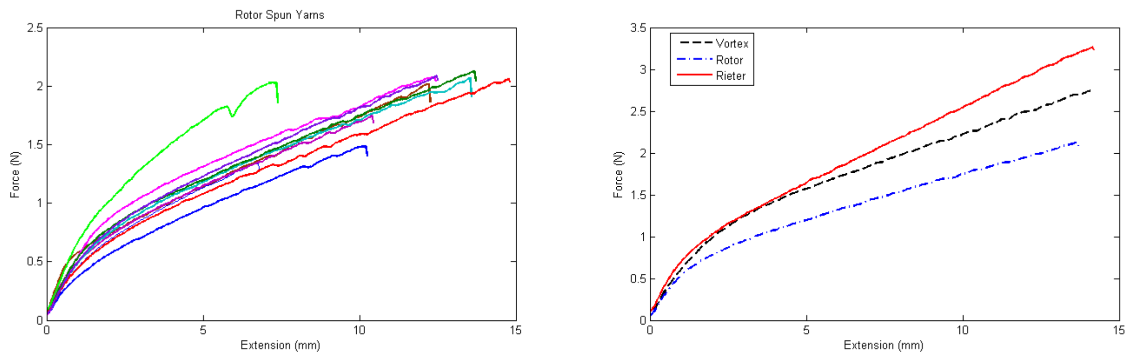
Rieter Vortex Rotor

Figure 3. SEM pictures for the longitudinal view of Rieter, MVS, and rotor yarns, respectively

The mechanical properties of the yarns were evaluated using the stress-strain response of yarns. Graphs are shown in Figure 4, where the individual curves for samples of Rieter (Figure 4. a), Vortex (Figure 4. b), and Rotor spun (Figure 4. c) yarns as well as the average curves for these samples are depicted (Figure 4. d). It can be seen from these curves that Rieter yarns have the highest elastic modulus among the tested samples followed by the Murata yarns then the rotor-spun yarns. The yarn strength as evaluated by the breaking force follows the same order for the different yarns. The average breaking extension is comparable for all tested yarns.



(a) (b)



(c) (d)

Figure 4. Force-extension relations for the Rieter, MVS, Rotor yarns; a-c individual curves, d shows the average curves

The mechanical behavior of the yarns under cyclic loading is shown in Figure 5 as average specimen from each yarn type. It was observed that these curves follow the same order and pattern pattern obtained for the yarns under normal loading conditions. The breaking strength, however, shows some differences with a slight decrease in values for Murata and rotor-spun yarns and Rieter yarns respectively after the cyclic loading. The width of the extension period for each yarn type can be considered as indicator for the permanent set and rearrangement of the fibers inside the yarn. Results of the rotor spun yarn show higher rearrangement which can be expected as those yarns are known to be bulkier with highly random orientation. The pattern for curves slope at each loading cycle is similar in all yarn types which indicate the dependency of this slope on the fiber material regardless of the technology of production.

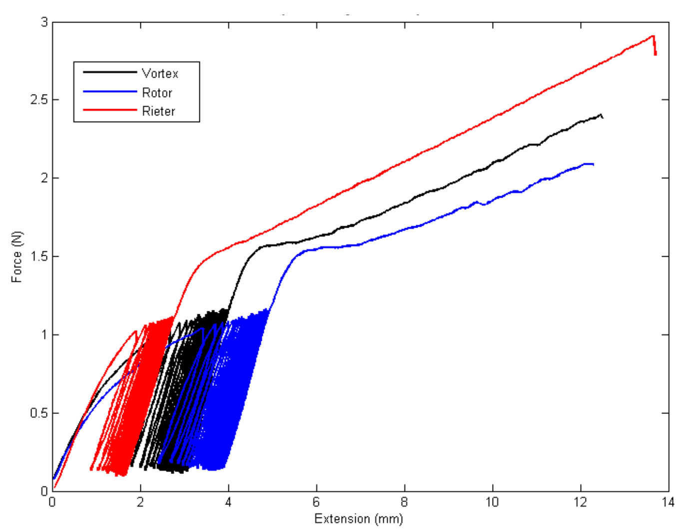


Figure 5. Average force-extension relations for Rieter, MVS, and Rotor yarns under cyclic loading

