

A SYSTEM FOR KNITTING PROCESS MONITORING AND FAULT DETECTION ON WEFT CIRCULAR KNITTING MACHINES

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ABSTRACT

From the production manager point of view, the knowledge of how well a knitting machine is working during production is very important. This information allows the manager to schedule all plans and also to know the overall production level of a manufacturing plant. For this purpose there are many system information packages. One of the most important items for production is the number of faults occurred while producing a fabric, since it directly influences productivity. With this subject in mind, this paper presents a system with a special emphasis on surveillance of the knitting process in order to detect, identify and locate faults during production, by monitoring the yarn input tension. The system also provides the user with a valuable set of information related with production. Finally, the paper presents some of the techniques used to detect the faults.

KEYWORDS

Knitting process, monitoring systems, fault detection

INTRODUCTION

The monitoring of the production of an industrial knitting machine is crucial for order planning and scheduling. For that purpose, several solutions are presently available by industry manufacturers which provide a very complete and valuable set of information, comprehending standstill periods, production in meters of the knitted fabric, knitting machine's speed, and other features [1,2,3,4,10].

One of the most important monitoring issues resides on fault occurrence during production of the knitted fabric. Faults are a problem that is impossible to avoid. This is due to some factors, namely the ageing of the knitting elements, the abrasive action of the raw material, exceeding forces, and the impacts between the knitting elements and cams [9]. So, during production it might well happen that one needle can be damaged and will produce a fault, which can be a permanent or a random behaviour fault. It is very important for production and quality statistics to know how many faults are present in a knitted fabric. The length and the number of faults can give an accurate idea about the amount of fabric that will have to be considered as non-conform and thus rejected. A monitoring system capable of providing this kind of information is thus very welcome one for the industrial point of view [1]. Several devices were developed in order to detect faults during production. Examples are closed latch detectors, techniques involving capacitive sensors and pattern recognition for detection of damaged needles [5,6]. Optic sensing is also used, mainly on fabric monitoring [7]. These examples present two of the possible approaches for fault detection. The third approach involves raw material inspection and it is however less explored; the most primitive sensing device is the yarn break detector, which functioning is based on gravity principles [8,10]. Even this sensor tends to be replaced by optical sensors, with no contact with the yarn. The replacement is probably due to the effect of this device in the yarn tension, which becomes somewhat more variable than when an optical sensor is used. As the cost decreases and performance increases for electronic sensors and devices, the equipment used up to now is replaced with new solutions.

The present technology for fault detection although effective is case specific, does not detect all the faults and there is neither integration nor value added information. For example, the widest used system, the needle detector, is only able to detect closed latches, or raised needles (promoted by broken butt) [5]. Damaged sinkers, broken hooks, or damaged needles are not detected. The system used for detecting faults in the knitted fabric faces problems related with the speed of the knitting machine and some kinds of patterns that can pass without being detected. In many machines there is no communication between these devices and the production information system, particularly in what faults are concerned.

Research made [10] exploring the third approach proved that is possible to detect faults by inspecting the raw material, in particular the *yarn input tension* – *YIT* parameter. *YIT* is indeed a valuable resource of information concerning in particular the knitting process, and in a more general term, the overall behaviour of the knitting machine, since *YIT* directly reflects the influence of the different mechanisms involved in the production of the knitted fabric [10,11,12]. In fact, through the *YIT* waveform is possible to: identify the appearance of a fault, which is represented by a sudden increase/decrease in the force; locate in the knitting bed the cause of the fault; identify the nature of the fault; determine eccentricities of the feeding systems, which are represented with sinusoidal waveforms; determine abnormalities that can degenerate in faults; determine the real *YIT* in each instant. Studies were also made in order to automatically distinguish the cause of faults and location [12]. Presently, there are solutions implemented by industry manufacturers that involve force sensors to give permanent information concerning the average *YIT* for each yarn involved in the knitting process. This data is gathered in a information system unit installed in each knitting machine, that in turn communicate with management systems of the entire industry plant. Thus, a significant set of data concerning production is now available for the manager.

