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Effect of Spindle Diameter and Spindle Working Period on the Properties of 100% Viscose MVS Yarns

Abstract
This study focuses on the effects of various spindle diameters and the spindle working period on the properties of 100% viscose MVS yarns. MVS yarn samples produced with four levels of spindle diameter, 1.1, 1.2, 1.3, 1.4 mm and five levels of the spindle working period: 0, 1, 2, 3, 4 month, were evaluated on the basis of unevenness, hairiness, elongation at break, tenacity and work-of-break (B-work) values. The results indicate that a large spindle diameter results in high hairiness, as well as low unevenness and tenacity values. The wear of the spindle increases with an increasing working period. The wear is mainly seen in two different zones: the proximal edge of the hole entrance (tip zone), and the hole surface of spindles. After a four month working period, spindle wear becomes a more critical factor for 100% viscose MVS yarns.

Key words: *MVS yarn, spindle wear, viscose yarn, spindle diameter.*

Introduction

Murata Vortex Spinning (MVS), which is a successful commercial implementation of fasciated yarn technology, was developed by Murata Machinery Company in Japan. This relatively new technology has significant advantages over ring, open-end and air jet spinning systems. One of the great advantages of MVS is that it is capable of producing yarns at speeds that are significantly higher than with any other system. Although the number of MVS frames operating in mills is still low, MVS installations are growing rapidly [1].

Up until now, limited studies have been carried out by researchers to establish a process-structure-property model for MVS yarns which can be used to optimise and improve MVS technology [2 - 5]. In an effort to supply additional information about the effects of process parameters on the properties of MVS yarns, we have undertaken this study.

Principle of yarn formation

In the MVS system a finisher sliver is supplied directly to a four roller/apron drafting unit. After coming out of the front rollers, the fibres approach the air-jet nozzle and are twisted by the force of the air-jet stream. This twist motion tends to flow upwards. At this point a bending action at the needle tip, protrudes from the orifice, prevents this upward propagation (*Figure 1*). Therefore, the upper portions of some fibers are separated from the nip point between the front rollers; however, they are kept “open”. After the fibers have passed through the orifice, the upper portions of the fibers begin to expand due to the whirling force of the air jet stream and twine over the hollow stationary spindle. The fibers twined over the spindle are whirled around the fiber core and made into MVS yarn as they are drawn into the hollow spindle. The finished yarn is wound onto a package after its defects have been removed [6].

