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The Measurement of Dynamic Tension Fluctuation in a Flat Knitting Machine

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Knitting is a dynamic process where tension fluctuates at each point. The tension fluctuates from one point to another on a flat knitting machine as the yarn runs over a large setup. The tension variation is dependent on factors such as yarn type, and knitting structures in different zones of the flat knitting machine etc. This paper evaluates the tension fluctuation for diverse yarn type, and knitting structures in different zones of the flat knitting machine and concludes that tension is at the lowest level when the yarn unwinds from the cone (i.e., back zone), which gradually increases in the middle zone and is at the highest level in the knitting zone. Moreover, yarn type also plays an important role in the tension variation during knitting. The wool yarn shows the maximum value of 18.843cN while the viscose yarn indicated the minimum value of 9.849cN. The tension variation within the yarns is 47%. The knitting stitches such as rib gives the maximum tension fluctuation with the value of 15.612cN, whereas the plain knitting indicated the lowest value of 12.630cN, although the tension variation within the stitch type is 19%. The tension in the knitting zone found the highest value of 25.94cN which is 89% higher than the back zone, whilst the tension rise from back zone to middle zone is 80%.

Key words: *Flat knitting machine, Tension fluctuation, Yarn type, Stitch type, digital yarn tensioner device*

INTRODUCTION

The process efficiency of both yarn processing and fabric manufacturing characteristically depends on the single parameter of yarn tension. It's worth mentioning that with precise tension control in textile processes, the efficiency can be increased up to 30% (Niedere, 2000).
An experimental study has been conducted in order to calculate the magnitude of knitting force for different types of fabrics in the knitting zone during the new loop formation. The whole setup has been installed on a stitch-cam to analyse a complete cycle of loop formation. Piezoelectric transducers (M/S Kisteler A.G, Switzerland) have been embedded to calculate the impact of forces in the form of signals. A computer-based program is used to record these signals into digital form (Ray, 2015).

Yarn tension plays a key role when it comes to force between knitting elements. A general model has been established for all the forces acting during the functioning of latch needle and cam, which is helpful to predict the action of mechanical forces in specified and most of the commonly used cam and needle arrangements (MacCarthy, Sharp & Burns, 1992).

This study utilises a mathematical model-based computer program to predict valuable information of the plain knitting and 1x1 rib knitting process. It can predict the course length, stitch length, yarn tensions in the knitting zone, robbing back length on the stitch or the course, RB%, and the value and position of maximum yarn tension. The study also performs a theoretical analysis of the effects of the stitch draw depth, cam angle, cam's step length, and the impact of input tension on the stitch length or course length. The study concludes that the increase in input tension adversely affects the stitch length. Furthermore, it has been observed that robbing back length and percentage increase as the depth of stitch draws and input tensions are increased (Murayama, Oinuma, Nishimura & Onodera, 2009a; Murayama, Oinuma, Nishimura & Onodera, 2009b).

As the yarn passes over and comes in contact with the machine parts, the tension is often enough to break the yarn and create fluff, resulting in the faults in fabric. For this reason, yarn tensions during knitting should be kept low in order to produce knitted fabrics of good quality. To maintain proper yarn tension during knitting, the friction between knitting elements and yarn needs to be low. Low frictional coefficient of yarn gives safe processing and good quality fabrics (Chapman, Pascoe & Tabor, 1955; De Jong, 1993; Knapton, 1963; Morrow, 1931; Ruppenicker & Lofton, 1979; Smith, Burns & Wray, 1974; Zurek, Piasecki & Frydrych, 1989).

The study focuses on the tension fluctuation against different knit stitch types along with the different yarn types and different zones of a flat knitting machine.

Experimental study

Yarn Specification and selection

The tension fluctuation for each zone has been measured for five different commercially used yarns which are common in the knitting industry i.e., cotton, polyester, viscose, acrylic and wool. The yarn specifications are given in table 1.

Table 1. Yarn Specification

Serial No.	Material	Linear density
1	Cotton	36 Tex
2	Wool	36 Tex
3	Acrylic	36 Tex
4	Viscose	36 Tex
5	Polyester	36 Tex

Digital Tensioner device

Computer aided software has been installed to record the signals for dynamic tension variation during knitting. The output data is collected in the form of peaks which clearly shows the dynamic tension variation in the form of wavelength that characterises the tension (cN) on the y-axis versus time elapsed on x-axis.

