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Characterisation of CVC Yarn with Different Drafting Ratios in Vortex Spinning

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Abstract

This study focuses on the impacts of the draft on the characteristics of MVS produced CVC blended yarn. The output of a finisher drawn sliver with a linear density of 3.54 ktex was converted into yarns of 18.45 tex (32 s/1 Ne) with the help of two separate delivery speeds: 350 and 410 m/min when possessing all constant spinning parameters. The properties of the yarn such as yarn anomaly, imperfections, tensile behaviour, and hairiness were investigated. The significance of independent variables and their relations with the physico-mechanical characteristics of CVC yarn was examined using two-way ANOVA at a 95% level of confidence.

Key words: *CVC yarn, vortex spinning, tex, draft, ANOVA.*

Introduction

Murata Vortex Spinning (MVS), the popular, successful and viable application of yarn technology, has become the most advanced development of air-jet spinning technology, which was first launched by the Murata Machinery Company in Japan at OTEMAS'97. With a rotor, air-jet, and ring spinning systems, this relatively new technology has great advantages. Furthermore, the removal of the roving processing phases and more output than other spinning systems form the principal features of this modern spinning technology [1, 2].

Typical characteristics of MVS are the ability to spin cotton fibre to obtain a ring-like yarn structure, as well as low hairiness, a reduced pilling tendency, high abrasion resistance, greater humidity absorption, and rapid drying properties of fabrics produced from vortex yarn. Due to these excellent characteristics, the setting up of MVS frames in operational mills is growing rapidly in the different regions of the world, which is highlighted by the recent air-jet spinning technology version [2-4].

The drawn sliver is shifted directly to a 4-line roller or apron drafting system in MVS spinning. The drafting zone consists of front rollers: L and M, middle rollers: M and N with controlling aprons, and one pair of back rollers: N and O, shown in ***Figure 1***. Drafted fibres, which are made into yarn, move through an air jet nozzle and hollow spindle [5-7].

Some researchers have investigated the function of different spinning parameters in developing an MVS yarn process-structure-property model that can be used for optimising and enhancing MVS technology [8-12]. Tyagi et. al. [13, 14] studied the impacts of spinning parameters on the low-stress features of vortex yarns, woven fabrics and thermal comfort. In addition, Ortlek et. al. [4, 8] studied the impacts of the spindle working time and spindle diameter on the characteristics of viscose vortex yarns as well as the influence of the delivery speed, nozzle pressures, and yarn count on the properties of vortex yarns produced using a Murata vortex spinning system.

In the vortex spinning method, the ranges of the total draft ratio and main draft ratio vary according to the delivery speed of the yarn, as defined by the circumferential speed of the middle roller pairs: M and N (***Figure 1***) [6]. A batch of samples was spun at two delivery speeds to evaluate the relations btween and dependency of the draft ratio and delivery speed.

From the literature review, it is found that several researches have been conducted on the characteristics of vortex spun yarn like 100% cotton & viscose and polyester-cotton blended yarn, but there is no research work exploring the properties of CVC vortex yarns spun using the MVS system. Thus, the key objective of this work was to analyse the impacts of draft ratios on the characteristics of vortex spun CVC yarns to provide extra features for spinners to adjust the spinning

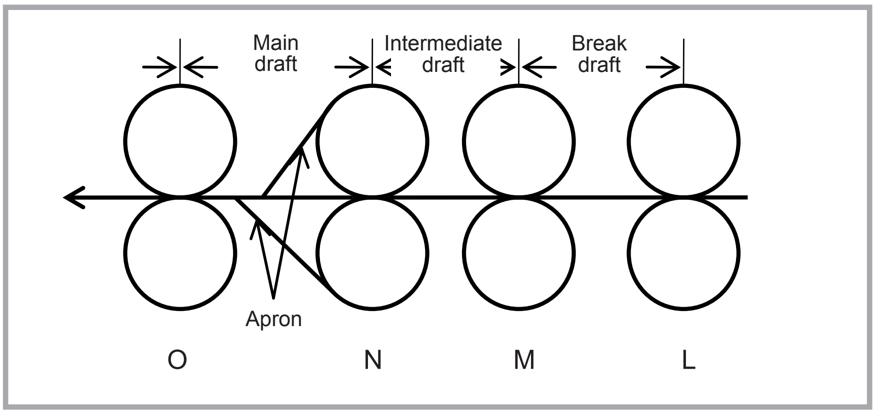

Figure 1. *Drafting arrangement of vortex spinning.*

process parameters before the process is started for making a better-quality yarn as per the requirements of the buyer. In addition, the secondary objective of this study was to establish a spinning method using spinner experience and also give a better understanding of the role of various inputs in the outputs.

