

Quality Assurance Circular in Knitting

Part I: Theoretical Analysis

Jearranai Lek-Uthai

Department of Physics, Faculty of Science and Technology ,
Thammasat University, Thailand

Tiluk Dias

Department of Textiles ,UMIST,UK

Abstract

The quality of the knitted fabric is an important factor in the knitwear industry. On circular knitting machines, the fabric is improved by using the positive storage feeding device which delivers the length of the yarn to the needles in order to form stitches at a constant rate. Yarn tension, yarn properties and elongation of the yarn are important parameters influencing course length in the knitted fabric. However, course length is the most important parameter that determines the dimension of the knitted fabrics. Therefore, a mathematical analysis was carried out to study the feasibility of using yarn length measurement in order to improve the fabric quality and the efficiency of the process.

A personal computer-based system was created to monitor important information such as run-in yarn length, running machine condition, yarn breakage, needle breakage, machine and time performance during the normal operation. An additional sensor had to be installed in order to determine the above parameters. Special hardware and software was developed for monitoring and analysing the knitting process parameters in real time.

1. Introduction

Due to the ever increasing demand for quality products a high quality standard is important for the circular weft knitting industry. Numerous research projects have defined those measures which must be taken by knitters to ensure high quality standards for knitted fabrics [1]. The high quality standard can be guaranteed by careful planning, incorporating appropriate quality assurance measures and by accurate allocation of incurred overheads to their origins. Industrial analyses indicate that product quality can be improved, and defect cost minimised, by real-time monitoring of the circular knitting process.

The important function of such a concept lies not only in detecting process interference but also in identifying their sources and ensuring their quick and cost effective elimination. Previously, prospects for a low cost system seemed remote, but the rapidly expanding microprocessor and semi-conductor technology now offer a base for creating cost effective smart real-time quality assurance systems.

2. Description of the problem

Labour intensive quality control methods are expensive and too slow to be used on modern high production systems. Monitoring fabric quality needs to be automated in order to reduce production costs. These measures must be applied at the point where most of the defects

will occur. From the viewpoint of production planning, such an approach will permit better control of the manufacturing chain by intervening at an early stage. Analyses of fabric faults have demonstrated that the majority of faults in knitted greige fabrics are caused by inconsistencies in yarn properties and improper knitting conditions. Yarn inconsistencies are influenced by fibres, spinning and texturing conditions, yarn unevenness, and the mechanical and frictional properties of the yarn [2-6]. Defects also occur due to improper knitting conditions especially at high production rates, incorrect machine settings, poor monitoring of the machine performance, and improper yarn delivery.

Therefore, the best way to improve the quality of knitted fabric is to monitor in real-time the important knitting parameters and process interference, and to apply counter measures when deviations are identified. Such an approach can provide useful information to the knitter, which would enable him to take appropriate action to improve the product quality, rather than simply detecting and counting the number of fabric faults.

3. Present situation on quality monitoring in circular knitting machine

All modern circular knitting machines are equipped with needle detectors to detect damaged needles and yarn stop motions to stop the machine in the case of a yarn break. These machines are also equipped with revolution

counters that can be set to stop the machine after a pre-determined number of revolutions. Although the machine manufacturers have improved the cams, the needle cylinders and dials and the fabric take down mechanisms and yarn feeding devices, very little has been achieved in the area of quality monitoring, especially on-line. Therefore the circular knitting machine can be considered as a high production machine without any feed back on the quality of its product and its efficiency.

3.1 New concept for quality monitoring in circular knitting machine

In view of the above situation, a new concept was created at UMIST for monitoring circular knitting machines in order to ensure the product quality. The UMIST quality assurance system was created on a Mayer & Cie, MV4 26 inch, E28, circular knitting machine. The new concept was based on the principal of continuously measuring the important process parameters during the circular knitting process and comparing these with predetermined set values of a particular product quality. In general such a concept must include all production areas originating from the yarn on the machine to the knitted fabric produced. In the case of circular knitting, parameters such as the course length, the yarn tension and the fabric appearance should be monitored, and controlled if possible. It is also essential to monitor the performance of the knitting machine continuously. The material flow

diagram of a circular-knitting machine indicating the important parameters that are to be monitored is given in *Fig 1*.