The calculation of the sonic modulus is based on the sonic speed in the yarn material as indicated earlier. Sonic speed is the relation of the distance between sending and receiving probes to the traveling time of the sonic pulses, as shown in Figure 6 for individual yarn samples. The average sonic speeds in km per second are also given in Figure 6. It is noticeable that sonic modulii (as expected form sonic speeds, providing the same material density) show a pattern order (Reiter, Rotor, Vortex respectively) that is different than those measured on the universal testing machine (Reiter, Vortex, and Rotor , respectively). The rotor spun yarn shows higher sonic modulus value as compared to the vortex yarn while this order is reversed for the commonly measured modulus. This may be explained by the debatable calculation method that utilizes the material density as an input for calculating the sonic modulus in MPa or ignoring it at all when calculating the modulus in g/denier. From the results in hands, we will follow up with further studies where this density should be corrected to reflect the actual arrangement of the fibers inside the yarn and the packing density as a corrective factor for the density. The parallel fibers of air-jet yarns allow higher packing density which (in case it was considered as a corrective factor) will increase the calculated sonic modulus and could result in a similar trend as the one obtained from the mechanical measurement of modulus.

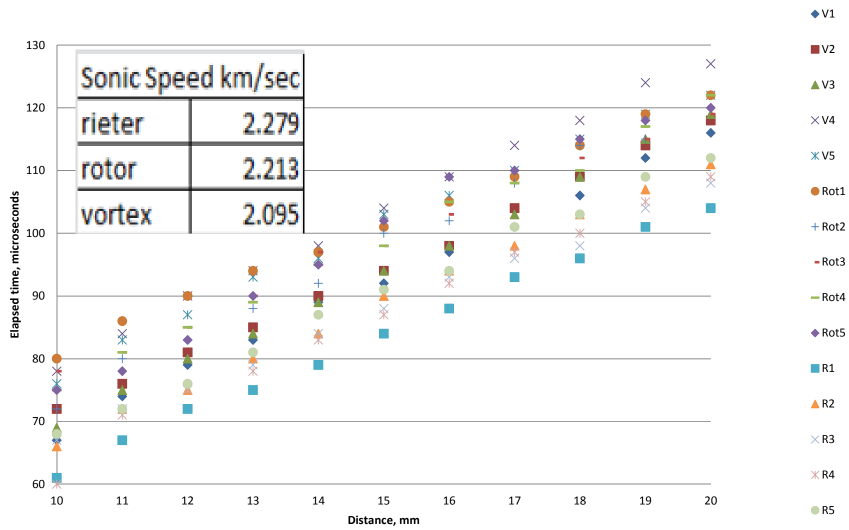


Figure 6. Plot of the individual readings of sonic pulse times at different probe distances used to calculate the sonic speed

Conclusion

Staple fiber yarns were produced on different systems of twist insertion mechanisms. All yarns were made of viscose fibers. Results show that the tested yarns have almost same elongation at break but different breaking loads: Rieter, MVS, and Rotor respectively. Vortex yarns tend to behave similarly under cyclic loading in terms of the permanent length gained where Rotor yarns have longer gain. Sonic tester showed differences in the sonic speed through different yarn technologies, some more work still needed for the sonic modulus to establish itself among regular yarn testing and/or used to indicate yarn structural properties.

Acknowledgements

This work was supported by ESF operational program "Education for Competitiveness" in the Czech Republic in the framework of project "Support of engineering of excellent research and development teams at the Technical University of Liberec" No. CZ.1.07/2.3.00/30.0065.

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