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The Influence of Mass Customization Strategy on Configuration Complexity of Assembly Systems

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Abstract

In current business environment many OEM companies are employing mass customization strategy, which has implication on the entire operations of an enterprise and especially influences the character of assembly processes. Increased product differentiation in context of customized production causes significant changes in complexity of assembly systems. Our focus in this paper is the development of methodological framework for generating all possible product configurations based on number of stable and optional components or modules from which a final product is completed. Subsequently, we propose an approach to determining so called product configuration complexity by specifying classes and sub-classes of product configurations. Then, for each sub-class of product configuration we can obtain upper bounds values of configuration complexity. Finally, configuration complexity scale based on the obtain upper bounds values is outlined and discussed.

Keywords: Mass customization, assembly system, product configuration, product variation

1. Introduction

The growing competition in the global market is always a challenge to find innovative approaches to business. The key to success in the highly competitive manufacturing environment is the firm's ability to design and develop products that can be individually tailored to customer needs. This can be achieved by employing a set of principles of mass customization. Even though mass customization is often confronted with a question of how to put the concept of Mass Customization (MC) into profit-making practice, there are many evidences that this strategy can improve, at least, product development process efficiency and reduce time and cost [1, 2] even in the design stage of a production development. Principally, Mass-Customized Production (MCP) systems can be classified into make-to-stock MCP, assemble-to-order MCP, make-to-order MCP, engineer-to-order MCP, and develop-to-order MCP [3]. Our focus in this paper will be on the issue of assembly-to-order production where we will monitor the generation of predefined product configurations and variants. In such situation, production planning and control involve not only product variety, but also process variety and therefore it is important to synchronize product and process variety in a coherent manner [4]. Usually, product variety is predominantly determined by customer needs. This approach gradually can lead to very complex assembly systems with unlimited number of product variants to choose from. The higher the number of product variants, configurations or the overall variety, the more complex difficulties in the production design and operational management of assembly systems or assembly supply chains (ASC) there are. It has already been proofed by theory, empirical data and simulations [5, 6] that variety itself has a significant impact on the performance (productivity, quality) and complexity, especially in automotive vehicle production, including assembly and parts supply. One of the major effort in the area of assembly variety induced complexity is to reveal and develop for variety-based complexity especially for assembly supply chain operations in MCP.

Our intent in this paper is to present a part of methodological framework for generating all possible product configurations and variation based on number of stable and optional components or modules from which a final product is completed. Subsequently, we propose an approach to determine so called product configuration complexity by specifying classes and sub-classes of product configurations.

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The purpose of this effort is to identify appropriate extent of product variety and complexity.

Variety of products in Mass-Customized Production is embodied in different components, modules, parameters, variations of structural relationships, and alternative configuration mechanisms. The different properties, mechanisms and/or variables of any MCP assembly operation, allow us to differ between structural, dynamic or a heuristic type of complexity. While the first one describes the state of a system in a pre-defined time point, the dynamic complexity describes and measures the change of a system in a pre-defined period of time. Any MCP layout solution consisting of numerous product configurations and variants at a certain time point allows us to sum all the product configurations and variants determining the structural complexity of the system. Dynamic complexity, on the other hand, is always linked with the size and frequency of changes in the system. The complexity, either the structural or dynamic, is even higher if a product or its configuration/variant is eliminated or newly introduced into the existing production system/layout. Today's producers have to be able to handle such a variety and conceptualize the integration between product variety and process variety. Mass-Customized Production is frequently defined as "producing goods and services to meet individual customer's needs with near mass production efficiency" [7]. The concept of Mass Customization as a theoretical and applied framework has been introduced in a research literature by Davis [8] and later presented in the book by Pine [1]. It is possible to identify two different concepts for the definition of mass customization, the broader and the narrower one. The broader concept defines mass customization as the ability to provide customers with individually designed products and services without the limitation of time, place and customer needs. The narrower concept defines mass customization as the use of flexibility processes and organization structures to provide a variety of products and services that are designed to individual customer specification [9]. Authors [10] pointed out, that success of mass customization system or MCP depends on customer demand for individualized and customized products. They explained that the demand for customized products is influenced by two main factors. The first is a degree of customer satisfaction. The second one is the firm's ability to produce products according to customer specification, with an acceptable time and reasonable costs. By them, the balance between these two factors is critical determinant for the success of the mass customization system. Product variety has been defined in several ways (see, e.g. [11, 12]). According to Ulrich [13] it is the diversity of products that a manufacturing enterprise provides to the marketplace.

Our effort in this paper is to determine all possible product configurations based on number component types divided into three categories, namely base, optional and compulsory optional components.

