Mansoura University
Faculty of Engineering
Mansoura Engineering Journal

Interaction of Spinning Parameters in Rieter Air-Jet Fabric Properties

التفاعل بين متغيرات غزل نفث الهواء بنظام ريتر وخواص الأقمشة

M. Eldeeb and A. Fouda

KEYWORDS:
air-jet spinning, yarn, fabric, knitting, bursting force, coefficient of friction, geometric roughness

الملخص العربي: **أطلقت شركة ريتر أحدث طريقة لغزل الخيوط بطريقة نفث الهواء. تتناول هذه المقالة تأثير التفاعل بين مختلف متغيرات عملية الغزل مثل سرعة الإنتاج، والكثافة الخطية للغزل، وضغط الفوهة على خصائص أقمشة التريكو السادة. أظهرت النتائج أن الكثافة الخطية للغزل لها أقصى تأثير على قوة انفجار القماش ومقاومته للتآكل تليها سرعة الإنتاج وضغط الفوهة. بشكل عام، الأقمشة المصنوعة باستخدام النمر الرفيعة ضعيفة، ومقاومتها للتآكل منخفضة، وسطحها ناعم. باستخدام سرعات إنتاج عالية تتأثر قوة انفجار القماش ومقاومته للتآكل سلبياً. علاوة على ذلك، من خلال زيادة ضغط الفوهة، تتحسن مقاومة تآكل القماش إلى مستوى معين ثم تتدهور عندما يقترب ضغط الفوهة من 6 بار.**

***Abstract*—The newest method of air-jet spinning is launched by Rieter. This article examines the interaction effect of various spinning process parameters such as delivery speed, yarn linear density and nozzle pressures on single Jersey knitted fabric properties. Results show that yarn linear density has the maximum effect on fabric bursting strength and abrasion resistance followed by delivery speed and nozzle pressure. Generally, fabrics made using fine counts are weak, low abrasion-resistant and their surface are smooth. Using high yarn delivery speed affected fabric bursting strength and abrasion resistance negatively. Moreover, by increasing nozzle pressure, the fabric abrasion resistance improves to a specific level then it deteriorates when nozzle pressure approaches 6 bar.**

I. INTRODUCTION

Ring spinning is the most common system among all available spinning systems. However, the air-jet spinning system is an emerging technique that competes with the classic ring spinning system. The major advantage of air-jet spinning is its high production speed along with low production cost. Since it started, this system was significantly developed, beginning with the tandem spinning through air-jet spinning and finally by air vortex spinning.

Recently, Rieter introduced the Rieter Air-jet Spinning machine (J20) that uses a different technique than its predecessor Murata to produce air-jet yarns. Numerous researches have been carried out to study the influence of process parameters on MVS yarn properties [1-6].

There are also available researches that have been carried out regarding the effect of Murata Vortex Spinning machine process parameters on the final fabric properties. They concluded that using fine yarns decreases the fabric coefficient of friction and compressional energy. Furthermore, increasing nozzle pressure from 4 to 6 bar results in an initial decrease in the coefficient of friction, compressional energy and shear energy followed by an increase in these properties at high pressures [7-8].

Yet, there are no available references about the role of the spinning process parameters on fabric properties made using the Rieter air-jet spinning machine. Therefore, the present article aims at studying the influence of Rieter air spinning machine parameters namely, delivery speed, yarn linear density

Received: (10 March, 2020) - revised: (16 July, 2020) - accepted: (21 July, 2020)

Moaaz Eldeeb, Lecturer at Textile Engineering Department, Faculty of Engineering, Mansoura University, 25 Elgomhoria St., Mansoura, Dakahlia Governorate, 35516, Egypt.

Abd El Monem Faheem Fouda, Lecturer at Textile Engineering Department, Faculty of Engineering, Mansoura University, 25 Elgomhoria St., Mansoura, Dakahlia Governorate, 35516, Egypt.

Corresponding Author: Moaaz Eldeeb, Eldeeb.moaaz@gmail.com

and nozzle pressure on single Jersey knitted fabric properties.

II. Material and Method

100% Viscose fibers (38 mm) were spun to produce air-jet spun yarns. After the carding process, the sliver was drawn using three consecutive drawing passages in order to enhance fiber orientation and sliver evenness. The sliver of 3.5 ktex drawn was spun using a Rieter air-jet spinning machine J20 (Switzerland) to produce yarns with different counts and machine parameters.

TABLE I
Spun yarn production parameters.

