Knitting Tension During Weft-Knitting

By Noboru Aisaka, Tatsuya Kawakami and Tadashi Shindo, Members, TMSJ

Textile Research Institute of Japanese Government, Yokoyama, Kanagawa-ken

Based on Journal of the Textile Machinery Society of Japan, Transactions, Vol.22, No.3, T39--50 (1969)

Abstract

Knitting tension during weft-knitting is experimentally investigated with the aid of a model apparatus and a circular knitting machine. Although the knitting velocity in our experiment using the circular knitting machine was much lower than the ordinary velocity, it is possible to estimate real knitting tension from the results given in this article and in the light of those obtained by the experiment using the model apparatus.

(1) The larger the input yarn tension, the larger the knitting tension and the shorter the stitch length.

(2) Reductions in yarn tension and stitch length by robbing back are estimable from figures showing the relations between input yarn tension and knitting tension and between knitting tension and stitch length.

(3) The relation between knitting tension and the amount of work done by robbing back has nothing to do with knitting condition. The curve of that relation is conditioned by the properties of the yarn used.

(4) The larger the yarn and the higher its flexial rigidity, the larger the knitting tension. The lower the flexial rigidity of the yarn used, the lesser the effect of input yarn tension on knitting tension.

KEY WORDS: KNITTING, WEFT KNITTED FABRICS, WEFT KNITTING MACHINES, CIRCULAR KNITTING MACHINES, KNITTING TENSION, YARN TENSION, ELONGATION, FRICTION, FLEXIAL RIGIDITY, STITCH CAMS, STITCH LENGTH, GAUGE, YARN.

1. Introduction

Knitting tension is an important quantity having a bearing on the stitch length of the knit fabric and therefore, on its quality and properties. A precise understanding of knitting tension is needed to fix yarn strength and decide what method to use for pre-processing the yarn.

In general, knitting tension T_k during weft-knitting is a function of input yarn tension T_I ; of yarn tension T_o at the exit of the knitting zone; of angle θ of the contact of the yarn with the knitting elements; and of frictional coefficient μ :

$$T_k = f_1(T_I, T_o, \theta, \mu) \dots \dots \dots (1)$$

Knitting tension T_k is a function of yarn tension T_o because robbing back shows in weft-knitting. This effect of robbing back on knitting tension can be eliminated by controlling the movement of the needles in the region between the knitting point and the exit of the knitting zone, i.e., by lengthening the step of the stitch cam. This done, eq.(1) transforms into:

$$T_k = f_2(T_I, \theta, \mu) \dots \dots \dots (2)$$

With the needle distance (gauge) constant, angle θ is a function of the needle position in the knitting zone. When knitting tension is measured at the knitting point, angle takes a constant value. Knitting tension, then, is a function of input yarn tension and of the frictional coefficient of the yarn used.

2. Experiment with Model Apparatus.

2-1. Model Apparatus and Method of Experiment

The model apparatus (Fig.1) was experimentally constructed to simulate knitting on a desk. Sinkers S_1 and S_2 were fixed on panel A . Distance G between S_1 and S_2 was variable. Needle N was fixed on rod R which was supported by bracket B . Rod R and needle N were pushed up and down by cam C which was rotated by a synchronous motor through a gear train.

When yarn Y was being fed between needle N and sinkers S_1 and S_2 while rod R was being pushed up, the yarn was bent in conformity to knitting action. The section (bc) of cam C was so shaped that needle N moved at a constant speed. Projection D of cam C was 3mm high.

Fig. 1 Model apparatus for knitting

The circular cross sections of needle N and sinkers S_1 and S_2 were all 0.8mm in diameter.

Yarn Y with load W imposed on at one end was fed through pulley P to the space between sinkers S_1 and S_2 and needle N , and was gripped at the other end by clamp K of unbonded-wire-strain-gauge U .

