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ScienceDirect

Procedia CIRP 52 (2016) 186 – 191

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Changeable, Agile, Reconfigurable & Virtual Production

# Interconnecting Product and Process Information to Enable Personalized Production

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**Abstract**

Manufacturing paradigms are currently shifting from mass production towards mass customization and personalized products. Customers demand individual, high quality products that are tailored to their needs at a low cost and reasonable delivery times. The shoe and fashion industry is one example. Currently, mass customizing textile products is possible but comes with long delivery times due to fragmented supply chains that are distributed all over the world. Therefore, companies are under the pressure to reduce their time to market and to respond to the dynamic requirements regarding lot sizes, lead times, and cost. Moreover, companies will shift to regional production to be closer to the customer to flexibly react to the market and reduce delivery times. This paper presents an approach to model personalized products and interconnect this knowledge with information about the manufacturing system and production processes. The approach allows using product information to assist the worker during the manufacturing process to enable quickly switching between different products. Connecting the shop floor with the supervisory control facilitates adapting to new products. The approach is evaluated using an experimental setup. Results and future research directions are illustrated here.



Peer-review under responsibility of the scientific committee of the Changeable, Agile, Reconfigurable & Virtual Production Conference 2016

*Keywords:* product modeling, information technology, customized products

## 1. Introduction

Manufacturing nowadays has to cope with dynamic markets and swiftly adapt to changes in demand. There is a shift away from mass production towards mass customization with customers actively designing their products [1]. An adaptation of products based on customer requirements is necessary [2]. The result is an increased number of variants per product. At the same time, product life-cycles are becoming shorter. These factors contribute to dynamic requirements on lot size, throughput, and cost of production. Changeable manufacturing systems [3] emerged to allow dealing with the increased number of variants and the diverse products. The goal is to decrease setup times and quickly switch between products and variants [4].

One industry where this trend is particularly visible is the fashion and shoe industry. Most of the German brand manufacturers for fashion and shoes have a globally distributed supply chain. The iterative process to develop a product from design, to prototype, and final approval is therefore time-consuming and expensive. Additionally, it also decreases the capability to quickly react on market changes.

In order to enable a fast transformation of an idea to a product, a local and flexible production of prototypes and final products is necessary. A regional production reduces shipping times and puts the customer in the focus of production. More flexible production planning and control systems have to be developed and it is necessary to shift decision-making closer to the shop floor [5]. Moreover, technologies that enable a fast processing of production orders while achieving lower costs, higher quality, and higher flexibility are desirable [6–8].

In this paper, an approach to model personalized products that allows automatically using the information to control production is presented. This approach models all necessary steps to describe what the product is without specifying how the production steps are actually performed. With such an approach, an adaptation of production programs is possible without reprogramming because the necessary information is derived from the product model. In addition, the same model can be used in different factories with varying production equipment. It is also suitable for supporting human workers during production.

The remainder of this paper is structured as follows: Section 2 gives an overview of current research developments. In Section 3 the current challenges for manufacturing in the textile industry are presented. The modeling approach developed is presented in Section 4. Section 5 explains how the developed models can be used to derive production parameters and schedules that are used to control and execute production. The evaluation on an application example is presented in Section 6. In Section 7, a critical view on the work is given. Finally, Section 8 concludes the paper.



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doi:10.1016/j.procir.2016.07.057

## 2. Related Work

The adaptability of manufacturing systems has been in the focus of research in the past years and there has been much work to improve it. However, the topic of explicit modeling of products is still in its first steps. Approaches to modularize production and standardize the description of processes are partly available. One example is the German guideline VDI 2860 [9] with the goal to define reoccurring tasks and processes for the assembly domain. The result is a classification of processes with a standardized symbol for their representation. The focus of the guideline is on the process itself without considering using the description to describe products and their workflows. Moreover, a combination of processes to describe final products is not part of the guideline.

