Towards Changeable Production Systems – Integration of the Internal and External Flow of Information as an Enabler for Real-Time Production Planning and Controlling

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Keywords: Changeability, real-time capability, production planning and control, machinery and equipment industry

Abstract. In this paper, it will be shown how information and communication technologies (ICT) act as enablers to realize changeable production systems within the German machinery and equipment industry. A cybernetic structure is proposed to design and operate systems that have to cope with a high degree of complexity due to continuously changing environment conditions. The integration of IT-Systems along the order processing of small-and-medium-sized enterprises (SME) is shown to be one of the missing links of changeable production systems in practice. A demonstration case is presented in which standardized interfaces of IT-Systems enhance real-time data exchange between the relevant planning levels of producing companies, their suppliers and customers.

1 Introduction

Nowadays, the German machinery and equipment industry faces many challenges. The increasing variety of products in combination with increasing market dynamics (e.g. shorter product life cycles) results in a growing complexity of the order management processes [1-4]. Additionally, the increasing and volatile demand of customers in combination with quantity and delivery time reduction has a direct impact on value creation processes of the order management [1]. On-time delivery of products has to be realized despite the volatile demand of customers[1] [5]. Today manufacturing companies cope with these turbulent market conditions by keeping extensive

[1] Incoming orders may show an average monthly variation of 20-40 percent in the German machinery and equipment industry [5]

stock levels. High stock levels are treacherous. They hide problems within the production systems, are very cost intensive and do not increase flexibility. Additionally, the rapid spread of new technologies, aggressive competition, closer integration of goods and capital flows as well as the fragmentation and dynamic reconfiguration of value chains pose unprecedented challenges for the German machinery and equipment industry [6]. These uncertainties directly affect the company's internal planning and control processes. The variety of these processes confronts organizations and information systems with a significant coordination effort [7]. According to a survey by the German association of the machinery and equipment industry (VDMA) the majority of companies considers the capability of order fulfillment processes as a key success factor for the future [5]. To this day, planning and execution of order processing – from offer processing to the final shipment of the product – is still a part of the production planning and control (PPC) [8]. Production planning and control is almost entirely integrated into information systems. In order to manage dynamic influences on processes within order processing, a deficiency in the processing of decision-relevant and real-time information can be observed [9], [10].

2 The human organism acts as a role model for a changeable production system

One solution to these turbulent market conditions discussed by academia in recent years are flexible production systems. Flexibility may be described as the ability of a system to adapt quickly and cost efficient within a pre-defined time horizon [11]. However, flexible production systems are not sufficient enough to establish a sustainable, competitive position for the German machinery and equipment industry because of their limited long-term potential to react to rapidly changing external influences [12-14]. A systematic approach is quickly required for a suitable design and operation of changeable production systems. In this context changeability stands for the development of flexibility, which allows changing the system reactively or even proactively beyond known uncertainties [6], [12], [13] (cf. **Fig. 1**).

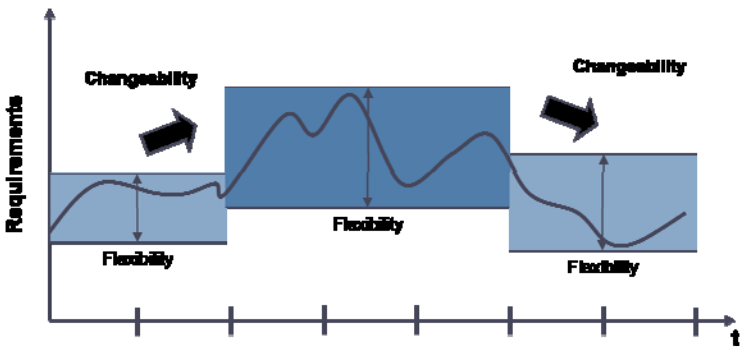

Fig. 1. Flexibility and Changeability [7]

The human organism has proven itself over millions of years as one of the most reliable and most flexible systems. Thus, it can be considered as a role-model of a functional, complex organization in management cybernetics [15-18].

