On-line Quality Assurance in Circular Knitting
Part II: Experiment Results

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Abstract

The theoretical analysis in Part I shows that a new yarn length measurement system can be used to monitor the variation in yarn run-in tension which is mainly influenced by the frictional properties of the yarn during knitting. The new yarn length system was designed using a measuring wheel principle. It is a simple construction and more reliable. In order to use the new system efficiently and accuratly the number of yarn turns wrapped around the measuring wheel is 3 turns to eliminate slippage problem. The number of turns on the positive storage feeder was also fixed at 15 turns to eliminate any variation on the yarn of wrapped yarn. The system is placed between the positive storage feeder and the needle. The run-in yarn tension that was affected by the system can be eliminated by adjusting the stitch cam setting. The run-in yarn tension must be set around 2-3 cN. The resolution of the new system is 0.48 mm. Special hardware and software was designed to measure the yarn delivery to the needles by the positive storage feeder per one revolution, by means of a personal computer. By experimental results it is shown that the new yarn length measuring system can be used to monitor the run-in yarn in real-time in order to improve the fabric quality.

1. Introduction

The run-in yarn length is the most important parameter of knitted fabric. It determines the dimensions, weight per unit area of the knitted fabric and the majority of the faults. The faults are caused by the yarn properties (i.e. evenness, coefficient of friction, etc.), yarn behavior in the knitting zone (i.e. yarn tension, yarn speed, etc.) and machine setting. The theoretical analysis in Part I [1] shows that the yarn length measurment can be used to monitor the variation in yarn run-in tension during knitting. In knitting the yarn tension is mainly influenced by the frictional properties of the yarn and it can identify yarn packages which do no meet the required quality standard. The important parameters that affect the knitted fabric in terms of the theoretical analysis was confirmed by experiments using the new yarn length measurement. Therefore, the monitoring of the run-in yarn length and the yarn tension guarantees the reproducibility of any fabric quality and must be included in any solution.

2. Accuracy of length measurement

The accuracy of the length measurement is adversely influenced by any slippage of the yarn on the measuring wheel surface. Yarn slippage can be prevented by wrapping the yarn around the surface of the measuring wheel. In order to determine the optimum number of turns this must be analysed.

The knitting trials were carried out on a fine gauge Mayer & Cie circular knitting machine with the following machine specifications :

- Machine cylinder diameter 26 inch
- Machine gauge E28
- Feeder density 2.8
- Active positive storage feeder 28
- Number of needles 2268

A measuring head described in Part I was fixed between the output sides of the positive storage feeder and knitting zone as shown in ***Fig 1***. A 14.5 tex spun polyester yarn, with a coefficient of friction 0.16 was pulled from a package with a constant stitch cam. The measured course length was determined in terms of the number of pulses per one cylinder revolution. The trial was carried out by varying the number of turns of the yarn on the measuring wheel.

The knitting trials which were carried out with the measuring head demonstrated that yarn slippage was influenced by the following factors:

a) The number of yarn turns wrapped around the measuring wheel;
b) the alignment of the measuring wheel with the yarn path;
c) the yarn vibration.

The knitting trials showed that the problem of yarn alignment with yarn path and the yarn vibration can be solved by placing a yarn guide pulley between the measuring wheel and the needles. Therefore the preliminary trials were concerned with the number of turns on the

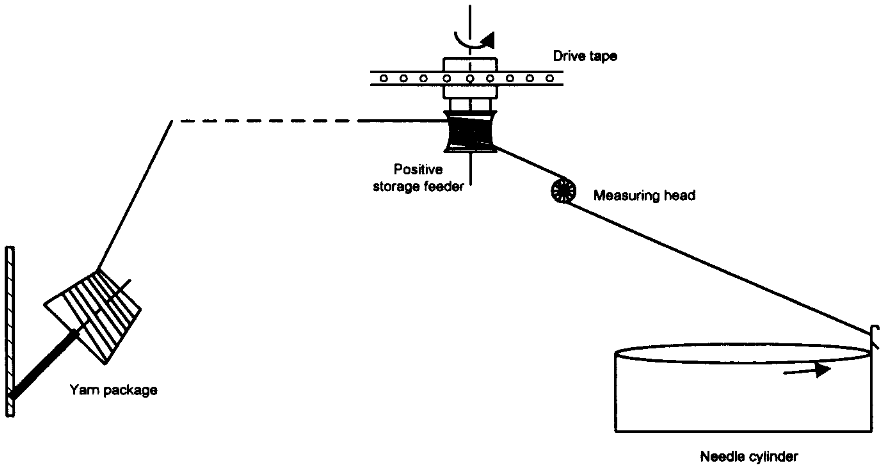

Fig 1. Position of the sensor on the circular knitting machine

measuring wheel; with the guide pulley to guide the yarn to the needles; and without the guide pulley. For all trials the run-in yarn tension was maintained at 6-9 cN by adjusting the stitch cams. The results are shown in ***Fig 2*** and ***Fig 3.***

The results show that the optimum yarn turns wrapped around the measuring wheel was 4 turns without the guide pulley and 3 turns with the guide pulley. The standard deviation was 2.40 and 2.03 respectively.

