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Correlation of Yarn Tension with Parameters in the Knitting Process

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Abstract: Tension control is an important factor in producing high quality knitted products and in maintaining good processing condition. Yarn tension during knitting is subject to be affected from many elements of the machine and process parameters. Several factors including yarn feeding speed, feeding angle, and needle gauge that are considered to influence on the tension variation were investigated. Yarn feeding speed did not show high contribution to the tension variation but feeding angle of yarn did show high correlation with the tension. No or negative correlation of the tension with needle gauge was found from the results. In order to keep well-determined process condition in the knitting manufacturing, it is strongly suggested that all knitting elements and parameters should be in the integrated control circumstance.

Keywords: Knitting, Yarn tension, Parameters, Process, Correlation

Introduction

In the textile industry, most of the manufacturers want to produce their products with high speed but without any faults in the process. This is achieved to some extent with the advance in many industrial areas, especially machinery and computer technology. High-speed production is also beneficial to the manufacturers in the knitting industry. However, it has been realized that it is impossible to increase the production speed infinitely without considering textile materials using on the machines because of material-related problems during the production. Therefore, it is desirable to understand characteristics and properties of textile materials to produce good quality products from the high-speed machines.

In the knitting industry, maximum production speed is restricted to a certain limit such as 300 m/min on circular knitting machines. This limit is generally caused by yarn tension, which breaks the yarn and creates several process troubles. Yarn tension is one of the important factors in the knitting industry not only to make high quality knitted products but also to prevent processing faults. Hence, tension control should be properly maintained during knitting process.

The importance of tension control in textile industry has already been recognized. Tension impacts many characteristics and properties of fiber and yarn, and changes performance and applications of following products[1-7]. Tension control is also one of the main factors to keep high quality condition in processing and to manufacture good quality products in the weaving process because there are many processing elements affected by the yarn tension during weaving. Currently, even though many high-speed looms are employed in the weaving industry, tension control of yarn is a key issue for high-speed production. Several researchers[8-11] concentrated to study the tension control system in the weaving process. In manufacturing knitted fabric with high speed knitting machines, the main thing to concern is to control appropriate and optimized yarn tension. As similar to the weaving process, yarn tension influences the characteristics and properties of knitted fabric and knitting process[12,13].

In this study, processing parameters, regarded to be relative to variation of yarn tension, were tested. Three parameters; yarn speed, needle gauge, and yarn feeding angle, were employed to investigate their influence on tension variation of yarn.

Currently, in the science research, statistical concept is required for qualified and reliable experimental data in analysis[14-16]. It is considered that all research data would be more reliable and accurate with statistical methods. We can obtain information of experimental variables from statistical analysis as follows;

1) Correlation of variables.
2) Type of correlation from data.
3) Intensity of the correlation.
4) Effective prediction from the data.

Therefore, correlation coefficient of tension variation with needle gauge and yarn feeding angle was calculated and their correlation was noted in this research.

Experimental

Test Equipment and Parameters

Tests were carried out with the same test rig developed for the research addressed in the former paper[17]. The test rig simulated the yarn path on the circular knitting machine. It has two yarn feeding rollers, yarn guides, a support to hold different types of needle gauge, and tension sensors on the way of yarn path. The tension sensor has 200 Hz of a maximum frequency, 0-100 cN of measuring range, and three yarn guides on the measuring heads. The yarn guides to adjust yarn feeding angle made of ceramic was placed on the test rig to facilitate the change of yarn feeding angle to

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Table 1. Characteristics of yarn

Fibre type	American cotton	Tenacity (cN/Tex)	12.25
Spinning method	Ring-spinning	Elongation at break (%)	4.05
Yarn twist (tpi)	16.8	Coefficient of friction (unwaxed)	0.245
Yarn count (tex)	20	Hairiness (>3 mm)	3.88

