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Manufacturing System Configuration: Flexibility Analysis For automotive Mixed-Model Assembly Lines

M. Lafou*,**, L. Mathieu*
S. Pois**, M. Alochet**

*Automated Production Research Laboratory (LURPA), ENS de Cachan,
61 Av. du Président Wilson, Cachan 94235 Cedex, France
(Tel.: +33-147-402-756; e-mail : meriem.lafou@ens-cachan.fr)
** Vehicle Production Engineering Direction, Technocentre RENAULT SAS,
1 Av. du Golf, Guyancourt 78288 Cedex, France

Abstract: Today's competitive and highly volatile markets are redefining the way manufacturing systems are designed. To meet the requirements of their customers, industries have to manage the wide variety that affects their entire production system in terms of processes, products and resources. Manufacturing system configuration has profound impact on the performance of the system in terms of productivity, flexibility and cost. To cope with production system configuration responsiveness, several flexibility measures were introduced. The purpose of this research work is to make an overview of the existing configuration flexibility factors and to propose a heuristic to deal with automotive mixed-model assembly line (MMAL) specificities. A short case study from the automotive industry is presented.

Keywords: Manufacturing system, Variety, Mixed-Model assembly line, Configuration, Flexibility.

1. INTRODUCTION

In order to respond to the increasing customer needs, accelerated lead-times, tight delivery times, and shorter products' life cycles, companies have widely increased their product variety. The increase in variety has several reasons including customers' constant demand for new products, different regional requirements and industry regulations, market fragmentation with different needs and certification specifications. Consequently, to deal with product variety and demand fluctuations, industrials should develop changeable manufacturing systems that help to produce wider product variety ElMaraghy et al. (2009).

Changeability, as described by ElMaraghy et al. (2013), "is an umbrella framework that encompasses many paradigms such as adaptability, modifiability, flexibility and reconfigurability, which are themselves enablers of product variety management". However, under time and budget constraints, it's very difficult to manage product variety while maintaining high system performance. Performance can be assessed in many areas including productivity and flexibility.

Chryssolouris et al. (2013) defines flexibility 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". In Chryssolouris et al. (2012), an overview of system production flexibility is provided. Flexibility includes both convertibility and capacity scalability. Convertibility is defined as the capability of a system to rapidly adjust production functionality, or change from one product to another. Scalability is defined as the ability to adjust the production capacity of a system through system reconfiguration with minimal cost in minimal time over a large capacity range at given capacity increments Koren (2010).

This research work will focus on manufacturing system configurations. It has been shown by Koren et al. (1998); Devise et al. (2000); Maier-Speredelozzi et al. (2002) that the configuration of a system can have significant effects on performance. Better responsiveness usually makes a system more expensive. A key research question asks what factors enable better systems configuration flexibility control, in order to be rapidly adjustable to current market fluctuations. And how are those factors used so that designers can compare multiple MMAL configurations and identify the best alternative.

In order to build some responses to these interrogations, an overview of the existing configuration flexibility measures is primarily presented. Then, a detailed description for the automotive assembly line is provided. After which, a heuristic is proposed to deal with configuration flexibility assessment for automotive MMAL.

2. LITERATURE VIEW

Manufacturing systems can be designed in many configurations, depending on company strategy, constraints and objectives. In the present section, different configuration classifications reported in the literature are presented, as well

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as the main factors and mathematical models for configuration flexibility assessment.

2.1 Manufacturing systems configuration classification

System configurations may be primarily classified on synchronous and asynchronous configurations. In synchronous systems, parts move from one station to the next at a constant pace. Consequently, synchronous systems are more appropriate for mass production and are used for high volume production of single product type. In asynchronous systems, different operation sequences may be processed in the same line. They are more commonly used in assembly systems, especially whenever subassemblies are used. The main assembly line is typically serial with feeders from other subassembly serial lines. A configuration may be single process, in which products have an identical flow path. Or, variable-process configuration, which is characterized by possible non-identical flow paths for the product; therefore it needs a preparation period of several process plans and corresponding setups.

For a given number of machines, the generating number of possible configurations may be quite high, including (a) serial, (b) parallel and (c) hybrid configurations, as illustrated in figure 1, Hu et al. (2011).

