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Effect of the Draft Ratio on the Properties of Vortex Spun Yarn

Abstract
In this study, the effects of draft ratios on the properties of vortex spun yarns were investigated. 100% viscose drawing slivers of three different counts (3.94 ktex, 3.19 ktex and 2.68 ktex) were spun into yarns with a count of 14.76 tex while keeping all other spinning conditions constant. The yarn samples were evaluated on the basis of yarn irregularity and imperfections, as well as hairiness and tensile properties. In addition, a 3rd passage draw frame sliver with a yarn count of 3.19 ktex was spun into yarns of 14.76 tex using two different delivery speeds: 350 and 400 m/min. The significance of independent variables and their interactions for the physical properties of the yarn were tested statistically at a 95% level of confidence.

Key words: *vortex, MVS, viscose yarn, intermediate draft, main draft, yarn properties.*

Introduction

The latest development in air jet spinning technology is the MVS (Murata Vortex Spinner), which was first introduced at OTEMAS'97 by Murata Machinery Limited. Besides the main characteristics of modern spinning technologies, such as the elimination of processing stages, ease of automation and high production speed, the distinctive features of the system are the capability of spinning 100% carded cotton yarn and obtaining a ring-like yarn structure. As well as the low hairiness of vortex yarns, the low pilling tendency, high abrasion resistance, high moisture absorption capacity and fast drying characteristics of fabrics made from vortex yarns are emphasised as outstanding features of this latest version of air jet spinning technology [1].

In the MVS spinning system, a drawing sliver is transferred directly to a 4-line drafting system. The drafting zone, which is illustrated in ***Figure 1***, is composed of front rollers, middle rollers with controlling aprons, and two sets of back rollers. Drafted fibres are passed through an air jet nozzle and hollow spindle to make them into yarn [2, 3].

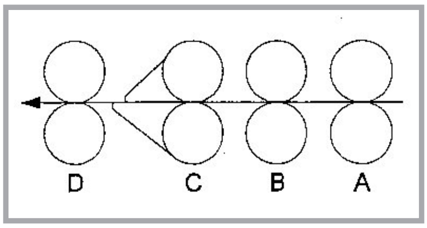

Figure 1. *Drafting system in the Murata Vortex Spinner [3].*

In the aforementioned 4-line drafting system, the draft ratio between A and B is defined as the break draft, the draft ratio between B and C as the intermediate draft and the draft in the zone between C and D is termed the main draft. The drafting unit in MVS is quite similar to that of MJS (Murata Jet Spinner); however, higher main draft ratios are achievable in MVS as it is possible to set optimum drafting conditions without considering the influence of the spinning part on the drafting part. In MVS, the drafting part is separated from the yarn spinning part, therefore the yarn twisting motion generated in the spinning part is prevented from being affected by the drafting part [3].

The effects of various spinning parameters, such as the delivery speed, nozzle air pressure, the nozzle angle, the spindle diameter, and the distance between the front roller nip point and the spindle on the structure of vortex yarn have been studied by some researchers to propose a process-structure-property model for vortex spun yarns [4 - 7]. Tyagi et al also analysed the effects of spinning parameters on the low stress characteristics of vortex yarns and woven fabrics as well as thermal comfort properties [8 - 10]. In addition to the parameters stated, Ortlek et al investigated the effects of the spindle working period and spindle diameter on the properties of viscose vortex spun yarns [11]. This study aimed to investigate the effects of draft ratios on the properties of vortex spun yarns to provide additional information about the effects of spinning conditions on the physical properties of vortex spun yarns. In the vortex spinning system, the ranges of the total draft ratio and main draft ratio vary depending on the yarn delivery speed, as it is determined by considering the circumferential velocities of roller pairs B and C, as shown in ***Figure 1*** [3]. In order to analyse the interactions of the draft ratio and delivery speed, a group of samples were spun at two delivery speeds.