THE MEASUREMENT SYSTEM

With the purpose of monitoring the knitting process and detecting faults during production, a system was developed [13,14]. At the present, the system was upgraded with new functionalities which are directly related with the consumption of yarn. The proposed system is capable of:

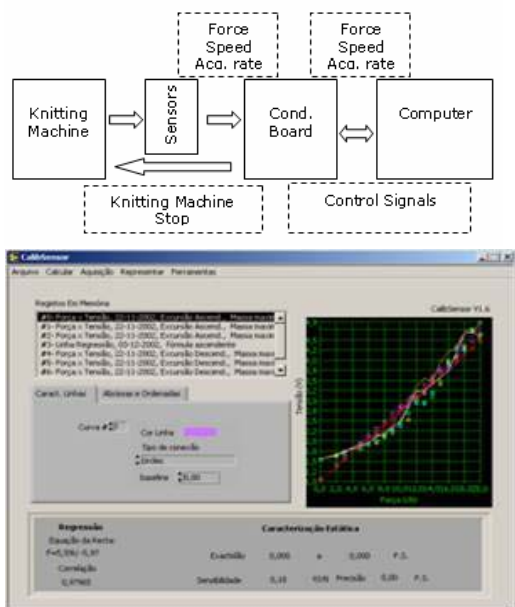


Figure 1. Measuring system general scheme and developed sensor calibration software.

- Represent the behaviour of the knitting process,
- Detect the presence of faults,
- Diagnose the cause of the faults,
- Identify malfunctions during production,
- Allow the adjustment of the yarn input tension,
- Calculate yarn and knitted fabric consumptions,
- Estimate loop length, tightness factor,
- Determine the knitting machine's speed

The system was designed in a way that its assemblage does not affect the structure of the knitting machine, and it is essentially based on force, position and optical sensors. The sensors are interfaced with a conditioning board whose hardware can be fully programmed by software in automatic or manual mode. This stage is connected to a data acquisition board which is responsible for the communication between the pc, the sensors and knitting machine

(Figure 1). The force sensor can measure from 0.0-5.0 cN up to 0.0-200.0 cN. The user can choose the desired force range, and the system will automatically adjust signal amplification and offsets for the selected range. Calibration procedures can then be performed in order to adjust the resulting signal into correct force magnitudes. The system can be used in any circular knitting machine and for the present knitting speeds.

Figure 2 illustrates the system assemblage on an industrial knitting machine. The force sensor (Figure 2 (a)) is located near the knitting zone, in order to give a more accurate *YIT*, increase the speed of detecting faults, and also to prevent the *YIT* damping phenomena (due to the transmission of the force variability through the yarn).

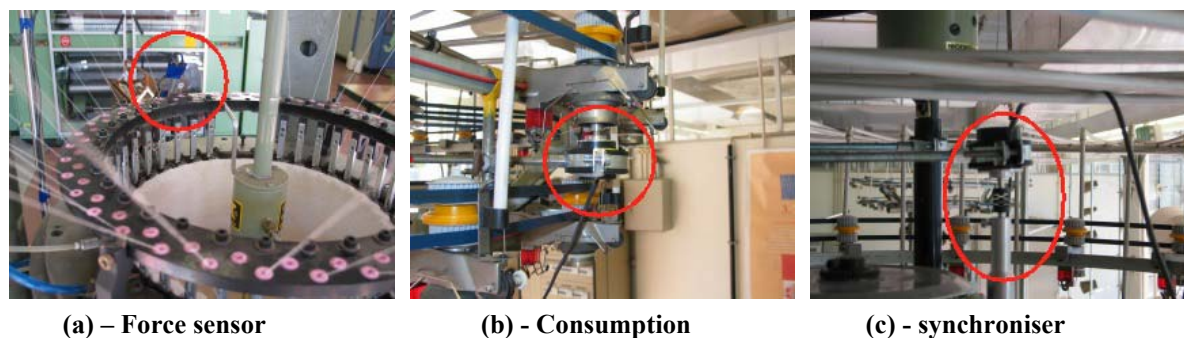


Figure 2. Sensors assembled in an industrial knitting machine.