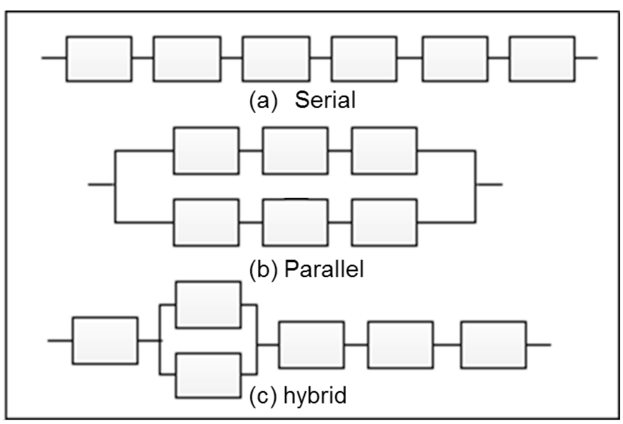

Fig. 1. Examples of manufacturing system configurations

Several algorithms were developed to reduce this number Shpitalni et al. (2002); Shpitalni et al. (2004). They showed that the practical number of different paths is far lower than the maximum theoretical number and that this number decreases with shorter lines and with higher machine reliability.

2.2 Factors for configuration flexibility assessment

In the literature, many factors were identified to select preferred manufacturing configurations. For machining systems, Spicer et al. (2002) introduced the configuration length and the configuration width. Configuration length is the number of operations or machines a part must go through. The maximum configuration length is achieved when only one machining task is assigned to each operation. For example, a part that requires 15 machining tasks has a maximum possible configuration length of 15 machines. The configuration width is defined as the number of machines in parallel for a given configuration. It is a function of the required production capacity and the configuration length. Its maximum value is achieved when a system is at its minimal configuration length and that parallel machines are required to meet capacity objectives.

For configurations selection, Maier-Speredelozzi et al. (2002) introduced metrics for the minimum increment of conversion and capacity. The first one gives information of how quickly new or different products can be introduced. Whereas the second gives information about the ability of the system to deal with volume fluctuations. A further selection factor introduced in Maier-Speredelozzi et al. (2003), shows the importance of the number of routing connections in configuration convertibility. It is counted by including connections between stations as well as connections to an input and an output. A greater number of routing connections indicates a higher degree of convertibility.

An additional aspect was studied by Devise et al. (2000), which is the layout of manufacturing system configuration. It is defined by the forms and the main structure of the workshop relative to the machines and the material handling system. Several layouts have been proposed such as (a) circular line, (b) S form line, (c) U form line and (d) straight line, as shown in figure 2.

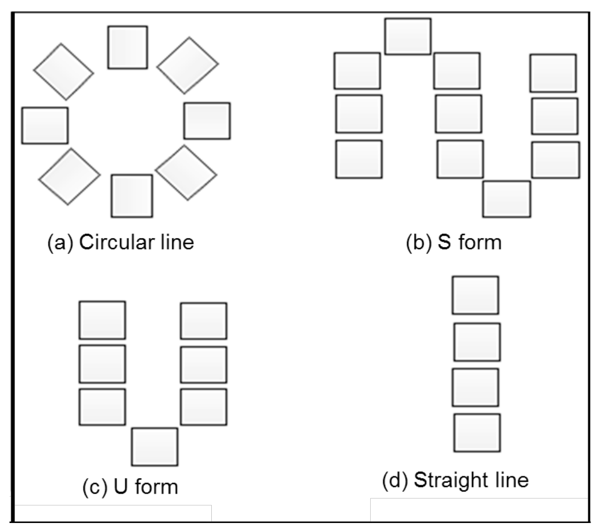

Fig. 2. Examples of manufacturing system layouts

Each layout possesses its advantages and disadvantages. Various criteria are considered in order to choose the adequate layout for a manufacturing system. These criteria include number of machines, the available floor space, management of material handling system and the number of operators. The layout enables a growth of the different production departments as needed.

To complete the aforementioned technological factors, a further performance metric that is almost always considered is cost. Indeed, a company should find a trade-off between the degree of changeability needed and its related cost as shown in figure 3. The aim therefore should not be providing maximum changeability but rather the identification and implementation of a company-specific optimal degree.