Material and methods

38 mm viscose staple fibre of 1.3 dtex was used to produce 100% viscose yarns with a count of 14.76 tex. After the 3rd passage of drawing, slivers with three different linear densities were transferred to a MVS 861 vortex spinning machine, in which the values of spinning parameters shown in ***Table 1***.

In order to determine the role of draft ratios on the properties of vortex spun yarn, two levels of the intermediate draft ratio and three levels of the total draft ratio were selected, which resulted in obtaining yarn samples with six different main draft ratios. The break draft and other spinning parameters were kept constant. In addition to the intermediate draft and main draft ratios, two levels of yarn delivery speed were used to produce yarn samples with a total draft ratio of 216 so as to analyse the impact of both draft ratios and the delivery speed on yarn properties. The availability of machine parts and the possible spinning ranges of existing machinery were considered when selecting the values.

The yarn counts were determined using an SDL yarn count measurement device and an Uster Autosorter 4. The yarns were tested for irregularity and hairiness on the Uster Tester 4, and for tenacity and breaking elongation on the Uster Tensojet. Tests were carried out on ten bobbins for each yarn sample under standard atmospheric conditions. The average values of 50 test results are presented for the yarn count, 30 test results for the irregularity, imperfections and hairiness, as well as 100 test results for the tensile properties. The results were analysed statistically at a 95% level of confidence using SPSS 15.0.

Results and discussions

Effect of the draft on yarn properties

The properties of the yarn samples measured on the basis of yarn irregularity, imperfections, hairiness and tensile behaviour are reported in ***Table 2***.

A two way analysis of variance was used to identify the effects of the intermediate draft and total draft as well as their interactions on the properties of the yarn samples, the results of which are displayed in ***Table 3***. The effect of the interaction of the intermediate draft and total draft was found statistically significant for the yarn irregularity, imperfections, hairiness, elongation and work to break values ($p < 0.05$), that is to say the effect of the intermediate draft on these properties depends on which total draft ratio is being considered. Subsequently, contrast tests were carried out to determine significant differences among the yarn samples [12].

The effect of draft ratios on the physical properties of the yarn are demonstrated in ***Figures 2 - 9***. The results reveal that the effect of the intermediate draft is significant at higher total draft ratios in terms of yarn evenness and the amount of thin places. More even yarns and a less amount of thin places were obtained at a low intermediate draft.

The yarn sample spun with the highest main draft ratio using the vortex spinning system appears to have the best irregularity and the fewest thin places on the contrary to the findings, which concluded that a higher main draft produces fewer even yarns and more thin and thick places in MJS (Murata Jet Spinner) spun yarns [13, 14]. At this point, the results should be evaluated on the basis of the intermediate draft rather than main draft. Several works have dealt with the investigation of the effects of the drafting force and its variability in 3-line roller drafting systems on yarn quality and concluded that there is a limited break draft beyond which the drafting force decreases, and consequently an increase in the variation of the drafting force causes deterioration in yarn evenness, leading to an increase in yarn faults [15 - 19]. In this study, it is evident that an intermediate draft level of 2.5 is far beyond the optimum level, and the behaviour of yarn irregularity can be attributed to the fact that when working with an intermediate draft level of 2.5, the resistance of the fibre assembly, namely the drafting force in the drafting zone, was lower than the basic peak value achieved by the optimum draft level, causing poor fibre slipping performance. The consequent lower main draft was not enough to acquire an appropriate fibre arrangement along the yarn.

