Advancements in on-line monitoring and control of parameters in knitting and sewing processes

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Abstract

This paper presents a summary of the developments in process control in textile processes at the University of Minho, by a multidisciplinary research group involving three different departments (Textile, Electronic and Mechanical Engineering). The studies target the automatic process parameter monitoring and control in the areas of industrial sewing and knitting.

1.Introduction

In order to be able to maintain an acceptable level of competitiveness of the textile apparel industry in European countries with the open market after 2004, two conditions should be met:

- Manufacturers should be able to respond adequately to reduced order sizes, short delivery dates and an increasing number of styles in production;
- The level of quality specifications should be set to a high level.

In this context, machine set-up and on-line process control acquire a great relevance. It is important that all kinds of non-productive times are reduced to a minimum. A greater control of the process, in both a planning as well during the actual production stages, should be available to the manufacturer. Only this way will allow the survival of a significant number of companies and thus labour for thousands of people which depend upon the competitiveness of the companies.

Within this research group, sewing and knitting machines have been equipped with sensors measuring the most relevant process parameters dynamically. Extensive studies have been carried out to relate the observed signals and values with the actual production occurrences (defects) and the final product quality. This has allowed the establishment of monitoring and in some cases control of the parameters by active actuation based on feedback control systems. A set of software tools have been created that allow a more objective appreciation of the process conditions and quality-related aspects. In the next sections, a brief overview over the developments and achieved results will be drawn.

2. Industrial sewing machines

2.1 Test set-up

The dynamics of the sewing process has been studied by the measurement of the main process variables on lockstitch and overlock machines. Machines have been equipped with sensors and systems allowing the evaluation of thread tensions and consumption, forces developed on the needle-bar, forces developed on the presser-foot bar and presser-foot vertical displacement. The system is composed of the several sensors and their conditioning hardware, a PC with a data acquisition board and software developed in LabView. It allows the integrated evaluation of three of the machine’s subfunctions: stitch formation, needle penetration and material feeding.

2.2 Results and current work

The analysis of the stitch formation parameters has revealed very interesting results using both thread tensions as well as consumption measurements. It has been possible to detect several types of localised defects (stitch distortions, skipped stitches and of course thread breakage), using signal processing techniques on thread tension signals. Two other methods have been developed to evaluate correct stitch geometry. The first uses a combination of features extracted from consumption and tension measurements[1][4] whilst the other compares thread consumption with the theoretically expected values (that can be computed automatically by the software)[2]. Currently, a new thread tensioning device, integrating a compression force sensor and a stepper motor, is in a test stage. This new tensioning device will allow the set-up of an adaptive thread tension control system, using thread consumption as feedback variable and computed theoretical consumption as reference. Thread tensions and the combined tension/consumption parameters will be used in quality monitoring.

The evaluation of quality aspects related to material feeding has shown to be very effective using both presser-foot force as well as vertical displacement measurements. Although the two measurements show complementary information, it has been found that most of the quality problems can be detected using just the displacement variable. These include localised defects (fabric curls or folds) as well as a recurrent feeding efficiency (loss of contact between presser-foot and material, resulting in an irregular stitch at high speeds). [2][3]

After this phase of feeding behaviour evaluation, the machine has been equipped with a controllable electromagnetic actuator, which by its own has improved feeding efficiency due to the inexistence of the mechanical spring (Fig.1). Extensive studies have then been conducted to determine force ranges in dependency of material characteristics and sewing speeds.

The first step in implementing a control system has been taken by the implementation of a speed-dependant force control. Next, the control loop has been closed using presser-foot displacement as a feedback variable. Several controllers, implemented on the PC using PID and/or fuzzy logic controllers have since then been successfully tested. Current work aims to create automatic teach-in methods to allow the control parameters to be automatically tuned. This will ultimately allow the control system to be fully adaptive. The feeding system will be adjusted to each fabric in a quick and automatic way, by making a simple sewing test before production. [5]