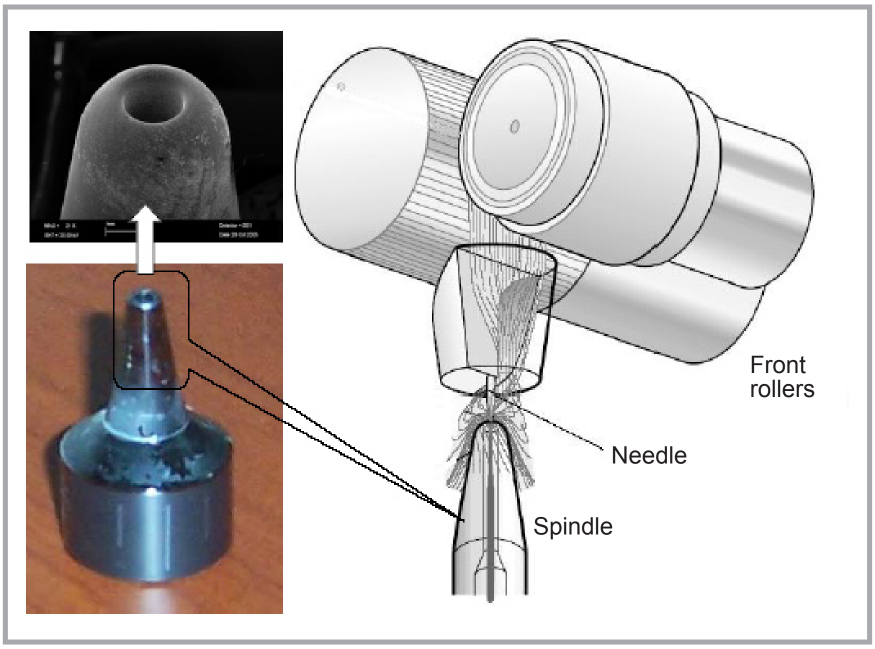

Figure 1. *Principle of yarn formation [6].*

Table 1. *Spinning conditions.*

Condition No.	Spindle diameter, mm	Spindle working period, month
1	1.1	0
2	1.1	1
3	1.1	2
4	1.1	3
5	1.1	4
6	1.1	5
7	1.2	0
8	1.2	1
9	1.2	2
10	1.2	3
11	1.2	4
12	1.2	5
13	1.3	0
14	1.3	1
15	1.3	2
16	1.3	3
17	1.3	4
18	1.3	5
19	1.4	0
20	1.4	1
21	1.4	2
22	1.4	3
23	1.4	4
24	1.4	5

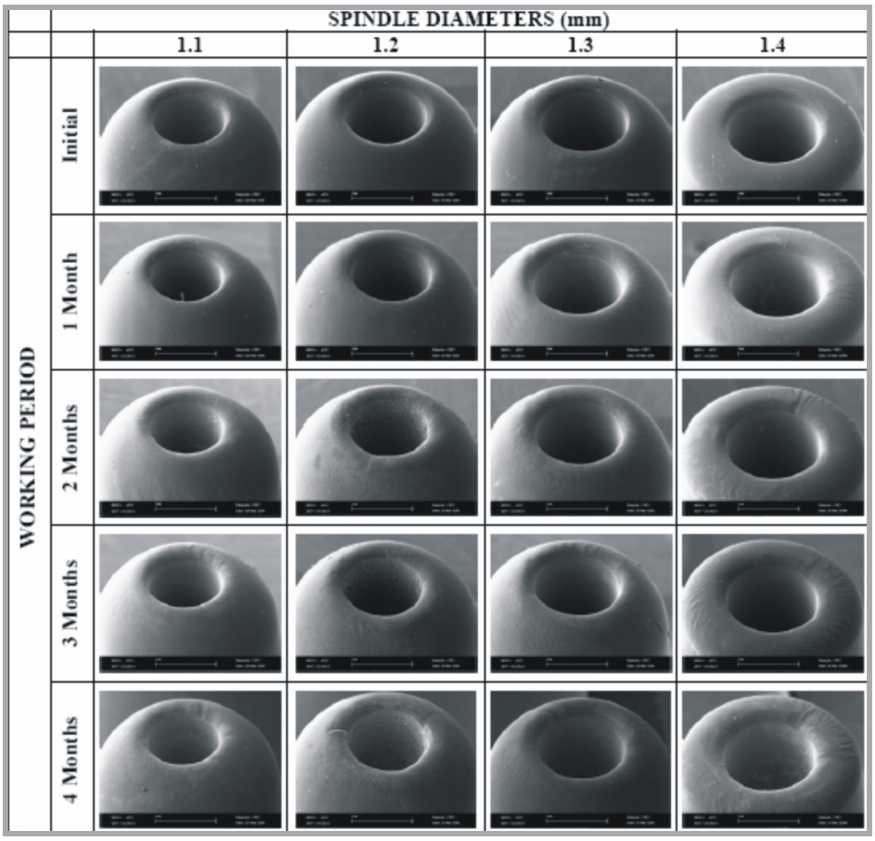

Figure 3. SEM images of spindle wear versus spindle working period for different spindle diameters.

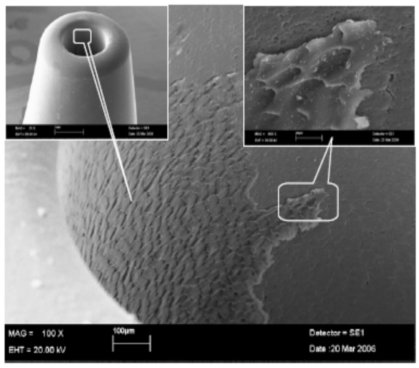

***Figure 4.** SEM images of the hole surface of a 1.4 mm spindle after 4 months.*

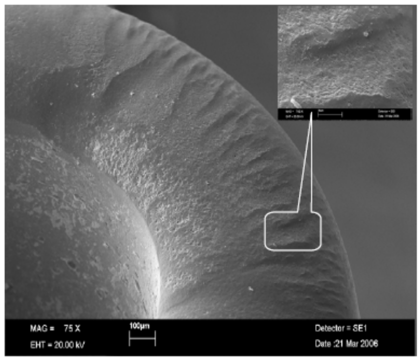

***Figure 5.** SEM images of the tip zone of a 1.4 mm spindle after 4 months.*

Materials and test method

Three drawing passages were given to the carded slivers to produce a finisher sliver of 3.58 ktex. All the yarn samples, which had a linear density of 20 tex (Ne 30/1), were spun with the following spinning conditions: a 70° nozzle discharge angle, a delivery speed of 350 m/min , an air pressure of 0.5 MPa, 43-43-49 mm top roller gauges, and 43-43-44.5 mm bottom roller gauges, on a MVS 851 vortex spinner.

