

TYOLOGY OF MANUFACTURING FLEXIBILITY IN THE ENGINEERING INDUSTRY: A REVIEW

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Abstract: Classification of manufacturing flexibility represents a risk for the company as face this challenge. Reactions to these changes, based on late responses market leading executives to flexible manufacturing. In other words, flexibility is the ability to cope with change and insecurity by configuration of system elements within target-oriented way to maintain stable performance in the context of changing conditions.

1 Introduction

Author Benjaafar classifies manufacturing flexibility related to the product or process. The flexibility of the product refers to the production possibilities associated with the product [1]. The flexibility of the process is characterized by the ability of the process to adapt to different operating conditions or functions. An example, it is a multi-purpose machining center [1], [2]. Operating and sequence, the processing flexibility are associated with the production of parts. Operational flexibility is intended to perform operations on more than one machine. Sequence flexibility allows you to change the order of operations [2], [3]. The processing flexibility is determined by the possibility to have the same production function with alternative operations or sequences of operations.

2 Classification of the flexibility

In view of the classification flexibility, author Hajduk categorized flexibility in the industry as:

- *Expansion flexibility* - declares the ability to expand the system. It is expressed on modularity and compatibility.
- *Volume flexibility* - is the ability to produce different amounts of products.
- *Operational flexibility* - represents an opportunity to perform the same operation on different machines.
- *The flexibility of the layout* - is consistent with structural flexibility.
- *The flexibility of the process* - reflects the ability to produce a given set of components using various methods, ability to machine a variety of materials.
- *Machine flexibility* - examines the speed of adaptation of production equipment to produce a given set of components.
- *Structural flexibility* - this is the flexibility of the material flow, reflects the diversity of material flow,

- it allows to change the flow of parts between machines, and strive to achieve occupancy machines.
- *Product flexibility* - ability to produce new products without worsening the efficiency of the system [4].

The value of production flexibility is divided into the basic level, the system level and at the aggregate level. Flexibility at a basic level includes machine flexibility, material handling, system responsiveness and flexibility of operation (Table1) [4].

Table 1 Correlation of production levels and types of flexibility[7]

		Types of flexibility							
		Machine flexibility	Process flexibility	Product flexibility	Routing flexibility	Volume flexibility	Expansion flexibility	Operating flexibility	Manufacturing flexibility
Flexibility level	Source flexibility level	x	x	x		x	x	x	
	Business flexibility level			x	x	x	x	x	x
	Industry flexibility level			x		x		x	x
	Network flexibility level		x	x	x	x		x	x

Flexibility at the system level concerns the whole production system and depends on the type of flexibility at ground level [2], [5].

The high flexibility and low sensitivity to the changes in the production system has the three major advantages that influence from different types of flexibility. Author Chryssolouris presented to him three essential types of manufacturing flexibility, which contribute to the high elasticity:

- *Production flexibility* enables the production system to discriminate in parts using the same equipment. This means that the system is economically capable of using a small amount of sizes to adapt to the changing demands of various products. In the long term, this means that system devices can be used in several product life cycles, rising investment efficiency.
- *Capacitive flexibility* enables the production system to change the volume of different products and adapt to changes in the volume of requests so that the company benefited. It is used in the construction contracts and so in mass production, in particular for high-value products such as automobiles.
- *Operational flexibility* is focused on the ability to produce a range of products using a variety of machines, materials, operations. Allows a sustainable production level and in case of failure of the machine or staff shortages [5].

An important starting point for measuring the manufacturing flexibility is the classification of the type of flexibility. Development of flexibility referred to the various breakdowns typology of flexibility in terms of different authors. Author Mandelbaum proposed two types of flexibility, elasticity, and action static elasticity. The first type occurs on a dynamic view of the situation in which the future is unknown. Static flexibility in situations occurs, the system is capable of working correctly in different circumstances [6].

According to Gerwin, exist five types of flexibility and the mixed elasticity, flexibility of products, flexibility in routing, flexibility of design changes, volume and material flexibility. Author Slack defined five types of flexibility and to flexibility, quality, volume, delivery and product range. Jaikumar introduced three types of flexibility product, program flexibility and process flexibility. Program flexibility related to the ability to operate the system on a computer [3], [5]. Flexibility divided the process into three types of flexibility: equipment, materials and product pallets. Yamashina et al. proposed three types of elasticity. Flexibility options, volume and product life. The flexibility of options is equal to the production flexibility. The flexibility of a product life refers to the flexibility of the product [3], [6].

2.1 Time classification of the flexibility

The main problem of manufacturing flexibility is time stability. Flexibility as elusive phenomenon, but within the existing production system comes in various lengths of time. The first time the classification of flexibility has been proposed according to Gustavson [2], [5].

Author Carter came to the proposition that different types of flexibility in different time frames have four categories of time and very short, short, medium and long term. This corresponds to one to three day, one to two months, six months to two years and five years or more [3]. Description of the different classifications defined author Hajduk, which categorized the flexibility for short-term and long-term flexibility.