Although the interaction of the effects of the intermediate draft and total draft were found to be significant with regard to thick places, the trend was not clear with respect to draft ratios. Concerning the amount of neps, the lower the intermediate draft, the fewer neps occurred in

Table 1. *Yarn spinning conditions.*

Sample Code	1	2	3	4	5	6	7	8
3rd passage drawframe sliver count (ktex)	3.94		3.19		2.68		3.19	
3rd passage drawframe sliver Irregularity (CVm%)	3.07		2.92		3.34		2.92	
Total draft	267		216		182		216	
Main draft	58	53	47	43	40	36	47	43
Intermediate draft	2.3	2.5	2.3	2.5	2.3	2.5	2.3	2.5
Break draft	2							
Yarn delivery speed (m/min)	400						350	
Yarn count (tex)	14.8							
Nozzle air pressure (Mpa)	0.5							
Distance between front roller and the spindle (mm)	20							
Spindle inner diameter (mm)	1.1							
Needle holder type	8.8 L8							
Feed ratio – Take up ratio	1.00 – 0.99							
Roller settings (mm)	45-43-45-43							

Table 2. *Properties of yarn samples.*

Sample code	1	2	3	4	5	6	7	8
Yarn count, tex	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.7
Yarn count, CV%	0.48	0.58	0.62	0.51	0.58	0.53	0.56	0.52
Yarn irregularity, CVm%	13.88	14.47	14.52	14.89	14.63	14.68	14.25	14.39
Thin places, -50%/1,000 m	15	23	24	32	24	24	22	24
Thick places, +50%/1,000 m	45	51	50	75	47	40	35	33
Neps, +200%/1,000 m	54	79	67	66	68	61	67	63
Tenacity, cN/tex	16.67	16.56	16.30	16.39	16.43	16.46	16.66	16.61
Tenacity, CV%	3.98	4.30	3.45	3.50	4.05	3.51	3.83	3.54
Elongation at break, %	8.83	9.41	9.47	9.42	9.34	9.47	9.52	9.22
Elongation at break, CV%	5.52	5.95	5.24	5.25	6.16	5.27	5.45	4.69
Work to break, N.cm	7.66	8.01	7.92	7.93	7.89	8.03	8.09	7.85
Hairiness, H	3.51	3.41	3.44	3.46	3.51	3.51	3.18	3.23
Hairiness, sH	0.78	0.80	0.81	0.84	0.85	0.84	0.70	0.71

Table 3. *Results of two way analysis of variance for intermediate draft and total draft; (s - significant, ns - non-significant).*

Source of variance	CVm%	Thin places	Thick places	Neps	Hairiness	Tenacity	Elongation	Work to Break
Intermediate draft	s	s	ns	s	ns	ns	s	s
Total draft	s	s	s	ns	s	s	s	ns
Int. draft*Total draft	s	s	s	s	s	ns	s	s

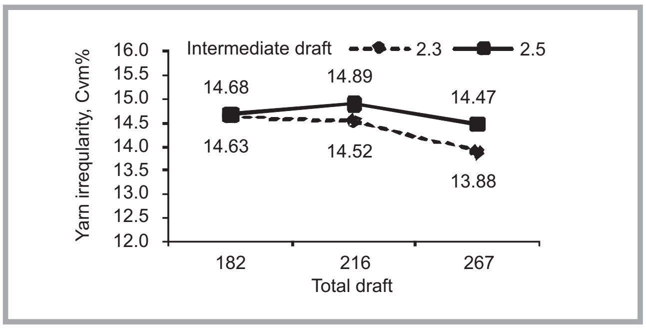

Figure 2. Effect of the draft on yarn irregularity.

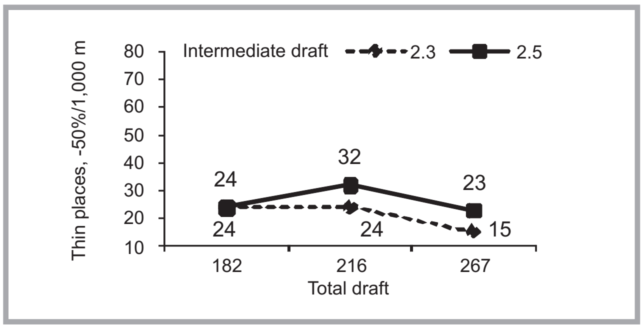

Figure 3. Effect of the draft on thin places.