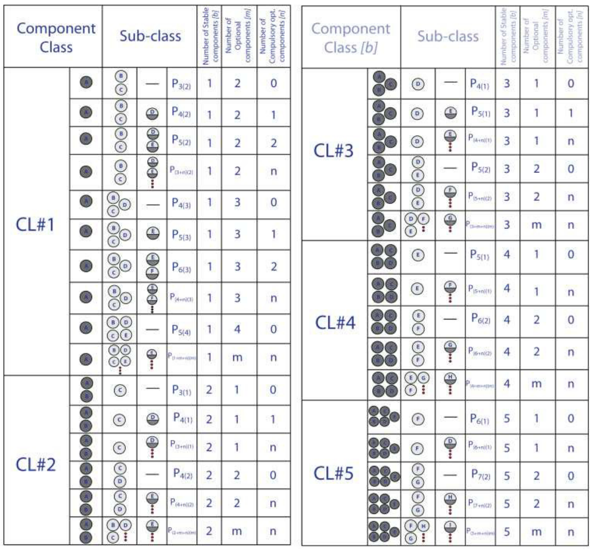
2. Generating of product configurations

So far, the possibility of having multiple optional components or more than one type of optional component has not been considered in our research. The procedure for generating product configurations is not much different from our previous methodology [14, 15] where we dealt only with base and optional component types. We will start with the following assumptions:

1. Let`s call the product class with a number of stable components a Class of product configurations *CL#b*, where b – number of stable components on entry to assembly unit/process;
2. Each of product classes *CL* consists of sub-classes $P_{b+m+n\,(m)}$ (see Fig.1), where:

m – number of optional components

n – number of compulsory optional components



Component Class		Sub-class			Number of Stable components [b]	Number of Optional components [m]	Number of Compulsory opt. components [n]
CL#1	A	B C	—	$P_{3(2)}$	1	2	0
	A	B C	D	$P_{4(2)}$	1	2	1
	A	B C	D E	$P_{5(2)}$	1	2	2
	A	B C	D E ⋮	$P_{(3+n)(2)}$	1	2	n
	A	B C D	—	$P_{4(3)}$	1	3	0
	A	B C D	E	$P_{5(3)}$	1	3	1
	A	B C D	E F	$P_{6(3)}$	1	3	2
	A	B C D	E F ⋮	$P_{(4+n)(3)}$	1	3	n
	A	B D C E	—	$P_{5(4)}$	1	4	0
	A	B D C E ⋮	F ⋮	$P_{(1+m+n)(m)}$	1	m	n
CL#2	A B	C	—	$P_{3(1)}$	2	1	0
	A B	C	D	$P_{4(1)}$	2	1	1
	A B	C	D ⋮	$P_{(3+n)(1)}$	2	1	n
	A B	C D	—	$P_{4(2)}$	2	2	0
	A B	C D	E ⋮	$P_{(4+n)(2)}$	2	2	n
	A B	B D C ⋮	E ⋮	$P_{(2+m+n)(m)}$	2	m	n
CL#3	A B C	D	—	$P_{4(1)}$	3	1	0
	A B C	D	E	$P_{5(1)}$	3	1	1
	A B C	D	E ⋮	$P_{(4+n)(1)}$	3	1	n
	A B C	D E	—	$P_{5(2)}$	3	2	0
	A B C	D E	F ⋮	$P_{(5+n)(2)}$	3	2	n
	A B C	D F E ⋮	G ⋮	$P_{(3+m+n)(m)}$	3	m	n
CL#4	A C B D	E	—	$P_{5(1)}$	4	1	0
	A C B D	E	F ⋮	$P_{(5+n)(1)}$	4	1	n
	A C B D	E F	—	$P_{6(2)}$	4	2	0
	A C B D	E F	G ⋮	$P_{(6+n)(2)}$	4	2	n
	A C B D	E G F ⋮	H ⋮	$P_{(4+m+n)(m)}$	4	m	n
CL#5		F	—	$P_{6(1)}$	5	1	0
		F	D ⋮	$P_{(6+n)(1)}$	5	1	n
		F G	—	$P_{7(2)}$	5	2	0
		F G	H ⋮	$P_{(7+n)(2)}$	5	2	n
		F H G ⋮	I ⋮	$P_{(5+m+n)(m)}$	5	m	n

Fig. 1. Component classes CL and their sub-classes $P_{b+m+n(m)}$

3. Each such Class consists of at least one stable assembly component in combination with at least two optional components (in class *CL#1*). The number of stable components is fixed throughout the whole assembly process, e.g. any assembly scheme can have pre-identified components divided into three categories, already in the assembly design stage.
   In cases when only one stable and one or two optional components enter the process, we are not talking about a customized assembly, since this operation only results in one product configuration, which is only a standard assembly process and not a customized assembly.
4. The following types of input components can be defined as follows:

(i) Stable components are those selected from among the input components of a certain assembly level and their amount is fixed through the whole assembly process. If a certain node performs the installation/assembly of optional and compulsory optional components at the same time, the previous configurations of base and optional components become fixed for further optional component level, as can be seen in Fig. 2.