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Model based self-optimization of the weaving process

Y.-S. Gloy *, F. Sandjaja, T. Gries

Institut für Textiltechnik der RWTH Aachen University, Aachen, Germany

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ABSTRACT

Warp tension is a critical variable of the weaving process. If the warp tension is too high or too low the weaving process will be interrupted. In order to find suitable setting for the weaving machine, the experience of the operator or data base systems are used. Within this paper an automatic setup routine following model based self-optimization strategies is proposed. Within the routine, data for a regression model are collected by the weaving machine. For given quality criteria the weaving machine is able to calculate an optimal setting point. Validation of the routine shows that the chosen regression model is suitable; stress on the warp yarns is reduced. In addition, a statistical validation proves the usability of the regression models.

Introduction

Weaving is one of the oldest manufacturing technology know to human kind. Woven fabrics are described a rectangular crossing of so called warp and weft yarns. Woven fabrics are produced on weaving machines or so called looms. The principle of a weaving machine is shown in Fig. 1 [1].

Warp tension is a curial process variable. If the warp tension is too high, the warp can break and the weaving process will stop. If the warp tension is too low, the warp prevents the weft insertion due to lose hanging warp thread in the weaving shed. Therefore, setting of a weaving aims at having constant stress on the warp. Fig. 2 shows a measurement of warp tension during weaving [1].

Setup of weaving machines is done, in general, by relying on the experience of machine operators. There are many parameters influencing the warp tension such e.g. horizontal and vertical position of warp stop motion or back rest system, speed of the machine, surface of contact elements, etc. In addition warp tension not only depends on the machine setting but also on the used materials (e.g. cotton, wool, polyester or polyamide) [1].

In case the operator cannot find a stable setting point, trial and error strategies are used to find adequate settings for the process parameters. This process can take up to several hours in the worst case (e.g. unknown material) and depends highly on the knowledge of the operator.

Due to demographic development in high-wage countries a lack of qualified and experienced workers is foreseen. Strategies for production industries dealing with these developments are currently investigated within [2]. Thereby, model based self-optimization strategies can be a possible solution in order to setup up the weaving process independent from machine operators experience.

State of the art

Self-optimization

Self-optimization systems are defined as systems, which can apply adoptions of their inner state or structure in case of changes in input conditions or disturbances [2]. By the examination of manufacturing processes target values can be e.g. capacity, lot size, quality, cost or processing time [2].

According to [3] self-optimization systems are characterized by the continuous steps:

- analysis of actual situation,
- determination of targets and
- adaption of system behaviour in order to reach the targets.

With the help of cognition, robots should be enabled to detected requirements for technical system. Therefore perception and orientation of robots is enabled by the use of cameras and microphone. The reactions of robots in case of unknown situation are also defined as self-optimization [2,4,5].

Furthermore in the use of mechatronic system the application of self-optimization is known (e.g. control module for railed

* Corresponding author at: Institut für Textiltechnik der RWTH Aachen University, Otto-Blumenthal-Str. 1, 52074 Aachen, Germany. Tel.: +49 241 803470; fax: +49 241 8022422.
E-mail address: yves.gloy@ita.rwth-aachen.de (Y.-S. Gloy).

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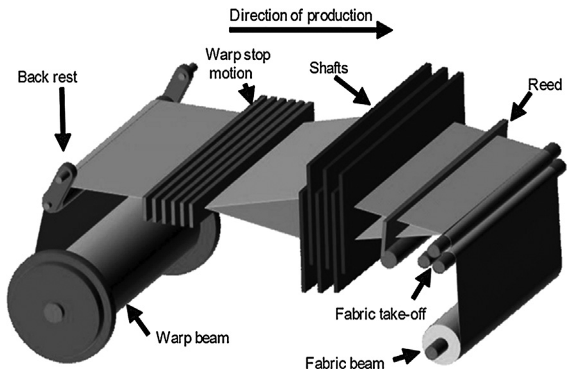

Fig. 1. Principle of a weaving machine.

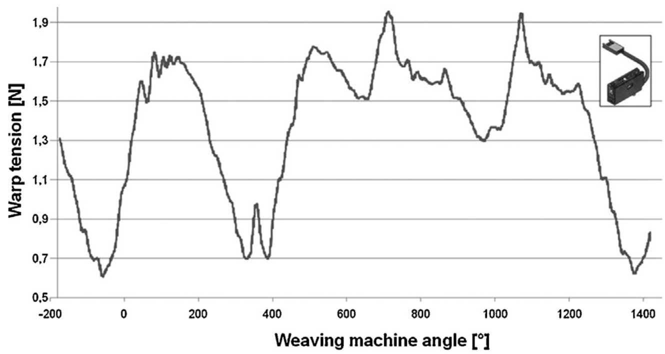

Fig. 2. Example of the course of warp tension during weaving.

vehicles), whereas the focus of research deals with the system design. Classical control algorithms are used [6,7]. In addition method and tools for realization of self-optimized products are developed. Such self-optimized products are used for control of mechatronic system. They use actors and sensors [8].