The variations in yarn tension by the simulated knitting were measured with a dynamic strain meter and recorded with Electro-Magnetic Oscillograph (YEW's "Photocorder") using a galvanometer of -3db at 1000c/sec . At the time of each measurement, cam C was placed at point (a) of contact with rod R , then the synchronous motor was set in motion. The first peak value in the record of each measurement was taken as knitting tension.

The yarns tested were worsted spun yarn 2/40's and stretched nylon yarn 110d/2, whose properties are listed in Table 1 and marked with asterisks. The conditions under which the tests were made were:

Gauge G (mm): 3, 6, 12

Load W (g): 2, 6, 10, 15, 20

Knitting velocity V (cm/sec): 5, 10, 17, 25, 50.

The knitting velocities were calculated from the records of variations in yarn tension at each measurement.

2-2. Results of Measurement Discussed

Fig.2 shows the variations in yarn tension T_k with input yarn tension T_I , i.e., load W , at a constant knitting velocity of $V=50\text{cm/sec}$ and a gauge of $G=3\text{mm}$. Yarn tension T_k of both yarns increased relatively to the increase in input yarn tension T_I . However, the relation between T_k and T_I was not linear but non-linear, and the degree of variations was high in a low range of the values of input yarn tension T_I .

Fig.3 shows the ratio T_K/T_I plotted against input yarn

Fig. 2 Relation between input yarn tension and knitting tension (model apparatus)

tension T_I from the results obtained from experiments in which gauge G was varied and cam C was manually rotated at a knitting velocity below 0.5cm/sec. The ratio T_k/T_I at $T_I=2g$ on the worsted yarn was particularly high and nearly constant at $T_I \geq 10g$. The same relation was noticed on the stretched nylon yarn, but the value at $T_I=2g$ was not so high as in the worsted yarn.

The lower value of the ratio T_{k1}/T_I at $T_I=2g$ on stretched nylon yarn was produced presumably because a good many crimps in the fibers remained and changed the condition of the surface of contact.

The relation between the ratio T_k/T_I and input yarn tension T_I is roughly the same, irrespective of gauge G , i.e., angle θ of wrap. Presumably, then, variations in the ratio to input yarn tension indicate variations in the coefficient of yarn friction. The conclusion is deducible, therefore, that, if we think of knitting tension as additional tension generated by friction, we should treat the coefficient of yarn friction as a function of yarn tension in a range of low input yarn tensions.

Comparing Figs.2 and 3 shows that the ratio T_k/T_I in Fig.3 is higher on the stretched nylon yarn than on the worsted spun yarn, but that the reverse is the case in Fig.2. This seems to suggest that knitting tension is influenced by knitting velocity.

In Fig.4, variations in knitting tension T_k at gauge $G=3\text{mm}$ are plotted against knitting velocity, with input yarn tensions written alongside the curves. This figure shows that knitting tension increased as knitting velocity increased in a range under $V=10\text{cm/sec}$, but was almost constant in a higher speed-range on both yarns tested. Presumably, the increase of yarn tension by knitting is held in check by the inflow of the yarn. However, if yarn elongation exceeds yarn inflow in speed at a high knitting ve-

Fig. 3 Relation between input yarn tension T_I and ratio T_k/T_I

locity, then the restraint is weakened, thus permitting knitting tension to take a high value.

The difference between knitting tensions on the worsted spun yarn and the stretched nylon yarn presumably comes from the difference in elongation property between the two yarns. In a velocity range over 10cm/sec, knitting tension is nearly constant. Therefore, in such a velocity range, the effect of the dragging tension of yarn on knitting tension is presumably slight, knitting tension being affected only by the frictional force and elongation property of the yarn.

Fig. 4 Relation between Knitting Velocity and knitting tension

3. Experiment with a Circular Knitting Machine.

3-1. Knitting Machine Used and Method of Experiment.

