The Effect of Yarn Input Tension on Knitted Fabric Properties

Elfadil M. M. A. Elkarsany[a], Amel A. Magboul[a]
[a]Textile Engineering Department, College of Engineering, Sudan University of Science and Technology

Corresponding author:
Elfadil M. M. A. Elkarsany
Textile Engineering Department, College of Engineering, Sudan University of Science and Technology, Khartoum , Sudan

Abstract

This work aimed at determining the effect of yarn input tension on some properties of a knitted fabric produced on a circular knitting machine. The properties studied were the stitch length, stitch density, fabric extensibility, abrasion resistance, weight per unit area and fabric thickness.
In order to achieve the aim a series of experiments was carried out on the knitted fabric and the results obtained were analyzed. The results obtained clearly showed that yarn input tension is a fundamental factor and has a significant effect on the properties studied.

KEYWORDS: abrasion resistance, extensibility, interloping, loop, needles, permeability, stitch length.

INTRODUCTION

Knitting is the process of forming fabric by interloping yarn in a series of intermeshed loops using needles. Knitted fabrics are preferred in many types of clothing because of its extensibility, lightweight, warmth, wrinkle resistance and ease of care. All knitting machines are sensitive to yarn input tension and hence to the amount of yarn fed to the knitting elements (needles and sinkers). The nature of the fabric produced by a knitting machine depends on the length of the yarn that enters the knitting point. If the length is very short, the knitting elements may break the yarn. This is because the tension applied to the the yarn will be very high. At lower tensions, the strain on the yarn should be less and the breakage rate could be reduced. Furthermore, the amount of yarn used in the formation of one course of stitches (course length) would also depends on yarn tension.
Input tension is the tension on the yarn just before entering the knitting elements. This tension affects the easy by which the needles draw the yarn from the supply package. Input tension may affect the length of yarn fed to the needles to form the loops and therefore, affect the knitted fabric structure and properties.
As the input tension increases, the pressure between the yarn and the knitting elements would increase and the yarn would lie in a flattened state on the needle hook. The shearing forces acting on the yarn would therefore increase. More force would be required to pull the new formed loop through the previous one and it would be difficult for the needles to draw the yarn from the package. Therefore, the needles would draw the yarn from the previously formed loop resulting in robbing back (Knapton & Munden, 1966/a; Knapton & Munden,

1966/b; Peirce, 1947). This is where the knitting needles instead of pulling the yarn from the package, it pull the yarn from the previously formed loop.

It has been reported (Baird & Mieszkis, 1955; Brunnschweiler, 1957) that as the yarn input tension increases, the friction between the yarn and machine elements may damage the element, abrade the yarn and change the twist regularity of the yarn. When yarns rub on themselves and then on machine elements, the effect of abrasion and wear are reinforced (Baralla et al., 1991).

The main objective of this investigation was to study the effects of yarn input tension in a circular knitting machine on the properties of the produced knitted fabric.

MATERIALS AND METHODS

A carded cotton ring spun yarn having a linear density of 36 Tex was used. The specifications of the yarn are given in table 1.

Single jersey circular knitting machine manufactured by Mayer & Ciewas was used to produce the knitted fabric. The knitting machine gauge was 5 needles per cm and the machine diameter was 55.9 cm. The total number of the cylinder needles was 878 and the machine speed was kept constant at 22 rpm.

Table 1. Specifications of the yarn used

Yarn count (Tex)	36
Yarn twist (T/cm)	7.4
Yarn coefficient of friction (μ)	0.171
Yarn tenacity c N/tex	14.3
CV of irregularity (%)	13.1
Elongation (%)	6.7

The knitting machine was adjusted to produce three knitted fabrics that differ in terms of courses per cm only. The number of wales per cm (9) was kept constant. The specifications of the knitted fabrics produced are given in table 2.

Table 2. Specifications of the produced knitted fabrics

Sample No.	Input tension (gm)	Courses / cm	Wales /cm
1	3	9	9
2	5	11	9
3	8	13	9

Three different types of knitted fabrics were produced using three levels of yarn input tension (Table 2). The fabrics were used in unwashed states. The effect of the yarn input tension on the properties of each fabric sample was investigated. The properties studied were the knitted fabric stitch length, stitch density, extensibility, abrasion resistance, weight per unit area and fabric thickness.