For determination of consumption and other parameters, an encoder is placed in the feeding system (Figure 2 (b)). In order to calculate the consumption for a given structure is necessary to install one encoder in each feeder representing the basic structure of the fabric. Figure 2 (c) shows another encoder installed in the quality shaft. This encoder is the responsible for generation of synchronisation of the entire monitoring system and subsequent force signal sampling. As it can be confirmed, no significant modifications were required to install the system in the knitting machine. Another system was also implemented on a sample knitting machine, on which the initial part of the research was made. The knitting machines used for the experiments were: a sample making circular

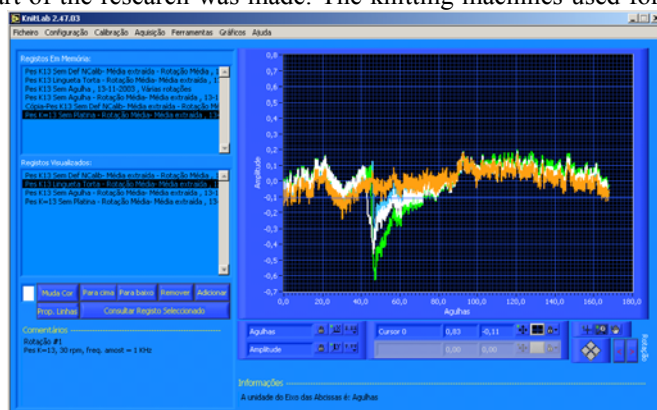


Figure 3. KnitLAB at work with four different waveforms of *YIT*, each one represent a different situation.

weft knitting machine with one positive feeding system, one cam, 168 needles and sinkers, 3.75" diameter cylinder, with speeds up to 200 rpm; and one industrial weft circular knitting machine with 36 positive feeding systems, 36 cams, 756 needles and sinkers, 12" cylinder diameter, and a top speed of 45 rpm.

The system is supported by a pc-based application – *KnitLAB* – that performs the communication with the hardware, allows acquisition, visualizing, analysis with several tools, storage, retrieval, and general configuration and parameterization for an application that is responsible for the monitoring of the production and knitting process. This application has all the techniques developed until now for

detecting faults and abnormalities during production. The *YIT* represents the core of the research, and thus the tension is recorded from the monitoring system and later can be inspected in their totality by using this particular application. The waveform is organized in slices, each one representing one course of knitted fabric, for the analysed yarn, i.e., the yarn in which the force sensor is assembled. This approach allows an easier understanding about the phenomena that is happening in each cylinder's revolution. Figure 3 illustrates four previously recorded experiments using polyester continuous filament yarn 240 dtex on the same machine, a tricolab sample knitting machine. They represent the resulting averaged signal of a course with no fault, a course with one sinker missing, one course with one needle without hook, and one course with a needle with a damaged latch. The experiments were taken at 30 rpm, meaning 0.15 m/s. Figure 4 presents the same fault and the resulting *YIT* waveforms of cotton yarn 21 tex, for four different knitting speeds: 35 rpm, 73 rpm, 110 rpm and 148 rpm. The highest speed represents a linear speed of 0.74 m/s, which is above the speed used on the industrial knitting machine – 0.65 m/s. As it can be confirmed, the accuracy is impressive. Whatever the speed, the fault occurs exactly at the same place.



Figure 4. Same fault represented in KnitLAB environment.

The application KnitLAB is used for research purposes, namely for study of the waveform in order to develop more accurate tools for automatic detection of faults on real time monitoring, since it was already proved that this approach allows to detect virtually all kind of problems. In fact, a periodic problem, produced by an eccentricity can be identified on the time waveform, and easily estimated by means of frequency analysis. Figure 5 illustrates the resulting power spectrum for cotton yarn 21 tex YIT at 73 rpm with no faults. The highest harmonic is the result of the movement of the 168 needles used in the knitting machine. The second highest harmonic belongs to the positive feeding system, which rotates about 5 times faster than the needles cylinder. There is a reference magnitude for this particular harmonic. If the feeder becomes more eccentric, the correspondent magnitude increases. The application KnitLAB allows the user to save the waveforms as a record in disk and later to retrieve them for further analysis. Many other features are available at KnitLAB software, and others are still under development and enhancement.

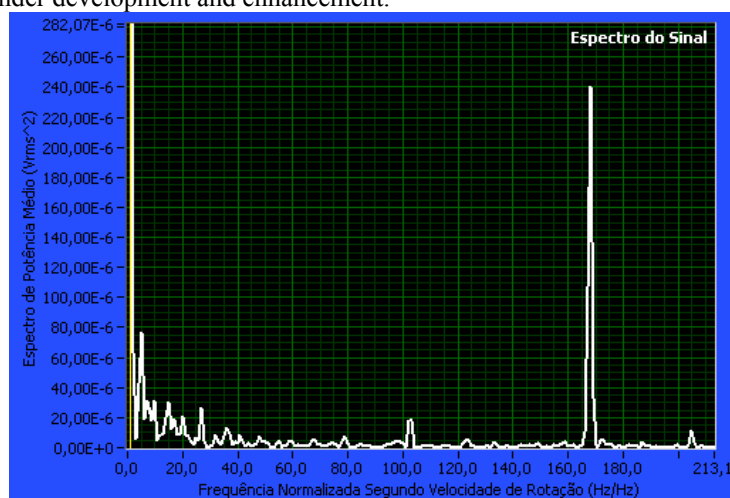


Figure 5. Power spectrum of YIT waveform.