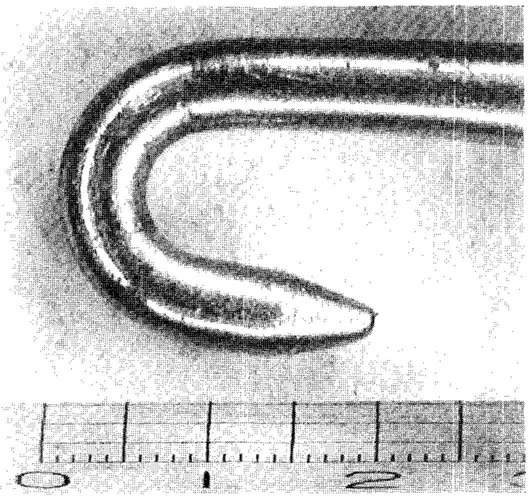


Figure 1. Thickness of needle hook.

the needle hook. Yarn feeding angle (F.A.) was differentiated with most acute (26°) and broad angle (89°), which is available on the test rig. Yarn was fed through the needle hook (Figure 1) under tension and the movement of the yarn was controlled with the two pairs of rollers, which were driven separately by two stepper motors. A hardware and software were used to control yarn feeding speed and to record tension variation. Yarn feeding speed was employed in the range of 100-400 m/min with a step of 100 m/min. Two different types of needle gauge, 18 G and 28 G, were used to investigate the tension variation according to yarn feeding speed. Some characteristics of yarn used for this research were described in Table 1.

During the tests, output tension, the tension after passing the needle on the test rig was mainly monitored by setting 10 cN of input tension, the tension before passing the needle. Tests were carried out 10 times each in order to measure tension variation.

Yarn feeding tension is generally sustained constantly, 3 cN in the circular knitting machine for instance. Hence, the feeding tension (so called input tension in this study) was established to 10 cN to maximize the condition of tension variation after passing the needle hook. The feeding tension was produced by differentiating the rotation speed of the two rollers on the test rig.

Calculation of Correlation Coefficient

Correlation coefficient of tension variation with needle gauge and yarn feeding angle was calculated and compared to examine the correlation of the two parameters on the tension with following equations;

$$S(xx) = \sum_{i=1}^{n}(x-\bar{x})^2 = \sum_{i=1}^{n}x_i^2 - \left(\sum_{i=1}^{n}x_i\right)^2/n \quad (1)$$

$$S(yy) = \sum_{i=1}^{n}(y-\bar{y})^2 = \sum_{i=1}^{n}y_i^2 - \left(\sum_{i=1}^{n}y_i\right)^2/n \quad (2)$$

$$S(xy) = \sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y}) = \sum_{i=1}^{n}x_iy_i - \left(\sum_{i=1}^{n}x_i\right)\left(\sum_{i=1}^{n}y_i\right)/n \quad (3)$$

$$r = \frac{S(xy)}{\sqrt{S(xx)S(yy)}} \quad (4)$$

$S(xx)$: Sum of deviation squared of variable x
$S(yy)$: Sum of deviation squared of variable y
$S(xy)$: Sum of deviation squared of variable x and y
r: Correlation Coefficient
x: Variable X
y: Variable Y
$\bar{x}$: Average of variable X
$\bar{y}$: Average of variable Y
n: No. of variable

Results and Discussion

Tension Variation

Figures 2 and 3 showed tension variation with 28 G needle at 26° and 89° of feeding angle. Yarn tension slightly increased with increasing yarn speed. However, scattering of tension variation shows different distribution at each speed. At the acute angle of yarn feeding, the distribution range of tension variation is wide. However, different result is observed at the broad angle of yarn feeding.

In Figures 4 and 5, tension variation using 18 G needle at 26° and 89° of feeding angle showed a little different results

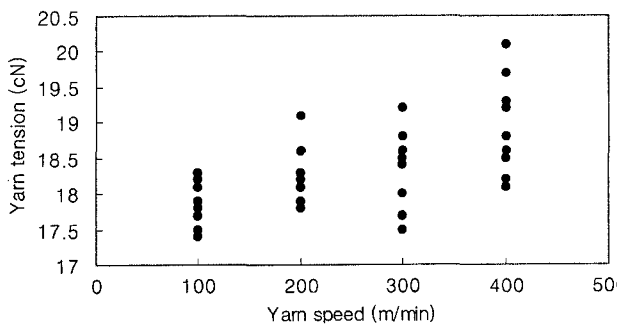


Figure 2. Tension variation with 28 G and F.A. 26°.

