Process Control in Next-Generation Sewing Machines: A Project Overview

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SYNOPSIS

The sewing machine created in the XIX century has roughly remained unchanged in its basic technologies. Although a great range of mechanical and electronic technologies has boosted its development enormously, the process of sewing itself, however, although perfected in many aspects, has remained uncontrolled.Many of the phenomena occurring at high-speed sewing (up to 10000 stitches per minute) are still not properly understood.

This project is creating a deeper insight into the sewing process, identifying and describing the variables that can be monitored and/or controlled in a way that ensures a better control of this production process. Some monitoring and control algorithms are already under test. Concurrently the project develops software support tools to allow the up-front engineering of the process, resulting in control parameters to be downloaded to the machine controllers. The software would also serve as a support tool for the textile manufacturer, to tune and improve materials' properties and define the relationship between materials and optimum sewing conditions.

1 INTRODUCTION

1.1 The sewing process

The process of interlacing threads in or around fabrics at high speed is quite complex, and there is little quantitative knowledge about it. Machine settings and accessory choice are commonly performed on basis of empirical knowledge of qualified technicians. The machine is set up prior to production and runs with these settings without being able to adapt itself to varying conditions. Moreover, the process is not monitored, implying that there is no in-process detection of quality problems and malfunctions. This aspect has become increasingly important in the manufacture of such critical products as airbags, safety belts and others. Additionally, the current market trends comprise high-quality products, small order sizes and an ever-increasing variety of materials. This results in great demands of quick re-configurability and machine' flexibility and raises the economical significance of machine set-up times and quality or productivity problems.

In the context of this research project, studies are carried out considering three different aspects of the sewing process:

- Problems due to needle-fabric interaction;
- Problems associated to improper material feeding;
- Problems related to stitch formation itself, i.e. the interlacing of the threads.

1.2 Machine settings, process variables and their influence on the quality of seams

There is a wide range of factors influencing the quality of a seam. Some of them are related to the choice of accessories and the mechanical design of the machine and cannot be altered in-process, but the most fundamental settings can theoretically be controlled and monitored on-line.

The research group has found many results indicating that the process may be monitored and in some cases feedback-controlled by some of its process variables, namely

- The forces applied to the threads during the process as well as their balance (commonly designated in industry as "thread tensions");
- Thread consumption on each thread and their balance;
- Force and displacement of the presser-foot (the component that holds the fabric when it is being fed);
- Force on the needle-bar during needle penetration/withdrawal.

2 DEVELOPMENT OF THE ACQUISITION SYSTEM

2.1 Sensors, conditioning and acquisition

The acquisition system begins with several types of sensors and devices measuring the previously described variables:

- Custom-designed strain gauge based force sensors are used in the thread paths to sense thread forces;
- A device based on rotating encoders measures thread consumption, the last version of this device is able to measure consumption during each stitch;
- Piezoelectric sensors are used in the bars supporting the needle and the presser-foot to measure force on these two components;
- A LVDT is used with the presser-foot to describe its vertical movement.

- Sewing speed is measured on a stitch-to-stitch basis using a synchronisation signal delivered by the machine's motor.

For each of these sensors, conditioning devices were developed in the laboratory, providing a set of specific functions (software controllable gain, calibration functions, etc.). The conditioning hardware plugs into off-the-shelf acquisition boards installed in PC's.

2.4 Software

The software, an application developed with the National Instruments Labview programming environment, started as an acquisition application providing acquisition, graphical display, file I/O, printing and a set of general-purpose analysis tools (statistical, spectral, etc.). In the meantime, many research results have been built into the application as specific algorithms. An overview of the acquisition system and a screenshot of the software's main panel, in which an acquired needle thread force signal is being displayed, can be observed in Figure 2.

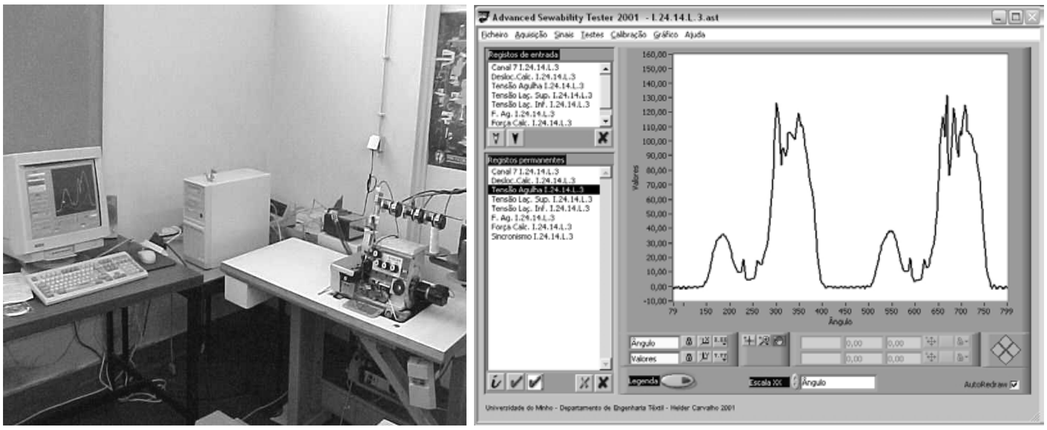

Figure 2: Overview of the acquisition system (left) and main panel of acquisition and analysis software (right)