- *Short-term flexibility*- is characterized by the capability of adapting to the system in its structure changes to the object of production, sorting plant, failure of a component replacement tools. This is a short-term time horizon of a few minutes, days or months. Decisive is the time of inactivity. The idea is to reduce the rearrange time resulting in continuous effect on the time of production parts. It is expressed as the ratio of "pure" time to the total time of production of a certain set of components for a certain period. The disadvantage is the requirement of the border, for which may be valid, and the size of dose and time operations. Otherwise it may happen that the system that over time a number of times in a short time is sorted, should some flexibility such as a system that is sorted once, but in a longer time.
- *Long-term flexibility* applies the changes that occur at intervals of several months to several years. These include new products as a result of modifications, resulting in the reduction of the original component spectrum that is being replaced by new parts. Life components is 3-5 years, the life of 6-10 years. With long-term elasticity of cell aging, loses its elasticity and the necessary investments. Cell aging, we understand a certain obsolescence of machines that have been designed for the building. Obsolescence of the machine can be understood if the system is no longer able to adapt to constant product innovation and by developments in the area, which hampers its functioning. Long-term flexibility is achieved by creating cell-based production of flexible compatible modules that allow easier and faster expansion in the future. In the short term flexibility able to adapt the changing conditions, using the existing settings and the resources. In the long term, measures the ability to introduce new

products, new production methods and sources and their integration into the existing production system [4], [7].

3 Classification of flexible manufacturing systems

There are several definitions of a flexible production system, but all definitions are based on the definition of the system. Browse et al. defined "flexible manufacturing system" as an integrated computer-controlled complex composed of NC machines and automatic handling, designed for the manufacture of parts in small and medium series [3].

For flexible manufacturing system is consider a system that meets the requirements for the area:

1. *Testing the variety of products* - enables manufacturing system to process a variety of products without benefits?
2. *Testing planning changes* - the system can easily accept changes in the production plan (volume, diversity of products)?
3. *The error recovery* - the system can be readily restored after a failure of the device, so that the production is not completely disrupted?
4. *Testing a new product* - new product can be introduced easily into the existing product range [3], [5], [6], [7].

Figure 2 shows an automated production cell with two machining centres and manipulators (robots), meeting the criteria of flexibility:

- 1- can be produced in a variety of products that are administered robot from the conveyor,
- 2- a possible change in the production program without affecting the operation of the robotic arm and two machining centres,
- 3- system is capable of operating activities and in case of failure on one machining centre,
- 4- allows to produce new types of products, based on the numerical control program that you can download the system for the implementation of production.

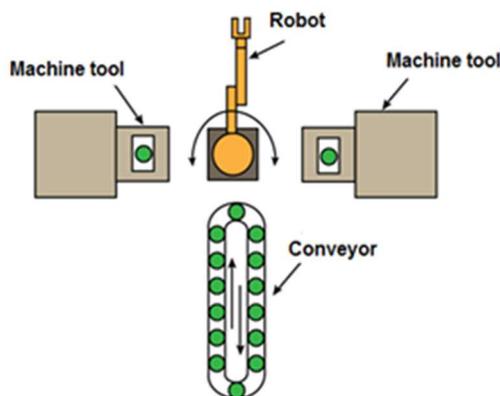


Figure 2 Automated production cell with two machining centres and robots [7]

Flexible manufacturing cell belongs to a flexible manufacturing system, consisting of technological equipment with program management and means of automation of technological processes, working autonomously. Automation tools are stacks of workpieces Pallet, equipment for exchanging tools, clamps, waste disposal and diagnostics. Flexible manufacturing cell is a system of two or more machines under the control of a central computer with or without automatic handling of the material in the system and the cell system in which cells are classified according to the production process, the production volume and the range of product types, in practice did not produce a clear classification of a grouping machine in respect of a defined type. Thus, it may form a group of parts that require one or more machines, according to next division [6]:

Flexible production machines - (SFM) is defined as a production unit formed by NC machines, supplemented by a manipulation device for the exchange of objects of production.

- *Multimachines flexible manufacturing system (MMFMS)* is a grouping of several production machines without interdependence of their activities. The machines are connected individually with no dependence on other machines. Characteristic is longer operating time. Substantially terms of machining centres, machines for special operations
- *Flexible manufacturing cells - (FMC)* is a manufacturing system consisting of multiple NC machines, designed for a particular group of components that combines the sequence of operations. The hallmark of the material and information connectivity between machines. Generally, use common handling equipment in inter-handling.
- *Multicellular production system - (MCFMS)*, is based on a number of production cells and flexible manufacturing machines and cells. Characteristic of the intracellular transport system as an integrating element. [1], [7]

Classification according to the manufacturing cell clusters:

- *Flexible manufacturing cells*-are characterized by their high automation of the handling process. They are used for medium volume production e.g. 400-2000 units of one product, and the average number of product types 4-100 kinds.
- *Production cell manned* - are highly flexible because the staff quickly accommodate changes in production conditions. They are designed for low-15-500 units of one type but for a large number of product types in the interface 40-800.

- *Flexible production lines* - are characterized by a high number of units from 1,500 to 15,000 pieces and a low number of product types 2-8 [7].

Conclusion

In generally we can say that one of the performance indicators in recent decades, after cost, quality and reliability becomes flexibility. Studies manufacturing flexibility were made more widely in developed countries such as Japan, the US and Western European countries. The requirements for flexibility of production systems differ in countries with different economic uncertainty. Current literature offers some flexibility definitions, classifications and speculative guesswork to understand and assess the flexibility of the production system. Literature offers a variety of studies have flexibility in production, but the only deal of flexibility at the operational level.

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