A key success factor for the ideal control of the human organism is the existence of reflexive and conscious coordination mechanisms of the different organs, muscles and nerves. The reaction of human beings depends on the situation and the type of external influences[2]. Any relevant information on biomechanical or electrical pulses is available to the central nerve system for both types of responses to dynamic environmental conditions in real-time [16], [18]. Therefore human beings adapt to change or anticipate the need to adapt by having a varied repertoire of actions and activities at their disposal. Thus, the human is in the position to take the appropriate action or reaction consciously or unconsciously, based on real-time information.

Transferred to a production system, it means that only the transparency of information in real-time and subsequent real-time processes make changeability possible. Furthermore, decision-making mechanisms have to exist in order to select and evaluate the sum of the possible, appropriate alternatives regarding the situation requirements (cost effectiveness vs. operational effectiveness). Transferred to the machinery and equipment industry and thus transferred to concrete practical problems, it means in order to establish the ability to coordinate in real-time value networks, it needs:

1. to increase the ability of integration of various companies and business units. The use of biunique information throughout the supply chain and also a consistent definition of standardized interfaces between different IT-systems, that are being used for planning and control processes, form the technological enablers for the realization of a changeable production system [11].
2. to improve the ability to respond in planning and control processes significantly. This implies, that the static planning and control logic, which is based on the Manufacturing Resource Planning (MRP II) concept, must be replaced by a decentralized operating and real-time capable planning and control logic with closed-loops.

3 Integration of ICT as a key enabler towards changeable production systems

In companies different IT-systems are used to plan, control and monitor production and logistic processes. These IT-systems may be assigned to one of the four planning levels, named shop floor, detailed, rough and intercompany planning level. In practice, an integrated information flow between these four planning levels is seldom (cf. **Fig. 2**). Standard interfaces exist just to functional and powerful ERP systems on the market like SAP, Infor ERP.LN or Microsoft Dynamics. Whereas standard interfaces are often not available to the great majority of small and medium-sized software engi-

[2] So e.g. they might react to heat on a reflex, but to cold they might react by making a conscious decision

neering companies. The resulting lack of transparency in production systems is one of the biggest weaknesses of ERP, MES, PDM and Supply Chain Management (SCM) systems. Consequences of the problem are unrealistic delivery times to the customers and inefficiencies within the business processes [22].

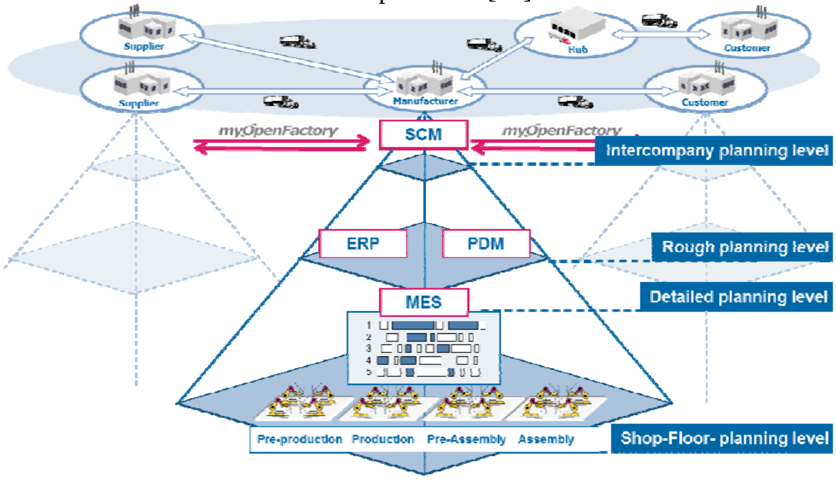

Fig. 2. Internal and external planning level

Therefore the research project "WInD" aims at improving the integration ability of supply chains fundamentally. This aspect is the technological and informational enabler for the realization of a changeable production system. Thus, the crucial standardization gaps of the concrete use case for the machinery and equipment industry are being closed in the framework of the project. Standardized interfaces should not only connect the rough with the detailed planning level (ERP- to MES-systems), but also guarantee the accurate synchronization of master data between ERP- and PDM-systems. Additionally the transfer of the electronic product code (EPC) to the machinery and equipment industry should also improve the data quality by implementing an opportunity to identify the product data (standard and custom parts) biunique in the future.