If the monitoring system can analyse the run-in condition of the yarn then this information can be used to identify yarn packages that do not meet the required standards and provide this information to the knitter for suitable action. Such a solution would improve the productivity and also the overall efficiency of the machine as well as the lifetime of the knitting elements. The system would also represent the closest solution to the testing of the entire length of the processed yarn.

4. Creation of on-line data monitoring system

As mentioned earlier the majority of the process interference of fabric defects originate from yarn. Very frequently the source of the process interference is a length of yarn in a yarn package. Such a length of the yarn would have different yarn properties, especially the frictional properties, and can be detected by continuously monitoring the yarn tension.

Current technology for measuring yarn tension is based on determining the deflection of a cantilever which is caused due to the tension in the yarn. The deflection can be determined by means of capacitive, inductive and resistive methods. A newer technology for measuring yarn tension

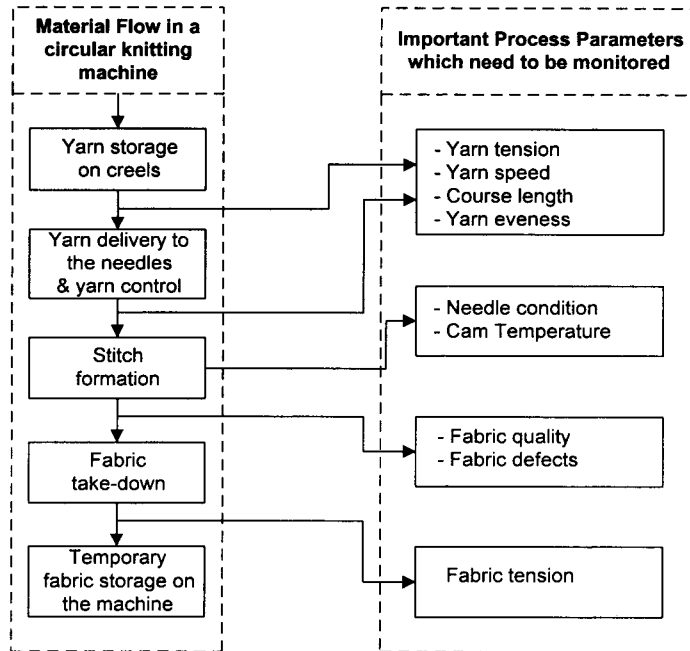


Fig 1: The material flow diagram of a circular knitting machine indicating the important process parameters which need to be monitored.

is based on the the piezo-electric method. Although the technology of yarn tension measurement has advanced during the last few years, it is still not feasible to monitor the tension of each yarn end on a circular knitting machine continuously due to high unit cost. Therefore it was decided to study the feasibility of using course length measurement instead of the continuous yarn tension measurement, in order to identify sub-standard yarn packages on the machine.

4.1 Theoretical analysis

A simplified version of the yarn path on a circular knitting machine equipped with

storage positive yarn feeder such as Memminger MPF, is shown in **Fig 2**. The storage feed wheel, that is rotating at a constant speed, pulls a length of yarn l_n from the yarn package with an input tension T_i . This length of yarn is delivered to the needles in order to form stitches. Theoretically; the needles should utilise this yarn length to form stitches. Although the length of yarn used by the needles to form stitches should depend on the stitch cam setting, in reality, it is also influenced by the following factors:

- the run-in yarn tension ; this is the tension under which the yarn is delivered into the

knitting zone;

- the yarn frictional properties;
- the yarn modulus;
- the robbing back effect.

Therefore on a circular knitting machine with storage positive feeding the run-in yarn tension is influenced by the difference in the length of the yarn delivered to the needles by the feed wheel and the length of yarn used by the needles to form stitches. This is the tension T_0 in **Fig 2**. The run-in yarn tension, therefore, on a circular knitting machine is regulated by the knitters by adjusting the stitch cam setting for a set drive tape speed.

In the present technology, the yarn packages are stored on free-standing creels and the yarns are guided to the storage feed wheels using enclosed plastic tubes. This arrangement leads to an increase in yarn tension due to frictional drag between yarn and contact points of enclosed feeding tubes. The tension T_i is also influenced by the setting of the cymbal tensioner on the storage positive feeder unit.