Figure 1. Digital tensioner device

Tensioner model

Wesco-MLT-, Germany
The magnitude of tension is higher when the cam carriage moves from left to the right than when it is in the reverse direction from right to left. The data is collected for twenty cycles of the cam-carriage for each sample and the same treatment is repeated for six times for each sample. It is hard to make an exact analysis for tension variation at every point just because the data is collected in a short interval of time as indicated in figure 2. So, in order to solve this problem, the highest peak of each cycle was taken and the average of twenty readings is calculated as a final reading.

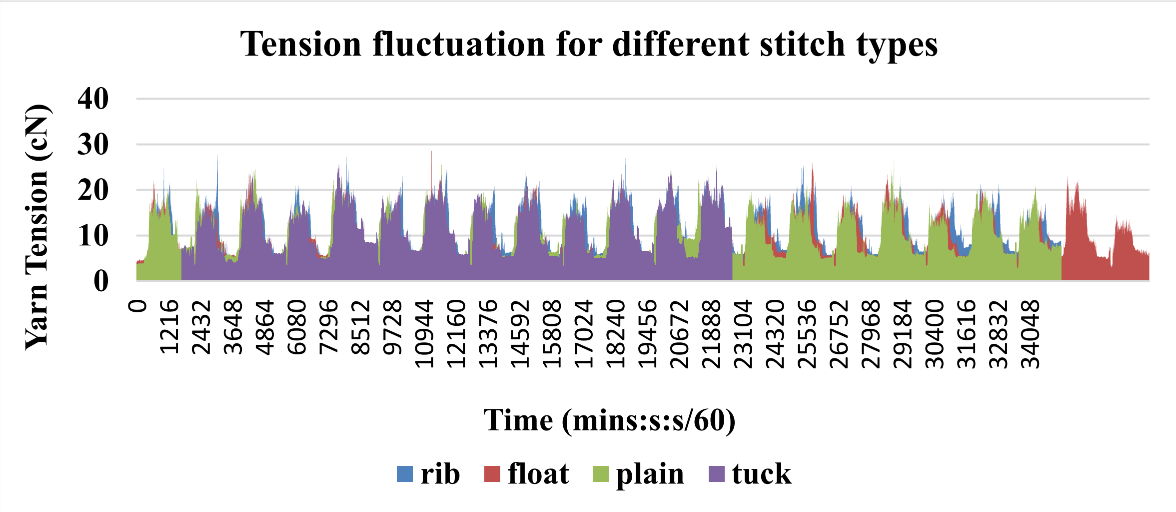

Figure 2. Tension fluctuation in a short interval of time for different knit stitches

Knitting Zones

The tensioner was attached at three points on a computerised flat knitting machine. The machine is divided into three zones: named as back zone, middle zone, knitting zone.

Figure 3. Knitting zones on a flat knitting machine (a) back zone (b) middle zone (c) knitting zone