REAL TIME MONITORING

As previously stated, the research made resulted in one application – *MonitorKnit* – that allows a real time monitoring of the knitting machine. This application is particularly focused on detection of faults, however it also provides the user with a set of parameters related with consumption and production. The monitoring system offers the following parameters during operation: *yarn input tension (YIT)* (in several modes), knitting machine's speed (m/s and rot/min), yarn speed (m/min), yarn consumption per course and global during production, fabric production in kg and estimated production in kg/minute or kg/hour, and tightness factor (*K*) and loop length.

The *YIT* can be represented in three different plots: one with the waveform as is acquired with synchronous time average applied, a second one with a specific processing technique and a third one with the one entire course waveform resumed in one single value. The speed, yarn consumption, and all the other remaining parameters are also represented.

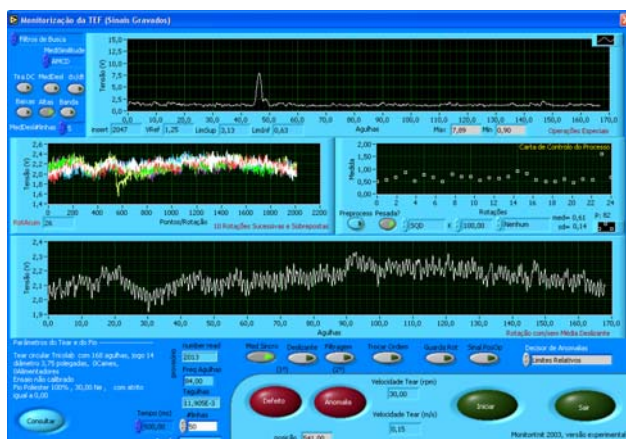


Figure 6. MonitorKnit general view

or a relative threshold.

On the other hand, the summarized representation constitutes a significant advantage for the technician, since he can observe the process evolution. Figure 8 illustrates a situation where a problem was detected during production. It is possible to identify in what course has happened and for some conditions the cause of the fault. Unfortunately this measure does not allow the technician to know where the fault happened. Moreover, variability on the *YIT* due to the irregularity of the yarn, dust, and other situations which does not constitute a fault, can influence the magnitude of this value and thus mislead to erroneous judgement. However, this measure is under refinement in order to avoid these undesirable situations.

FURTHER DEVELOPMENTS

One of the biggest challenges is to implement one force sensor in each feeder. The problem is the cost involved. With that purpose, a cost effective measuring device was developed and is being refined which can allow the implementation of this technology on each yarn used on the knitting machine at an affordable price. Another important field is related with the implementation of a pattern recognition system. Some tests were already performed with excellent results, which allowed the distinction of the fault with more than 90% successful attempts. However, refinements in the systems are needed in order to improve this success rate. Other techniques involving the detection of the fault are presently under test. Further development, namely experiments with many more knitted structures and knitting machines will also be made in order to confirm the universal efficiency of this approach. Finally, a more complex system is under development which will involve a large set of sensors and will provide a complete information concerning the production of a knitting machine.

CONCLUSIONS

This paper presented a monitoring system for weft circular knitting machines, which is capable to provide information concerning production parameters, and moreover, to inspect the knitting process with very high accuracy. The monitoring of the knitting process is particularly important since there is a lack of this kind of information on the systems used up to now. On the other hand, this approach allows the detection of problems which were not detected by those systems. This system is able to produce a significant set of relevant information for improving the production of knitwear as the present solutions do, thus contributing for a quality and productivity increase.

It is interesting to observe that the simple inspection of the *YIT* waveform allows the detection of faults and malfunctions on the knitting machine.

