The future of textile production in high wage countries

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The future of textile production in high wage countries

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Abstract. It is undisputed that smart production in the context of industry 4.0 offers significant potential for industrial production in Germany. Exploiting this potential provides an opportunity to meet the growing competitive pressure for textile production in high-wage Germany. The complete cross-linking of textile mills towards Textile Production 4.0 means substantial savings. However, currently there are still some challenges that have to be overcome on the long way to Textile Production 4.0. This paper initially reflects the particular challenges of textile production in high-wage Germany. Later, the vision of the future of smart textile production will be outlined. In addition, first pilot solutions and current research approaches which pave the way for Textile Production 4.0 are described.

1. Challenges of textile production in high wage countries

Because of the low production costs, the textile production has been relocated to the Asian countries, whereas the production of high-quality and technical textiles is progressively shifted to Europe [1]. The textile industry in high-wage countries is facing numerous challenges. For example, the tendency to small lot sizes requires shorter cycle times and aggravates the economical production of goods [2]. The use of Industry 4.0 in textile machinery and textile production has been examined at the Institute of Textile Technology at RWTH Aachen University [3]. The study on German textile machinery manufacturers and textile producers shows that terms such as Industry 4.0, cyber-physical system or Smart Factory are not yet sufficiently known. The challenges regarding Industry 4.0 also include: standardization, process and work organization, protection of know-how, availability of technology and shortage of skilled workers. Important preconditions for the successful implementation of Industry 4.0 require information gathering, testing technologies, convincing decision-makers in the company and, ultimately, the ability to raise capital [4].

Another challenge for textile production in high wage countries is the average return on sales of around 2.5% [5]. The low profit margins make it difficult for textile producers to accumulate reserves and thus indirectly force major investments. The companies are more focused on conventional production methods and carefully invest in new technologies and developments. This way innovation of textile machine manufacturers meets difficulties on the market, which in turn weakens the innovative strength. Thus, textile production in high wage countries is caught in a vicious circle. Looking at the overall industry environment in those countries, there is an increasing risk of being superseded in terms of technological forefront.

Multi scaling and additive fabrication is a special problem of the textile process chain. The simple way of the textile process chain is to make yarns out of fibers, yarns to surfaces, and textile surfaces to complex textile products (see Figure 1). The whole creation of value of the process chain is rarely done by only one company. Normally products are exchanged between companies for different processes like spinning and weaving. Every machine is separately equipped and adjusted by the machine operator (see Figure 1). The operator makes decisions based on the information of the semi-finished products and adjusts production and quality parameters.

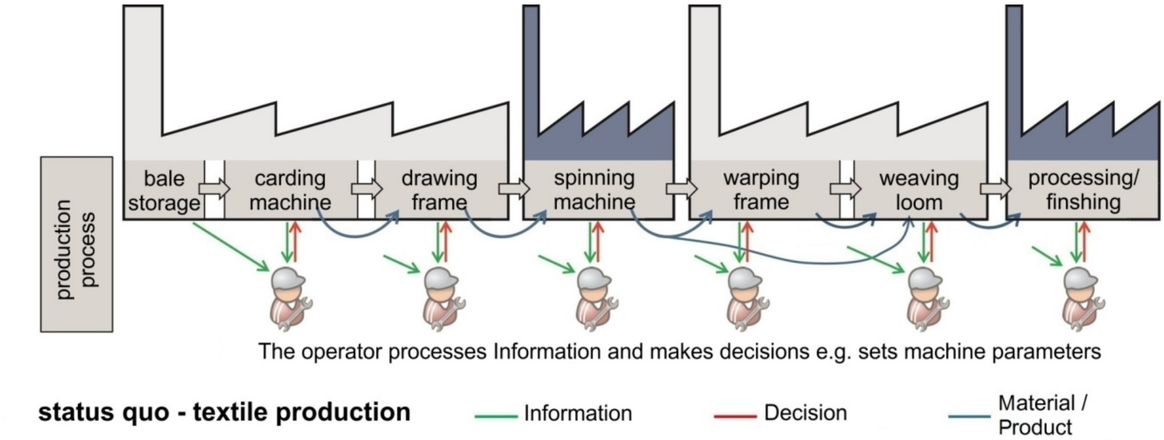

Figure 1. Example of the typical fragmented textile process chain in high wage countries

This fragmented process chain, where highly specialized companies overtake single production steps is not the only exception in German textile industry. In addition the way of textile production from yarn building to the finish product an ever changing process. Fibres, yarns, textile surfaces and textile products showing heavy varied length scale and weight (see Figure 2). Furthermore, the efficiency varies depending on the production process from line to single production.

