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Integrated Product and Assembly Configuration Using Systematic Modularization and Flexible Integration

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Abstract

Dealing with the varying demands deriving from the market, the technical innovations and the public authorities in a dynamic way, offers great potential to improve the competitive situation in the global market. The introduced approach supports the ability of manufacturing companies in the field of mass customization to respond to these changes in an effective and efficient way. The focus is on the understanding of the product and its assembly as a complex, socio-technical and integrated system to realize a target-oriented modularization. Configuration concepts are used to integrate the created functional self-contained and well-defined modules in a flexible way.

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1. Introduction

Manufacturing companies are subject to a permanently changing environment. Megatrends like individualization, globalization and sustainability induce shorter product life cycles and increasing numbers of product variants that force the factories into a continuous adaptation to stay competitive in the global competition [1]. Fig. 1 illustrates the factory that is subject to manifold internal and external demands that are continuously changing and partially competing with each other.

Mass Customization [2] represents a concept to use volume production to produce customized products. For that matter the advantages in the sense of economies of scale and economies of scope or possible optimization activities that are offered for instance by the concept of lean production [3] are tried to be applied. This demands enormous flexibility and changeability in the production. In this paper, flexibility subsumes the ability of production systems to answer to variations in the type or the volume of the products to be produced in a predefined corridor. Changeability stands for the characteristic of a production system that enables an adaptation of the production system [4]. Therefore not only technical conditions like the consequent modularization, standardization and mobilization of production equipment but also the organizational conditions have to be created [5].

The approach introduced here aims at the support of the flexibility and changeability of production systems with a special consideration of the products to be produced. Therefore, a method for integrated product and assembly configuration is proposed.

The following two sections outline the state of the art in the field of flexible and changeable manufacturing and product systems and create a common understanding of the used terms. Afterwards the method for integrated product and assembly configuration is described. The focus of the method is the systematic understanding of the product system and the accordant assembly system. The creation and use of this understanding is supported by an ontology-based information system that is also presented.

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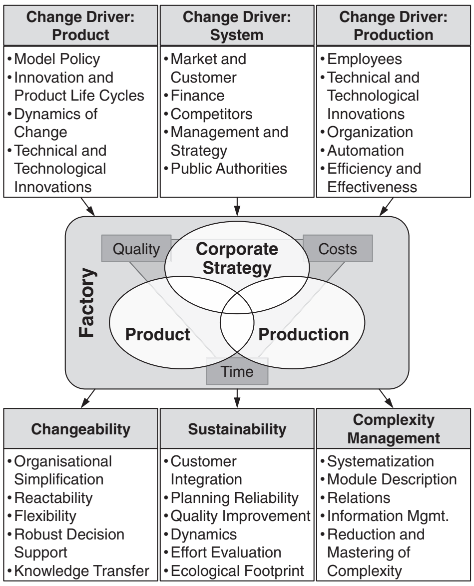

Fig. 1. Factories in dynamic environment

For validation purposes, the method has already been applied in scientific and industrial environment. The results of this validation are outlined before the paper closes with a discussion, a summary and an outlook.

2. Basics

This section is to create a common understanding of the terms used to describe the integrated product and assembly configuration.

2.1. Configuration

A configuration task creates configured solutions out of a "fixed, pre-defined set of components, where a component is described by a set of properties, ports for connecting it to other components, constraints at each port that describe the components that can be connected at that port, and other structural constraints." [6] This definition stipulates that a configuration task needs components that are well-defined and the possible connections under consideration of the respective contribution to the function of the configured solution have to be described (Fig. 2). Following the definition, individual products are not under consideration of this research task, because with individual products at least some components are not yet defined. But individualized products in the sense of products with many variants and a high degree of customer integration are in the focus of the approach introduced here. For the demarcation of individual and individualized products see [7]. Individual products are also identified as personalized products and individualized can be used similarly to customized products [8]. The configuration can be separated into the following two aspects: modularization and integration.

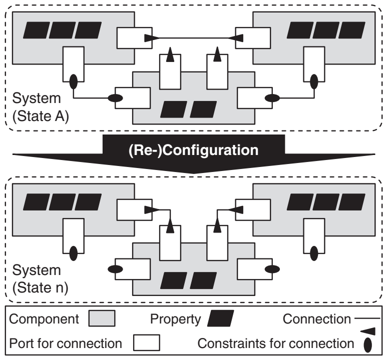

Fig. 2. Configuration

2.2. Modularization

The above mentioned components can be considered as modules. Modules are independent and self-contained elements that can be combined to achieve an overall outcome of the superior system (so called supersystem) [9], where the functional interactions take place within rather than between the modules [10]. Thus, modularization is a way to reduce the complexity of systems by separating it in partial functions [11].

2.3. Integration

The target-oriented combination and connection of the modules to realize a valid functional unit is considered as integration. So the integration with its impact in the direction of reducing elements, that have to be considered separately by constructing supersystems, competes with the modularization. It is challenging to find the right balance between modularization and integration or to find the ideal granularity of the modules within the system boundaries [12].

2.4. Theory of Technical Systems

It is mandatory to understand the elements of a system and their interdependent behavior as a whole before identifying the ideal balance between modularization and integration to realize a target-oriented separation of a system into subsystems (modules). System Theory provides a reliable fundament for this task [13]. Fig. 3 illustrates the categorization based on the general system theory following [14] and [15].

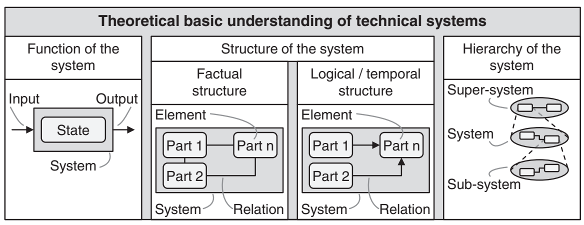

Fig. 3. Categorization of technical systems