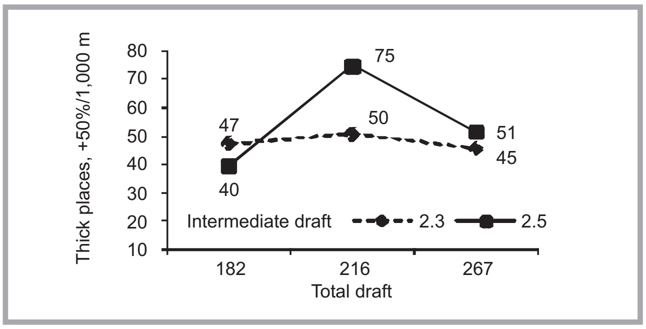

Figure 4. Effect of the draft on thick places.

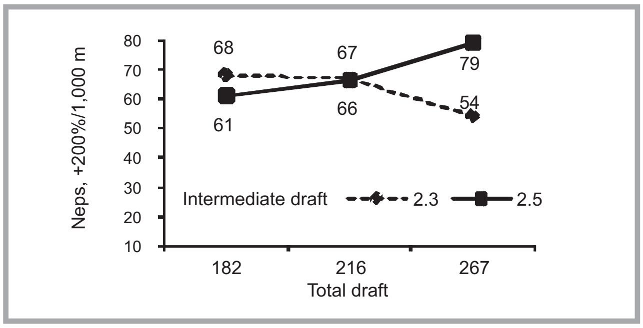

Figure 5. Effect of the draft on neps.

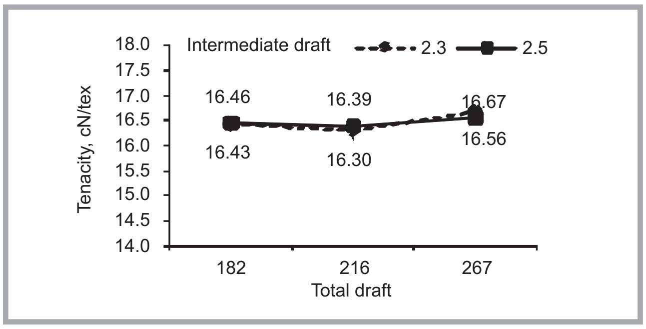

Figure 6. Effect of the draft on tenacity

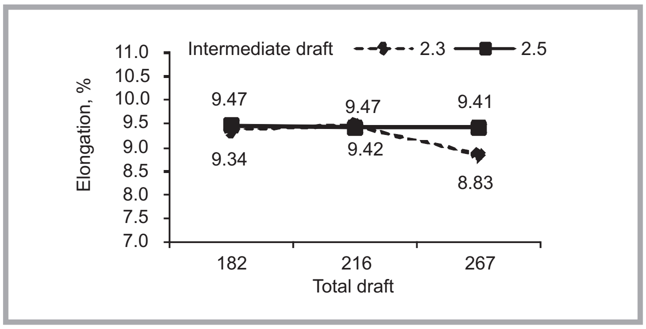

Figure 7. Effect of the draft on elongation.

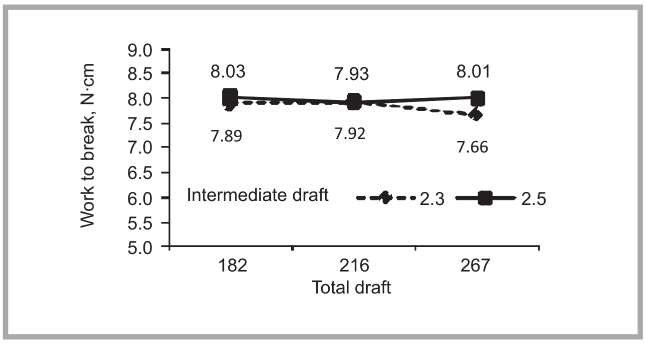

Figure 8. Effect of the draft on work to break.