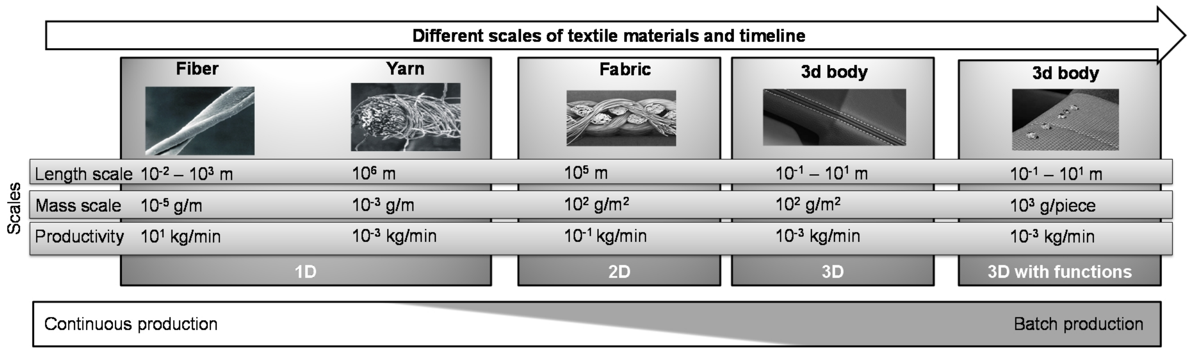

Figure 2. Manufacturing character of textile production

The particular features of textile production in high wage countries can be defined by the following:

- fragmented production chain
- switching between continuous production and piece production
- different orders of magnitude
- lack of standardization of communication interfaces
- low return on sales and investment affinity resulting from it

These peculiarities complicate the introduction of cross-process technological innovations such as Industry 4.0. Solving these problems will be the chance for the high wage countries to keep their technical leadership.

2. The Vision - Concept of Textile Production 4.0

To be able to continue production of textiles in a highly competitive environment, several factors have to be considered. Cost reductions and efficiency improvements ensure economical production.

However, the individual production processes are already highly automated. Hence it is pretty expensive to archive cost reductions and higher efficiencies via technological enhancements.

To reduce costs and stay competitive Industry 4.0 comes into play. Linking the whole textile process chain (see Figure 3) makes information available everywhere in the process. With use of enhanced machine cognition, those machines become capable to react on changing process- and boundary conditions.