Parameters / Level code	-1	0	1
Yarn count, Tex	16	23	30
Delivery speed, m/min	350	400	450
Nozzle pressure, bar	4	5	6

The Box-Behnken factorial experimental design is an efficient method to reduce the number of experiments required to study the parameters and their combined effect, and in the current study, it was used to obtain the combination of yarn count, delivery speed and nozzle pressure. Table I shows the chosen parameters and their values. It is notable to mention that spinning one sample with the level code (-1, 1, 0) was impractical because the end breakage rate was very high, which obstructed the spinning process. Therefore, 12 yarn samples were spun.

Yarn diameter was measured using Uster tester according to ASTM D1425. Plain single Jersey knitted fabric was produced using these yarns maintaining the same fabric tightness factor for all samples according to the specifications shown in Table II. For this purpose, SNOER WSD-6FPT, 5-inch sample knitting machine having a gauge of 25 with a single yarn feeding system was used. Afterward, fabric samples were conditioned in the standard conditions before testing. The fabric thickness was measured according to ASTM D1777 – 96 (2019). Fabric samples were weighed using a digital balance of two decimal digits accuracy.

Fabric bursting strength was measured using Testometric M350-10CT according to ISO 13938-2. Fabric abrasion resistance was evaluated using Martindale pilling and abrasion tester according to ASTM 4966. Five readings were recorded for each fabric sample and the mass weight loss ratio was calculated after 10,000 rubbing cycles.

As spinning parameters affect yarn and fabric properties, and in order to evaluate the extent of spinning parameters on fabric handle, fabric surface properties including surface roughness and friction coefficient were tested using the KES-FB4 Surface Tester. Ordinary least squares regression model was used to analyze the test results and to obtain the regression equation (1).

TABLE II
Knitted fabric constructional characteristics.

Sample code	Actual count (TEX)	Delivery speed (m/min)	Nozzle Pressure (Pa)	Loop length (mm)	Stitches density (stitches/inch^2)	Tightness factor (tex$^{1/2}$/cm)	Fabric weight (gm/m^2)	Thickness (mm)
1	15.9	350	5	3.2	1254	12.5	96	48.6
2	15.6	400	4	3.1	1292	12.7	90	50
3	16.4	400	6	3.2	1270	12.7	93	49.6
4	22.6	350	4	3.8	930	12.5	132	59
5	22.6	350	6	3.8	992	12.5	124	58.4
6	22.6	450	4	3.8	965	12.5	114	57.8
7	22.7	450	6	3.8	983	12.5	122	57.6
8	22.4	400	5	3.8	1040	12.5	117	56.2
9	29.4	350	5	4.3	728	12.6	140	69.8
10	29.4	450	5	4.3	672	12.6	133	66.8
11	29.5	400	4	4.3	713	12.6	134	67.6
12	29.4	400	6	4.3	680	12.5	139	68.8

TABLE III
Spun yarn production parameters.

Property	Response surface equation	Squared multiple regression coefficient (R^2)	P-value
Yarn diameter (mm)	$0.001+0.008X_1+0.00037X_2-0.0006X_3-0.0000057X_1X_2+0.00007X_1X_3-0.00009X_2X_3-0.00003X_1^2+6E-7X_2^2+0.0025X_3^2$	99.9	0.00
Bursting force (N)	$57.9+39.5X_1-1.1X_2-24.5X_3+0.016X_1X_2-1.4X_1X_3+0.15X_2X_3-0.7X_1^2-0.0001X_2^2-0.5X_3^2$	97.4	0.00
Weight loss (%)	$57.8-0.6X_1+0.028X_2-18.9X_3+0.001X_1X_2+0.036X_1X_3+0.01X_2X_3+0.00047X_1^2-0.0001X_2^2+1.35X_3^2$	85.3	0.00
Coefficient of friction (-)	$-0.04-0.003X_1+0.0007X_2+0.006X_3+0.000004X_1X_2+0.00008X_1X_3-0.00002X_2X_3+0.00003X_1^2-9.7E-7X_2^2-6.3E-11X_3^2$	85.3	0.00
Geometric roughness (µm)	$-19.7-0.025X_1+0.08X_2+1.9X_3-0.0002X_1X_2+0.001X_1X_3-0.0015X_2X_3+0.003X_1^2-0.00009X_2^2-0.14X_3^2$	96.8	0.00