The knitting machine used was a circular open-top machine having a cylinder 20 inches in diameter and 12 needles per inch. The experiment was made at the rate of 3rpm of the machine (knitting velocity was about 8cm/sec), using one yarn feeder. Input yarn tension was limited to a range of 1–13g by a parallel disk-type tensioner pressed by a coil spring at a point on the route of yarn-feeding. Knitting tension was measured with a knitting-force-detector^[1] developed by the authors. The cams used were of 5 different shapes. Their steps were, respectively, in widths corresponding to 2, 3, 4 and 5 needles' distance as shown in Fig. 5. The regular stitch cam of this knitting machine was a CF-1 cam with a step of two-needles' distance.

Fig. 5 Shapes of steps of stitch cams

3-2. Results Discussed.

Fig.6 shows the relations between input yarn tension and knitting tension, and between knitting tension and stitch length obtained from experiments made at a constant cam setting of $h=2.9$ mm, using the stitch cams shown in Fig.5. The curves expressing the relation between input yarn tension and knitting tension where the CF-4 stitch cam was

Fig. 6-1 Worsted spun yarn 2/40s

Fig. 6-2 Worsted spun yarn 2/40s

Fig. 6-3 Stretched nylon yarn 110/2d

Fig. 6-4 Stretched nylon yarn 110/2d

Fig. 6 Relations between input yarn tension, and between knitting tension and stitch length (circular knitting machine)

used are all similar to that in Fig.2. Furthermore, the variations in stitch length in these experiments are a little smaller than those of input yarn tension.

These facts imply that robbing back did not show in knitting where the CF-4 cam was used. The effect of robbing back did show up in both knitting tension and stitch length where the regular CF-1 stitch cam was used.

Presumably, then, the difference between knitting tensions, F_{k4} and F_{k1} for cams CF-4 and CF-1, respectively, indicates a decreases in yarn tension by robbing back. Presumably, too, the difference between stitch lengths L_4 and L_1 for cams CF-4 and CF-1, respectively, at knitting tension F_k indicates the decreases in the yarn length of the stitch by robbing back. These two decreases will be referred to hereinafter, respectively, as "robbing back tension f_r " and "robbed back yarn length l_r ." In other words:

$$f_r \equiv F_{k4}(T_I) - F_{k1}(T_I) \dots \dots \dots (3)$$

$$l_r \equiv L_4(F_{k1}(T_I)) - L_1(F_{k1}(T_I)) \dots \dots \dots (4)$$

The product of f_r and l_r means the amount of work consumed by robbing back, or saved in the formation of the

stitch, and will be referred to as "robbing back work W_r ." In other words:

$$W_r \equiv f_r \cdot l_r \dots \dots \dots (5)$$

Eqs.(3), (4) and (5) can be solved for input yarn tension T_I , but robbing back shows up primarily because of knitting tension F_k . Therefore, it seems reasonable to investigate those values in terms of knitting tension F_{k1} in knitting with the regular stitch cam CF-1.

In Fig.7, robbing back tension f_r and robbed back yarn length l_r obtained from experiments made on the stretch nylon yarn with three different cam settings are plotted against knitting tension F_{k1} .

Fig.8 shows work W_r by robbing back on both the worsted spun yarn and the stretched nylon yarn.

Fig.7 shows that both f_r and l_r increase as knitting tension does. The similar relation is found in the worsted spun yarn, although it is not illustrated by a figure in this article.

Fig.8 shows that variations in W_r differ according to the kind of yarn used, and that W_r is indicated with the same curve, on the same kinds of yarns, regardless to the cam

Fig. 7 Relations between knitting tension and robbing back tension and between knitting tension and robbed back yarn length

Fig. 8 Relation between knitting tension and robbing back work

setting. This means that a curve showing the relation between knitting tension and the amount of work by robbing back represents the difference between yarns in properties.

Fig. 9 Relation between knitting tension and robbing back work

Fig.9 contains curves on several kinds of knitting yarns whose properties are given in Table 1.