3 DEVELOPMENT OF MONITORING AND CONTROL ALGORITHMS

3.1 Signal interpretation

Although an extensive treatment of the signal processing tools provided by the developed system is out of the scope of this paper, a basic understanding of the methods used will be given in this and the next sections. Further treatments of this subject can be found in (1),(2) and (3).

The production of a seam has, as its basic unit, one stitch cycle, which corresponds to one complete rotation of the machine's shaft. During this stitch cycle, several events occur in fixed phases of the cycle, e.g. needle penetration, needle withdrawal, material feeding, thread interlacing, etc. The most used way to observe the signals is to divide the stitch cycle into phases limited by fixed rotation angles and extract features from the signals at these intervals (peak values, power, average, etc.). These values and the relation between some of them provide indicators for some types of sewing defects and quality problems.

Other parameters are computed on basis of the thread consumption, by itself and in combination with thread tension peaks. It has been shown that they are useful as indicators for correct thread tension adjustment, and it is expected that they can be used as feedback variables for a thread tension control system to be developed.

Regarding the feeding system, two types of feeding performance evaluators have been found. On one hand, the displacement values measured directly on the signal during certain stages describes the presser-foot's trajectory and indicates, by comparison with the fabric thickness, if contact losses between the presser-foot and the fabric occur. On the other hand, it has been found that the force signals get distorted when these contact losses occur (normally at higher speeds), which is easily detectable by computation of some harmonic distortion parameters on the signal.

3.3 Automatic sewing parameter computation tools

The system's software has been permanently enriched with the functions enabling the user to compute the previously described parameters individually on acquired signals. At this stage of the project, at which a clear picture of the processing needs for each variable has been gained, these functions have been integrated and provided as a fully automatic tool that can very quickly process and display all the relevant parameters for each of the process variables. Moreover, the parameters are compared to pre-defined limits and compliance to the defined quality standards and/or the occurrence of defects is indicated. The development of this tool is considered to be a fundamental step towards the objective of designing control and monitoring systems. It significantly boosts the research work by computing in a few seconds a vast set of parameters on the signals that can be immediately evaluated as quality indicators. Furthermore, reference values are being defined and it is being used to assess the efficiency of control systems under development. Some examples of the results obtained are presented in the next section.

4 RESULTS

4.1 Stitch formation

An obvious defect related to stitch formation is a skipped stitch, occurring when a thread interlacing fails. This is one of the most common defects being very important to detect it in certain applications (seat-belts, airbags, etc.). The direct measurement of some of the thread tension peaks indicates the skipped stitch because a lower value occurs in that moment, but this can be easily confused with normal tension variations or a low tension setting. More reliable indicators are certain peak ratios, which produce much larger differences. Some experiments performed point to the fact that these ratios are able to indicate less evident defects and even give some information about the thread tension settings themselves.

4.2 Feeding efficiency

One of the techniques developed by Silva for feeding efficiency monitoring (4)(5), using the tools provided by the system, is the calculation of the presser-foot displacement in two phases of the stitch cycle. These values are then compared with pre-defined experimental values. The author has suggested obtaining these values from the presser-foot trajectory in an ideal (i.e. low speed) situation, and has developed the adequate functions for doing this in a quick and efficient way. ADL (Admissible Displacement Limits) are defined with a certain tolerance from the ideal values, and the displacement values are compared to the ADL's (Figure 4).