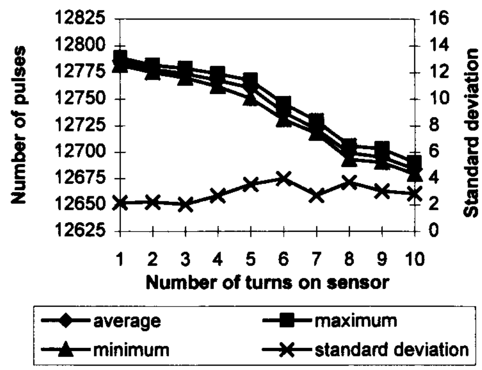

Fig 2 Relationship between the number of turns on the measuring wheel and the number of pulses with guide pulley

3. The effect of the number of turns on storage positive feeder

In order to investigate the number of turns on the storage positive feed wheel on the measured length, the 27 tex spun polyester yarn, with a coefficient of friction 0.15, was pulled from a package with the same stitch cam.

The two measuring heads were fixed, one on the ***input side***, which was positioned between the feed wheel and the cymbal tensioner, and the second one on the ***output side,*** which was fixed between the positive feeder and the needles.

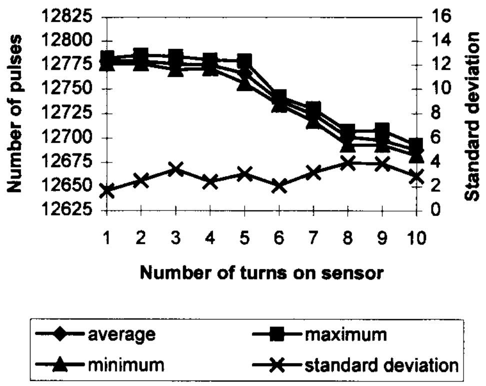

Fig 3 Relationship between the number of turns on the measuring wheel and the number of pulses without guide pulley

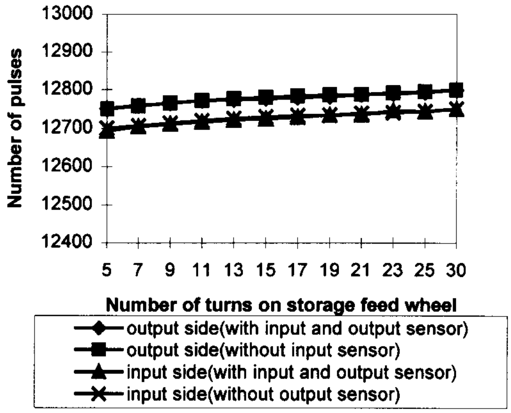

Fig 4 Relationship between the number of turns on the positive storage feeder and the number of pulses

The results are shown in *Fig 4*. The measured course length increased when the number of turns on the positive feeder was increased, because the yarns could warp over each other during the knitting operation. It indicates that the longer length of the yarn delivered to the needle to form the stitches. Therefore, the number of turns on each feeder should be kept constant to avoid making a variation in the length of the wrapped yarn on the working feeders that can cause variation of measuring length. However, the measuring heads at the output side and at the input side do not disturb each other.

4. *The effect of the measured head on the run-in yarn tension*

The run-in yarn tension was measured by using a Rotschild tension measuring head. The Rotschild yarn tension measuring head was placed between the yarn length sensor and the needles. The yarn tension was recorded with the Data Acquisition Processor system at intervals of needle cylinder revolution. The run-in yarn tension between the positive storage feed wheel and the knitting zone was set at 2-5 cN by adjusting the stitch cam setting. When the machine was running, the run-in yarn tension fluctuated at low knitting speeds of 0.36 m/s as shown in *Fig 5*.

The run-in yarn tension was set at 5-10 cN. When the machine was running, the run-in yarn tension fluctuated at low machine speeds as shown in *Fig 6*.