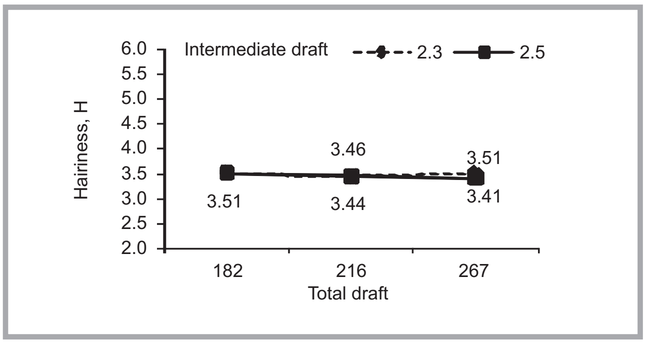

Figure 9. Effect of the draft on hairiness.

the samples spun with the highest total draft ratio.

While the interaction of the intermediate and total drafts did not have a significant impact on the tenacity of the yarn samples, applying an intermediate draft of 2.5 rather than 2.3 increased the elongation and work to break values in the case of the highest total draft ratio. According to the ANOVA results, the total draft influenced the hairiness not only as a main factor but also by means of interaction with the intermediate draft; however, the effect did not result in a proportional change.

Effect of the delivery speed on yarn properties

A 3rd passage draw frame sliver with a count of 3.19 ktex was spun into yarns of 14.76 tex using two different delivery speeds: 350 and 400 m/min. The results of the two way analysis of variance, which was employed to observe