Experimental

Materials

Blended CVC carded slivers were processed in a cotton processing sequence i.e. through carding, and finally on 1st, 2nd, and 3rd draw-frame machines. A 3rd drawn sliver (3.54 ktex) was spun by a Muratec Vortex III 870 spinning machine to produce a linear density of 18.45 tex (32 s/1 Ne) in CVC yarn. Properties of the polyester and cotton fibres used in this experiment are given in ***Table 1*** and ***2***.

Methods

On a Rieter blow room line, a predetermined amount of cotton (60%) and polyester (40%) fibres was processed. Using Rieter's Card C 70 and a Rieter draw-frame RSB D50, the conversion to a drawn sliver was carried out.1st, in which the 2nd, and 3rd draw passages were used for the carded sliver to produce a finisher sliver of 3.54 ktex. The output of the 3rd drawn slivers was spun into yarns on a Muratec Vortex III 870 (Japan) spinner, whose spinning parameter values are given in ***Table 3*** and ***4***. Three levels of the total draft and two levels of the intermediate draft were considered to estimate the position of the draft ratios in relation to the properties of CVC yarn, resulting in the acquisition of yarn with six different key draft ratios. The different spinning parameters and break draft were kept constant. Two yarn delivery speeds, two levels of the intermediate draft and the main draft were used to generate yarn with a total draft of 180, in order to analyse the effect on the yarn properties of both draft ratios and the delivery speed. Under each experimental condition, eight baby yarn packages of about 125 g each were prepared, respectively.

Fibre properties

Polyester fibre (Indro-rama) and medium staple cotton fibre (Brazil) were kindly supplied by Pahartali Textile & Hosiery Mills Ltd., Chittagong, Bangladesh. The fibre properties of both are illustrated in ***Table 1*** and ***2***.

Characterisation

An Uster Auto sorter 3 was used to calculate the yarn count and a Uster tester 6 for the study of CVm%, Um%, hairiness, thick and thin places, and neps. For the measurement of tenacity and elongation, a Uster Tenolab (Mesdan) was used. For each yarn sample, experiments on eight bobbins were carried out under normal atmospheric conditions [15]. Mean values of the different quality parameters of the yarn are tabulated in ***Table 5*** and ***6***. At a 95% confidence level, the findings were statistically analysed using SPSS 15.0.

ANOVA analysis

ANOVA is a mathematical investigation technique that divides experimental aggregate inconsistency contained in a dataset into two modules: random factors and systematic factors. Random factors do not affect the dataset generated, while

Table 1. *Polyester fibre properties.*

Characteristic	Value
Length, mm	38
Linear density, den	1.20
Tenacity, g/den	6.40
Breaking extension, %	22.0

Table 2. *Uster HVI1000 test report of cotton (Brazil) fibre properties.*

Fibre properties	Mean value
Spinning consistency index (SCI)	145
Staple length	29.85 mm
Uniformity index (UI)	83.6%
Fibre strength	32.7 g/tex
Elongation	5.50%
Micronaire value	4.5
Fineness	0.177 tex
Short fibre index (SFI)	8.5
Color grade (CG)	Middling
Moisture %	7.3%
Reflectance %	75.3%
Yellowness (degree)	9.4

Table 3. *Draw sliver unevenness (Um% and CV %) test report.*

Parameters	1st drawn sliver	2nd drawn sliver	Finisher drawn sliver
Drawn sliver fineness, ktex	3.94	3.60	3.54
Drawn sliver uniformity Um%	2.38	2.09	1.90
Drawn sliver irregularity CVm%	3.03	2.90	2.40