As a result, the input tension T_i is much higher than the output tension T_0 , and therefore the length of yarn pulled from the yarn package by the storage feed positive wheel, l_{Ti} , will be longer than the length of the yarn delivered by it to the needles, l_{T0} , to form stitches. The relationship between the input tension T_i and the yarn length l_{Ti} can be derived with the yarn

modulus. By considering the yarn modulus E , and the yarn count in tex, T_t , the length of yarn in a fully relaxed condition (i.e. at zero-tension, l_{FR}) can be calculated as follows:

$$T_i = E \cdot T_t \cdot \frac{l_{Ti} - l_{FR}}{l_{FR}}$$

assuming that E and T_t remain constant.

By substitute

$$E \cdot T_t = K$$

where $K = \text{constant}$

$$\text{Therefore } l_{FR} = \frac{l_{Ti}}{\left(\frac{T_i}{K} + 1\right)} \quad (1)$$

The length of the yarn drawn by the storage feed wheel during one cylinder revolution can be calculated by considering the average circumference of the feed wheel C_{FW} and the number of revolutions of the feed wheel per cylinder revolution, N_{FW} .

$$l_{Ti} = C_{FW} \cdot N_{FW} \quad (2)$$

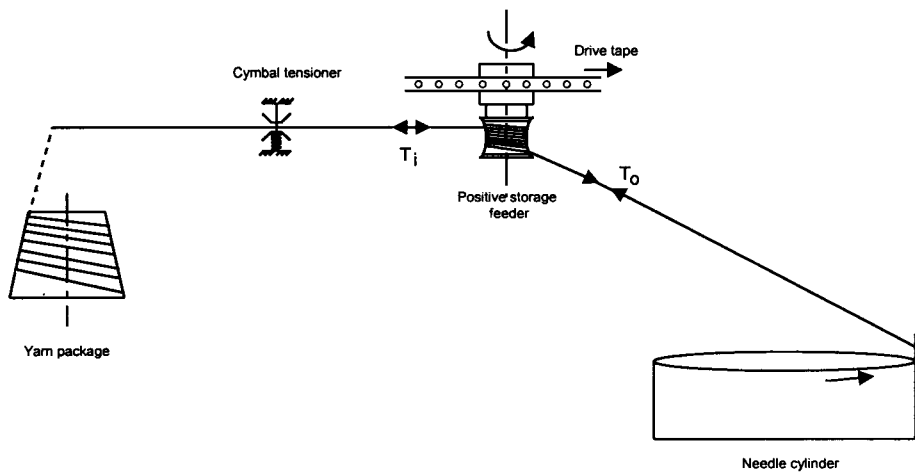


Fig 2 : Yarn path on a modern circular knitting machine
with storage positive yarn feeding.

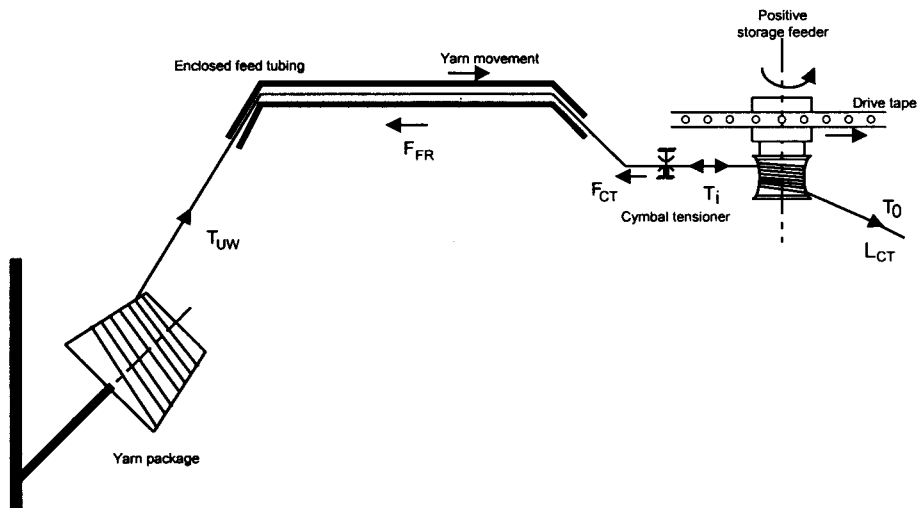


Fig 3: Frictional drag on the yarn and yarn unwinding tension

By substituting the value of l_{Ti} in equation (1)

$$l_{FR} = \frac{C_{FW} \cdot N_{FW}}{\left(\frac{T_i}{K} + 1\right)} \quad (3)$$

