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Effect of MJS Spinning Variables on Yarn Quality
Vpliv nastavitve procesnih parametrov MJS curkovnega predilnika na kakovost preje

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Abstract
Air-jet spinning variables play a significant role in determining MJS (Murata Jet Spinner) yarn structure and quality. This research work is an attempt to highlight the effect of a few imperative MJS spinning parameters on yarn quality characteristics. In order to investigate the effect of the MJS spinning speed, first-nozzle pressure and feed ratio on resultant yarn quality parameters, a Box-Behnken experimental design for three factors and three levels was adopted for research design and sample preparation. An analysis of variance (ANOVA) was performed to test the statistical significance of all effects.
Keywords: spinning speed, first-nozzle pressure, feed ratio, air-jet yarn

Izvleček
Procesni parametri curkovnega predenja imajo pomemben vpliv na strukturo in kakovost preje, izdelane na curkovnem predilniku MJS Murata. Raziskava se osredinja na vplive nekaterih pomembnih parametrov MJS Murata curkovnega predenja na lastnosti preje. Priprava vzorcev za proučitev vplivov hitrosti predenja, tlaka v prvi šobi in dovajalnega razmerja na kakovost končne preje je temeljila na eksperimentalnemu načrtu po Box-Behnkenu za tri faktorje in tri stopnje. Z analizo variance (ANOVA) je bila preizkušena statistična pomembnost vseh učinkov.
Ključne besede: hitrost predenja, tlak v prvi šobi, dovajalno razmerje, curkovna preja

1 Introduction

The effect of MJS spinning variables on yarn quality has been studied by many researchers in the past. It has been demonstrated in air-jet spinning machines that yarn tensile properties improve with an increase in delivery speed and first-nozzle pressure up to a certain limit, but that yarn quality deteriorates due to an increase in imperfection levels [1–3].Yarn hairiness increases with an increase in spinning speed due to a reduced number of wrapper fibres, which become inadequate for binding all protruding fibres [4–6]. It has been reported that an increase in first-nozzle pressure significantly improves MJS yarn tenacity and breaking elongation [7]. The number of core fibres decreases, while wrapper, wild and wrapper-wild fibres increase with an increase in first-nozzle pressure. First-nozzle pressure has a significant effect on yarn evenness due to the increased concentration of mass in a very short length on account of an increasing number of wrapper fibres [8–9]. It is believed that the yarn uniformity will improve with an increased feed ratio. The optimum value was found to be 0.98 (ratio of the surface speed of the delivery roller to the surface speed of the front roller). It has been reported that fibre orientation improves with an increase in feed ratio [10–11]. MJS yarn flexural rigidity and abrasion resistance improve with an increase in feed ratio [11–13].

In order to study the effect of scrutinised MJS spinning variables on viscose yarn quality, spinning speed, first-nozzle pressure and feed ratio were taken into account. For this purpose, draw-frame sliver was processed precisely on a MJS machine during sample preparation.

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2 Materials and methods

2.1 Material

Air-jet spun viscose yarns of 14.76 tex were produced from 51 mm fibre length and 1.5 denier fibre fineness, taking into account a fibre density of 1.52 g/cm^3 Drawn viscose sliver hank of 3.28k tex was processed on a Murata air-jet spinner 802 machine for the preparation of yarn samples.

Preparation of yarn samples and experimental plan

In order to investigate the effect of MJS spinning variables on yarn quality parameters, a three-factor and three-level Box-Behnken experimental design technique was adopted for research design and the optimisation of the number of standard runs of manufactured yarn samples. The Box-Behnken design for three variables, together with the actual values of variables corresponding to the coded levels, is presented in Table 1 and Table 2 respectively. The most influential MJS spinning parameters, such as spinning speed, first-nozzle pressure and feed ratio, were shortlisted and taken into account as independent parameters to monitor their effect on dependent parameters, such as yarn unevenness and imperfections. The numerical values of each independent parameter were scrutinised in such a way that the difference between the low-to-middle and middle-to-high values remains constant, as seen in Table 2. An appropriate randomisation and replication technique was taken into account during sample preparation for an effective statistical analysis.

Conditioning of sample

The yarn sample was conditioned under standard atmospheric conditions, in a tropical atmosphere of 27 ± 2 °C and 65 ± 2% relative humidity, while the number of readings was determined according to the variation in the sample in order to achieve a 95% confidence interval.

2.2 Methods

Design of experiment

Table 1 and Table 2

Statistical analysis

The effect of the independent MJS spinning variables were statistically investigated using an ANOVA at a 95% confidence interval using statistical software. The independent factors taken into account were spinning speed, first-nozzle pressure and feed ratio to check for any statistically significance.