X1: Yarn count (Tex), X2: Yarn delivery speed (m/min), X3: Nozzle pressure (bar)

$$Y = \beta_0 + \beta_i X_i + \beta_j X_j + \beta_k X_k + \beta_{ij} X_i X_j + \beta_{ik} X_i X_k + \beta_{jk} X_j X_k + \beta_{ii} {X_i}^2 + \beta_{jj} {X_j}^2 + \beta_{kk} {X_k}^2 \quad (1)$$

Where Y is the dependent variable, X_i, X_j, X_k are independent variables, β_0 is the regression equation constant, $\beta_i, \beta_j, \beta_k$ are the linear coefficients, $\beta_{ij}, \beta_{ik}, \beta_{jk}$ are the interaction coefficients and $\beta_{ii}, \beta_{jj}, \beta_{kk}$ are the quadratic coefficients

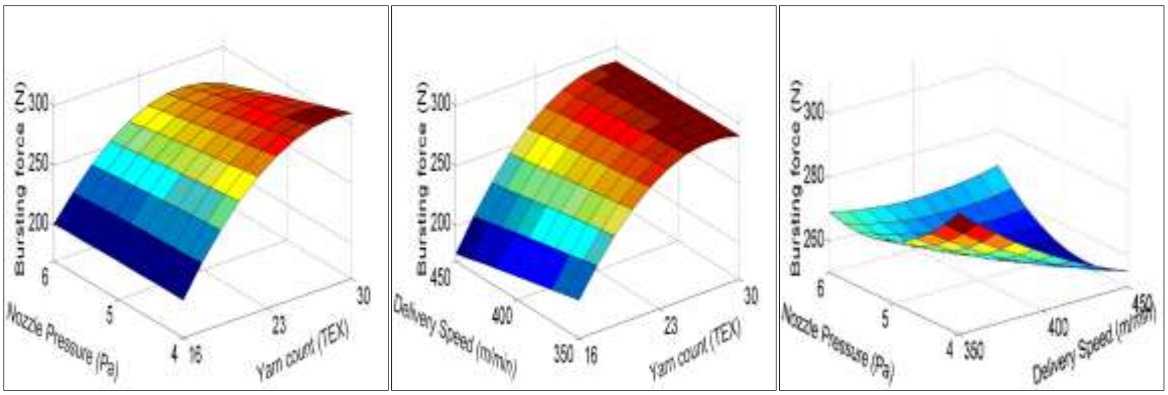
III. Results and Discussion

A. *Bursting strength*

Table III presents the response surface equations for the tested fabric properties. By using this model, it is possible to predict fabric property based on yarn count X_1, yarn delivery speed X_2 and nozzle pressure X_3. Since the P-value in the ANOVA results is less than 0.05, there is a statistically significant relationship between the variables at the 95.0% or higher confidence level. Figure 1 shows the influence of linear density, delivery speed and nozzle pressure on fabric bursting force. It is obvious that the linear density has a maximum effect on fabric bursting strength. Except for some differences when using different nozzle pressure, results show that air-jet fabrics bursting strength almost follows the strength trend of its corresponding yarn tenacity reported earlier [9].

As shown in Figure 1, coarser knitted fabrics made of 30 Tex yarns have higher bursting strength by about 50% than finer fabrics made of 16 Tex yarns and this is because increasing number of fiber in yarn cross-section resulted in increasing the proportion of core fibers that bears the load exerted on the single yarns during the loading process. Regarding nozzle pressure, Figure 1-a shows that for coarse yarns, fabric bursting strength decreases gradually when nozzle pressure increases from 4 to 6 bar and this is because high pressure causes the incidence of irregular wrappings and the creation of wild fibers. However, no significant difference is recorded when using fine yarns 16 Tex.

Continuous Increase in yarn delivery speed shown in Figure 1-b resulted in decreasing fabric bursting strength by about 12.5% and this result is mainly attributed to the fact that the insufficient time for the whirling action to take place in the vortex chamber leads to portions of the yarn which has unwrapped core fibers. However, this effect is not seen when using coarser yarns, whereas the value of the bursting strength did not change markedly.