Knitting machine

Flat knitting machine: Long Xing, 12 G

Knitting structures

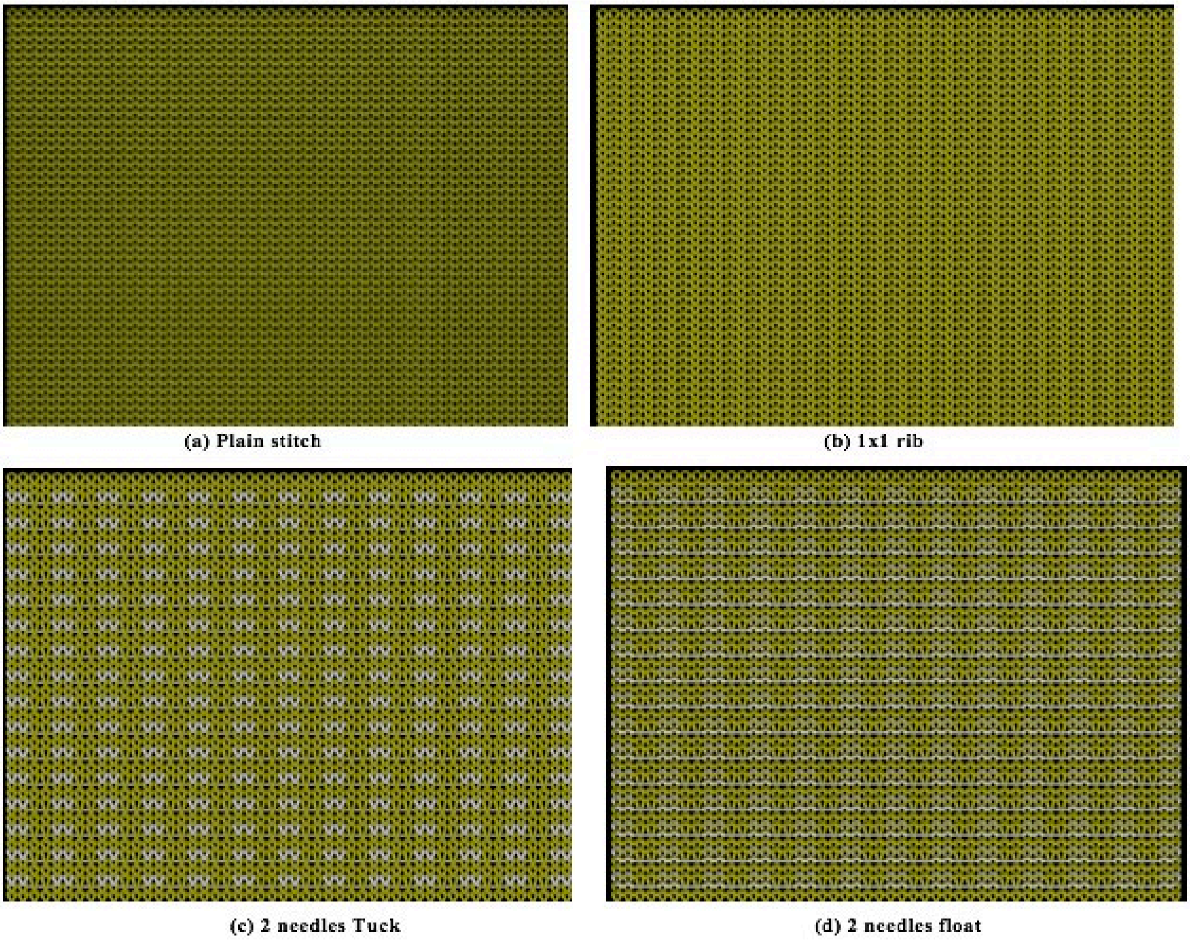

Figure 4. Stitch types (a) plain jersey (b) 1x1 rib (c) 2 needles Tuck (d) 2 needles float

The digital tension tester has been used to measure the dynamic tension fluctuation on the different machine points for different materials and for different loop transferring methods or stitch types (i.e., simple loop, rib, tuck, and float).

Abbreviations

The Abbreviation used to express the stitch types, yarn types as well as knitting zones are given in below:

S_1 = rib stitch, S_2 = tuck stitch, S_3 = float stitch, S_4 = plain stitch
Y_1 = Wool, Y_2 = cotton, Y_3 = acrylic, Y_4 = polyester, Y_5 = viscose
K_1= back zone, K_2 = middle zone, K_3 = knitting zone

Results and discussions

The knitting is done by intermeshing the loops and loop transfer is the dynamic process which allows the tension fluctuation at each stage during knitting. The fluctuation basically depends on the stitch types, yarn type and in different zones of the knitting machine and many other factors.

Table 2. Analysis of variance of tension fluctuation for different stitch type, yarn type and knitting zones

Source	***DF***	***SS***	***MS***	***F***	***P***	
Stitch	3	214.9	71.64	214.48	0.0000	***CV 4.13 %***
Yarn	4	2123.8	530.94	1589.60	0.0000	
Zone	2	16309.6	8154.81	24414.7	0.0000	
Stitch*yarn	12	75.7	6.31	18.88	0.0000	
Stitch*Zone	6	73.2	12.20	36.52	0.0000	
Yarn*Zone	8	970.4	121.31	363.18	0.0000	
Stitch*Yarn*Zone	24	77.2	3.22	9.63	0.0000	
Error	120	40.1	0.33			
Total	179	19884.9				