The necessary data quality and information allocation in the machinery and equipment industry is currently not available due to heterogeneously constructed IT-environments (lack of standardized interfaces and subsystem diversity) [19]. Non-bidirectional data results in inconsistent master data for planning and control activities of the entire production network. Parallel manipulated master data (parts lists or material master data) in Enterprise Resource Planning- (ERP) and Product Data Management- (PDM) systems are not sufficiently (logically and in regard of content) synchronized. The concept of Manufacturing Resource Planning (MRP II) still represents the central logic of production planning and control. However, the centralized and push-oriented MRP II planning logic is not able to plan and measure dynamic processes adequately due to diverse disturbances, which often occur in production environments [20]. The traditional hierarchical planning method leads to an iterative planning process that dissects PPC-tasks into smaller work packages. Therefore, individual optimization is far away from a holistic approach and therefore from the achievement of an optimal solution [21]. Consequences of these problems are unrealistic delivery times to the customers and inefficiencies within the business processes [22].

A new decentralized and real-time capable planning and control logic, developed in the framework of the project WInD, is supposed to enable the processing of obtained real-time data according to the requirements. For this the Aachener-PPC-model as a science-accepted reference model for tasks and processes of production planning and control and particularly the enhancements of the process view for "contract manufacturers" by Schmidt will be the basic reference for the machinery and equipment industry [5] in this project. Based on the process model by Schmidt a demonstration case will be shown applying a cybernetic structure into an industry environment.

4 Demonstration case of changeable production systems based on an integrated ICT-structure

One of the main issues of ICT research is that its results as presented by educational institutions are not directly accessible to industry. Therefore it is difficult for industry, especially SMEs, to comprehend and to adapt to the technological advances in a direct way. To overcome this gap numerous works have been conducted in the field of manufacturing education and industrial learning [23-25]. Demonstration is an established instructional method for manufacturing education. Within the research project WInD funded by the German Research Foundation DFG as part of the Cluster of Excellence "Integrative Production Technology for High-Wage Countries" the Institute for Industrial Management at RWTH Aachen University and participating SMEs develop a demonstration setting that visualizes the IT-integration as an enabler for changeability. Therefore, the academic solution to changeable production systems as described in chapters 2 and 3 is consequently transferred into a practical environment to be accessible for industry. **Fig. 3** illustrates the process and information flow model of the demonstration case. The process and information flow model visualizes the integration of five IT solutions: Enterprise Resource Planning (ERP), Product Data Management (PDM), Manufacturing Execution Systems (MES), an electronic market place (VDMA eMarket[3]), an Electronic Product Code Information Services (EPCIS)[4] framework and the myOpenFactory (myOF) platform[5]. The main goal of the demon-

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[3] The VDMA-E-Market (http://www.vdma-e-market.de/en/) is a platform for product search established the VDMA (Verband Deutscher Maschinen- und Anlagenbau - German Engineering Federation)

[4] EPCIS is a standard to capture EPCIS-events containing the information *What* (e.g. a certain product), *Where* (e.g. outgoing goods), *When* (e.g. 3.05 pm) and *Why* (e.g. product shipped)

[5] The myOpenFactory platform acts as a standardized interface between the different ERP-systems of participating SMEs. Their ERP-systems only have to be mapped once to the platform allowing automated exchange of order processing relevant data within the whole production network.

stration case is to show how the order processing with such a heterogeneous IT-structure can be automated through the integration of IT-Systems.