Table 4. *Experimental design for CVC yarn spinning*

Parameters	1	2	3	4	5	6	7	8
Total draft	260		210		180		210	
Main draft	45	43	38	36	36	34	38	36
Intermediate draft	1.56	1.76	1.56	1.76	1.56	1.76	1.56	1.76
Break draft	3.2							
Delivery speed (m/min) of the yarn	350				410			
Yarn count, tex	18.45							
Nozzle discharge angle	70^0							
Air pressure (Mpa) of the nozzle	0.50							
Distances (mm) between the spindle and the front roller	20							
Inner diameter (mm) of the spindle	1.10							
Holder type of needle	Orient							
Feed and take-up ratio	0.99-1.0							
Top roller gauge, mm	35-38-49							
Bottom roller gauge, mm	35-38-44.5							
Twisting jet pressure, kg/cm^2	5							

Table 5. *Physical properties of cotton-polyester (CVC) blended yarn processing using a Muratec vortex spinning machine.*

Sample features	1	2	3	4	5	6	7	8
Nominal yarn count, tex	18.45	18.45	18.45	18.45	18.45	18.45	18.45	18.45
Actual yarn count, tex	18.57	18.55	18.57	18.57	18.55	18.57	18.57	18.57
Yarn linear density CV%	0.46	0.45	0.45	0.50	0.51	0.52	0.45	0.52
Yarn irregularity, CVm%	14.83	15.49	15.53	14.86	15.62	15.67	15.29	15.38
Thin places, -50%/km	35	43	44	52	43	44	42	45
Thick places, +50%/km	63	69	68	70	65	58	53	51
Neps, +200%/km	75	88	82	84	86	82	86	84
IPI/km	173	200	194	206	194	184	181	180
Hairiness, H	4.52	4.41	4.44	4.46	4.51	4.50	4.19	4.64
Hairiness, -SH	1.0	0.99	1.0	0.98	0.95	1.01	0.93	0.99

Table 6. Tenacity and elongation % of cotton-polyester (CVC) blended yarn processing using a Muratec vortex spinning machine.

Sample features	1	2	3	4	5	6	7	8
Nominal yarn linear density, tex	18.45	18.45	18.45	18.45	18.45	18.45	18.45	18.45
Tenacity of the yarn (cN/tex)	15.77	15.52	15.27	15.41	15.53	15.45	15.65	15.59
Tenacity of the yarn CV%	8.99	8.8.2	8.44	8.15	8.51	8.54	8.50	8.82
Elongation at break, %	5.82	6.45	6.37	6.42	6.37	6.47	5.51	6.37
Elongation at break, CV%	12.46	12.46	12.24	12.25	12.08	12.11	11.27	11.51
Work-to-split, N.cm	7.66	8.01	7.90	7.92	7.88	8.01	8.05	7.80

Table 7. Effects of two-way analysis of variance for the intermediate draft and total draft. ***Note:*** *s – significant, ns – non-significant.*

Parameters	Intermediate draft	Total draft	Intermediate draft × Total draft
Yarn irregularity, CVm%	s	s	s
Thin places	ns	s	s
Thick places	s	s	s
Neps	s	s	s
Yarn tenacity	ns	s	s
Elongation at break, %	s	s	s
Work to split	s	s	s
Hairiness	s	s	s

Table 8. Effects of two-way analysis of variance for the intermediate draft and delivery speed. ***Note:*** *s – significant, ns – non-significant.*

Parameters	Intermediate draft	Delivery speed	Intermediate draft × Delivery speed
Yarn irregularity, CVm%	s	s	ns
Thin places	ns	s	s
Thick places	ns	s	ns
Neps	ns	ns	ns
Yarn tenacity	ns	s	ns
Elongation at break, %	s	ns	ns
Work-to-split	s	s	s
Hairiness	s	s	s

Table 9. Estimation of the blending ratio of the blended yarn.