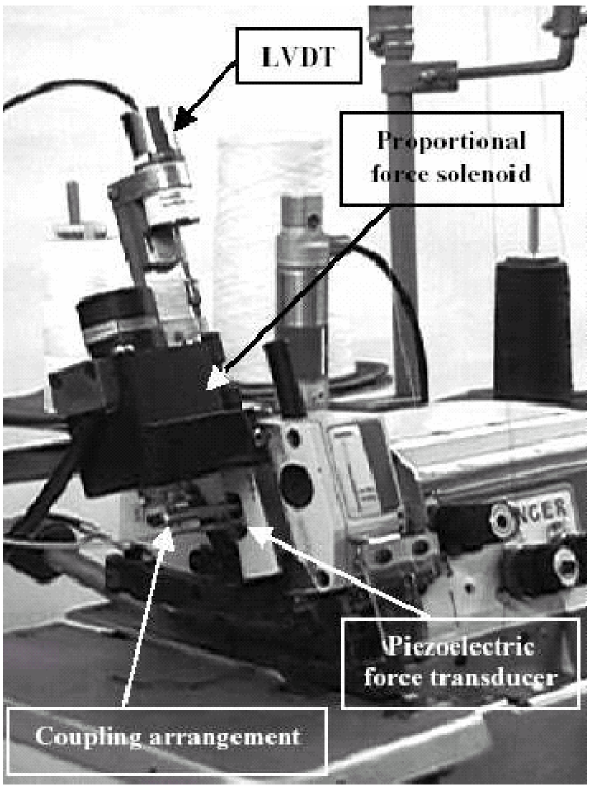


Fig. 1. Overlock machine with displacement sensor(LVDT), force sensor and actuator

The measurement of needle penetration and withdrawal forces is the most difficult one. Due to machine-specific factors, the signals obtained are blurred by parasitic components. Complex filtering techniques have been devised and optimised to attenuate these components and extract the relevant penetration and withdrawal information as accurately as possible. This allows the comparison of different needle sizes, tip shapes or damage, fabric finishing, etc. On-

line needle wear detection is possible at constant sewing speed using a force trend analysis. At variable speed, however, the variation of the parasitic components renders the measurement too inaccurate in the current setup.
At present time, a lockstitch machine is being equipped with sensors to measure the same variables. Most of the measurement hardware will be similar, with machine-specific differences. The measurement of bobbin thread consumption is not possible using the same techniques used in the overlock machine due to lack of space for sensors. An innovative contactless method has thus been developed to provide this measurement. On the other hand, this machine allows another setup for the needle penetration force measurement, avoiding parasitic components.
The team expects most of the results to be similar on this type of machine, with obvious particularities. The studies are expected to provide information for a generalisation of the developed control and monitoring techniques.

3.Knitting machines

In the knitting industry, important advances were made in order to maximize quality and productivity: the best tradeoff between production speed and courses produced during one needle's cylinder rotation were obtained. A set of solutions in the accessories area were also proposed by the manufacturers for production reports, yarn feeding systems and fault detection devices. However, there still are some issues which are not completely solved. In the quality area, fault detection is one of the most important tasks, and the solutions commercially available do not detect all kinds of faults. Moreover, they are incapable of preventing faults. A combination of needle and yarn break detectors with optical sensors is required to fulfill only part of this task. The solutions fail on some kind of faults, which can seriously impair production and delay the repair of the damaged element.
Another important issue is the control of the yarn input tension, where the trip-tape based systems are the most successful between the currently available. The problem occurs when yarn feeding is not continuous: this system is "blind". However, new solutions are now available with feedback for controlling the feeding rate of all feeders.
A third issue concerns the production data. The main knitting machine producers have advanced software systems for information purposes, but they are generally very expensive.

3.1 Test set-up

In order to detect faults during production, a novel approach was proposed, by monitoring the yarn input tension – YIT. One force sensor located near the knitting zone is enough to detect all the faults that the present solutions are capable (Fig. 2.). This is possible because YIT reflects the knitting process behavior. If a needle for some reason fails to work, it will be reflected on the YIT and thus quantified.
The analysis of the resulting waveform is made by signal processing techniques, namely matching pursuit filters – like AMCD (Average Magnitude Cross-Difference) as Fig. 3. illustrates [8].

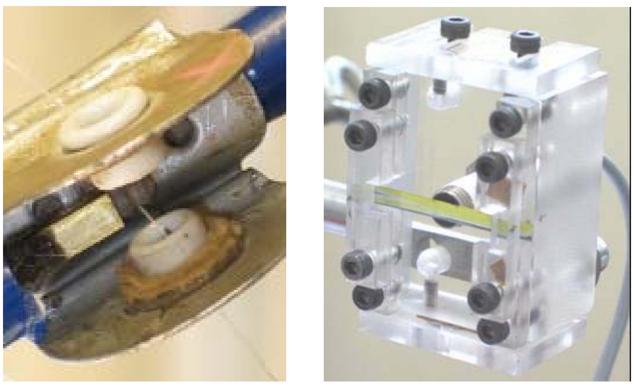
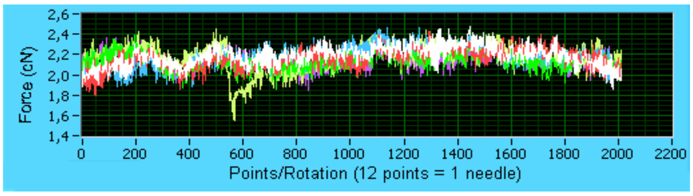