Level of significance = p-value < 0.05

The unwinding tension of yarn during knitting is an important factor to be maintained. After unwinding, the yarn passes over a large number of yarn guides, metal elements of machines. Such condition of yarn passing over machine elements causes yarn tension. The magnitude of tension is dependent not only on the frictional coefficient but also the angle of wrap between the yarn and the machine parts. Then the yarn comes into the knitting zone. Inside the knitting zone, the yarn runs over the needles and sinker or machine verge or needles of other bed as the case may be and is progressively intermeshed into loop. So, tension in the yarn fluctuates from zone to zone in the machine and eventually at the time of completion of theoretical loop formation at knitting point, tension becomes much higher than the yarn unwinding tension as well as the tension in yarn while entering the knitting zone. So, it is relatively apparent that the length of yarn forming one loop unit at knitting point is under sufficient tension. The magnitude of yarn tension in knitting can be governed by the tensile modulus, frictional coefficient of the yarn as well as the extent of total wrap of the yarn with sinkers, needles of the other bed (in case of double jersey knitting) and machine parts (Koo & Kim, 2002; Van, Ko, & Beevers, 2003; Knapton & Munden, 1966a; Knapton & Munden, 1966b; Ray & Banerjee, 2003).

The statistical analysis of the data obtained in respect of tension variation under different variables of stitch type, yarn type and different knitting zones is presented in table 2. The analysis depicts that the effect of stitch type, yarn type and different knitting zones on tension fluctuation are highly significant. However, the combined effect of different yarns and stitch types, different stitch types and knitting zones, different yarn types and knitting zones are also statistically highly significant at the level of significance (p-value<0.05). So, we interpret the data by using mean values given in table 3 and figure 5.

The individual mean values of tension fluctuation due to different variables are shown in table 3. They indicate the mean values of tension fluctuation are 15.612, 14.249 and 13.513 and 12.630cN due to different stitch type S_1, S_2 and S_3 and S_4, respectively. It can be observed that the highest value of tension has been recorded for rib structure followed by the tuck, float and plain stitch. From the different possible stitch structures, including combinations of the basic stitch types: knit stitches; i.e., tuck stitches (incomplete stitches), plain stitch on one needle bed whereas, rib stitch on two beds, which involves knitting on all the needles within the knitting width that exerts maximum force on the yarn during knitting thus ultimately helps to raise the tension during knitting. The present research gets authenticity from the work of (Fouda, El-Hadidy & El-Deeb, 2014) who concluded that tension for rib structure is higher than for plain structure. Whilst, in tucking the yarn in elongated in wales direction and for two consecutive tucks. Furthermore, the knitting tensions in tuck stitching are higher than in float stitch and differ from those in plain stitch. The fact is that during the tucking, the needles draw the yarn fed and pull down the old loops at the same time. Moreover, for the float or miss stitch the yarn is elongated in horizontal direction so, it is easier to rob yarn for new loop formation, thus it can bear the tension and the yarn tension can be less than that of tuck and plain stitches. In the case of a single float, the tension will be lower than that of plain stitch, because of the robbing back. As in float stitch, it can easily get yarn from the previous loop, while in case of plain stitch it is complicated to get the yarn from the old loop, so the tension value will be higher for plain stitch. Whereas, for two consecutive floats, the tension increases which is higher than that of plain stitch.

Table 3 and figure 5 show the mean values of tension against different yarn types, wool causes the maximum value of tension followed by the cotton, acrylic, polyester and viscose, respectively. Wool yarn is comparatively thick and it covers more contact against the machine elements. Moreover, wool has scales on its surface which results in more frictional value, thus results the higher tension value. Whereas, the cotton being natural fiber is not homogenous in structure, the fiber differs in length, strength and fineness. There are some other factors that play an important role in tension rising during the knitting process like yarn quality, fineness, hairiness and yarn package diameter.