Yarn count in tex	Theoretical Blending ratio (%) Cotton: Polyester	Sample weight in g	Weight of polyester in g	% of polyester	Actual blend composition Cotton: Polyester
18.45	60: 40	0.250	0.102	40.80	59.20:40.80

systematic factors have a predictive effect on the dataset. Predictors use the analysis of variance to assess the effect that independent variables in a regression analysis have on the dependent variable. The Fisher analysis of variance is also called ANOVA, which is a continuation of the t- test & z-test [16]. The word was first coined in 1925 in Fisher's book, "Statistical Methods for Research Workers" [17]. Two-way ANOVA is a one-way ANOVA extension that displays the effects of two independent variables on a dependent variable. In this experiment, two-way ANOVA was carried out at a 95% level of confidence.

Chemical analysis of the blends

The definite proportions of the blend were evaluated chemically according to the ASTM D276-12 method for estimation of the blend. The actual percentages of the blend were estimated chemically using 70% H_2SO_4 at s 250 °C temperature for 5 minutes, where the cotton was totally dissolved and the polyester remained insoluble [18]. All samples were extracted using a mixture of benzene (3:2) to extract oil and any finishing materials which were added during processing. Each blended sample was investigated twice and the mean value recorded, given in ***Table 9***.

Results and discussion

Impact on yarn properties of the draft

Table 5 and ***6*** display the properties of the yarn samples calculated based on yarn irregularity, imperfections, hairiness, and tensile behaviour. Hence, to describe the effects of the total draft and intermediate draft as well as their interconnections on the characteristics of the yarn samples, the findings of the two-way variance analysis were used, given in ***Table 7***. The impact of the interconnection between the total draft and intermediate draft was found mathematically significant for the yarn anomaly, thin and thick places, neps, hairiness, the extension at break and the work-to-split values (0.05 > P), and the conclusion was drawn that the impact of the intermediate draft on these properties depends on the total draft ratio being studied [19].

The impacts of the draft on the physico-mechanical characteristics of the yarn are depicted in ***Figure 2***.

The results reveal that the impact of the intermediate draft is responsive at higher total draft ratios in terms of the number of thin places and yarn evenness. A low intermediate draft created a smaller quantity of thin places and more even yarn (***Figure 2***).

Comparing the results, the yarn produced by the highest main draft with the help of the MVS method tends to have the most irregularity and the least thick & thin places. The findings should be determined at this stage on the basis of the intermediate draft rather than the main draft. A few works have investigated the impact of the drafting action on yarn quality as well as its inconsistency in 3-over-3 roller drafting systems and resolved that there is a restricted break draft above which the drafting action diminishes, with a subsequent upsurge in the variance of the drafting force, causing the yarn evenness to deteriorate and leading to a surge in defects of the yarn [20-24].

According to the ANOVA findings, the intermediate draft and total draft, not only as main factors but also through interaction with each other, affected the hairiness; however, the outcome was not a proportionate improvement. Nevertheless, the interrelation between the total drafts and intermediate drafts did not have a major effect on the tenacity of the samples.