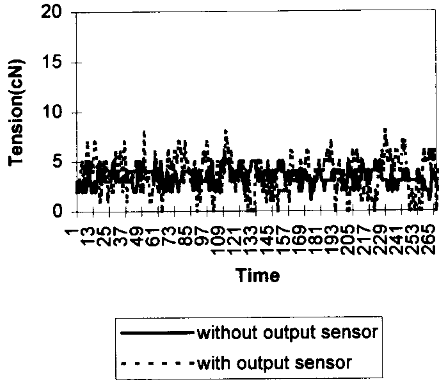

Fig 5 Effect of the measuring wheel on run-in yarn tension at a slow knitting speed of 0.36 m/s

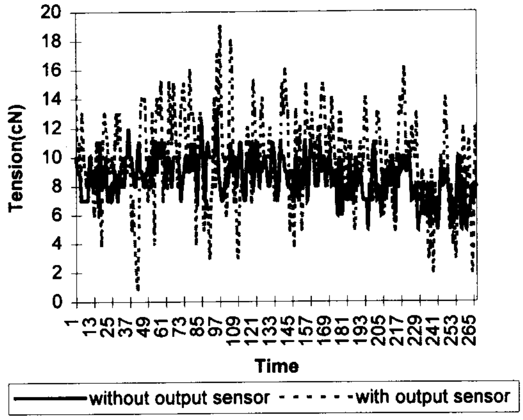

Fig 6 Effect of the measuring wheel on run-in yarn tension at a slow knitting speed of 0.36 m/s

When the yarn tension between the positive storage feed wheel and the needles was adjusted at low tension, the yarn tension variation without the measuring head was 1-5 cN whereas the yarn tension variation with measuring head was 0-8 cN.When the yarn tension without the measuring head was adjusted at higher tension, the variation of tension without the measuring head was 6-12 cN whereas the variation with the measuring head was 1-18 cN. The results showed that the run-in yarn tension with the sensor was high if the stitch cam setting was adjusted to a low position.

5 The effect of yarn tension on the run-in yarn length

The results of the knitting trials described in the previous section showed that the yarn tension was increased by the new yarn length measuring head. In order to investigate the effect of the yarn tension between the positive storage feeder and the knitting zone on the measuring length, knitting trials were carried out for different run-in yarn tensions. The yarn tension was set by adjusting the position of the stitch cam. The run-in yarn tension increases when the stitch setting cam is adjusted to a lower position. The influence of the run-in yarn tension on the measured course length at the input side of the positive storage feeder is shown in *Fig 7*.

When the run-in yarn tension is set at 3 cN, the measured yarn length between the input side and output side is not different because the yarn is less stretched. However, when the stitch cam is set at the lower position, the yarn length at the output side of the positive storage feeder becomes longer than the length at the input side.

Equation (5) and equation (8) in Part I [1] show that the run-in yarn tension increases as a result of increasing run-in yarn length. The results of this trial confirm the theoretical analysis. The results also show that the yarn was stretched when the run-in yarn tension was increased because the positive feed wheel delivers the yarn into the needles to form stitches at a constant rate.

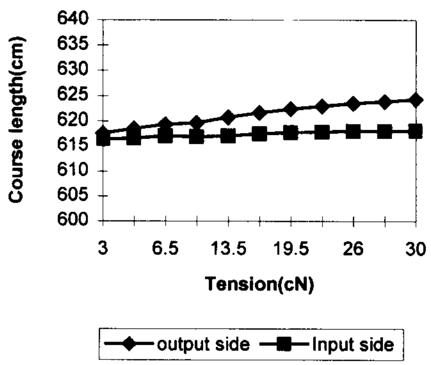

Fig 7 The effect of run-in yarn tension on measured length

6. *The effect of cam setting position on the run-in yarn length*

Knitting trials were carried out to study the effect of cam setting on the run-in yarn length using 26.7 tex polyester spun yarn. Theoretically by adjusting the stitch cam position to a lower position the needles would form larger stitches. As the positive storage feeders are set to deliver a constant stitch length the yarn was stretched by the needles because the amount of yarn is delivered into the needles at the same rate. Therefore, the run-in yarn tension increases when the position of the stitch cam setting is lower and the length of the measured yarn at the output side increases as shown in ***Fig 8***. The actual course length is determined by unravelling the knitted courses and measuring them. These results are also shown in ***Fig 9***. The results show that the yarn length measured at the input side is not affected by the stitch cam setting.