A list of the experimental spinning conditions is given in ***Table 1***. Spindle diameter values were determined according to the limitation dictated by the instruction manual for the MVS 851 [6]. The working periods of the spindle were chosen according to manufacturing experience. Three baby cones of about 150 g each were prepared under each experimental condition.

The effects of the spindle diameter and spindle working period on the properties of 100% viscose MVS yarns were investigated on the basis of yarn unevenness (CVm %), hairiness, elongation at break, tenacity and work-of-break (B-work) values. Yarn samples were tested for unevenness and hairiness on an Uster Tester 3, and for elongation, tenacity in cN/tex and B-work values on an Uster Tensojet. Yarn hairiness tests were also performed on a Zweigle G566 Hairiness Tester. We analysed the test results for significant differences using two-way replicated ANOVA, and the means were compared by conducting Student-Newman-Keuls (SNK) tests at a level of 0.05 using a Costat statistical package. In the interpretation of SNK results, abbreviations a, b, c, d, and e represent factor level; factor levels that have the same letters are not different from each other at a significance level of 0.05.

In addition to the physical tests of the yarns, the wear of the spindles were examined under a LEO 440 model scanning electron microscope (SEM).

Results and discussion

Table 2 summarises the unevenness and hairiness properties of MVS yarns produced with different spindle diameters and different spindle working periods.

***Table 2.** Effects of spindle diameter and spindle service life on the unevenness and hairiness properties of 100 % viscose MVS yarn, Student-Newman-Keuls test (SNK test).*

	CVm, %	H (Uster index)	S3	Num. of hairs	
				(1 mm class)	(2 mm class)
Spindle diameter					
1.1 mm	12.25 a	3.32 d	14.67 c	5299.87 d	156.33 c
1.2 mm	12.19 a	3.50 c	13.13 c	6026.53 c	154.67 c
1.3 mm	11.97 b	3.76 b	23.00 b	8020.20 b	252.73 b
1.4 mm	11.97 b	4.30 a	93.40 a	12235.67 a	630.07 a
Spindle working period					
Initiall	11.83 bc	3.49 e	41.00 a	8009.50 a	318.83 a
After 1 months	11.80 cd	3.56 d	26.75 b	8264.92 a	290.75 ab
After 2 months	11.73 d	3.72 b	39.75 a	7428.17 b	287.5 ab
After 3 months	11.90 b	3.65 c	28.42 b	7797.50 ab	268.08 b
After 4 months	13.23 a	4.18 a	44.33 a	7977.80 a	327.08 a

According to ANOVA results, the spindle diameter and spindle working period and the combination of these two factors had a significant effect on the unevenness and hairiness properties of the MVS yarns. ***Figure 2*** shows the results of yarn unevenness measurements. From the SNK test results (***Table 2***) there were no significant differences between the mean unevenness values of MVS yarns produced with spindles of 1.1 mm and 1.2 mm diameter. Similar results were observed between unevenness properties of yarns produced with spindles of 1.3 mm and 1.4 mm diameter. However, there were significant differences between the unevenness results for these two groups (1.1, 1.2 mm and 1.3, 1.4 mm). A decrease in spindle diameter from 1.3 mm to 1.2 mm resulted in a significant increase in the yarn unevenness value. A possible explanation for such unevenness properties is that fibers have more freedom to arrange themselves with a large spindle diameter.

The generation of spindle wear depends on the working period for different spindle diameters, which are given in ***Figure 3***. As the spindle working period increases, spindle wear also increases. Spindle wear was specially observed in two different zones: the hole surface and tip zone of the spindles, as shown in ***Figures 4*** and ***5***, respectively. The SNK test results from ***Table 2*** reveal that an increase in the spindle working period generally resulted in a significant increase in the yarn unevenness value. The highest unevenness values were obtained for MVS yarns produced with a spindle which has a 4 month working period. The possible reason for the higher unevenness values of MVS yarns produced with a spindle that has a longer working period is the deterioration effect of spindle wear on yarn formation.