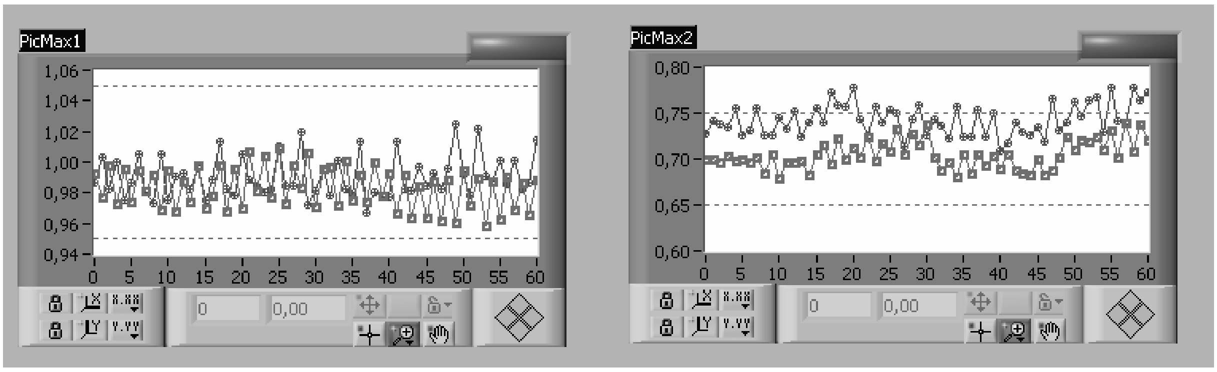

Figure 4: Peaks of displacement signal in phases 1 and 2 of the stitch cycle[mm]

4.3 Needle penetration

This measurement divides the penetration signal in three phases: first contact, penetration, withdrawal. The parameters calculated are represented in 3-D graphs, each point being one stitch (the coordinates are the parameter values in each phase).Clearly distinct results have been found in various situations, as in the example shown in Figure 5, where two different needles are being compared. A new experiment series is being performed to determine if defect situations, produced deliberately, can be detected automatically.

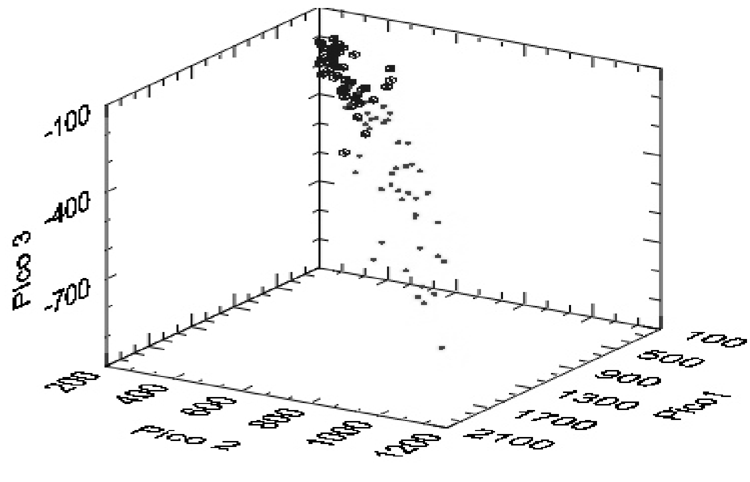

Figure 5: 3-D representation of needle penetration parameters, needle type 1 (thick dots) compared to needle type 2 (thin dots)

5 CONCLUSIONS

The measurement system presented in this paper has made possible to determine relationships between the variable measurements and the quality of the seams (1)(2)(3)(4). This insight has allowed the development of fully automatic signal processing algorithms delivering parameters that can actually describe the efficiency of the process and that represent the core for the outset of partial or integrated process controllers or monitoring systems. Some of these parameters are being used as feedback variables in closed-loop control systems to control some of the machine's subsystems, which is a fundamentally new application in the field (4).

The development of the system has been continuously enhanced with the results obtained by the researchers using it. This is a recursive process, in which the results provided by the researchers are progressively built into the software that in this way will provide more possibilities and power to obtain new results and test new control and monitoring strategies.
The objective of a full and integrated process control, with off-line process planning tools, still demands for more studies that are being performed and planned by the research team.

ACKNOWLEDGEMENTS

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REFERENCES

(1) Carvalho, M. and Ferreira, F. N. (1996) Study of thread tensions in an overlock sewing machine. Proceedings of the ViCAM – Vision and Control Aspects of Mechatronics, University of Minho, pp. 223-226.

(2) Carvalho,H., Rocha,A., Monteiro,J (2001). Operation Diagnosis and Real-Time Control of Industrial High-Speed Sewing Machines. Proceedings of the IASTED International Conference Measurement and Control 2001 , pp 68 -73, IASTED/ACTA Press, ISBN 0-88986-279-6, Pittsburgh, Pennsylvania, USA.

(3) Carvalho,H., Rocha,A., Monteiro,J.(2002). Measurement and Processing of Sewing Variables towards Real-Time Control and Off-line Process Planning. Proceedings of the International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems, ISBN 2-9516453-5-X (CD-ROM), Annecy, France.

(4) Silva, L. F., Lima, M., Rocha, A. M., Carvalho, H., Ferreira, F. N., Monteiro, J. and Couto, C. (2002) Presser foot actuation and fabrics feeding monitoring on an industrial sewing machine. Proceedings of The 8th Mechatronics Forum International Conference – Mechatronics'2002 (CD-ROM), University of Twente, Netherlands.

(5) Silva, L. F. (2002) Estudo de mecanismos alternativos de controlo do sistema de alimentação de máquinas de costura industriais. PhD Thesis, School of Engineering, University of Minho.