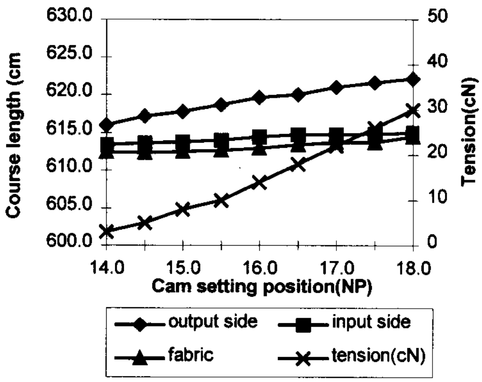

Fig 8 Relationship between cam setting position and measured value

7. *The effect of yarn coefficient of friction on the run-in yarn length*

The effects of the coefficient of yarn friction on the yarn length measurement at the output side of the positive storage feeder when using a 26.7 tex spun cotton yarn with different coefficient of friction of 0.16 are shown in **Table 1**. When the coefficient of yarn friction is increased, the needles have difficulty in pulling the yarn to form stitches, and as such the needles require less yarn. Therefore the yarn length at the output side becomes shorter.

However, when the storage feed wheel delivers the yarn to the needles at a constant rate, the yarn between the feeder and the needles becomes relaxed. The yarn tension at the output side decreases, but the measured course length after relaxation is mostly constant.

The results summarised in **Table 1** clearly indicate that run-in yarn length measurement can be used in order to identify variation in the frictional behaviour of yarn during knitting. It is questionable that the run-in yarn length measurement can be used to determine the absolute value of the coefficient of the friction of a yarn, but for a given yarn at machine setting a relative monitoring of the coefficient of friction should be possible. By comparing the run-in yarn length between individual knitting systems of a circular knitting machine one should be able to identify discrepancies leading to fabric defects such as barriness and shadow barriness.

8. The effect of cymbal tensioner on measured yarn length measurement

The objective of these knitting trials was to investigate the effect of the yarn input tension, i.e. shortly before the yarn is delivered to the positive storage feed wheel on the measured course length. A 14.6 spun polyester yarn with a coefficient of friction of 0.16 was knitted with a constant stitch cam setting.

Initial trials, the run- in in yarn tension was adjusted at around 2.0-3.0 cN by adjusting the stitch cam. The yarn input tension and run-in yarn tension was measured by using a standard yarn tension meter. The yarn input tension was increased by increasing the pressure between the discs of the cymbal tensioner. The run-in yarn tension and the input yarn tension were recorded. On the knitted fabric the course length was measured.

Table 1. Relationship between coefficient of friction and measured value

Coefficient of friction	Average tension(cN)	Course length(cm)	Fabric length(cm)
0.24	4.9	627.0	619.6
0.17	6.6	627.6	619.4
0.14	8.3	628.1	619.5
0.12	8.3	628.6	620.1

In the second series of knitting trials, the run-in yarn tension was adjusted to 4.0-5.0 cN. The trials were carried out in the same way as the first knitting trial. The result are shown in **Table 2.**

At the stitch cam position 13, the run-in yarn tension was 2.0-3.0 cN whereas yarn input tension was 3.0-4.0 cN. The average number of pulses was 12728. When the yarn input tension was increased, the run-in yarn tension was 3.0-4.0 cN and the average number of pulses was recorded at 12701. The result of the second experiment was similar to the first experiment. The number of pulses generated by the measuring head at the higher yarn input tension was lower than when the input yarn tension was low.

This means that the yarn was stretched and the needles pulled the stretched yarn to form the stitches. The results support equation (5) and equation (8) of the analysis in Part I [1], and it shows that the increase in input yarn tension results in a decrease in the run-in yarn length.

9. The effect of the knitting speed on the run-in yarn length

In order to study the efficiency of the new measuring head at higher knitting speeds additional knitting trials were carried out with two different types of yarns, namely a nylon 66 textured yarn (8.5 tex) and a polyester/cotton (65/35) spun yarn (19.9 tex). The knitting trials were carried out at two knitting speeds 0.36 m/s and 0.72 m/s respectively.

Table 2 Relation between stitch cam position, yarn tension and run-in yarn length

Stitch cam position (scale reading)	Yarn input tension(cN)	Run-in yarn tension (cN)	Run-in yarn length in number of pulses	Standard deviation in pulses.	C.V.
13	3.0-4.0	2.0-3.0	12728	2.344	0.018
13	5.0-6.0	3.0-4.0	12701	1.749	0.014
14	5.0-6.0	4.0-5.0	12763	2.397	0.019
14	8.0-9.0	5.0-6.0	12712	1.860	0.015

The results are shown in ***Fig 9*** and ***Fig 10.*** At higher knitting speeds, the coefficient of friction of yarn increases. However the yarn is delivered to the needles at the same length and therefore the run-in yarn tension decreases. This means a higher reading for the run-in yarn length.