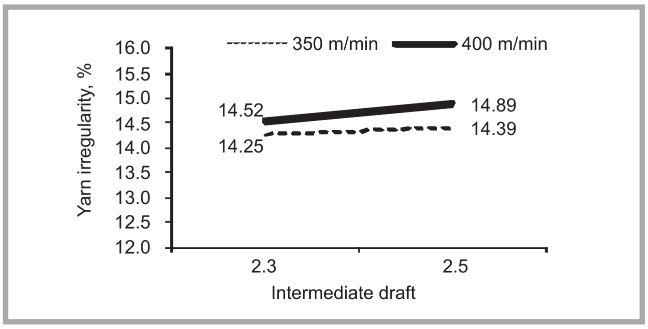

Figure 10. *Effect of the delivery speed on yarn irregularity.*

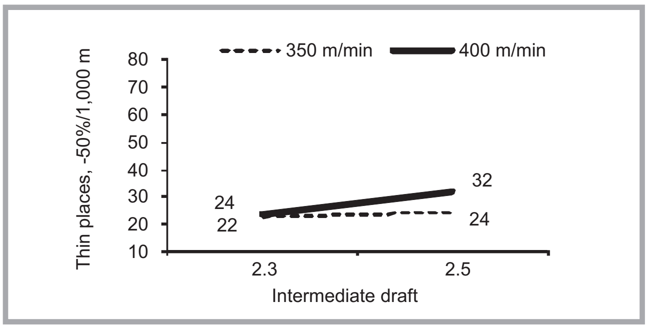

Figure 11. *Effect of the delivery speed on thin places.*

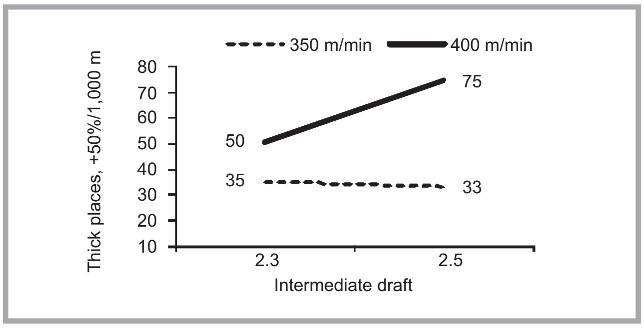

Figure 12. *Effect of the delivery speed on thick places*

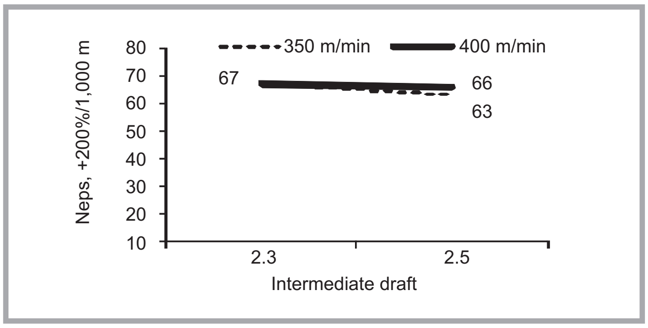

Figure 13. *Effect of the delivery speed on neps.*

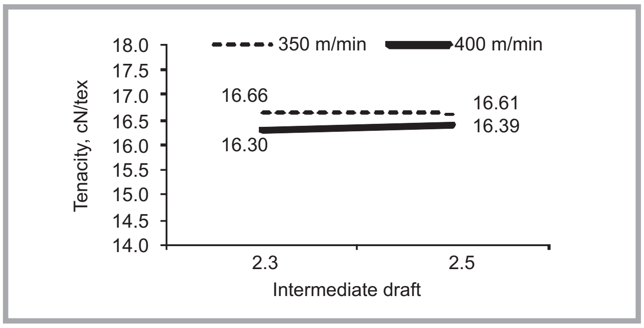

Figure 14. *Effect of the delivery speed on tenacity.*

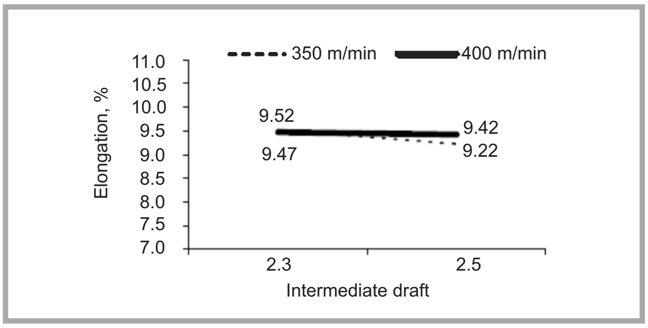

Figure 15. *Effect of the delivery speed on elongation.*

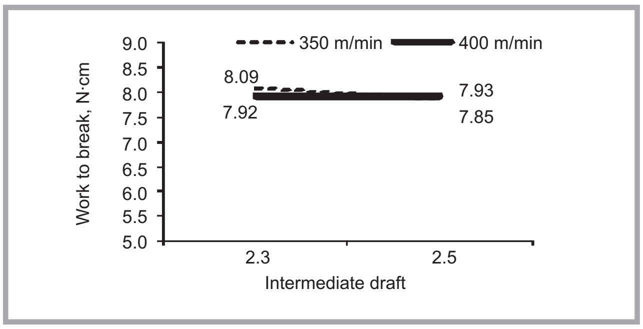

Figure 16. *Effect of the delivery speed on work to break.*

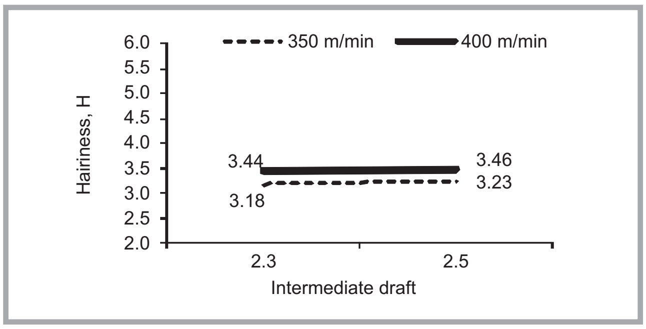

Figure 17. *Effect of the delivery speed on hairiness.*

the effect of the intermediate draft and delivery speed as well as their interactions on the physical properties of the yarn samples, are displayed in ***Table 4***. As the interactions of the following two independent variables: the intermediate draft and delivery speed had significant effects on yarn properties in terms of thin places, elongation and work to break, contrasts tests were used to identify significant differences between samples. Otherwise independent sample t-test was performed for pairwise comparisons of the samples to designate the simple main effects of the independent variables in cases where they were found to be significant. The effects of the variables on yarn properties are demonstrated in ***Figures 10 - 17*** (see page 42).

As mentioned in the previous part, better irregularity and fewer thin places were obtained with an intermediate draft level of 2.3 at the higher delivery speed. In other words, a higher main draft yielded better irregularity and lower imperfec-

Table 4. Results of the two way analysis of variance for the intermediate draft and delivery speed; (s: significant, ns: non-significant).

Source of variance	CVm%	Thin places	Thick places	Neps	Hairiness	Tenacity	Elongation	Work to Break
Intermediate draft	s	s	ns	ns	ns	ns	s	ns
Delivery speed	s	s	s	ns	s	s	ns	ns
Int. draft*Del. speed	ns	s	ns	ns	ns	ns	s	s

tions in terms of thin places at the higher yarn delivery speed. On the other hand, the intermediate draft did not have a significant impact on the mentioned yarn properties at a delivery speed of 350m/min; however, better results were obtained for both levels of the intermediate draft at a delivery speed of 350m/min when compared to the results obtained using a speed of 400 m/min.