The demonstration case features the following highlights:

- Automation of the order processing of a customized product in a heterogeneous IT-landscape.
- Full integration and bidirectional information flows between ERP and MES (ERP-MES interface).
- Automated Engineering Change Requests (ECR) in PDM based on customer changes in ERP-system.
- Full integration and bidirectional information flows between ERP and PDM (ERP-PDM interface).
- Integration of a web shop for special demands and automated inquiry to potential suppliers.
- EPCIS communication framework to facilitate real-time information on changes of delivery dates.

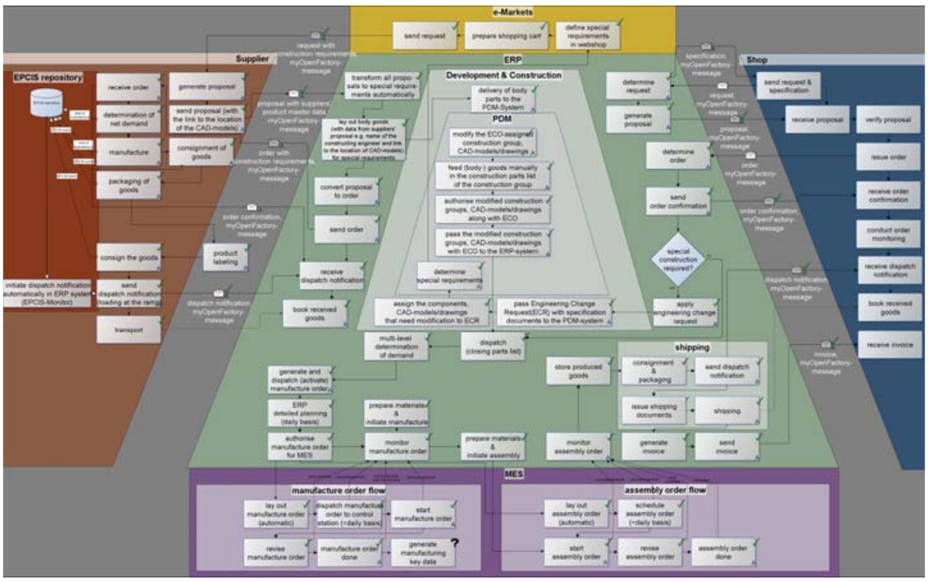

Fig. 3. Process and information flow model of the WInD demonstration case

5 Conclusion and outlook

In this paper an approach for changeable production systems enabled by ICT-integration has been presented. It was shown how cybernetic principles have been transferred to a production network representative for the German machinery and equipment industry. A framework for the ICT-integration was introduced to facilitate changeable production systems in practice. To overcome the barriers between the research conducted by educational institutions and industry a demonstration case has been presented reflecting a typical setting within the SME-dominated industry. The main features of the demonstration case have been presented.

The demonstration case will be implemented at the Campus Cluster Logistic (CCL) which is currently under construction at RWTH Aachen University. Within the CCL a demonstration factory will be erected demonstrating the principles of changeability and IT-integration in the manufacturing industry. Further development stages of this demonstration case at the CCL will be the integration of a generator of transaction data. Therewith, it will be possible to simulate the effects of varying different setting within ERP-Systems in the whole supply chain. This research is part of the Cluster of Excellence "Integrative Production Technology for High-Wage Countries" at RWTH Aachen university were ontologies and design methodologies for cognition enhanced, self-optimizing Production Networks are being developed.

Acknowledgement

The research project "WInD - Changeable production systems through integrated IT-structures and decentralized production planning and control" (02PR2160), sponsored by the German Federal Ministry of Education and Research (BMBF) and supported by the Project Holder Karlsruhe at the Karlsruhe Institute of Technology (KIT) for Production and Manufacturing Technologies (PTKA-PFT). The authors wish to acknowledge the Federal Ministry and the Project Holder for their support. We also wish to acknowledge our gratitude and appreciation to all the WInD project partners for their contribution during the development of various ideas and concepts presented in this paper.

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