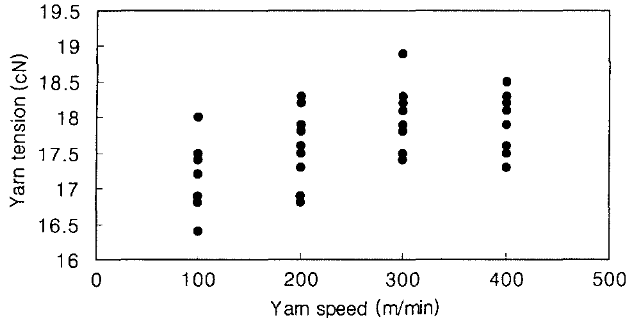


Figure 3. Tension variation with 28 G and F.A. 89°.

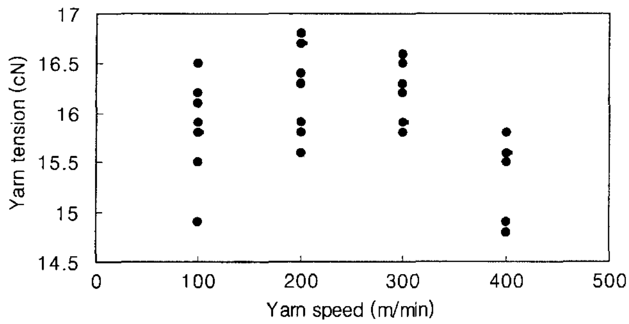


Figure 4. Tension variation with 18 G and F.A. 26°.

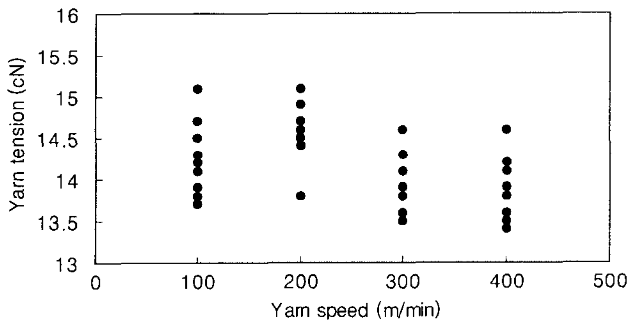


Figure 5. Tension variation with 18 G and F.A. 89°.

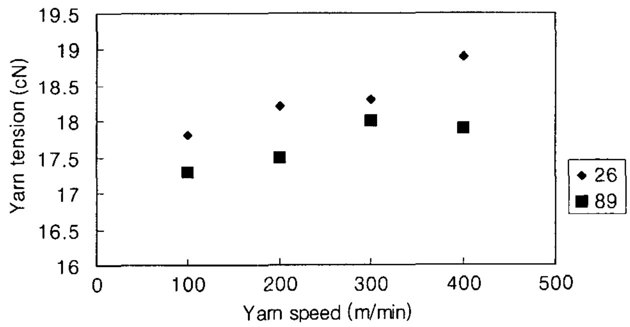


Figure 6. Average tension variation with 28 G needle.

from Figures 2 and 3. As increasing the yarn feeding speed, tension variation decreased, and distribution of the tension

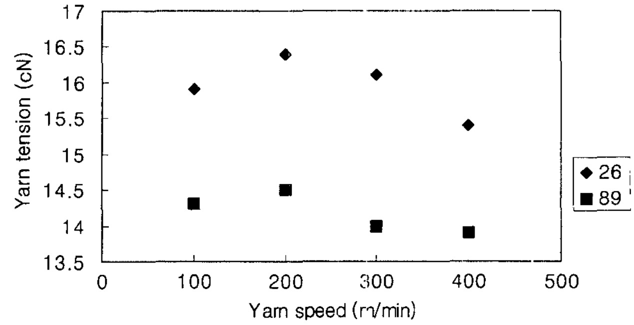


Figure 7. Average tension variation with 18 G needle.

showed no significant deviation at each speed.