All physical and mechanical tests unless otherwise stated, were carried out in the testing laboratory under standard testing atmosphere having 65% ± 2% relative humidity and 27 C^{o}± 2 C^{o}.

Extensibility measurement

The Extensometer tester was used to measure the extensibility of the three different fabric samples. The load applied by the tester was 3 Kgs. Ten tests were performed on each fabric and the mean value was calculated.

Abrasion resistance measurement

The standard Martindale abrasion tester was used to study the abrasion resistance of the knitted fabrics in terms of the weight loss resulting from a number of abrasion cycles. The British Standard Handbook (11, 1974, Section 4) and TMEN (2006) were followed with regard to the abradent fabric used and the preparation of the test samples (TMEN, 2006). The abrasion test was performed under a load of 12 KPa. Before testing, all the knitted fabric samples were laid flat on a table without tension for at least 48 hours in standard testing atmosphere.

The weight loss was determined taking test specimens (20) of the same size, cut randomly from each fabric according to the test recommendation (TMEN, 2006), weighted each to the nearest mg (Table 3). Five abrasion runs, each involving four tests pieces were carried out on each fabric. At the end of each run, the four specimens, carefully removed from the holder of the apparatus, and stored for at least 24 hrs, in the standard testing atmosphere, were re-weighted. The weight loss for each fabric piece was calculated accordingly.

Table 3. Original samples weight

Sample No.	Sample weight (gm/cm^2)
1	0.0143
2	0.0166
3	0.0181

Fabric thickness measurement. The thickness of each sample was measured using the thickness gauge tester with 50-gf load. Ten tests were performed for each sample and the mean was then calculated.

Courses, wales, stitch length and density measurement. A course is defined as a row of loops across the width of the knitted fabric and it determine the fabric length. The number of course per unit length was measured along the wale direction by using a counting glass and a needle (Ogulata, 2006; Tokarska, 2008).

Wales are perpendicular lines of loops along the knitted fabric length. They determine the knitted fabric width. The number of wales per unit length depends on the type of the knitted fabric. The number of wales per unit length was measured along the course direction by using a counting glass and a needle.

Stitch length is the length of yarn knitted into one stitch in a weft knitted fabric. Theoretically, stitch length is a single length of yarn that includes one needle loop and half the sinker loop on either side of (Ogulata, 2006; Tokarska, 2008), according to the equation (1).

$$\textit{stitch length} = \textit{one needle loop} + \textit{two half a sinker loop} \qquad (1)$$

Stitch density is the total number of loops per unit area (i.e. per square cm). It is obtained by multiplying the number of courses and wales per unit length together as given in equation (2).

$$Stitch\ density = Wales\ per\ cm\ X\ \ courses\ per\ cm. \qquad (2)$$

RESULTS AND DISCUSSION

Stitch length

The results are given in table 4. As can be seen from table 4 for all types of the knitted fabrics, the stitch length decreases as the yarn input tension increases and this was mainly due to the increase in the stitch density. On the other hand, the stitch density increases as the input tension increases because of the increase in the course count. (Table 4).

Table 4. Stitch length and density values

Samples	Input tension (g)	Course/cm	Wales/cm	Stitch length (mm)	Stitch density (mm^2)
1	3	9	9	4.70	0.893
2	5	11	9	4.53	1.004
3	8	13	9	4.12	1.265

Furthermore, the ease by which the knitting needles can draw the yarn from the package and from new loops through the preceding loops is dependent on the tightness factor. An increase in the tightness factor would result in greater frictional rubbing between the yarn and the knitting elements and between the yarns themselves. This would also affect the length of yarn fed to the knitting needles and therefore the stitch length and density. The results showed that the stitch length and stitch density values were correlated. An increase in the latter led to a decrease in the former. However, these values might largely differ in the case of washed state fabrics due to fabric shrinkage after washing.