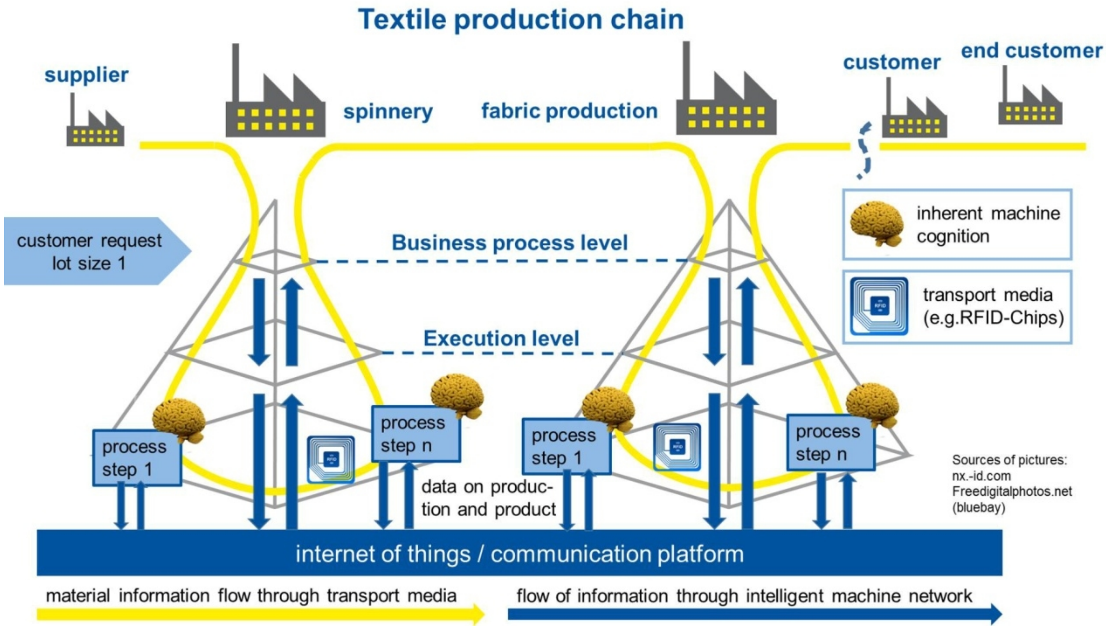

Figure 3. Concept of Textile Production 4.0

A hallmark of Smart Textile Factory is complete communication of various physical systems [6]. Those from the known boundaries between the individual levels of the company's automation pyramid have to be destroyed and assembled into a vertical system. Serving as a comprehensive communication platform of the Internet of Things it offers an unrestricted exchange of data on the horizontal plane between all physical systems [7].

Another feature of smart textile factory is inherent machine cognition. The machine recognises itself and the other devices belonging to the same system. In addition, the machine is able to act on changing processes and conditions individually and to make production-related decisions w.r.t. its own abilities. Application of distributed physical information carriers such as RFID tags is another part of Textile Production 4.0. RFID tags support textile production and include either product data or certificates used to retrieve partially sensitive product data over the Internet of Things. In addition to it, the RFID-enabled products are able to control their own processes.

3. Successful example - Self-optimising textile machinery

It was shown in the previous sections how Smart Textile Production of the future may look like. It is obvious that it is a great way to achieve this vision. Successful pilot projects like the smart bobbin using RFID information carriers [4] or the self-optimizing machinery [8] lead to measurable reductions of processing costs. Exemplary the multi-objective self-optimization is described in the upcoming subchapter.

3.1. *Cognitive machinery – Self-optimizing weaving loom*

A fundamental concept of maintaining competitiveness in high-wage countries is to reduce the manual production effort. In particular, the initial setup of textile production requires substantial amount of

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manual work that lead to significant production costs. It is essential to reduce the duration of the manual setup processes in order to reduce these costs.

In addition to manual work, a significant amount of setup time is spent in search for the optimal process parameters. Despite usage of process databases providing initial parameters based on historical data, these parameters are determined by means of the time-consuming Trial & Error principle. In this case, knowledge and experience of the operator play an insignificant role.

A multi-objective self-optimization of the weaving machine was developed at ITA. Self-optimizing systems are defined as "systems [...], which are capable of making changes in their internal state or its structure independently due to changes in input conditions or disorders" [9]. The following objective functions are considered by the multi-objective self-optimization (MOSO) of the weaving process:

- warp tension
- energy consumption of the weaving machine (air- and active power consumption)
- quality of the fabric

The objective functions are optimized according to the following parameters:

- basic warp tension (bwt)
- revolutions per minute (n)
- vertical warp stop motion position (wsmy)

With the MOSO routine, a weaving machine is enabled to automatically find an optimal configuration. Figure 4 shows the concept of the self-optimizing weaving machine.