The amount of work by robbing back increases as knitting tension does. On stretched nylon yarn having a small elastic modulus E , the amount of work by robbing back increases abruptly in some range of knitting tension. It increases gradually on spun-doubled yarn with a large elastic modulus. On spun-single yarn whose modulus E differs only slightly from that of spun-doubled yarn, variations in the amount of work by robbing back are similar in trend to those on stretched nylon yarn. Therefore, it is difficult to explain differences in variations in the amount of work by robbing back work in terms of differences in elastic modulus E or of frictional coefficient μ of the yarn.

In Fig.10, knitting tensions are plotted against yarn width calculated from the nominal counts or denier of the

Table 1 Properties of yarns used

Sample	Count or Denier	Strength (g)	Elongation (%)	Elastic modulus E	Frictionad index T_0/T_1 ($T_I = 20g$)	Flexial rigidity $G (\times 10^{-3} g.cm^2)$
Worsted spun yarn	1/40s	362	32.8	5580	1.65	4.78
Wool and Acryl mixed spun yarn	1/36s	364	23.8	6100	1.69	5.76
"	2/48s	414	30.0	5870	1.74	8.56
Worsted spun yarn*)	2/40s	342	24.0	7620	1.66	8.68
"	2/32s	376	21.0	6920	1.78	12.4
Stretched nylon yarn	100d	520	38.0	1550	1.65	1.47
"	70/2d	428	22.4	1880	1.69	1.35
"	*) 110/2d	876	38.8	2580	1.70	2.71

Fig. 10 Relation between yarn Width and knitting tension

yarns. It seems from this figure that knitting tension is influenced by some properties related to yarn width.

Fig. 11 Relation between flexial rigidity of yarn and knitting tension

In Fig.11, knitting tensions are plotted against the flexial rigidity of yarn measured by the ring method.^{[21],[3]} The notations in parentheses show data on stretched nylon yarns and others on the spun yarns.

Presumably, variations in knitting tension and in stitch

length are influenced by the flexial rigidity of the yarn used. In other words, variations in a small range of yarn tension relate mainly to yarn bending, or to the yarn movement if yarn tension is in a large range. Therefore, it is necessary to look further into such matters as the angle of wrap in the knitting zone, state of yarn-bending by the knitting elements and the proportions of the elastic and plastic portions in the cross section of the yarn bent.

4. Conclusions.

(1) The larger the input yarn tension, the larger the knitting tension. Variations in knitting tensions are influenced by the properties of the yarn used, especially by its frictional and elongational properties.

(2) The larger the knitting tension, the shorter the stitch length.

(3) The coefficient of yarn friction should be treated as a function of yarn tension if knitting tension is thought of as additional tension generated by friction.

(4) Comparing the results of experiments made with the regular stitch cam and the results of experiments made with a stitch cam whose step is too wide for robbing back to show up, we find that decreases in yarn tension and stitch length by robbing back are estimable from figures showing the relations between input yarn tension and knitting tension and between knitting tension and stitch length.

(5) The amount of work done by robbing back is defined by the product of the decreases in yarn tension and in stitch length. The relation between knitting tension and the amount of work done by robbing back has nothing to do with knitting condition. The curve of that relation is conditioned by the properties of the yarn used.

(6) The larger the yarn width and the flexial rigidity of the yarn used, the larger the knitting tension. The relation between knitting tension and the flexial rigidity of yarn is almost linear. The lower the flexial rigidity of the yarn used, the lesser the effect of input yarn tension on knitting tension.

The authors are much indebted to Prof. S. Ishikawa of the Tokyo Institute of Technology for valuable suggestions on the experiments.

Literature cited

- [1] Aisaka, Kawakami Shindo; *J. Fib. Sci. Tech. Japan*, **24**, 70 (1968)
- [2] Kawakami, Ikeda; *Bull. Text. Res. Inst. Japan*, No. **32**, 14 (1955)
- [3] Shimizu Ikemura Tabata Uno; *J. Text. Mach. Soc. Japan*, **19**, T301 (1966)