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Manufacturing System Flexibility: Product Flexibility Assessment

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Abstract

Current manufacturing industries are experiencing a paradigm shift towards more flexibility to respond quickly and efficiently to constant changing customers' requirements, new technologies and increasing product variety. Product flexibility is the ability of the manufacturing system to cope with the growing product variety to ensure better system performance.
The aim of this paper is to point out the importance of product - resources interfaces in product flexibility assessment. Based on industrial experience, three product flexibility inductors are identified, which are gripping, setting and tooling interfaces, in order to build indicators as close as possible to real industry conditions. This research work investigates new factors to quantify product flexibility and provide manufacturing system designers with efficient decision-making support tools. In order to show the relevance of our approach, experimental results from the automotive industry are presented.

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Keywords: Manufacturing system; Product flexibility; Product variety

1. Introduction

In the context of increasing customer requirements and changing needs, improved manufacturing methods, new technologies and government regulations, the lifecycle of the individual products is shortened. Consequently, manufacturing industries need to continuously upgrade their products, processes and technologies to remain competitive, which is a great challenge in an environment full of uncertainties.

In [1], 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". Various types of flexibility are introduced in the literature. In [2], Chryssolouris summarized the flexibility in three main forms, which are Operation flexibility, Product flexibility and Capacity flexibility. This research work will focus on Product flexibility assessment. It has been shown in [3-6] that the product 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 [2].

Product flexibility, as defined in [1], is the ability of a manufacturing system to make a variety of part types with the same equipment. The aim of this research work is to identify inductors that enable high product flexibility, in order to rapidly respond to current market fluctuations. Those inductors are then used to build new product flexibility indicators in order to provide designers with the required decision-making support tools to deal with product variety.

In the following sections, an overview of the existing methods for product variety management is primarily presented. Then, a summary of the main measures for product flexibility assessment are provided. After which, a detailed description of our approach is introduced as well as the results of its application to an automotive industry case.

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2. Framework and motivation

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 [7]. Many academic publications have pointed out that the quantification of flexibility is difficult to be handled and mostly limited to special cases [8]. These difficulties lay in some flexibility characteristics, such as its property of being a potential and its inherent multi-dimensionality [9].

However, under time and budget constraints, it's very difficult to manage product variety while maintaining high system performance. The aim of this paper is to build indicators to quantify and evaluate product flexibility by integrating product-resources interfaces information. The originality of this approach lies in the consideration of the physical technological aspect, in an explicit way, for product flexibility modelling.

We define resources as the entire physical elements which compose the manufacturing system, such as machines, tools, operators and material handling system. Hence, product-resources interfaces are the physical interfaces that describe the contact surfaces between the product and the resources, either with the material handling system (Setting and gripping interfaces), or the machines and tools (Tooling interfaces).

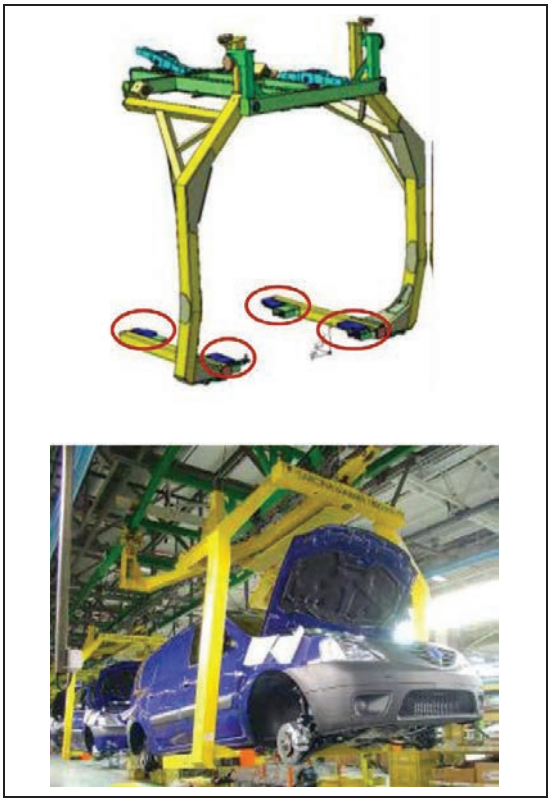

Fig. 1. Example of setting interface from the automotive industry.

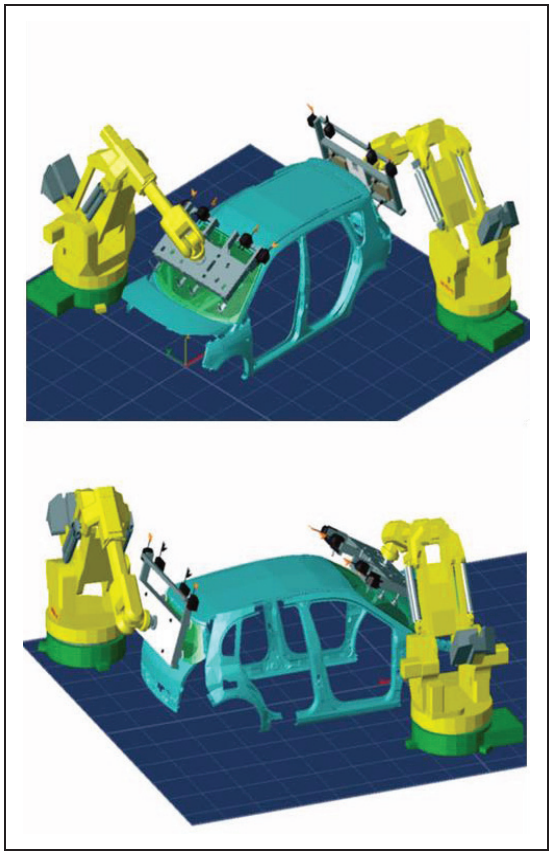

Fig. 2. Example of gripping interface from the automotive industry.

Two examples of interfaces, from the automotive industry, are shown in figures 1 and 2. For example, the encircled parts, in fig. 1, represent the interface between the body of the vehicle and the hanger. Whatever the body's form, its variety is absorbed if it fits to the existing interface.

As part of Design For Manufacturing (DFM) practices, these indicators will, firstly, be useful for the product designer who needs to integrate resources information to reduce the product technical variety and facilitate the introduction of new variants with minor modifications in the manufacturing system.

Consequently, sharing technical information between the product and manufacturing system designers reduce the setup time and cost caused by the introduction of a new product by integrating adaptable interfaces, either in the product or in the resources, in an optimal way. Collaboration between these actors is a key to build real cost-effective and flexible production lines, which is the basis of the co-evolution concept introduced in [10].