Similarly to equation (1), the yarn length, l_{T0} used by the needles to form stitches can be calculated as shown below.

$$l_{FR} = \frac{l_{T0}}{\left(\frac{T_o}{K} + 1\right)} \quad (4)$$

Therefore by substituting this value l_{FR} in equation (3):

$$\frac{l_{T0}}{\left(\frac{T_o}{K} + 1\right)} = \frac{C_{FW} \cdot N_{FW}}{\left(\frac{T_i}{K} + 1\right)}$$

$$l_{T0} = C_{FW} \cdot N_{FW} \cdot \left(\frac{T_o + K}{T_i + K}\right) \quad (5)$$

When T_{UW} = yarn unwinding tension

F_{FR} = frictional drag of enclosed feed tubing

F_{CT} = frictional of cymbal tensioner

T_i = input yarn tension

T_o = output yarn tension

The yarn tension T_i can be determined with the yarn unwinding tension and the frictional drag on the yarn, as shown in **Fig 3**.

Therefore $T_i = T_{UW} + F_{FR} + F_{CT}$

The unwinding tension in the yarn T_{UW} is influenced by the package geometry which is determined by the package winding process.

Generally, variation in yarn tension is reported with a decrease in package diameter. The frictional drag F_{FR} depends on the yarn frictional properties. At present, lubricants are applied to the surface of knitting yarns in order to improve their frictional properties, i.e. to reduce the yarn-metal coefficient of friction.

The yarn-metal coefficient of friction will depend on the amount of lubricant on the yarn surface, and it is important to apply a constant amount of lubricant per unit length of yarn. The circular knitters are aware that there are packages with poorly lubricated or unlubricated lengths of yarn in them, and it is practically impossible to detect such packages prior to knitting by means of accepted laboratory yarn test methods.

For a given machine setting C_{FW} and N_{FW} are constant. Therefore equation (5) can be simplified as follows:

$$l_{T0} = K_1 \frac{(T_o + E \cdot T_i)}{(T_i + E \cdot T_i)} \quad (6)$$

where $K_1 = C_{FW} \cdot N_{FW}$

If one assumes that for a given yarn the factors E and T_i are constant, then it should be possible to detect yarn tension variation during the stitch formation process by continuously monitoring the yarn length, l_{T0} and it also should be possible to detect a poorly lubricated or unlubricated yarn length in a package. The increase in frictional drag on such a length of yarn would cause the tension T_i to increase and

T_0 to decrease, and this will influence the measurement, l_{TV} . The above analysis shows that equation (6) provides an alternative solution for detecting irregularities in yarn frictional properties during knitting. This would require the real-time measurement of the yarn delivered to the needles by the positive storage feed wheels in a pre-determined time interval.

4.2 Yarn length measuring system

The course length is one of the most important parameters that determines the dimensions and the weight of a knitted fabric. Therefore yarn length counters and yarn speed meters have been developed to measure or determine the course length.

The yarn length counter is based on the measurement of the length of yarn delivered during a certain time period, generally one needle cylinder revolution. However, the yarn length measuring instruments in use today operate on a measuring wheel principle, which records the number of revolutions by means of a mechanical or an electronic counter, and the appropriate yarn length is obtained by a simple calculation. The accuracy of the measurement will depend on yarn slippage on the measuring wheel surface and also on the inertia of the wheel. Commercially available yarn length measuring systems are not designed for on-line monitoring on circular knitting machines, therefore a new cost effective system was developed at UMIST.

The new yarn length measuring head consists of a plastic wheel that rotates on metal bearings as shown in *Fig 4*. A film disc, with black and white stripes, was fixed to the extended shaft of the wheel. These black and white stripes were detected with a reflective opto-sensor when the wheel was in motion. The number of black and white stripes and the diameter of the wheel determine the resolution of the system. The new system has a resolution of ± 0.48 mm.