Yarn testing

Adequate numbers of yarn samples were tested taken into account a coefficient of variation. Yarn evenness and total imperfections, including thick +50%, thin –50% and neps +200%, were measured on a Star Evenness Tester, while maintaining a yarn speed of 50 m/min. Yarn hairiness was measured using a ZWEIGLE G565 instrument. An Instron tensile tester was used to test 20 samples per run of the single yarn strength and elongation percentage at break. Testing gauge length was kept at 500 mm at a 200 mm/min extension rate. Flexural rigidity was calculated using Owen's ring-loop method [14].

Table 1: Box-Behnken design for three variables

Standard runs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Spinning speed	–1	1	–1	1	–1	1	–1	1	0	0	0	0	0	0	0
First-nozzle pressure	–1	–1	1	1	0	0	0	0	–1	1	–1	1	0	0	0
Feed ratio	0	0	0	0	–1	–1	1	1	–1	–1	1	1	0	0	0

Table 2: Actual values of variables corresponding to the coded levels

Variables	–1	0	+1
Spinning speed [m/min]	150	170	190
First-nozzle pressure [kg/cm^2]	2	2.5	3
Feed ratio	0.96	0.97	0.98

3 Results and discussion

Table 3: Box-Behnken sample design, together with variables and their corresponding responses

Runs	Variables			Responses				
	Spinning speed [m/min]	First-nozzle pressure [kg/cm^2]	Feed ratio	U [%]	Total imperfections	Tenacity [g/tex]	Flexural rigidity [g·cm^2×10^{-3}]	Hairiness [S3hairs/ 100 m]
1	–1	–1	0	12.29	200	8.81	1.59	130
2	1	–1	0	14.10	304	9.38	2.58	155
3	–1	1	0	13.02	424	9.71	1.87	86
4	1	1	0	15.20	488	9.67	3.65	127
5	–1	0	–1	12.80	400	8.51	1.55	110
6	1	0	–1	14.50	520	7.77	2.62	155
7	–1	0	1	12.90	304	9.73	1.89	112
8	1	0	1	14.50	376	10.31	2.9	152
9	0	–1	–1	13.10	272	6.72	1.92	170
10	0	1	–1	14.20	544	9.31	2.15	121
11	0	–1	1	12.62	208	9.35	2.39	175
12	0	1	1	13.60	408	9.98	2.44	123
13	0	0	0	12.46	216	6.41	1.5	154
14	0	0	0	12.56	228	6.69	1.54	149
15	0	0	0	12.61	240	6.92	1.57	145

Table 4: ANOVA of MJS yarn quality parameters

Spinning variables	Effects				
	U [%]	Total Imperfections	Tenacity [g/tex]	Flexural rigidity [g·cm^2×10^{-3}]	Hairiness
Spinning speed [m/min]	0.00[a)], s [b)]	0.00, s	0.00, s	0.00, s	0.00, s
First-nozzle pressure	0.00, s	0.00, s	0.00, s	0.00, s	0.00, s
Feed ratio	0.00, s	0.00, s	0.00, s	0.03, s	0.62, ns[c)]

[a)] p-value
[b)] significant if $p < 0.05$ at a 95% confidence interval
[c)] ns- not significant if $p > 0.05$

