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Approach for production planning in reconfigurable manufacturing systems

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Abstract

To stay competitive and to fulfill the changing market needs, manufacturing companies have to adapt their manufacturing systems in frequent and short intervals. Hence, changeable and reconfigurable manufacturing systems (RMS) are proposed and discussed in a multitude of research publications. While production planning becomes increasingly complex in this context, it has to be reliable and quick at the same time. Therefore, the performance and flexibility of manufacturing systems depends on actual and suitable planning data with high quality and wide range. In this context, a new approach for production planning in reconfigurable manufacturing systems is exposed in this paper. Data models, a configuration management and a sequential method for the resource planning help to integrate reconfigurable manufacturing systems' key characteristics in production planning and control (PPC). Finally a prototypical application scenario, for the evaluation and demonstration of the feasibility of the planning approach, is outlined.

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Keywords: Production Planning; Reconfiguration; Scheduling

1. Introduction

Nowadays, manufacturing companies are affected by high dynamics [1] due to shortening product [2] and technology life cycles [3], increasing numbers of variants as well as the rising demand for individual products. Some of the central market requirements are: short delivery times, a competitive pricing due to low production costs and high product quality standards. The ability to adapt to these constantly changing market requirements therefore is a prerequisite for the global competitiveness of manufacturing companies [4, 5].

One approach to ensure companies' ability to act successfully in this environment is changeability. Changeable systems can be distinguished by the fact that they are able to react with their inherent flexibility but can also respond to unpredictable situations [1]. To fulfill this requirement, several approaches have been discussed in the research community. In production, major approaches for increasing changeability are reconfigurable manufacturing systems (RMS) [6]. However, planning is becoming complex. Hence, challenges in managing manufacturing companies include support systems for reconfiguration, e.g. production planning and control (PPC) [7].

The PPC is an essential interface between costumers' needs and manufacturing processes and is not able to manage changes in the short time and is limited by its flexibility [8]. The success of PPC highly depends on exact and high-quality planning data. A survey among companies of machine and plant engineering illustrates that todays' planning systems suffer from low quality, inactuality and low range in planning data which results in unrealistic delivery times [9]. In order to cope with these challenges, a more sophisticated planning approach and data for higher validity concerning planning results are needed. To ensure sustainable quality and good performance of production planning, reconfigurations and the ability of change in configurations of manufacturing systems as well as resources have to be considered in PPC.

In this publication an approach of a system for production planning with focus on reconfigurable manufacturing systems is proposed. The planning approach, including a capacity planning, machine scheduling and optimization, and the necessary data models as well as a configuration management are presented.

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2. Reconfigurable manufacturing systems (RMS)

The characteristics and descriptions of reconfigurable manufacturing systems had been analyzed in several research activities in the past [e.g. 5-7, 10-12]. In the following chapter definitions, applications as well as differentiations to flexible manufacturing systems (FMS) are outlined. Furthermore, requirements for production planning with RMS are stated.

2.1. Definition and classification

Reconfigurable manufacturing systems can be described as highly dynamic and evolving systems designed to cope with unpredictable situations [6]. In this context, reconfigurability is defined as the ability to change systems' behavior by changing its configuration [13]. Additionally, ElMaraghy differs between hard and soft reconfiguration [7]. While hard reconfiguration is realized through changes and modifications of hardware (e.g. changing spindles), soft reconfiguration is fulfilled with adaptions in software or organizational aspects (e.g. additional shifts) [7, 12]. One main characteristic of RMS is their rapid adaptability concerning hard- and software as well as their structure (e.g. adding, removing and modifying machine tools) [6, 7]. These changes are implemented with minimal efforts in time and costs [1, 6]. Due to this main characteristic, their functionality and capacity can be configured and reconfigured as needed to respond to changes in market conditions [1, 5, 6]. RMS can be described by key characteristics: modularity, integrability, customization, convertibility and diagnoseability (see Table 1) [6]. For reducing efforts for reconfiguration time and costs, modularity, integrability and diagnoseability are the key enablers. In contrast, customization and convertibility open up the opportunity to reduce the operational costs of these systems.

Table 1. Key characteristics of RMS [according to 6].

Characteristic	Description
Modularity	Modular structure of components and controls
Integrability	Standardized interfaces for quick integration of new components and technologies
Customization	Customized flexibility and control
Convertibility	Short conversion times
Diagnoseability	Traceability of product quality during ramp-up

In contrast, flexible manufacturing systems are built up with all possible set-ups concerning flexibility and functionality [5] and can adapt only within their a priori pre-determined flexibility with different flexibilities (e.g. process and product flexibility). This includes producing only a pre-defined product spectrum and production amount within their flexibility corridor [7]. Adaptions, which go beyond this flexibility, require substantial efforts. To summarize, FMS are limited in capacity as well as in functionality [6]. Adaptions inside their flexibility can be managed rapidly and at low cost. However, one disadvantage is the high initial capital investment for the inherent and often not used flexibility [6, 7].

The significant differences between FMS and RMS are systems' flexibility and scalability concerning capacity and flexibility in particular (see Fig. 1). To meet market requirements, reconfigurable manufacturing systems provide on demand customized flexibility through scalability to incrementally realize different functionalities and capacities [5, 7]. In contrast, flexible manufacturing systems feature a general a priori-fixed flexibility and are able to change inside their inherent flexibility. Whereas FMS can produce multiple products at installation time, RMS are designed for a certain product portfolio (e.g. product A at the beginning and B+C in the last extension stage).

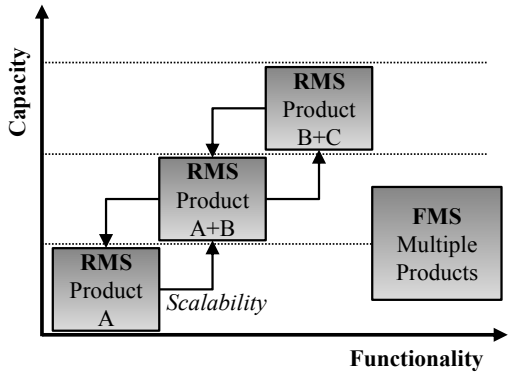

Fig. 1. Capacity and functionality of RMS and FMS [according to 6].

2.2. Requirements for production planning

The significance of scalable functionality and capacity of RMS as well as the availability and quality of planning data are the main enablers to cope with todays' constantly changing requirements in the field of PPC.

Due to these challenges, the key characteristics of RMS, as discussed before, need to be integrated in the production planning and control. For this purpose, the planning data primarily have to feature the functionality and scalability of these systems and their manufacturing resources. In this context, different capacities subjected to systems' and resources' configuration are one possible approach. Additionally, planning data are to be distinguished by their convertibility e.g. changes between different planning data sets have to be described and proceeded in short time. In order to cope with the characteristics of RMS, planning data need to be adaptable and the integration of changed data has to be enabled. As a consequence of the change in planning data, new methods for production planning and allocation need to be developed. The consideration of different configurations and the scalability concerning functionality and capacity is inevitable to increase flexibility and adjustability of planning approaches for RMS.

3. State of the research

The production planning and control (PPC) supports manufacturing companies in their order processing. As one main function, the PPC fulfills the task to plan and control production processes in terms of quality, schedule and