Knitted fabric extensibility

The results showed that tighter fabrics had the highest values for extensibility (Figure 1). The highest extensibility values could be attributed to the increase in the stitch density, which entails the use of more yarn length to knit the same number of courses and wales compared with looser fabrics.

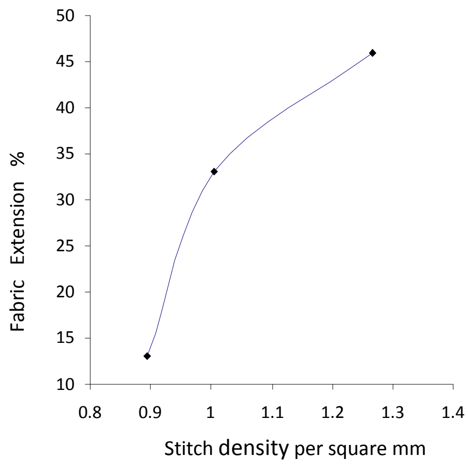

Figure 1. The effect of stitch density on fabric extensibility

Abrasion resistance. The loss in fabric weight showed a progressive increase with increasing number of abrasion cycles (Figure 2). However, the factor by which the weight loss increased with the number of abrasion cycles differed for the different types of fabric. The fabric having a higher stitch density was more affected by abrasion than those having lower stitch densities. The trends were however, inconsistent at lower abrasion cycles. The results showed that at all five abrasion levels, increasing the stitch density had effects on weight loss thus suggesting that the abrasion resistance can possibly be improved by decreasing the stitch density of knitted fabrics. At higher stitch density levels, the abrasion force acts on a large number of stitches and therefore increased the abrasion area. However, at lower stitch density levels, the stitches would absorb the friction energy through relative movement between the free spaces in the fabric and the abrading element. However, it is likely that lower weight loss at lower abrasion cycles is due to a tendency of pills produced during the abrasion process to cling onto the fabric surface and thus compensate at least in part, the loss in weight. The increase in the weight loss at the high abrasion cycles (12000, 15000, and 22000) could be attributed to the removal of pills from the fabric surface.

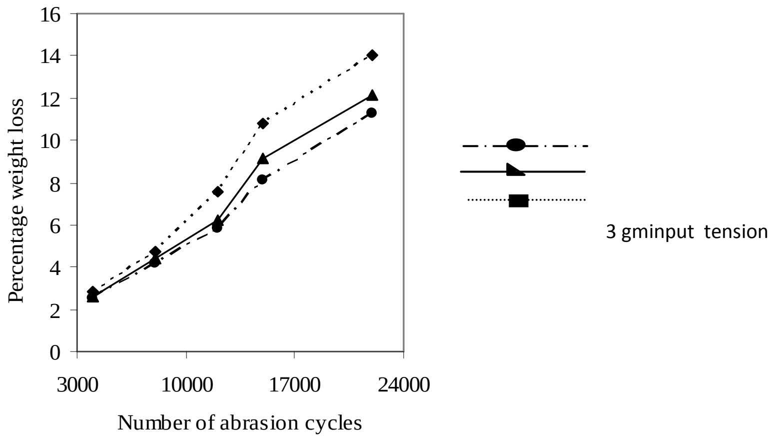

Figure 2. Abrasion resistance of the knitted fabric samples

Fabric thickness

The results are given in Table 5. Compared to the original fabrics thickness, the thickness increased as the yarn input tension increased for the different fabric types. The increase in fabric thickness with increasing input tension may be attributed to the increase in the stitch density of the fabric. The results obtained were for unwashed fabric state, but it would be expected that for washed fabric state, sample number one would give the highest value of fabric thickness. This can be explained by the fact that, the fabric that have the greatest *l/d* values (i.e. have the loosest fabric structure) will shrink the most in area upon washing, where *l = loop length* and *d = yarn diameter*.

Table 5. Samples thickness before and after abrasion cycles (dry state)

Sample No.	Input tension (gm)	Original thickness (mm)	Thickness after abrasion (mm)
1	3	0.60	0.61
2	5	0.61	0.62
3	8	0.65	0.67

The tightness factor (the looseness) varied with fabric type (Table 6). Sample one displayed the highest tightness factor i.e. the highest *l/d* value and this is mainly due to the increase in the stitch length needed to knit the fabric.