As shown in Figures 6 and 7, average tension variation did not show any clear correlation except in the result of 28 G and 26° of feeding angle.

However, it was found that acute feeding angle produced high tension than broad feeding angle.

These results are concerned to be produced not only by the tested parameters but also by integrating all testing condition including surface condition of yarn, smoothness of needle hook, speed variation of yarn feeding, etc. However, yarn speed seemed not to be the main factor to affect tension variation of yarn from the results. Furthermore, even the yarn tension showed slightly high figures with acute feeding angle than broad one. Hence, it is difficult to find any distinct correlation of yarn tension with the feeding speed.

Correlation

Tables 2-5 showed calculation of correlation coefficient in several different testing conditions. The calculation was mainly carried out to investigate correlation coefficient of feeding angle and needle gauge that influenced on tension variation. As can be seen from the Tables 2 and 3, the correlation of feeding angle with 18 G and 28 G needle showed high correlation with the yarn tension, especially 28 G needle gauge. As already observed in the scattering diagram in the previous Figures 2 and 4, it was confirmed that tension variation increased at the acute feeding angle. Among many reasons to explain these results, the cause seemed to be the morphology of the needle hook. The acute feeding angle causes a wide contact angle, so a contacting area to the needle hook should be more increased than the broad feeding angle. It is also explained that the yarn should contact to the inside of the needle hook more tightly on the small gauge needle and acute feeding angle. It means that the friction between yarn and needle hook accordingly increased, which produced high tension. This may also be explained by the fact that the yarn will have a higher frictional force in the 28 G needle due to the smaller radius of the hook. The tension was increased at acute feeding angle with 18 G needle. However, lower tension variation of

Table 2. Calculation of correlation coefficient (r) of tension variation at 26° and 89° of feeding angle with 18 G needle

No.	X (26°)	Y (89°)	$x-\bar{x}$	$y-\bar{y}$	$(x-\bar{x})^2$	$(y-\bar{y})^2$	$(x-\bar{x})(y-\bar{y})$
1	15.96	14.30	–0.05	0.13	0	0.02	–0.01
2	16.40	14.50	0.45	0.33	0.20	0.11	0.15
3	16.10	14.00	0.15	–0.17	0.02	0.03	–0.03
4	15.40	13.90	–0.55	–0.27	0.30	0.08	0.15
Sum	63.80	56.70	0	0	0.53	0.23	0.26
Avg.	15.95	14.18		Correlation coefficient		0.76	

Table 3. Calculation of correlation coefficient (r) of tension variation at 26° and 89° of feeding angle with 28 G needle

No.	X (26°)	Y (89°)	$x-\bar{x}$	$y-\bar{y}$	$(x-\bar{x})^2$	$(y-\bar{y})^2$	$(x-\bar{x})(y-\bar{y})$
1	17.80	17.30	1.85	3.13	3.42	9.77	5.78
2	18.20	17.50	2.25	3.33	5.06	11.06	7.48
3	18.30	18	2.35	3.83	5.52	14.63	8.99
4	18.90	17.90	2.95	3.73	8.70	13.88	10.99
Sum	73.20	70.70	0	0	22.71	49.33	33.24
Avg.	18.30	17.68		Correlation coefficient		0.99	

Table 4. Calculation of correlation coefficient (r) of tension variation with 18 G and 28 G needle at 26° of feeding angle

No.	X (18 G)	Y (28 G)	$x-\bar{x}$	$y-\bar{y}$	$(x-\bar{x})^2$	$(y-\bar{y})^2$	$(x-\bar{x})(y-\bar{y})$
1	15.90	17.80	–0.05	3.63	0	13.14	–0.18
2	16.40	18.20	0.45	4.03	0.20	16.20	1.81
3	16.10	18.30	0.15	4.13	0.02	17.02	0.62
4	15.40	18.90	–0.55	4.73	0.30	22.33	–2.60
Sum	63.80	73.20	0	0	0.53	68.68	–0.35
Avg.	15.95	18.30		Correlation coefficient		–0.05	