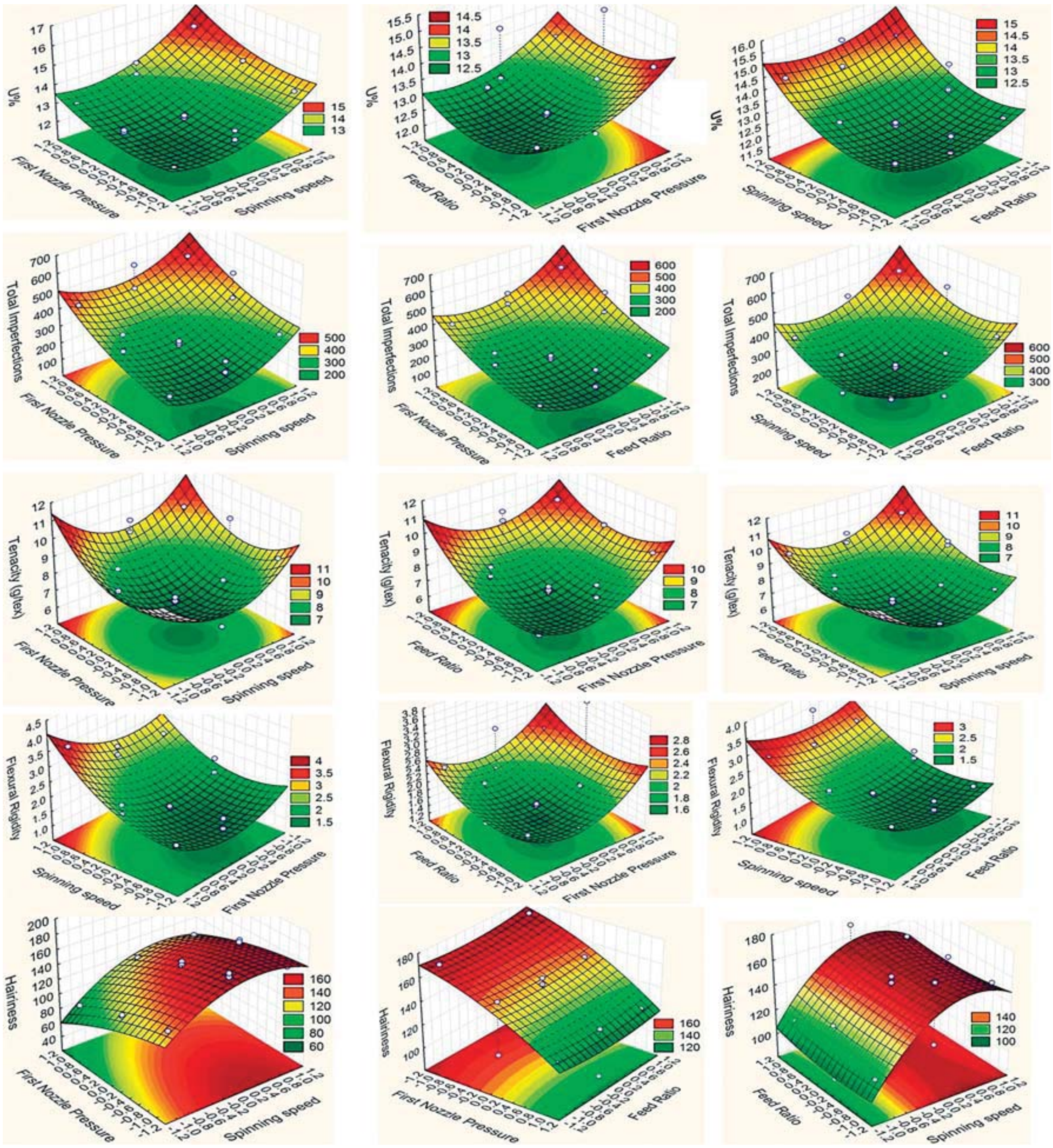

Figure 1: Effect of spinning variables on MJS yarn quality parameters

3.1 Effect of spinning speed on MJS yarn quality

At a high spinning speed, the air flow at the front roller nip causes the edge fibres to move away from the main bundle of fibres and increase the proportion of wrapper fibres. For this reason, yarn hairiness increases with an increase in spinning speed from 150 m/min to 190 m/min. Yarn unevenness increased slightly from 150 m/min to 170 m/min, while a further increase in spinning speed resulted in an increased number of imperfections in yarn, and thus, contributes to a deterioration in yarn quality, as seen in high level of unevenness. The interpretation of the experimental results shown in figure 1 reveals that yarn strength improves with an increase in spinning speed from 170 m/min to 190 m/min, but that yarn unevenness and total imperfections also increase. Yarn tenacity and flexural rigidity also increase slightly at a higher spinning speed due to the presence of more wrapper fibres and a compact yarn structure. Analysis of variance confirms the experimental findings.

3.2 Effect of first-nozzle pressure on MJS yarn quality

First-nozzle pressure has a significant effect on yarn structure, and due to an increased concentration of mass in a very short length as the result of an increasing number of wrapper fibres at a higher first-nozzle pressure. Thus, yarn hairiness decreases with an increase in first-nozzle pressure. It was observed that yarn unevenness and the total number of imperfections increases with an increase in first-nozzle pressure. Moreover, an increase in first-nozzle pressure will lead to an increase in yarn tenacity, while increased flexural rigidity may be due to the presence of an increased number of wrapper fibres.

3.3 Effect of feed ratio on MJS yarn quality

It was observed that there is no significant change in yarn quality characteristics with a change in the feed ratio from 0.96 to 0.98. However, the twist level of the yarn increases at a lower feed ratio, resulting in a harsher yarn.

4 Conclusion

It was observed that the spinning speed and first-nozzle pressure have a significant effect on MJS yarn quality parameters, while the feed ratio has a marginal effect on yarn quality parameters. The experimental results demonstrate that both unevenness and total imperfection increase with an increase in spinning speed and first-nozzle pressure. This study shows that an increase in spinning speed results in an increase in yarn hairiness, while the latter decreases with an increase in first-nozzle pressure. The effect of spinning variables on yarn tenacity and flexural rigidity was found to be marginal.

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