Comparison of the textured yarn and the spun polyester/cotton yarn shows that differences in the run-in yarn length for different knitting speeds were noted. These were due to differences in modulus of the two yarns used in the trials.

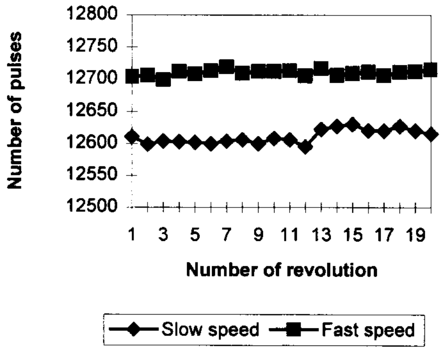

Fig 9 Effect of knitting speed on the number of pulses for nylon 66

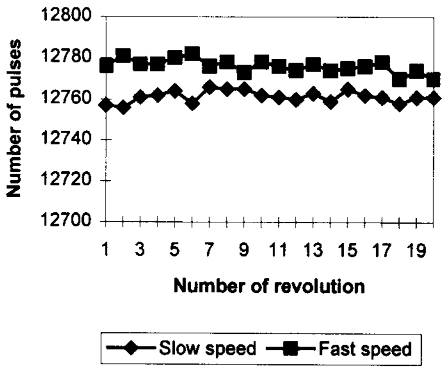

Fig 10 Effect of knitting speed on the number of pulses for spun polyester/cotton yarn (65/35)

10. Summary

The knitting trials have demonstrated that the new yarn length measuring system can be used to monitor the run-in yarn length or real-time course length. The trials have also shown that the most suitable position for placing the measuring head on the yarn path is to fix it onto the output side of a positive storage feeder, i.e. between the positive storage feeder and the knitting needles. Such an arrangement would minimise the run-in yarn tension.

The new measuring head system can be used to improve the quality of the knitted fabric by measuring the run-in yarn length per cylinder revolution and comparing the measured value with a set threshold value. If the measured yarn length is outside the threshold, it means that the fabric quality may be affected by:

- different cam setting;
- high variation of yarn frictional properties;
- different type of yarn;
- different yarn count.

When fixing the measuring head it must be adjusted to prevent the yarn that is wrapped on the measuring wheel from moving freely from rim to rim. Such free movement of the yarn would result in a high standard deviation of the data.

In order to use the new yarn length measuring system effectively the following conditions need to be satisfied:

- the number of yarn turns on the measuring wheel should be around 3;
- the run-in yarn tension should be adjusted to 2-5 cN by adjusting the stitch cam settings

The quality of the fabric can be improved by using the real-time monitoring system. However, there is still a need for a real-time automatic inspection system to detect fabric faults in real time after the fabric leaves the knitting area. For example, avoiding holes, thick and thin places, needle marks and cloudiness will improve fabric quality and minimise production cost. This area would offer a significant research opportunity for development in the field of quality assurance.

11. References

[1] Lek-Uthai, J., and Dias, T. (1999), Quality Asurance in Circular Knitting, Journal of Science and Technology, Vol. 4, No.1, pp. 72-81.

[2] Latzke, P. (1982), Quality Assurance of Knit Goods, Melliand Textilberichte, Vol.63, p. 31.

[3] Bühler, G., Schilpp, D., Bodenschatz, St.,and Haid, H., Masnahmen zur Qualitat-ssicherung von Maschenwaren aus Faser-garnen, Abschlussbericht , AIF-Nr 5653.

[4] Bühler, G., Schilpp, D., and Haid, H., Die Bedeutung der Fehlerkosten in der Masche-Nindustrie, Wirkereiu. Strickerei-Technik, Vol.36, p. 7/694.

[5] Dias, T. (1989), Automatische Fehlererkennung und Betriersdatenerfassug an der Rund Strickmaschine, Ph.D. Thesis, Denkendorf Wissenschaftliche Institute der Universitat Stuttgart, Melliand English, p. 1.

[6] Bühler, G. (1982), Auswirkung der Garneigens-Chaften auf die Herstellung von Maschenwaren, Wirkerei- u. Strickerei-Technik, Vol. 32, p. 2.

[7] Bühler, G., Haid, H., and Pestel, L.(1994), Requirements in Regard to Future Circular Knitting Quality Assurance Systems, Practical Trial with a Future Oriented Monitoring System, Melliand English, pp. 11-13.