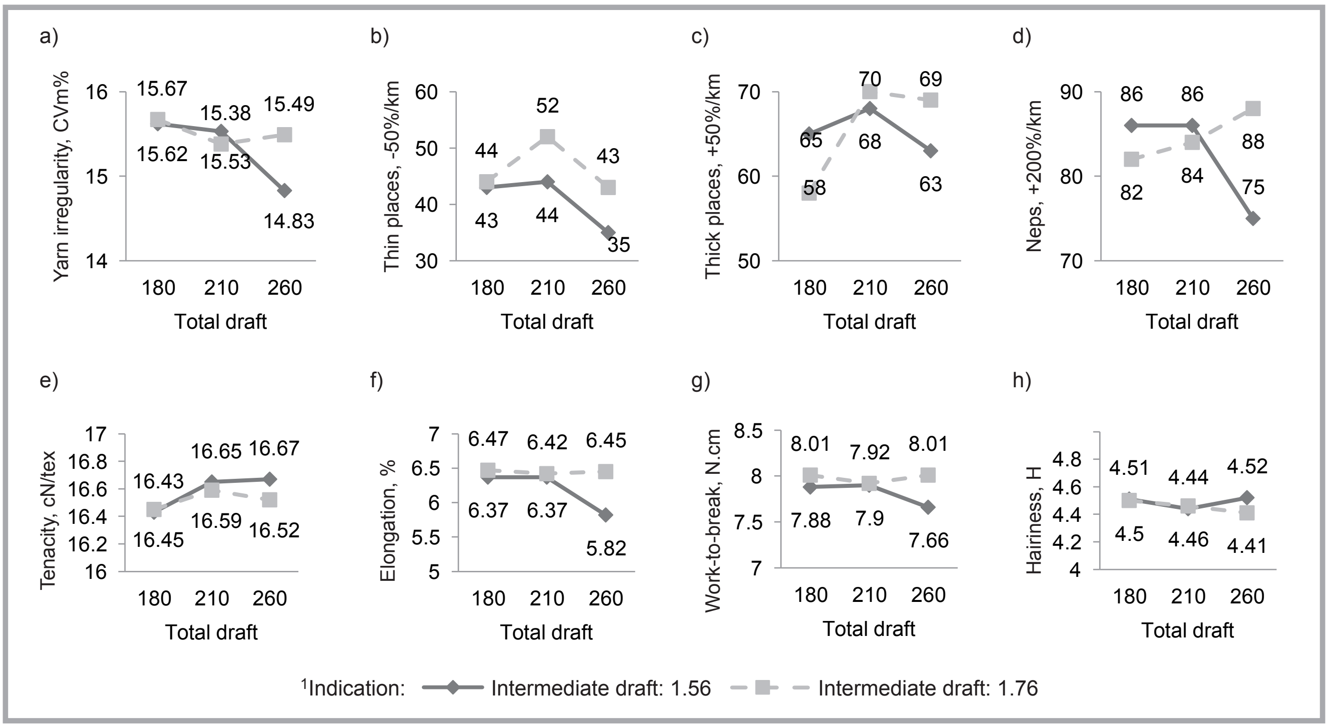

Figure 2. *Impact of the draft on yarn irregularity (a), thin places (b), thick places (c), neps (d), tenacity (e), elongation (f), work to break (g), and hairiness (h).*