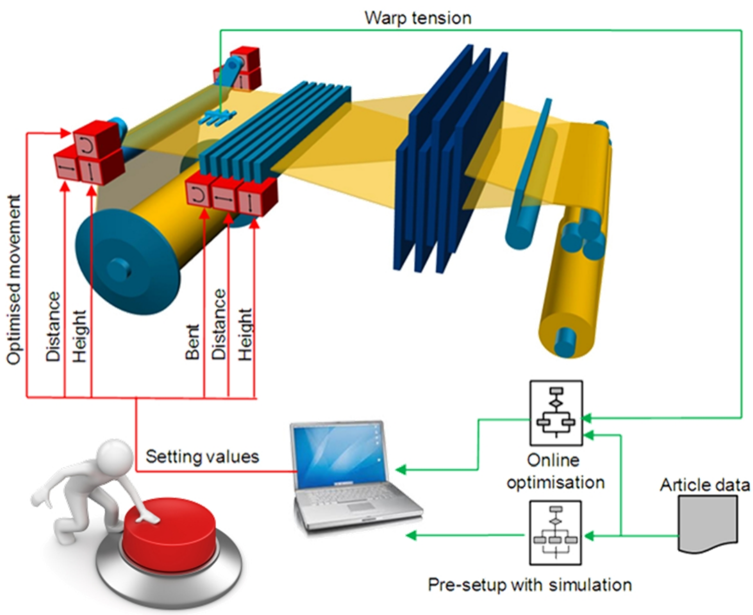

Figure 4. Concept of the self-optimizing weaving machine

The MOSO of the weaving process is validated during a long-term test in the laboratory of ITA [6]. To establish industrial conditions, the duration of the long-term test is eight hours, like usual shift duration. A long-term test is carried out using the MOSO against not using the optimization procedure respectively, to examine the influence of MOSO on production figures.

The long-term test is conducted with an air-jet weaving machine OmniPlus 800 by Picanol n.v., Ieper, Belgium. During the long-term test, polyester filament yarn with 330 dtex for warp and weft was used (binding: twill 3/1). The configurations of MOSO used for the long-term test are listed in Table 1. After program execution of MOSO, the algorithm calculates the following optimal parameter settings: bwt = 3,71 kN; n = 522 RPM; wsmy = 20 mm.

Table 1. Configuration of MOSO for long-term tests [6]

	bwt	n	wsm_y	TW warp tension	TW energy consumption	TW quality	Algorithm start point bwt/n/wsm_y
min	2 kN	400 rpm	0 mm	LOW	LOW	HIGH	3,5 kN / 750 rpm / 15 mm
max	4 kN	900 rpm	20 mm				

The following settings are used as reference settings coming from an industrial weaving mill that processes the same material as mentioned above: bwt=4 kN; n=900 RPM; wsmy=0 mm. The results of the long-term test using MOSO and reference settings are shown in Table 2.

Table 2. Long-term test results of MOSO weaving machine in comparison to reference settings

Recorded data	Unit	Results	
		MOSO	Reference
Efficiency (prod. Time / total time)	%	98,60	37,20
Weft insertions		125157	215982
Weft meters	m	237798	410365
Average quality category		0,93	1,55
Weft defects		2	6
Quality efficiency	/mio m	**8,41**	14,62
Average warp tension	N	1,27	1,49
Average air consumption	m³/h i. N.	134,23	155,26
Air consumption efficiency	m³/mio m	564,47	**378,35**
Average active power usage	kW	2,49	4,62
Active power consumption efficiency	kW/mio m	**10,47**	11,26
Set-up time	Min	**30**	120

The program for self-optimization successfully enables the weaving machine to autonomously find an operating point, which improves the targeted objective function compared to conventional (reference) machine settings for at least 14 % [6]. Without MOSO a machine operator needs around 120 min. for the configuration of the weaving machine and to find appropriate settings for the process. The program for self-optimization is concluded in 30 minutes and successfully reduces the set-up time by 75 %.

4. Conclusion and Outlook

The specific properties of textile products and the special characteristics of the textile manufacturing chain may involve a number of challenges that need to be considered on the way to Textile Production 4.0. There already exist various approaches and first pilot projects. Also, the federal governments have recognized the challenges and provide support by several research projects such as Speedfactory, Factory Store and Smart Factory related to development of smart textile production. Nevertheless, the textile industry must increase investments into the research field of Industry 4.0 in order to preserve technological and economical connections.

Acknowledgement

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