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Ad-hoc Rescheduling and Innovative Business Models for Shock-Robust Production Systems

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Abstract

Reconfigurability, flexibility, transformability and agility become key enablers of success. This leads to new business models and the necessity of new concepts for production planning along the whole value chain. Adequate methods have to integrate the possibilities of a migration of the network and the changeability of each single plant. Moreover these approaches should be able to cope with uncertainty and reduce the complexity for the decision-makers to a minimum. Consequently, this paper focuses on two major aspects: ad-hoc rescheduling of reconfigurable plants as well as new innovative business models between equipment or component supplier and OEM. Cyber-physical systems will enable new decentralized and autonomously working production equipment and in doing so, reduce complexity and boost up the speed of possible reactions to market shocks. Component suppliers will enrich their portfolio by new bundling approaches including warranties to their products in terms of risk prevention (e.g. warranties for needed time to react to market changes or bottlenecks).

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1. Introduction and current challenges

The last decade showed how, complexity and dynamics dominate the economies around the world. The natural and nuclear disaster in Japan showed in very dramatic ways how fragile our supply chains can be. Sustainable moves in economic crisis and fast reactions to changed market or legal conditions become of crucial importance for all companies as they all are part of a global chain.

Moreover, customers expect a high degree of individuality and short delivery times. Consequently, reconfigurability, flexibility, transformability and agility become key enablers of success. This leads to new business models and the necessity of new concepts for production planning along the whole value chain. These methods have to integrate the possibilities of a migration of the network and the changeability of each single plant. Moreover these approaches should be able to cope with uncertainty and reduce the complexity for the decision-makers to a minimum.

These current challenges have to be addressed on very different levels reaching from the global network level on the one hand to the production systems level on the other hand. This paper presents corresponding approaches and is structured as follows. In chapter 2 a brief overview of state of the art approaches concerning these topics are given. Chapter 3 introduces Enablers for reaching the named goals. Chapter 4 is focusing on the reactions of internal shocks on a plant level, while chapter 5 expands these considerations to a global network level. Chapter 6 closes with the summary.

2. State of the Art

This chapter gives an overview of approaches facing the current challenges of reconfigurability, flexibility, transformability and agility within a complex producing environment on the levels of production networks and production systems.

On the network and supply chain level different approaches can be found. Fleischmann et al [1], Stephan et al [2] and Leung et al [3] focused on capacity planning of production networks on a strategic level.

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Lanza and Peters dealt with capacity planning for highly volatile horizons for instance caused by economic crisis [4] and integrated possibilities of supply chain adaptations.

Robust supply chains that are able to adapt to a highly volatile environment consist of robust plants which in turn include robust production systems. However, shock-robust plants do not only consist of changeable production systems which have been and are still extensively studied. Besides the ability of adapting to external changes like economic crises, global disasters or changes in local markets, they also have to be robust concerning internal shocks. An internal shock can for example be given by a sudden machine breakdown. A shock-robust plant has to be able to adapt to this new situation within a minimum of time in order to ensure production.

In this context the significance of rescheduling becomes obvious. In this field of research several approaches exist. Guilherme et al [5] describe a framework to classify existing rescheduling approaches. In the following this framework is used to survey existing approaches. The framework differentiates between rescheduling environments, rescheduling strategies and rescheduling methods.

The term 'Rescheduling environment' identifies the set of jobs and refers to their dynamic nature. Most approaches consider static jobs, in which a finite set of jobs exists (e.g. Guilherme et al [6]). Since dynamic rescheduling environments are the ones most relevant to manufacturing systems, the dynamic environment nowadays is increasingly taken into account, as the random job arrival in Gao et al [7]. Thus rescheduling literature considers different manufacturing types like cyclic production, flow shops or job shops when focusing on dynamic environments. Flow shops are e.g. considered by Gao et al [7] or Tan et al [8] whereas Dong et al [9] and Hao et al [10] present algorithms solving rescheduling problems in job shops.

Guilherme et al describe two rescheduling strategies for controlling production in a dynamic environment. They propose dynamic strategies and predictive-reactive strategies. The latter are the ones most commonly used in practice and according to Aytug et al [11] also the ones most studied in literature. Predictive-reactive strategies first generate a production schedule and then update the schedule according to different rescheduling policies. This rescheduling policies can be either periodic, event-driven [6, 9] or hybrid [10, 12]. Periodic policies reschedule periodically at a fixed time, whereas event-driven rescheduling is only taking place, when specific conditions hold. Hybrid policies reschedule a production schedule at a fixed time periodically but also reschedule whenever random disruptions occur. Rescheduling methods are either focusing on schedule generation or schedule repair. Guilherme et al subdivide schedule repair into right-shift rescheduling, partial rescheduling and complete rescheduling. The former simply postpones all remaining operations. Right-shift rescheduling is very easy to implement and e.g. observed by [13] who propose right-shift rescheduling with respect to efficiency and stability. Partial Rescheduling, also known as Affected Operations Rescheduling (AOR) [9], only reschedules operations affected by the disruption. According to Guilherme et al [5] most of the approaches consider affected operations only. Wang et al [14] consider machine breakdown at a permutation flow shop. As a solution method a partial rescheduling procedure for the permutation flow-shop scheduling problem is developed. Dong et al [9] extend the typical AOR by proposing heuristic rescheduling procedures considering tardiness of jobs in a job shop as their main objectives but also other performance measures like efficiency and stability. Complete regeneration methods reschedule the entire remaining operations, also the ones not affected by the disruption.

Another approach focusing on the area of stability, more precise the topic of reducing the interference with producing anomaly by shortening the searching space is given by [15]. Within the approach of Tan et al [8] the rescheduling methods of machine-learning and data-mining techniques generating a knowledge-based decision making system are addressed. Other approaches like Gao et al [7] use genetic algorithms as a solution method. Gao et al propose a 3-stage rescheduling based on the rolling window rescheduling strategy considering the minimum completion time, minimum cost, maximum utilization rate, and minimum deviation degree as objectives. The number of approaches considering stability and robustness of rescheduling solutions by using different rescheduling methods is rising.

Most approaches however do not consider the increase in cost when rescheduling a production schedule. Moreover according to Aytug et al [11] the connection between rescheduling literature and literature on structural control of automated manufacturing systems is also missing.

Many approaches are only focusing on a single production system instead of a whole production network. But in fact lots of production anomalies are not only caused by machine breakdowns, but also by missing components and other disturbances caused by problems in the network. On the other hand the network defines the criticality of a break-down as it is the network suffering under the consequences. So seeking the goal of increasing reconfigurability, flexibility, transformability and agility the whole production network including all its production systems has to be considered.