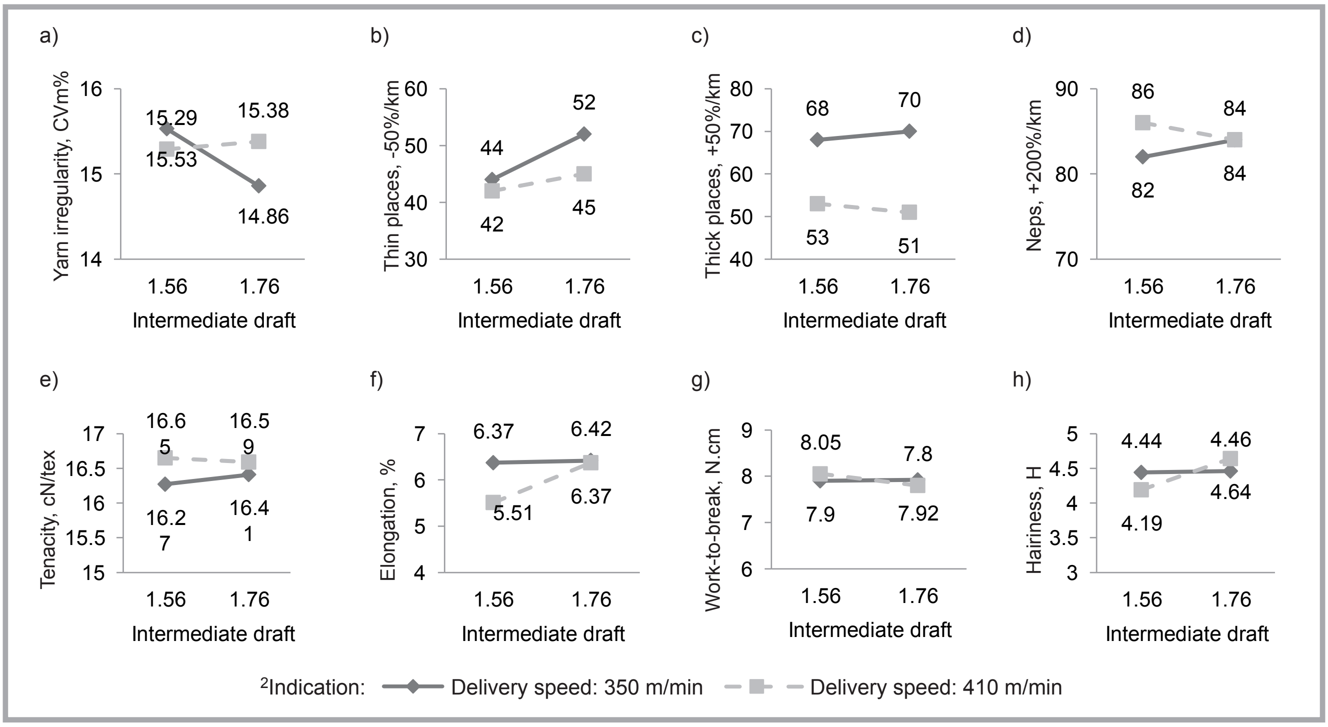

Figure 3. *Outcome of the delivery speed on yarn irregularity (a), thin places (b), thick places (c), neps (d), tenacity (e), elongation (f), work to break (g), and hairiness (h).*

Consequence of the delivery speed for yarn properties

Two separate delivery speeds were used: 350 and 410 m/min to spin a finisher drawn sliver with a linear density of 3.54 ktex into yarns of 18.45 tex. For ***Table 8***, two-way analysis of variance was used to observe the consequence of the delivery speed and intermediate draft along with their inter-relations among the different physical properties of the CVC yarn samples. In order to identify significant differences between samples, contrast experiments were used to identify the interactions between the two subsequent independent variables: the intermediate draft and delivery speed had a significant impact on yarn properties with regard to thin areas, extension and work-to-split. While for pair wise comparisons of the tests, an independent sample t-test was conducted to identify the basic impacts of independent variables in cases where they were deemed important. ***Figure 3*** displays the impact of the variables on yarn properties.

It is well known that a higher main draft generates lower irregularity and fewer imperfections for thin places at a higher speed of yarn delivery. Furthermore, at a speed of delivery of 350 m/min, the intermediate draft does not have a major effect on the yarn properties cited above; however, better results were gained at a delivery speed of 350 m/min for both levels of the intermediate draft, similar to results gained at a delivery speed of 410 m/min (***Figure 3***). Similarly, a lower yarn delivery speed resulted in fewer thick areas on the yarn in relation to inconsistencies and thin areas. As shown in the variance analysis findings, however, neither the intermediate draft nor the speed of delivery had an effect on the values of neps in the samples. Yarn samples that were produced at a delivery speed of 350 m/min had substantially greater tenacity, regardless of the intermediate draft stage, as per ANOVA test results. Higher values were found with a lower intermediate draft and delivery speed of 350 m/min for the extension and function-to-break values. The results of hairiness show that as the speed of yarn delivery increases, hairiness also increases for both levels of the intermediate draft [25].

Chemical analysis of the blends

The blending ratios of yarns based on the theoretical blending proportions of cotton-polyester CVC yarns spun on a Murata vortex spinning system investigated by the chemical method are shown in ***Table 9***. The results achieved show a high degree of precision in the exact compositions as estimated by the chemical method.

Conclusions

From the results of the experimental study, the following conclusions were derived: i) Concerning the yarn imperfections (IPI/km), the tensile behavior, breaking extension and work to split values were found to be higher at an intermediate draft of 1.76 than in the case of the highest total draft (260); but no substantial difference was detected with regard to yarn tenacity. ii) The results showed that the characteristics of the yarns with regard to yarn evenness, thin places, tenacity and hairiness were degraded by a high delivery speed. The lower the speed of delivery, the stronger the properties of yarn observed. iii) It can be noted that the actual blending ratio is slightly lower than that of the theoretical blending ratio, but the difference is insignificant. MVS yarns consist of maximum core fibres and the rest of wrapper and wild fibres. iv) The wrapper and wild fibres increase with an increase in the delivery speed and jet pressure. Thus, the blending performance of the MVS is satisfactory. Therefore, more emphasis should be put on the installation of MVS frames in operating mills to manufacture better cotton or polyester blended yarn for weaving and knitting less faulty textiles as per the demand of the buyer.

Acknowledgments

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