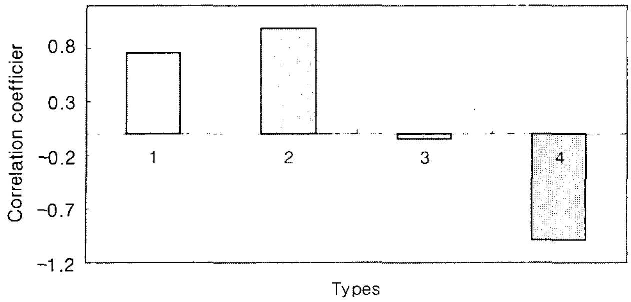
Table 5. Calculation of correlation coefficient (r) of tension variation with 18 G and 28 G needle at 89° of feeding angle

No.	X (18 G)	Y (28 G)	$x-\bar{x}$	$y-\bar{y}$	$(x-\bar{x})^2$	$(y-\bar{y})^2$	$(x-\bar{x})(y-\bar{y})$
1	14.30	17.30	-1.65	3.13	2.72	9.77	-5.16
2	14.50	17.50	-1.45	3.33	2.10	11.06	-4.82
3	14	18	-1.95	3.83	3.80	14.63	-7.46
4	13.90	17.90	-2.05	3.73	4.20	13.88	-7.64
Sum	56.70	70.70	0	0	12.83	49.33	-25.07
Avg.	14.18	17.68		Correlation coefficient		–0.99	

18 G than 28 G can be described by the fact that the curvature of the needle hook of the 18 G needle is bigger than that of the 28 G needle, which reduces frictional contact between yarn and needle hook.

On the other hand, there was no or negative correlation of tension variation observed between needle gauges in the established feeding angle in the Tables 4-5. Figure 8 showed strong negative correlation at broad feeding angle but no correlation at acute feeding angle.

This can be explained by the one yarn count used on the different needle gauges. As known, one of the key parameters in the knitting elements is a knitting needle, and selecting the most suitable needle gauge on the knitting machine according to yarn count is an important factor to produce qualified knitted products. In addition, factors related to the needle such as a needle type and a needle gauge highly influence the knitting process. Therefore, depending on the stitch formation in the knitted product, it is hghly recommended to



1: 18 G of needle, 26° and 89° of feeding angle.
2: 28 G of needle, 26° and 89° of feeding angle.
3: 26° of feeding angle, 18 G and 28 G needle.
4: 89° of feeding angle, 18 G and 28 G needle.

Figure 8. Average tension variation with different conditions.

choose required needle type and gauge for the high-quality knitting process.

Conclusions

In the knitting process, many individual elements on the machine are working together to produce knitted products. One of the important elements is a knitting needle, which takes an important role in the quality of products and process. Stitch formation in most of the knitting points on the machine was dependent on the dynamic movements of needles. The movement of needle is subjected to many different factors during the processing. As one of them, the tension control is a key parameter to the needle movement. In the research, correlation of tension variation with several factors including needle gauge, yarn feeding angle, and yarn feeding speed was observed. Yarn feeding speed did not affect the tension variation significantly, contrary to manufacturers' expectation, which is necessary to carry out more research with a well-established experiment rig. From the results of the calculation of correlation coefficient of tension variation with two parameters, needle gauge and feeding angle, it was found that yarn feeding angle positively correlated to the tension variation but needle gauge did not or negatively to it. It is estimated that the results in this experiment are not produced with one or two factors. As already addressed, all knitting elements and processing parameters during knitting interrelates with the machine. Therefore, in the knitting manufacturing, it is very necessary that all knitting elements and parameters should be under integrated control to reduce production failures and to develop optimized manufacturing process.

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