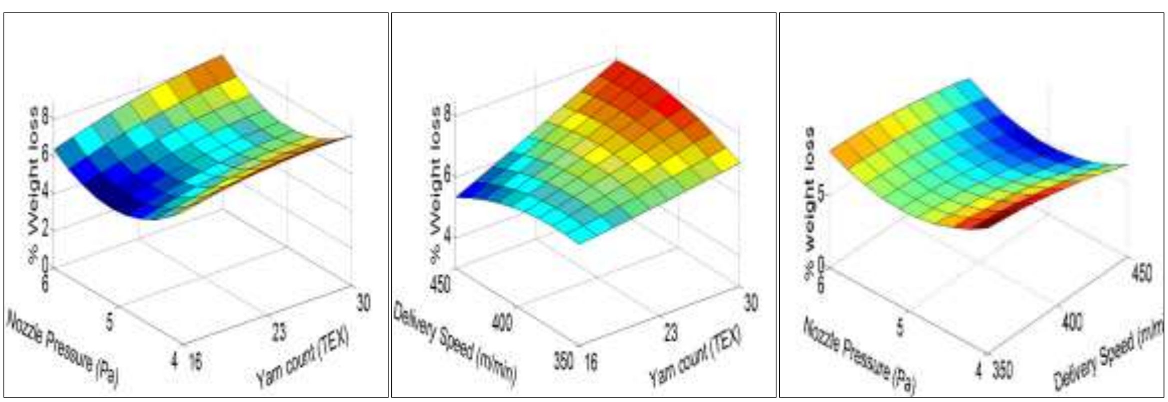


(a) (b) (c)

Fig. 1. Effect of yarn count, nozzle pressure and delivery speed on fabric bursting force.

B. *Abrasion resistance*

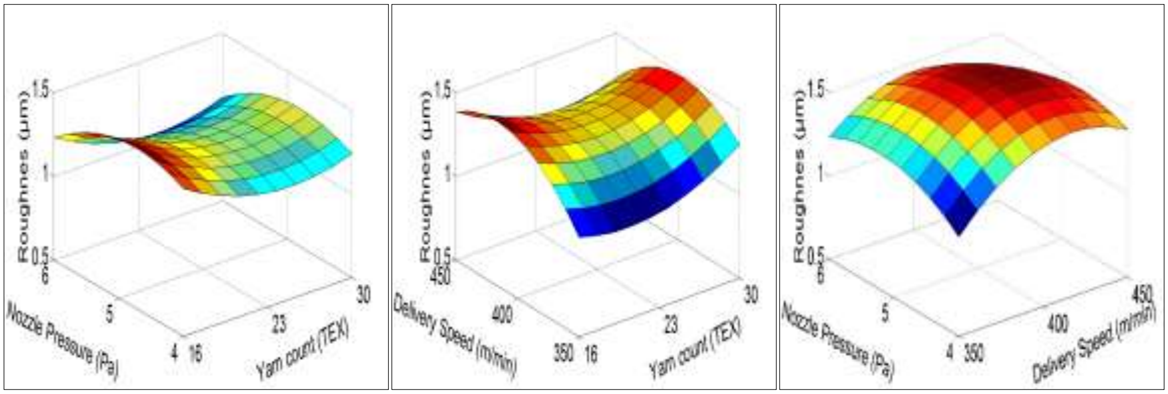
Figure 2 shows the effect of nozzle pressure, delivery speed and yarn count on percentage fabric weight loss due to continuous abrasion cycles. It is clear from Figure 2-a that increasing nozzle pressure from 4 to 6 bar initially reduces percentage fabric weight loss i.e. improve fabric abrasion resistance but at high pressure, % weight loss eventually increases again. At low nozzle pressure 4 bar, the low number of twist exists in the yarn cannot resist the abrasive cycles. At 5 bar, the fiber twist increases and sheath fibers are wrapped tightly and regularly so that it can resist the abrasion forces.



(a) (b) (c)

Fig. 2. Relationship between yarn count, delivery speed, nozzle pressure, and fabric abrasion resistance.

When using 6 bar pressure, yarn abrasion resistance and tenacity reported earlier [9] decrease, hence, fabric abrasion resistance deteriorates. It is evident that fabric abrasion resistance deteriorated by about 30-40% when yarn count changed from 16 to 30 Tex, since yarn abrasion resistance is affected by yarn count. Besides, this is due to the increase in hairiness in fabrics knitted from coarse yarns that help the fibers come out off the yarn body by the rubbing action of the abrasive surface. Regarding the effect of delivery speed, as shown in Figure 2-b, increasing the delivery speed resulted in a deterioration in fabric abrasion resistance by about 14% while this trend is not observed with fabrics knitted using fine yarn counts.



(a) (b) (c)

Fig. 3. Influence of nozzle pressure, yarn count and delivery speed on fabric roughness.