Target values are provided to standard control loops. These target values control system behaviour of the control loop. In case of adaptive control, the control loop is able to change his parameters based on observed modifications. One aim of self-optimization is the dynamisation of the target system, Fig. 3.

A self-optimized system is able to dynamically change the controlled system. In addition, a self-optimized system is able to change single components on the basis of internal decisions [2].

Fig. 4 shows the principle of model based self-optimization for manufacturing systems. First, determination of process status within an operating point is done with help of a meta model. A meta model is a numeric surrogate model which describes relation between input and output based on data [9]. The operating point is compared to an optimized setting point. The optimized operating point is defined as this point, where external targets are optimally fulfilled. Potential of optimization can be defined by the comparison. Then, a model based optimization system determines new internal targets. These internal targets are realized under use of intelligent sensor-actor systems. Intelligent sensor-actor systems have to

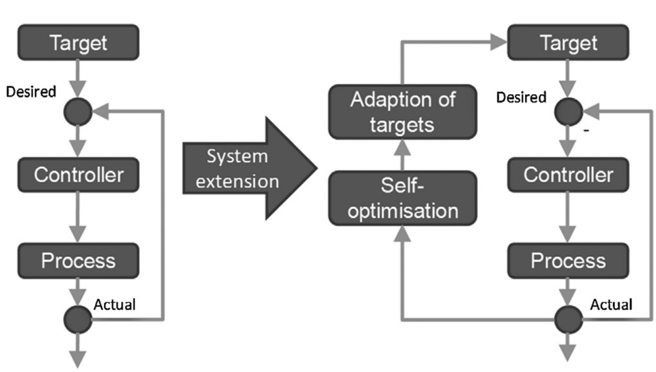

Fig. 3. Classic controller in comparison to self-optimization [2].

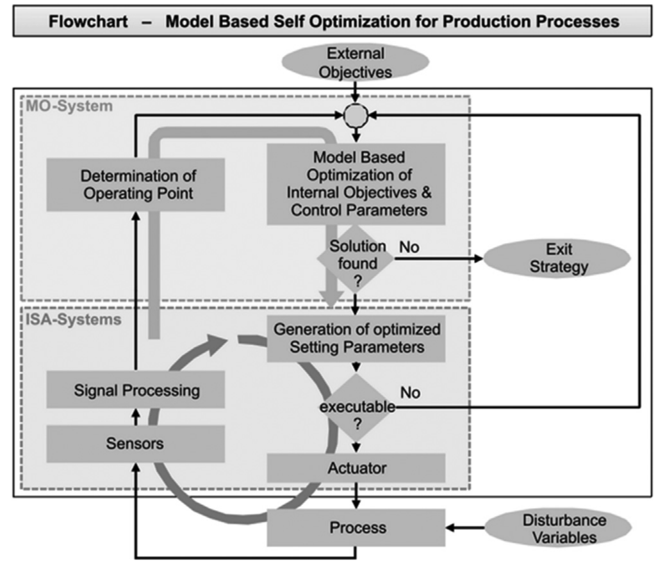

Fig. 4. Flow chart of model based self-optimization for manufacturing processes [10].

- translate internal targets into actuating variables,
- control of actuating variables and
- reconfigure processes in real-time [10].

Optimization of warp tension in the weaving process

Importance of warp tension for the weaving process and possibilities for optimization is described in e.g. [11–16]. Picanol nv, Ieper, Belgium sell the so called EasyStyle-System for weaving machines. The EasyStyle-System is data base in which setup parameters of good running weaving machine is stored. The operator receives optimal setting parameters form this data base after inserting material and article data. For material and article data, which are not stored in the data base, optimal setting parameters are calculated based on the existing data. So called Weave-Assist-System from Toyota Industries Cooperation, Kariya, Japan and so called Weave-Navigation-System from Firma Tsudakoma Corp., Kanazawa, Japan work in a same manner [17,18].

I-POS system form Firma Itema S.p.A., Colzate, Italy calculated automatically an optimized weaving machine speed regarding the amount of weaving machine down times. A pilot trial with 20 weaving machines resulted in a raise of weaving efficiency of 2.5% [19]. Further data base systems are described in [20–22].

Autowarp – self-regulating weaving machine

For the optimization of the weaving process, the Autowarp concept was develop with Institut für Textiltechnik der RWTH Aachen University, Aachen, Germany, Fig. 5. This concept includes

- an automatic adjustment of the weaving shed geometry,
- a computer programme for the simulation of the warp tension course,