Table 3. Mean values of tension fluctuation for different stitch type, yarn type and knitting zones

Stitch	Yarn Type	Knitting zone
S1= 15.612 A	Y5 18.843 A	K3 25.940 A
S2 = 14.249 B	Y1 17.062 B	K2 13.418 B
S3= 13.513 C	Y3 13.103 C	K1 2.645 C
S4 = 12.630 D	Y2 11.149 D	
	Y4 9.849 E	

Whereas; S_1= rib stitch, S_2= tuck stitch, S_3= float stitch, S_4= plain stitch, Y_1= Wool, Y_2=cotton, Y_3= acrylic,

Y_4= polyester, Y_5=viscose, K_1= back zone, K_2= middle zone, K_3= knitting zone

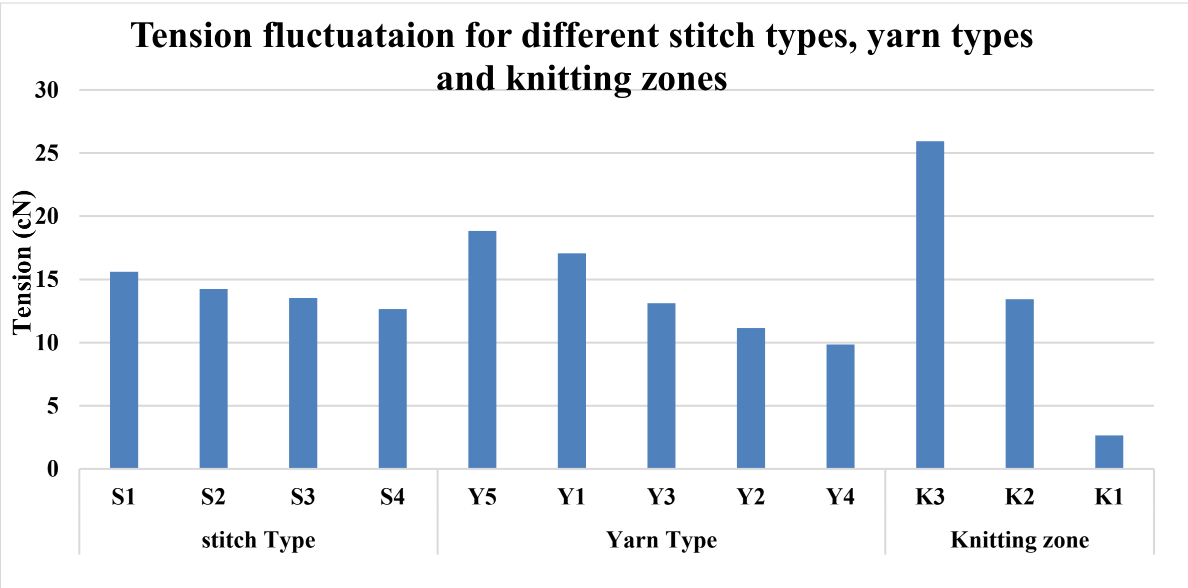

Figure 5. Mean values of tension fluctuation for different stitch type, yarn type and knitting zones; whereas; S_1= rib stitch, S_2= tuck stitch, S_3= float stitch, S_4= plain stitch, Y_1= Wool, Y_2=cotton, Y_3= acrylic, Y_4= polyester, Y_5=viscose, K_1= back zone, K_2= middle zone, K_3= knitting zone

It's also worth mentioning that yarn tension during the knitting process varies from zone to zone. For instance, the tension in the knitting zone is higher as compared to yarn unwinding zone as well as in the middle zone. In fact, the yarn tension is at its highest during the completion of loop formation as compared to when the yarn first enters the knitting zone.

As expected, yarn tensions in the knitting zone are comparatively higher than in the other two regions, i.e., in between 20 cN to 40 cN. The tension rise in the knitting zone is 48% higher than the middle zone whereas an increase in tension value of about 89% has been found for the back zone whilst the tension rise from back zone to middle zone is 80%.

Conclusion

The following conclusions can be drawn out:

1. The tension varies from point to point on a flatbed knitting machine and its magnitude goes on increasing from unwinding to knitting zone as the yarn contact with the machine elements is in a long way.
2. The knit stitch types play an important rule during knitting. The value of tension will be higher in case of the more complicated knit structure. The yarn remains in contact with the knitting needles and frictional values increase.
3. The tension fluctuates for different types of yarns, the thicker the yarn is the tension will be higher. The tension against natural fibers is usually found to be higher over the human-made fibers, as those lack in homogeneity, length, strength, fineness etc.
4. These experimental results can help knitters to acknowledge the intensity of tension fluctuation which can be lowered down in order to optimise knitted fabrics quality.

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