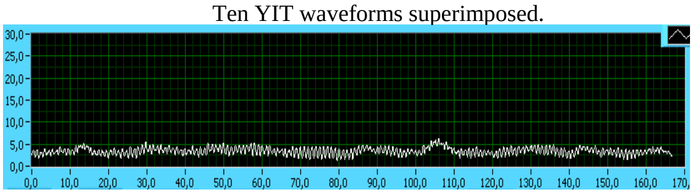
Fig. 2. Force sensors for fault detection and YIT inspection. Left: sensor based on strain gages. Right: Inductive-based YIT sensor

3.2 Results

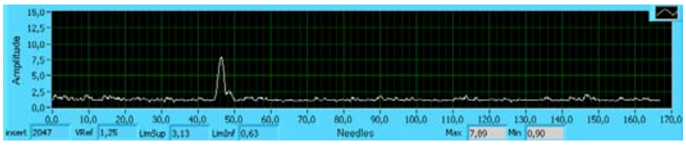
The signal processing technique produces a signal that clearly marks a fault. It has also been shown that it even allows detecting malfunctions at an early stage, at which defects are not yet being produced in the fabric. At the same time they allow the distinction of false alarms, produced by neps and friction. The cause of the fault is located with an excellent accuracy and precision (within one needle), which saves time and money for repair. It is also possible to identify the kind of fault, by means of a developed pattern recognition system, based on discriminant analysis. The developed system can represent one entire rotation of the needle's cylinder in a single number, thus allowing the use of quality control charts, easier to understand. With this setup, it was observed that the present yarn break detectors, based on gravity principles, introduce some variability on the YIT. Some knitting machine producers, namely those concerned with very high quality products, are replacing these systems by optical devices with no contact with the yarn. An alternative low cost solution was also developed [7] that not only detects the yarn breakage but also presents the magnitude of the YIT which is very useful for tuning purposes (Fig. 2.).



Ten YIT waveforms superimposed.



AMCD applied to YIT. No fault present.



AMCD applied to YIT. One broken needle present.

Fig. 3. YIT waveforms for cotton yarn using a sample knitting machine

For the control of the YIT, a novel actuator was proposed and is presently under refinement, which is based on an electromagnetic arm and can be placed in any kind of knitting machine. Finally, a low cost solution was also implemented for acquiring the parameters necessary for determining the production rates and other parameters such as loop length, yarn speed, machine speed,etc. All these proposed solutions are integrated in a single software application called *Monitorknit* and developed with LabVIEW. These sensors communicate with a data acquisition board trhough a preconditioning software programmed board [6].

4.Conclusions

The studies of process variables initiated some years ago have provided information that has shown to be most valuable to implement new process control and monitoring techniques. Currently, some monitoring and control techniques are being successfully demonstrated as prototypes, and other are under development. The integration of these devices in a higher-level process planning and quality control system is being envisaged as the next step for a broad shop-floor control in the sewing and knitting industry.

References

[1] Carvalho, Miguel, Estudo das relações entre os parâmetros de controlo, propriedades dos materiais e condições de regulação numa máquina de costura corta-e-cose PhD thesis, University of Minho, Portugal. 2002

[2] Carvalho, H., Optimization and Control of Processes in Apparel Manufactoring, *PhD thesis*, University of Minho, Portugal, 2004.

[3] Silva, L. F., Estudo de Mecanismos Alternativos de Controlo do Sistema de Alimentação de Máquinas de Costura Industriais, *PhD thesis*, University of Minho, Portugal. 2002

[4] M.A.F. Carvalho, F.B.N. Ferreira, E. Cabeço Silva "Ajuste Automático em Máquinas de Costura e Controlo On-Line da Qualidade da Costura", XXI CNTT, Natal, Brasil, 2004.

[5] Florian Guhr, Luís F. Silva, Filomena Soares, Helder Carvalho, Fuzzy Logic Based Control Strategies for an Electromagnetic Actuated Sewing Machine Presser Foot, accepted for presentation in the IEEE International Conference on Industrial Technology 2004

[6] A. P. Catarino, A.M. Rocha, J. L. Monteiro, "Monitoring Systems for fault detection on circular knitting machines through yarn input tension", in Proceedings of the ICOM 2003 – International Conference on Mechatronics, ISBN 1 86058 420 9, pg 465-470

[7] André Catarino, Ana Rocha, João Monteiro, "Low Cost Sensor for the Measurement of Yarn Input Tension on Knitting Machines", in proceedings of the ISIE 2003 – International Symposium on Industrial Electronics, ISBN 0-7803-7912-8

[8] André Catarino, Ana Rocha, João L. Monteiro, Filomena Soares, "A System for Knitting Process Monitoring and Fault Detection on Weft Circular Knitting Machines", in proceedings of AUTEX 2004 – 4th Autex World Textile Conference, ISBN 2-9522440-0-6