For detecting faults several techniques involving mainly specific filtering were implemented and tested. Figure 7 illustrates the use of *AMCD* (Average Magnitude Cross-Difference) [15,16]. As it can be easily confirmed, a threshold is evident, which allows implementing a decision module capable to distinguish between normal functioning and faults, as well to locate with excellent accuracy and precision the cause of the fault. The application graphically represents the waveform both in needles as well in cams, thus facilitating the problem repair. The decision module is already implemented on *MonitorKnit*, and it can decide based on an absolute

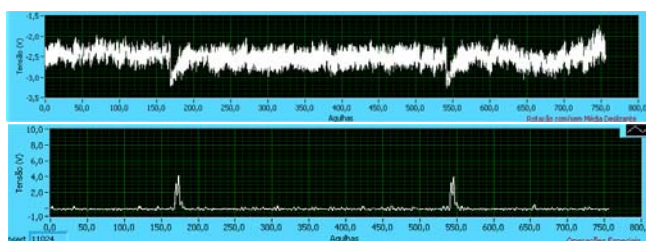


Figure 7. Two missing needles. The picture above shows the *YIT* as it was acquired, and the second picture shows the processed waveform.

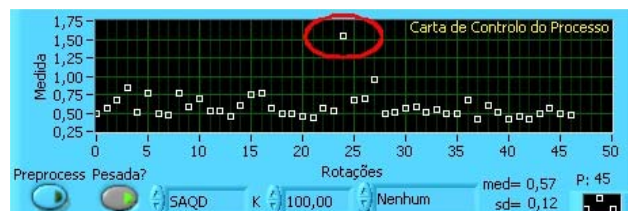


Figure 8. *YIT* resumed in one single value and plotted on a process chart.

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REFERENCES

- [1] G. Buhler, L. Pestel, H. Hait, “Requirements in regard to future circular knitting assurance systems-Paractical trial with a future-oriented monitoring system”, *Melliand textilberichte*, 1, 1994, p 39-42
- [2] T Push, I. Wunsh, R. Seifert, P. Offermann, “Fine struture of yarn tension on large-diameter circular knitting machines”, *Melliand textilberichte* 1-2, 1997, p 52-55
- [3] H. Behr, “Accessories for circular and flat knitting machines”, *Knitting Technology*, 1996, Vol. 18, 4, p. 184-189
- [4] J. Bauer, “Positive yarn feed on knitting machines”, *Knitting Technology*, 1996, Vol 18, 4, p. 190-193
- [5] Needle Detector NW from Memminger-IRO , reference 335.905.001.07 DSNL/5, official website <http://www.memminger-iro.de/>
- [6] Digital Needle Sensor Type 4020, Protechna, official website http://www.protechna.de/e/nadtast_dd.htm
- [7] Fabric Scanner LMW 3, Memminger-IRO, reference 040.905.000.01 DUDD/40, official website <http://www.memminger-iro.de/>
- [8] Yarn detectors OFW/UFW, Memminger-IRO, official website <http://www.memminger-iro.de/>
- [9] *Groz-beckert INFO KN newsletters* numbers 2, 4, 7, 8, 9 and 10, now available at http://www.groz-beckert.com/sprache_english.asp
- [10] A. Catarino, *Dinâmica da Tricotagem: Estudo da Dinâmica da Tensão de Entrada do Fio e sua Aplicação em Controlo de Qualidade*, Msc Thesis, University of Minho, 1998
- [11] M. Araújo, A. Rocha, H. Hong, A. Catarino, “Towards the Automatic Control of Sewing and Knitting Operations”, *World Automation Congress 2000*, pp. 636-641
- [12] A. Catarino, A. M. Rocha, J. Monteiro; “Automatic Fault Identification in Knitting Machines”, *SPPRA 2001 IASTED International Conference*, pp.5-10
- [13] André Catarino, Ana Rocha, João Monteiro, "Monitoring Knitting Process through Yarn Input Tension: New Developments", *IECON 2002*, ISBN 0-7803-7475-4
- [14] A. P. Catarino, A.M. Rocha, J. L. Monteiro, “Monitoring Systems for fault detection on circular knitting machines through yarn input tension”, *ICOM 2003 – International Conference on Mechatronics*, ISBN 1 86058 420 9, pg 465-470
- [15] E. C. Ifeachor and B W. Jervis, *Digital Signal Processing a practical approach*, 2nd edition, Harlow, 2002, pg 877-887
- [16] B.U. Kohler, C. Hennig, R. Orglmeister, “The Principles of Software QRS Detection”, *IEEE Engineering in Medicine and Biology*, January/February, 2002, pg 42-57