Another example stems from the processes industry. The process industry already established the separation of process knowledge from production equipment [10]. The German guideline VDI 3682 [11] aims at dividing continuous processes in discrete steps. It provides a formal description language that is based on Polke's phase model [12] and is used to describe technical process knowledge [13]. The guideline allows describing processes graphically in terms of sub-processes, products, and energies [10,14,15]. Final products are the result of transforming products and energies in process steps [14]. Although this formal description emerged from the process industry, it is neutral in its concepts and could be applied to the discrete manufacturing domain [14]. However, using it for the textile industry requires considering material constraints.

One important aspect when considering modeling approaches is that the same languages or methodologies have to be used to describe both the production resources as well as the processes and products. This is also confirmed by the work of *Rehage et al.* [16]. The focus of their work is on the design and conceptual planning of a manufacturing system with the goal to support the user in finding suitable machines during planning. In contrast, the work presented here aims at using product descriptions to automatically control production and adapt to changing manufacturing requirements. The provided description and models are used to assign respective resources and define process parameters for production.

In the field of robotic assembly processes there are examples for modeling products and systems to increase adaptability of systems and reduce configuration efforts. *Backhaus and Reinhart* [17,18] use a modeling approach to achieve a task-oriented assembly process. In their work, they utilize AutomationML to model the resource, process, and product. However, they do not reveal the details of a product model. *Michniewicz et al.* [19,20] utilize CAD data to describe the project. Assembly sequences are determined by interrelations between parts within the CAD model. In addition, production graphs can be extracted from CAD data. Since this approach is tailored for the robotic systems, it needs to be extended with concepts of the textile industry. While these approaches share our vision and provide concepts that can be reused for our approach, they do not address all the challenges of the textile industry. At the same time the work is focused on assembly steps with robots while the human needs to be integrated for the textile industry.

*Baumberger* [21] investigates the definition of customized products. The work develops method to specify customer requirements within the product and to adapt processes accordingly. This approach focuses on the design phase and design elements of the product. However, the concepts can be used as a foundation for our work.

The literature review shows that there are several approaches to model products and include customer requirements in discrete manufacturing and for robotic assemblies. However, the challenges of the textile industry are not fully addressed yet. There is a need to develop models for customized products that can be automatically analyzed and used to control production. Information must be derived from the models to assist workers as well as to control machines and steer production. Therefore, this paper will present an approach to model information about the product. The approach will be explained through the example of shoe manufacturing.

## 3. Challenges of Shoe Manufacturing

Shoe manufacturers face two major challenges: increased product variation and shorter delivery times. A wide range of shoes can be considered as regular consumer products. As in many other industries, the shoe industry offers the opportunity to create individual designs by modifying properties such as size, color and material for certain parts. Nike and adidas, for example, provide respective services online[1]. Those unique shoe design may be produced only once and therefore require a manufacturing system to handle lot size one economically.

Manufacturing of shoes is labor-intensive and therefore mostly performed by human workers nowadays. As a result, typical production lines are semi-automated and include human workers as well as machines. The increased complexity of manufacturing systems requires a planning and execution system that handles different factory setups as well as a high variety of products. Additionally, advanced product and factory modeling is required to enable a flexible and adaptable system.

Another challenge is to reduce the time to manufacture prototypes and final products. This requires that the complete manufacturing system from design to production and delivery is optimized. Using semi-automated production lines requires an easier integration of machines within the IT landscape of manufacturers as well as an integration of human workers. This is especially important and useful in order to move production to high-technology regions such as Europe and North America. Hence, design engineers as well as customers would not have to wait for products to be shipped from Asia. Usual delivery time for a customized shoe is approximately 3 to 6 weeks. Moreover, all data within the ecosystem of manufacturing has to be aligned and consistent throughout all phases. This includes new approaches to describe and distribute information about products in order to optimize manufacturing. Current processes involve manual steps to share the required data with all involved manufacturing sites and transform it into executable actions. The introduction of automatic production steps enhances the complexity of manufacturing and therefore increases the effort to plan production manually. Therefore, a product model is required that enables an adaptable manufacturing system which reduces the need of manual interim steps to a minimum.

[1] Nike customization webpage: http://www.nike.com/de/de_de/c/nikeid, adidas customization webpage: http://www.adidas.com/us/customize