C. *Surface roughness*

As the general trend of fabric coefficient of friction is almost similar to fabric surface roughness, the influence of spinning parameters on fabric surface roughness only is shown in Figure 3. It indicates that all parameters affect fabric roughness. Results show that changing yarn count from 16 to 30 Tex resulted in a slight reduction in fabric roughness followed by an increment at coarser fabrics.

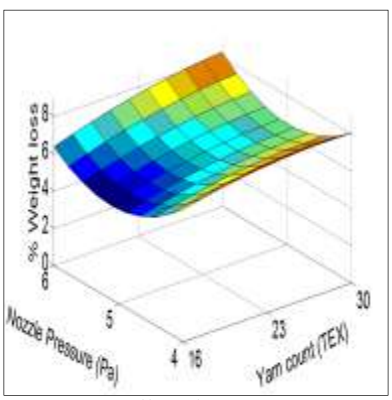


Fig. 4. The combined effect of nozzle pressure and delivery speed on yarn diameter.

Fabric knitted from yarns spun with high nozzle pressure is smother than their counterpart spun with low nozzle pressure due to the presence of an area of yarns covered tightly with wrapper fibers. In addition, the fabric produced using yarns spun with high delivery speed exhibits high roughness values and this is attributed to the improper and irregular wrapping, which exists in the yarns, spun using high delivery speed.

The previous trend can also be explained by observing the variation of yarn diameter at different spinning parameters as shown in Figure 4. It is evident that increasing nozzle pressure resulted in reducing yarn diameter by about 15% while increasing delivery speed resulted in increasing yarn diameter by about 20%. In Fabric, if the constituent yarn diameter is big, the total gap area between the fabric surface and the friction surface enlarges, so the load shared by each contact point will be more, therefore, the fabric coefficient of friction increases and the fabric becomes rougher. However, these conclusions are limited to the used row material (Viscose) and the count range (16-30 Tex).

IV. CONCLUSION

In this paper, the interaction of various Rieter air-jet spinning process parameters on single Jersey knitted fabric properties has been studied. Results show that yarn linear density has the maximum effect on fabric bursting strength and abrasion resistance followed by delivery speed and nozzle pressure. Generally, fabrics made using fine counts are weak, low abrasion-resistant and their surfaces are smooth. Using high yarn delivery speed affected fabric bursting strength and abrasion resistance negatively. Moreover, by increasing nozzle pressure, the fabric abrasion resistance improves to a specific level then it deteriorates when nozzle pressure approaches 6 bar.

ACKNOWLEDGEMENT

We would like to show our gratitude to the KTT Department, Faculty of Textiles, Technical University of Liberec, Czechia, for helping us conducting the testing processes.

REFERENCES

[1] Huseyin O., and Sukriye U., Effect of some variables on properties of 100% cotton vortex spun yarn, Textile Research Journal, 2005; 75:458-461.

[2] Johnson W., The impact of MVS machine settings and finishing applications on yarn quality and knitted fabric handle, MSc. Thesis, Institute of Textile Technology, Charlottesville, 2002.

[3] Guldemet B., and William O., effects of some process parameters on the structure and properties of vortex spun yarn, Textile Research Journal, 2006; 76:492-499.

[4] Nazan E., and Bulent O., Effect of the draft ratio on the properties of vortex spun yarn, FIBRES & TEXTILES in Eastern Europe, 2010; l:38-42.

[5] Huseyin O., Fehmi N., et al., Effect of spindle diameter and spindle working period on the properties of 100% viscose MVS yarns, FIBRES & TEXTILES in Eastern Europe 2008; 16:17-20.

[6] Tyagi K., and Dhirendra S., and Salhotra K., Process-structure-property relationship of polyester-cotton MVS yarns: Part II-Influence of process variables on yarn characteristics, Indian Journal of Fibre & Textile Research. 2004; 29:429-435.

[7] Yukihiro S., and Sachiko S., Mechanical and tactile properties of plain knitted fabrics produced from rayon Vortex yarns, Textile Research Journal, 2013; 83(7):740-751.

[8] Tyagi G.K., and Sharma D., low-stress characteristics of polyester-cotton MVS yarn fabrics, Ind. J. Fibre & Text. Res., 2005; 30: 49-54.

[9] Eldeeb, Moaz, and Ali Demir. "Optimising the production process of Rieter air-jet spun yarns and a model for prediction of their strength." Fibres & Textiles in Eastern Europe (2018).