Table 6. Fabric tightness factor (*l/d*)

Sample No.	Fabric tightness (*l/d*)
1	19.54
2	17.62
3	16.08

However, sample one having the highest *l/d* value would be expected to shrink most after washing and accordingly to have a higher thickness value than the other two samples upon washing. This means that sample 3 having the lowest *l/d* value (tightest fabric) would be expected to shrink least after washing and therefore to have a lower thickness value than the other two samples.

Furthermore, the ease with which the knitting needles can draw the yarn from the package and from new loops through the preceding loops is dependent on the tightness factor. An increase in the tightness factor would result in greater frictional rubbing between the yarn and the knitting elements and between the yarns themselves. This will also affect the length of yarn fed to the knitting needles and therefore the stitch length and density. However, it would be expected that these values might largely differ in the case of washed state fabrics due to fabric shrinkage after washing. The results showed that the stitch length and stitch density were highly correlated. An increase in the latter led to a decrease in the former.

CONCLUSIONS

The work reported in this paper was carried out to study the effect of the yarn input tension on the structure and properties of single jersey plain knitted fabric. From the result obtained, the following conclusions could be drawn:

As the input tension increased, the stitch length decreased due to the increase in the stitch density values.

Stitch density increases as the input tension increased because of the increase in the course count.

An increase in the yarn input tension increased the fabric extensibility. This is mainly due to the increase in the stitch density. This is can be explained as follows; in the case of tighter fabrics, more yarn length is needed to knit the same number of courses and wales compared with looser fabrics.

As the stitch density increased, the weight loss increased. This trend may be attributed to the fact that, at higher stitch density levels, the abrasion force acts on a large number of stitches and therefore increasing the abrasion area. Furthermore, at lower stitch density levels, the stitches would absorb the friction energy by their relative movement between the free spaces in the fabric and the abrading element. The results obtained suggest that the abrasion resistance for knitted fabrics can possibly be improved by decreasing the stitch density.

The results obtained showed that, as the yarn input tension increased, the fabric thickness also increases. This may attributed to the increase in the stitch density of the fabric with an increase in the input tension. However, this is only true for unwashed fabric state but, it would be expected that in the case of washed fabric state, fabric knitted with the lowest input tension would give the highest thickness values. These results also demonstrated that an increase in the stitch density directly increases the knitted fabric weight.

Future study

Future research should focus on valuation of other types of yarns. Furthermore, it is of interest to study the effects of the yarn input tension on the porosity and air permeability of knitted fabrics.

References

Baird, M. E., Mieszkis, K. W. (1955) "Interaction between textile Yarns and Machine Elements", Journal of Textile Institute, Manchester, 46, pp. 101–103.

Baralla, A., Bardi, X., Castro, L. (1991) "Measurement of Yarn of Hairiness", Melliand Textil Berichte, 72, No. 1, pp. 19-22, (English edition).

British Standard Handbook 11 (1974) Section 4, pp. 125-225.

Brunnschweiler, D., (1957) "Abrasion Resistance of Ring-spun Yarns", Textile Manufacturing, 83, No. 990, pp. 271-275.

Knapton, J. I. F., Munden, D. L. (1966/a) "The Knitting Action of Circular Knitting Machine", Textile Research Journal, 36, pp. 1072-1078.

Knapton, J. I. F., Munden, D. L. (1966/b) "The Mechanism of Robbing Back during Loop Formation", Textile Research Journal, 36, pp. 1081-1085.

Ogulata, R. T. (2006) "Properties of Knitted Fabrics", Journal of Textile and Apparel, Technology and Management, Volume 5, Issue 2, pp. 1-10.

Peirce, F.T., (1947) "Geometrical Principles Applicable to the Design of Functional Fabrics", Textile Research Journal, 17, pp. 144-147.

TMEN (Test Method and Explanatory Notes). (2006) Air permeability. Available online at www.awat.com.au.

Tokarska, M. (2008) "Parameters Affecting Knitted Fabric Dimensions" , Fibers and Textiles in Eastern Europe, Volume 16, No. 1 (66), pp. 76–80.