Based on equation (6) the new measuring head was fixed below the storage feed wheel in order to monitor the course length i.e. the length l_{TV} . The conventional yarn path between the feeder wheel and the yarn feeding point was altered slightly by wrapping the yarn around the wheel three times to obviate any yarn slippage. The moving yarn sets the measuring wheel in rotation causing the reflective opto-switch to generate a stream of voltage pulse signals. In order to monitor the course length, the total number of voltage pulses generated during a needle cylinder revolution was determined. This was achieved by interfacing the voltage pulse signal to a 16 bit counter of a personal computer. Special software was written to determine the total number of the pulses per needle cylinder revolution.

The corresponding course length l_{CL} was calculated from the equation (7) given below.

$$l_{CL} = \sum N_{rev} \cdot \pi \cdot D_w / R_w \quad (7)$$

where $\sum N_{rev}$ = the total number of pulses
per cylinder revolution

D_w = the diameter of the mea-
suring wheel in mm

R_w = the number of reflective
stripes on the wheel

The resolution of the sensor equal to $\pi D_w / R_w$.

According to equation (6)

$$l_{To} = l_{CL} = K_1 \left(\frac{T_0 + K}{T_i + K} \right)$$

Therefore by substituting the above in equation
(7)

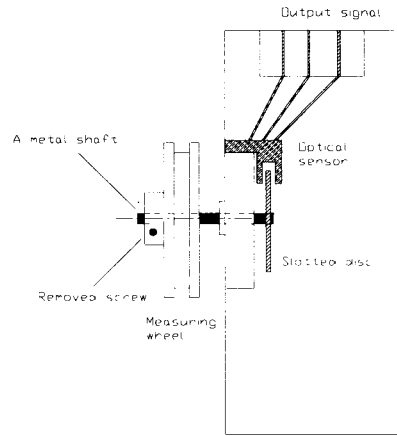
$$\sum N_{rev} \cdot \frac{\pi D_w}{R_w} = K_1 \frac{T_0 + K}{T_i + K}$$

By substituting $K_1 = C_{FW} \cdot N_{FW}$

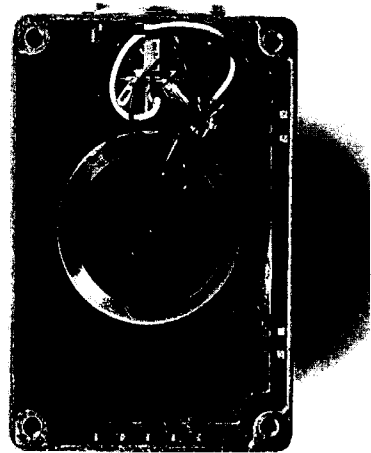
Therefore

$$\sum N_{rev} = (N_{FW} \cdot C_{FW}) \cdot (R_w / \pi \cdot D_w) \cdot \left(\frac{T_0 + K}{T_i + K} \right) \quad (8)$$

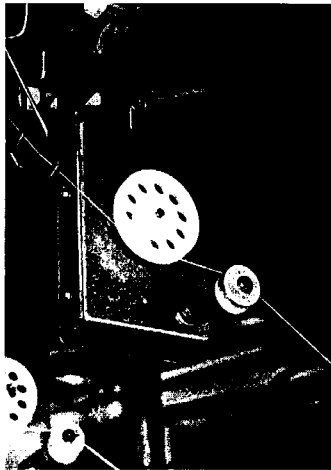
Equation (8) shows the relationship between the yarn tension components T_0 and T_i and the counted pulses. Therefore, if the input tension T_i or the coefficient of yarn friction is increased, the measurement of counted pulses, which is the measurement of yarn length will decrease.



(a)



(b)



(c)

Fig 4 : Schematic diagram of the arrangement of the measuring wheel and the optical sensor system

The advantage of the system is that all yarn packages can be continuously checked. If a monitored parameter is outside a pre-set tolerance limit, the system can identify these automatically, and indicate it to the knitter for necessary action.

5. Summary

The theoretical analysis shows that the irregularities in yarn frictional properties during knitting can be detected by measuring the yarn length delivered to the needles from the positive storage feeder in a pre-determined time interval. The new yarn length measurement can be created based on a measuring wheel principle by using the above theoretical analysis in order to measure the course length in real-time.

6. References

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