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Assessment of Production System Alternatives During Early Development Phase

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Abstract

The development of modern mechatronic systems is characterized by a rising complexity and an increasing necessity to develop product and according production system in a close interplay. Model-based Systems Engineering has been introduced to cope with these challenges by means of an integrated system model. It enables the consideration of possible interdependencies and allows the analysis of the whole system model from the beginning. Especially during the early phase of the production system development many interdependencies have to be considered while the information are still vague and most system specifications yet have to be determined. The objective of the approach presented in this contribution is therefore to compare and assess early alternative production system specifications parallel to the development in order to reduce the relevant solution space and save valuable development resources. For that purpose a three stage evaluation procedure is proposed and methodologically founded. Additionally an according multi criteria structure that is based on common specification languages like CONSENS or SysML is presented and the practicality of the approach is demonstrated with an application example.

Keywords: Model-based Systems Engineering (MBSE), Integrative Production System Development, Production System Assessment, Multi Criteria Decision Support, Analytic Network Process

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1. Introduction

Increasingly global competitions as well as decreasing product life cycles force companies to constantly improve their engineering capabilities. To succeed in an agile and highly competitive business environment, it is mandatory to avoid wasting time and money during development through resource-intensive iteration loops. To accomplish this objective, future improvements must not only comprise merely technical optimizations but also a broader perspective on product design and development. In industrial practice the production system development is usually not begun with until the product development is almost finished. However many product design decisions highly affect the production system development and vice versa, so it is more than ever important to consider the relations as early as possible and develop product as well as production system in a close interplay[1]. An example for relevant interdependencies is the material selection during product development that requires certain manufacturing technologies, e.g. aluminum welding. If these capabilities are not available within the company it might be more efficient to select another material during the product development phase[2].

The example illustrates the potentials of an early and integrative development of product and corresponding production system, i.e. starting the production system development as soon as a principle solution of the product has been defined. However the grand challenge of the early development phase is the high amount of incomplete and vague information. Additionally the consideration of all relevant interdependencies between product und production system development comes with the price of an exponentially rising complexity of the engineering task. Since domain-specific engineering methodologies cannot sufficiently handle this complexity, Model-based Systems Engineering (MBSE) has been introduced to solve this challenge[3]. MBSE relies on a general system model that comprises all the required domain-spanning interdependencies and coordinates the involved domain-specific models. The system model structures the relevant information and defines clear interfaces between the subsystems as well as to the environment. Its purpose is not only to serve as a starting point before the domain-specific system development is pursued, but also to act as a common information exchange layer for the involved disciplines throughout the whole product engineering process[4].

Modeling systems according to MBSE principles from the beginning enables a highly efficient system development that requires less iteration loops, thus reducing development time and money spent. Since potential inconsistencies of the development between different domains or subsystems are discovered immediately, the engineers receive a continuous feedback if certain adaptions violate the boundary conditions of other domain-specific systems or decrease the overall performance of the system. This procedure avoids the isolated optimization of independent subsystems that might cause conflicts in the system integration phase of the development process.

The integrative development of product and production system can therefore particularly benefit from the MBSE methodology. Especially early analyses of the integrated system model offer significant potentials to realize a leaner development process. When only a first concept of the product is available, a high degree of freedom results for the according production system development. For this reason the main objective of the production system development during the early design phase is the exclusion of unsuitable processes from the solution space. This enables an evaluation of the most promising production system alternatives so developers can focus on the best solutions right from the beginning. The criteria for the evaluation must be chosen in accordance with the overall objective of the production system development, e.g. flexible, sustainable or low-cost manufacturing. Each overall objective is determined by a multitude of criteria with different importance that are individually assigned depending on the specific planning task. Besides the differences between the criteria's importance the criteria themselves are also different in nature, i.e. quantitative as well as qualitative. Despite these challenges it is necessary to merge all criteria within a unified methodology to achieve an efficient and objective-oriented engineering process.

This contribution proposes an MBSE-based multi-criteria decision support approach for the evaluation of production system alternatives during the early design phase. For that purpose the development of a general system model as well as existing approaches for multi-criteria decision support will be described in more detail in section 2. The approach for the analysis of the general system model with regard to the overall objective is then introduced in section 3, followed by an application example that validates the proposed procedure in section 4. The contribution is finished with a conclusion as well as an outlook to the future research challenges in section 5.