With regard to yarn hairiness, the MVS yarns were tested on both the Uster Tester 3 and the Zweigle G566 hairiness tester. We determined yarn hairiness in terms of the number of hairs in the 1 mm class, 2 mm class, S_3 values, which represent the total number of hairy ends that rise from 3 to 25 mm for the yarn surface and Uster Hairiness Index. The SNK test results from ***Table 2*** reveal that a small spindle diameter resulted in low hairiness values. The fiber bundle has more freedom to move inside a spindle of large diameter. Hence some twist is lost, wrappings become looser and yarn gets hairier. An increase in the spindle working period generally resulted in higher hairiness values in terms of the Uster hairiness index. This trend is not clear for other hairiness values. ***Figure 6*** shows the test results of yarn hairiness in terms of the Uster hairiness index.

Figures 7 and ***8*** show the tenacity and elongation at break results of the MVS yarns versus the spindle working period for different spindle diameters. Based on the ANOVA results, the spindle working period, spindle diameter and a combination of these two factors have a significant effect on the tenacity, elongation at break and B-work values of MVS yarns.

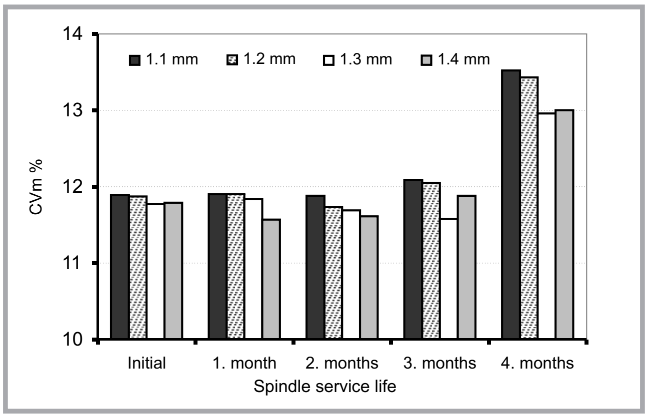

Figure 2. *Yarn unevenness versus spindle working period for different spindle diameters.*

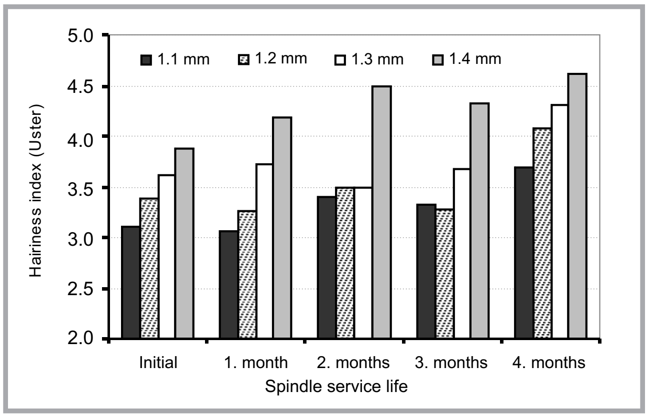

Figure 6. *Yarn hairiness index (Uster) versus spindle working period for different spindle diameters.*

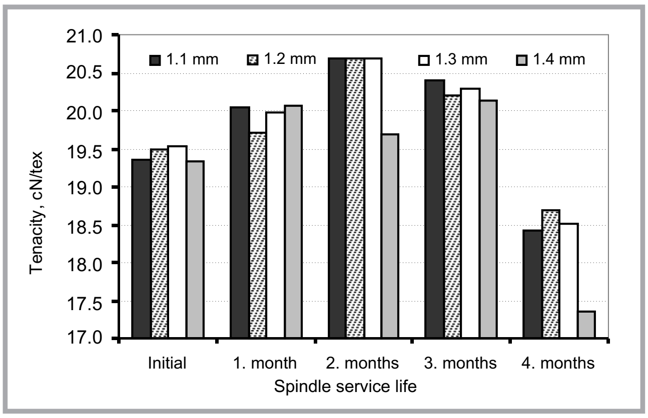

Figure 7. *Yarn tenacity versus spindle working period for different spindle diameters.*

