Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 23 (2014) 258 – 263

www.elsevier.com/locate/procedia

Conference on Assembly Technologies and Systems

5th CATS 2014 - CIRP Conference on Assembly Technologies and Systems

Modeling and Determining Product Variety for Mass-customized Manufacturing

V. Modrak[a,*], D. Marton[a], S. Bednar[a]

[a]*Technical university of Kosice, Faculty of Manufacturing Technologies with seat in Presov, Bayerova 1, Presov 08001, Slovakia*

* Corresponding author. Tel.: +421-51-772-2828; fax: +421-51-773-3453. *E-mail address*: vladimir.modrak@tuke.sk.

Abstract

A great challenge facing final manufacturers of final products and OEMs today is product variety management which is crucial for mass-customized manufacturing. Product variations in most industries tend to be very numerous and firms often find themselves under pressure to solve problems with over-inventories, planning and product assembly complexity. In this paper, we investigate and present an approach to creating all possible product configurations and variations based on a given number of base components and optional number of complementary components. The idea of determining all possible product architectures is to investigate the influence of product variety on complexity of assembly processes.

Selection and peer-review under responsibility of the International Scientific Committee of 5th CATS 2014 in the person of the Conference Chair Prof. Dr. Matthias Putz matthias.putz@iwu.fraunhofer.de

*Keywords:*Configuration Complexity; Sequence Complexity; Shannon`s entropy; Vertex degree;

1. Introduction

Nowadays, producers of final products are facing increasing pressure to manage their supply chains due to emerging factors such as the lengthening of supply chains and the necessity for mass-customized manufacturing. Especially, mass customization is, in this context, considered to be one of the main business strategies focused on design and development of products that can be individually tailored to customer needs [1]. The key to mass customization is to provide products with high variety. In mass-customized production, the products are made by flexible assembly processes consisting of several different modules. Modules or sub-modules are created from initial components. At the last station, an operator assembles components or modules into the final product. Thus, the number of all possible components determines at least two facets of assembly process' complexity. These are e.g., product complexity, managerial complexity, sequence complexity and others. Our intent in this paper is to propose a mathematical model for determination of all possible product variations and configurations based on the number of initial components assuming that two initial components are considered to be invariable ones. Then the number of all possible product configurations directly reflects product complexity of assembly process and indirectly influences other complexity aspects related to mass-customized manufacturing strategy. Subsequently, in this paper, we propose a procedure for calculation of the sequential complexity of the assembly process that can be derived from the number of all possible initial components and their combinations. The numbers of all initial components (base and optional) determine Class and Subclass of product configurations. The Class and Subclass of product configurations will be described in the next section of this paper. In order to transform the product complexity of the assembly processes into the sequential complexity, we will use a realistic assembly process of kettles. Then, the sequential complexity of the assembly process will be computed based on Vertex degree index. Finally, summarized comments and conclusive remarks are provided in the conclusions of the paper.

Selection and peer-review under responsibility of the International Scientific Committee of 5th CATS 2014 in the person of the Conference Chair Prof. Dr. Matthias Putz matthias.putz@iwu.fraunhofer.de
doi:10.1016/j.procir.2014.10.090

2. State of the art in manufacturing complexity management

Variety of products increased drastically in last decades due to rising mass customization strategy. Manufacturers are highly motivated to make products in large quantities and, of course in a number of variations to satisfy the needs of the market and of the end users. Therefore production systems, these days, should be able to cope with such a variety to achieve the desired quality and quantity.

There are number of approaches to managerial aspects of manufacturing complexity in today`s literature. Some methodologies are aimed to partial complexity inducing problems and therefore reflect only a subjective view on the complexity solution. On the other hand, there are approaches covering as many manufacturing complexity aspects as possible, and therefore, these give back much more realistic view on the complexity problem. Generally, the complexity of any system is mainly influenced by three complexity variables, namely states of system elements, their number and relationships among them. The three variables then determine the structural (static) or operational (dynamic) complexity. The very first base metric applied to production is the Shannon`s information theory [2]. It relates to the amount of information (in bits) associated with the amount of uncertainty of the system, originally information systems. It is the amount of information linked to the occurrence of all possible states of the system. Therefore, it is evident, that the fewer processes, fewer machines, fewer product alternatives – configurations and variations, the lower is the entropy. Zhu et al. [3] applied the entropy to the generation of complexity model on the level of station and the whole system within the mixed-model assembly systems. Desmukh et al. [4] proposed an entropic measure combining part types and their ratios within a manufacturing system, and defined a code based structural complexity index [5]. Suh [6] used the complexity in the context of product design by achieving functional and design requirements. Authors [3, 7, 8] tried to explore the reasons of high complexity within a production. But up till now, there is only a little evidence about the main source of complexity in such environments due to various definitions of mass customization. It is evident, that assembly configurations and variations have great impact on complexity and on performance of the system in mixed-model assembly lines. Therefore it is important to reveal and understand the linkages behind the complexity, product variety in mixed-model assembly lines, and not least in mass customized assembly (MCA) lines. Wildemann [9] presented one of the applications in the field of mass customization related to complexity. Ulrich and Eppinger [10] assigned performance parameters to product configurations and their variations, development, purchase, logistics, production, IT, but practically to every facility sub-process. Finally authors [11, 12] developed an information-based measure applicable in complexity assessment of any manufacturing system.

It is important to say, that the complexity will always be present in the facilities and their production. For example according to [13] large number of product configurations and variations need not necessarily yield a large number of internal parts. Usually, production architects try to redesign the product structure but such functional makeovers may then result in extra hidden cost [14].

3. Initial assumptions for generation of product variations and configurations

In the meantime, a huge progress has been made on the evolution of the manufacturing systems. They had evolved from moving assembly lines to complex mixed–model assembly systems considered as main the enablers of currently increased variety. The Assembly Supply Chains (ASC) are further divided into modular assembly supply chains and non-modular assembly supply chains [7, 15, 16, 17, 18, 19]. The application of mixed-model systems is challenging not only for production companies. Beamon and Chen [20] noted that each functional level of supply chain network is represented by numerous facilities that along with the structure of the material and information flows contribute to the complexity of the chain. It is apparent that arising assembly variations and configurations have profound impact on production complexity of the system. Therefore it is important to reveal and understand the linkage behind the two types of complexity, product variety and assembly variation in mixed-model assembly lines [21].

Knowing the complexity of designed system depending on the number of product variations and/or product configurations can be helpful in finding the best balanced design for a new product or whole production.

Before we begin with description of our Generating framework for creation of all possible product variations through all possible product configurations based on optional components, we need to describe a notation:

- Class of product configurations CL (based on number of basic components),
- Sub-class of product configurations P_i, i = 1,…, a, where i – number of initial components,
- Sub-configurations of the i-th sub-class G_{ji}, j = 1,…, b, where j – number of sub-configurations of the i-th sub-class,
- Initial assembly product configuration component C^{Σ}_{ji}, where ∑ – summary number of initial components,
- Optional assembly product configuration component C^{o}_{ji}, o = 0,…, d, where o – number of optional components,
- Base assembly product configuration component C^{b}_{ji}, b = 1,…, e, where b – number of base components,
- Product variations of the i-th sub-class, of the j-th sub-configuration v_{kij}, k = 1,…, f, where k – number of product variations i-th sub-class, j-th configuration,
- Total number of variations of the i-th sub-class $\sum v_i$,
- Number of component sub-configurations of the i-th sub-class for the given number of initial components G^{Σ}_{i}.

Firstly we need to establish the total number of component configurations of the product in relation to the definition of