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Utilization of State Drivers to Support Design for Manufacturing

Thorsten Wuest[a,]*, Ang Liu[b], Wei Wei[c], Stephen C.-Y. Lu[b], Klaus-Dieter Thoben[a,d]

[a]BIBA – Bremer Institut für Produktion und Logistik GmbH, Hochschulring 20, 28359 Bremen, Germany.
[b]University of Southern California,University Park Campus, DRB-260, Los Angeles, CA 90089, USA.
[c]Beihang University, Beijing, 100191, China.
[d]Universität Bremen, Bibliothekstrasse 1, 28359 Bremen, Germany.

* Corresponding author. Tel.: +49-421-218-50171; fax: +49-421-218-50007. *E-mail address:* wue@biba.uni-bremen.de

Abstract

Together with the fast paced technological advances, the complexity and dynamic in manufacturing is steadily increasing. At the same time, the (functional) requirements derived from the customers are becoming more challenging to fulfill. In order to cope with this challenge, designers have to focus more on design for manufacturing besides taking the requirements derived from the customers into account. This is not only important from an economic perspective, e.g., to reduce avoidable expenses during manufacturing but often also directly related to the fulfillment of customer requirements from a quality perspective, e.g., structural behavior of highly stressed products.
In manufacturing, the product state concept describes the subsequent development of a product along the process chain by its accumulated state. It can be used to increase the understanding of the manufacturing processes from a system's point of view and can be applied e.g., to support quality management. Within the concept it is possible to identify so-called 'state drivers', by means of Support Vector Machine based feature ranking on an accumulating product and process state vector. These state drivers take explicit and implicit intra- and inter-relations between states into account and provide an insight which parameters are most relevant for the final quality outcome and where the critical points along the process chain are.
In this paper, the relation between design for manufacturing and the product state concept will be discussed with a special focus on the state drivers. The question, if and how state drivers can be utilized to support the design phase and designers will be examined in detail, whilst the overall question of the appropriate detail of manufacturing feedback to design is also examined.

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1. Introduction

Over the last decade, significant developments transpired concerning manufacturing technology including supporting activities like control, monitoring and analysis. Wide availability of cheap and capable sensors in combination with data storage, communication and corresponding ICT infrastructures lead to a steadily increasing amount of data [1]. This availability of manufacturing data, often in real time, is a big chance to improve different dimension like quality. However, large amounts of data may increase the complexity and present significant challenges to companies [2].

At the same time, the (functional) requirements derived from the customers are becoming more challenging to fulfill. This is first of all a challenge for product development and design. However, when the design is becoming more complex this often leads to more challenging requirements towards manufacturing processes and operations. In the end, design is in most cases a compromise of conflicting goals [3].

Overall, it can be stated, that the fast paced technological advances together with increasing customer requirements has an impact on complexity and dynamic of today's manufacturing process chains.

One established approach to support manufacturing is to take manufacturing requirements and/or constraints into consideration during the design phase. This so-called Design for Manufacturing (DfM) (also known as Design for Manufacturability and Design for Manufacture) brought forth

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considerable benefits incl. reduction of manufacturing cost, improvement of quality and reduced time to market [4]. Since the first steps taken by DfM, the method developed along with new technologies, business models and emerging challenges [5].

In this paper, the current level of detail of information and knowledge feedback from manufacturing to design is investigated. Based on that, the possibility and potential benefits of a more product (family) specific, higher level of detail and rather individual feedback is discussed.

To achieve this goal, the possible combination of the DfM methodology with the product state concept is investigated. This combination corresponds loosely with the recommendation of Kuo et al. [4] who suggest the use of Artificial Intelligence and Intelligent Systems in the DfM. The product state concept is an approach to describe the development of a product along the manufacturing programme by its state. It can be used to identify so-called state drivers of a process sequence utilizing a growing data vector along the process chain and supervised machine learning analysis. These state drivers represent relevant parameters of manufacturing that have an impact on the final product quality [6].

The main question is if knowledge of those manufacturing state drivers may benefits designers in the spirit of DfM. And therefore may help handling the previously mentioned increasing complexity in today's manufacturing in return.

The scope of this paper and the introduced ideas are focused on the design and development of next generations of products and/or similar products and not 'new' product development. This is a prerequisite for rerouting such particular input from manufacturing experiences back to the design phase.

The paper is structured as follows. Following the introduction, the two basic concepts, DfM and the product state concept is presented. In the next section, the two concepts are combined. Based on that, section four critically assesses the idea, discussing the requirements, benefits and limitations of an application. Section five concludes the paper and gives an outlook on open questions and further research.

2. Background

In this section, the theoretical foundation for the subsequent concept development is illustrated in form of a description of DfM and the product state concept.

2.1. Design for Manufacturability

As mentioned in the introduction, DfM is an established design method, which has been applied since the 1970s and evolved continuously [5]. DfM is part of the larger Design for Excellence (DfX) methodology, along with design for assembly, recyclability, lifecycle, quality, etc. [4]. The idea behind DfX and all related methods is to include knowledge about manufacturing requirements and characteristics to basically allow lowering manufacturing cost and/or time while not compromising on or even improving product and process quality [3; 7]. As there are different target dimensions, e.g. quality, ease of assembly, etc., the different DfX methods may be inter-related to one another. This has to be taken into account before implementation as optimization of one may have a negative effect on the other. In this case, the focus is solely on DfM without taking potential inter-relations with other DfX methods into consideration.

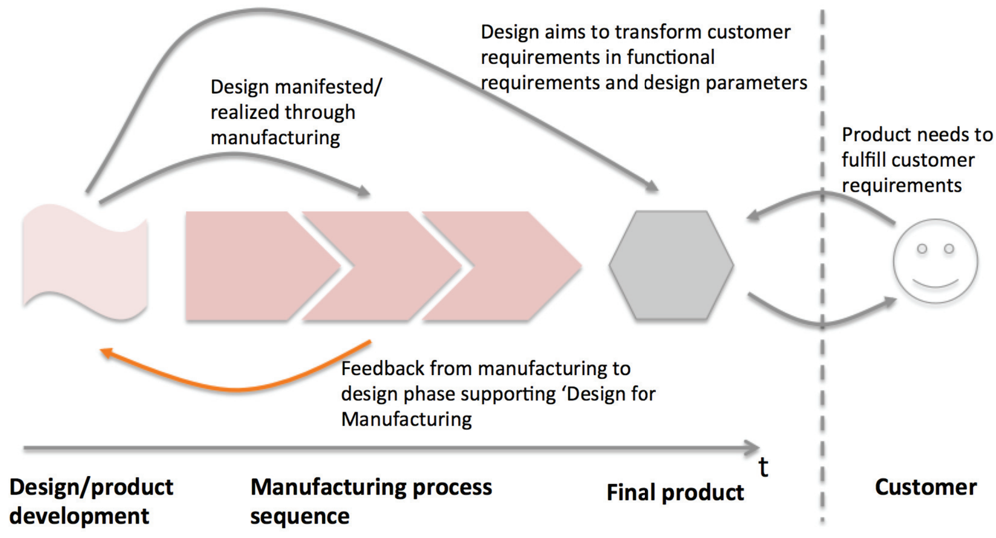

Fig. 1. Feedback from Manufacturing to Design to improve processes

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