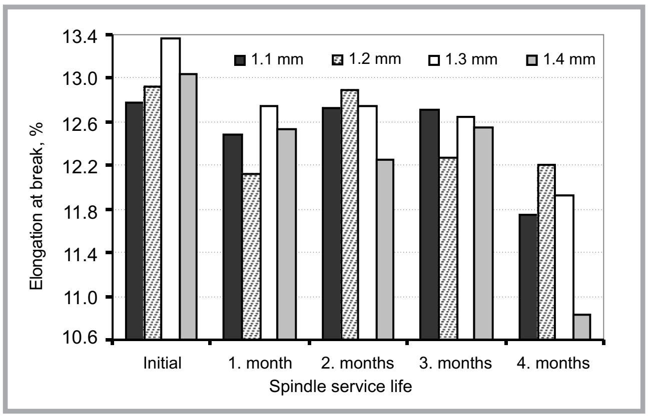

Figure 8. *Yarn elongation at break values versus spindle working period for different spindle diameters.*

Table 3. *Effects of spindle diameter and spindle service life on the mechanical properties of 100 % viscose MVS yarn , SNK test.*

	Tenacity, cN/tex	Elongation, %	B-work, cN·cm
Spindle diameter			
1.1 mm	19.78 a	12.49 b	1494.47 b
1.2 mm	19.76 a	12.49 b	1494.27 b
1.3 mm	19.80 a	12.69 a	1515.80 a
1.4 mm	19.32 b	12.24 c	1443.40 c
Spindle working period			
Initiall	19.44 d	13.03 a	1559.58 b
After 1 months	19.95 c	12.47 c	1553.33 b
After 2 months	20.44 a	12.65 b	1593.67 a
After 3 months	20.26 b	12.54 c	1566.33 b
After 4 months	18.25 e	11.67 d	1162.00 c

As seen in ***Table 3***, there were no significant differences between the mechanical properties of MVS yarns produced with spindles of 1.1 mm and 1.2 mm diameter. The lowest tenacity, elongation at break and B-work values were obtained for those produced with a spindle of 1.4 mm diameter (***Table 3***). This is mainly due to higher friction between fibers within the yarns, which were produced with smaller spindle diameters. Since a small spindle diameter gives less freedom to the fiber bundle to expand as it enters the spindle, higher friction occurs between fibers and results in tighter wrappings, higher twist and in turn denser yarns.

Even though there were no significant differences between the mean tenacity values of MVS yarns produced with spindles of 1.1 mm, 1.2 mm and 1.3 mm diameter. The mean elongation at break and B-work values of yarns produced with spindles of 1.3 mm diameter were higher than those of yarns produced with all other spindle diameters (***Table 3***).

The tenacity, elongation at break and B-work values of MVS yarns produced with a spindle that has a 4 month working period are significantly lower than those of yarns produced with spindles which have other working periods. Spindle wear mainly occurs after a three month working period (***Figures 3, 4, 5***). After a 4 month working period it is probable that wear occurred in the tip zone. Furthermore, the hole surface of the spindle negatively affects the arrangement of fibers and resulted in a greater decrease in the mechanical properties of the MVS yarns.

Conclusions

Our findings show that various properties of MVS yarns are significantly affected by the spindle diameter and spindle working period.

Using larger spindle diameters results in higher hairiness values. Since the fiber bundle has more freedom to move inside a spindle with a large spindle diameter, wrappings become looser and yarn becomes more hairy. With spindle diameters of 1.3 and 1.4 mm, lower unevenness values were obtained compared to spindle diameters of 1.1 and 1.2 mm.

The spindle diameter determines the tightness of the wrapper fibers. With a spindle diameter of 1.4 mm, relatively lower friction occurs between fibers and results in lower tenacity values. The best elongation at break values were obtained for MVS yarns produced with 1.3 mm spindle diameters. The choice of spindle diameter depends on not only yarn count and raw material, but also on the end-use properties of MVS yarns.

Spindle wear is a major problem as it negatively affects MVS yarn properties. Spindle wear mainly occurs in the tip zone and the hole surface of the spindle. After a 4th month working period, the negative effetcs of spindle wear becomes more critical with respect to the unevenness, hairiness, tenacity and elongation properties of MVS yarns. The wear results put forward in this study are valid only for this particular case, and may be different for other types of fiber.

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