Likewise, regarding irregularity and thin places, a lower yarn delivery speed resulted in fewer thick places in the yarn. However, as revealed in the results of the variance analysis, neither the intermediate draft nor the delivery speed had an impact on neps values of the samples.

The effect of delivery speed on yarn irregularity and imperfections is related to the efficiency of the air jet stream, and the reduced time for the fibre strand to pass through the nozzle at higher delivery speeds results in the deterioration of yarn properties in terms of irregularity and imperfections due to an increase in uneven and irregular wrappings as well as in the amount of wild fibres [4 - 7].

According to the t-test results, yarn samples that were spun at a delivery speed of 350 m/min had significantly higher tenacity irrespective of the intermediate draft level. In terms of elongation and work to break values, higher values were obtained with a low intermediate draft and delivery speed of 350 m/min. The hairiness results revealed that as the yarn delivery speed increases, hairiness also increases for both levels of the intermediate draft. Furthermore, using a low intermediate draft ratio resulted in lower hairiness at 350 m/min. Higher hairiness at an increased delivery speed is in agreement with earlier findings, which concluded that increased frictional forces acting on the yarn and the decreased efficiency of the air jet stream due to the reduced time for the fibres to whirl over the hollow spindle, as noted for yarn irregularity and imperfections, lead to higher hairiness values [4 - 7].

Conclusions

This paper mainly focused on the investigation of the effects of the intermediate draft, total draft, main draft, and delivery speed on the properties of viscose vortex spun yarn. The following conclusions were derived from the results of experimental analysis:

- While working with high levels of the total draft, i.e. using a heavy sliver, the lower the intermediate draft, the better the yarn evenness and thin place values obtained.
- Regarding tensile properties, the breaking elongation and work to break values were observed to be higher at an intermediate draft level of 2.5 in the case of the highest total draft (267); however, any significant difference was not observed in terms of tenacity.
- The results revealed that a high delivery speed deteriorated the physical properties of the yarns in terms of yarn evenness, thin places and tenacity. The lower the delivery speed, the better the yarn properties. Additionally, as the yarn delivery speed increased, hairiness also increased for both levels of intermediate draft.
- A low intermediate draft yielded better evenness and fewer thin places at a high level of yarn delivery speed.

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