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Manufacturing System Flexibility: Sequence Flexibility Assessment

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Abstract

Manufacturing industry is facing new challenges in a competitive and constantly changing environment, with growing complexity and high levels of customization. Mass customization caused that product variety increased drastically and affects production system flexibility. System flexibility is the ability of the system to cope with product variety. Based on industrial experience, the production system may be represented by three main elements, which are products, processes and resources. This paper, which is a part of an overall research work, studies the products - processes interaction. This interaction investigates the ability of the processes to manage existing and potential product variety. Based on a set of constraints, which are used to build sequences, an indicator is introduced to provide decision support capabilities to guide the changes to perform in the production system for better sequence flexibility. Experimental results from the automotive industry are presented.

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Keywords: Manufacturing system; Flexibility; Sequences; Product variety

1. Introduction

For many decades, cost and production rates were the most important performance criteria in manufacturing, and manufacturers relied on dedicated mass production systems in order to achieve economies of scale. Nowadays, manufacturing organizations understand that these criteria have been diversified. The competition has increased and the customer base is more mature. This makes flexibility an increasingly important attribute to Manufacturing.

Modern manufacturing systems are facing continuous changes in the environment they operate. These changes include the rapid introduction of new products, abrupt changes in product demand and more frequent modifications to existing products. Many academic publications have pointed out that the quantification of flexibility is difficult to be handled and mostly limited to special cases [1]. These difficulties lay in some flexibility characteristics, such as its property of being potential and its inherent multi-dimensionality [2].

In [3], flexibility is defined as "the sensitivity of a manufacturing system to changes. The more flexible a system, the less sensitive to changes occurring to its environment it is". Our approach consists on modelling flexibility on three main forms which are configuration flexibility [4], interfaces flexibility [5, 6] and sequence flexibility. This research work will focus on sequence flexibility assessment.

Sequence flexibility, can be defined as the ability of a manufacturing system to master a variety of sequences in order to cope with product variety. It has been shown in [7, 8] that the sequence flexibility is an important aspect of manufacturing system performance. Nevertheless, in order for flexibility to be considered in the design and operation phase, it should be defined in quantifiable terms. A key research question asks what factors enable better systems sequence flexibility control, in order to be rapidly adjustable to current market fluctuations. And how those factors are used so that designers can compare multiple mixed model assembly line sequences and identify the best alternative.

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In order to build some responses to these interrogations, an overview of the existing sequence flexibility measures is primarily presented. Then, a detailed description of our approach is introduced as well as the results of its application to an automotive industry case.

2. Framework and motivation

In the mixed model assembly line, the assembly sequence plays a key role in determining the quality of the assembled product, as well as assembly process design issues. The challenge is to find the right sequence flexibility to cope with the exiting product variety, and that could be adjustable for potential variants with minimum modification and consequently with less cost and time.

Several methods are available to represent the relationship among component parts in an assembly. One of the commonly used assembly representation is assembly operation precedence graph (Fig.1).

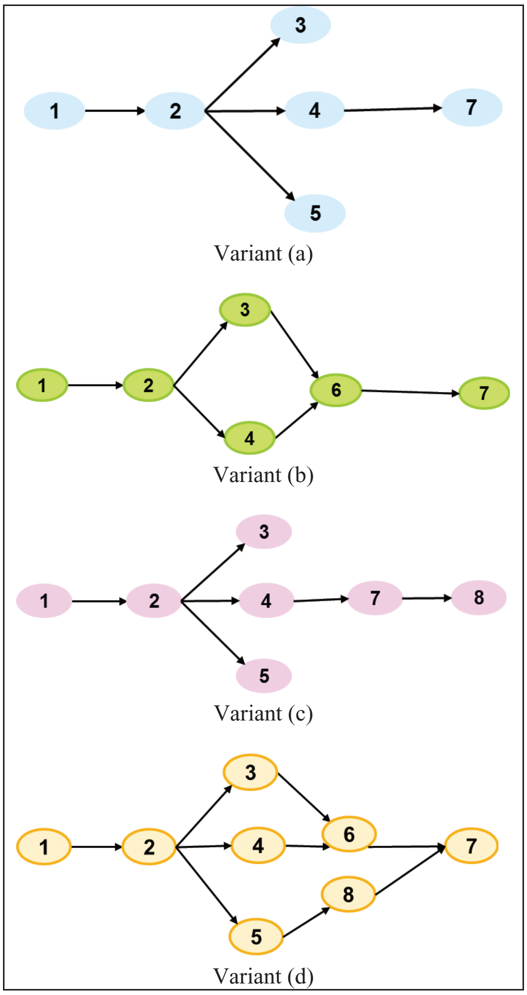

Fig. 1. Assembly operation precedence graphs for an example of a family with 4 variants

It is a graphical network wherein nodes represent mostly the assembly operations and the arrows between nodes the precedence relations. The assembly task precedence graph is useful to generate all feasible assembly sequences. Most precedence graphs use assembly tasks rather than components, but if a base component is first established, then the operation of adding each subsequent component can simply be represented by the component on the precedence graph [9].

An assembly sequence is defined as the set of operations required to assemble a given product. Different sequences may co-exist in a same assembly line in order to deal with product variety. An assembly sequence is composed of a set of operations which is common to all the variants (as illustrated in Fig. 1 by the operations 1,2,3,4 and 7), and a set of operations which is specific to a given variant (The operation 8 of variant (c), in fig.1).
Some operations have flexibility to be processed before or after each other or could be done simultaneously (for example, operations 3, 4 and 5 in fig. 1), which makes sequence flexibility management more complex. Consequently, in addition to precedence constraints, complementary studies should be conducted in order to identify additional considerations to build a robust indicator to sequence flexibility assessment in order to be as close as possible to real industry conditions.

This paper investigates the importance of designing flexible sequences and identifies the constraints that should be considered to evaluate sequence flexibility and compare different mixed model assembly lines, in which a new variant is candidate to be introduced.

3. Related work

3.1. Product variety management and sequence commonality

Effective management of product variety can provide important competitive advantages for a company. However, it is a challenge of manufacturing to produce variety of products with limited resources. There are various strategies that suggest several methods for variety management; these methods are well known in industries. In fact, to handle variety, manufacturers use several product design methods, including product family development [10] and parts commonality [8].

Usually the product specifications are the ones that define the sequence of operations carried out on the product. In order to accommodate the increasing product variety, developing product families has been recognized as an effective means to achieve the economy of scale (the same basic components are used across different products of the family). Through product family organization, sequence commonality could be increased and then the introduction cost of a new variant minimized.

In fact, the same logic is used in building assembly sequences, in which a common sequence may be dedicated to common components and specific operations are included