

# Flexible Manufacturing System

Peter Kostal, Karol Velisek

**Abstract**—Flexible manufacturing system is a system that is able to respond to changed conditions. In general, this flexibility is divided into two key categories and several subcategories. The first category is the so called machine flexibility which enables to make various products by the given machinery. The second category is routing flexibility enabling to execute the same operation by various machines. Flexible manufacturing systems usually consist of three main parts: CNC machine tools, transport system and control system. A higher level of flexible manufacturing systems is represented by the so called intelligent manufacturing systems.

**Keywords**—drawing-free manufacturing, flexible manufacturing system, industrial robot, material flow

## I. INTRODUCTION

AT the end of 2008 our institute – Institute of Production Systems and Applied Mechanics responded to the call No. OPVaV-2008/2.2/01-SORO of the ASFEU Agency of the Ministry of Education and prepared a project named Laboratory of flexible manufacturing systems with robotized operation for environment of drawing-free production. The main target of the project is to build up a laboratory with a flexible manufacturing system consisting of minimum two NC controlled machines (milling machine, lathe). These machines will be interconnected by a transport system and operated by industrial robots. This flexible manufacturing system will also include a quality control station including the camera system and shelf storage. [7]

In the final phase of the project in 2012 this flexible manufacturing system will be linked with the CAD laboratory in our Institute creating thus the „Laboratory of flexible manufacturing systems with robotized operation for environment of drawing-free production“.

After project completion, our Institute will have available a fully functional flexible manufacturing system prototype with robotized operation of individual production machines, integrated with CAx laboratories. However, the final goal is to build up an intelligent manufacturing system. This prototype will enable further exploration of relations and properties of the manufacturing process itself but also in its relation to process of production preparation and planning.

We expect several other consecutive projects (incl. international ones) which should further extend possibilities of the laboratory.

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The main advantage of the flexible manufacturing system is its high flexibility in management of production facilities and resources (time, machines and their utilization, etc.). The largest application of these systems is in the area of small batch production where its efficiency is getting near to the mass production efficiency. Its disadvantage is the high implementation price.

To achieve project goals it is necessary to revise curriculum and to use such teaching forms and methods that enable to exceed the scope of cognitive knowledge of scientific disciplines and professions that means to develop key competencies of students. These gains extraordinary significance not only for the personal development but also in a term of lifelong education and employability of technical university graduates. [8]

## II. PRESENT SITUATION AT SLOVAK INDUSTRY

At present, industrial production structure and management in Slovakia suitable for large batch production of a narrow product spectrum is predominating. However, such a production structure and management is not satisfactory anymore as the tendency of user individualization manifests more and more also among customers of Slovak industrial companies. In consequence of small flexibility in responding to market demands (customers), the competitiveness of manufacturers is going down and they are outrun by competitors with no or small tradition in machine industry but with an ability to respond to requirements of customers much more flexibly. [9]

Another frequent problem of Slovak industrial companies consists in high production costs. Many manufacturers try to reduce these costs at the expense of wages of their employees depressing them in various ways (directly or indirectly). However, this attitude to production cost reduction is system less and in the long term does not lead to desired objective that is to increase demand for products from Slovakia and thereby support development of individual companies and general living standard increase.

The only practicable way to that objective (what individual manufacturers can directly influence) is production efficiency increase saving production costs, not at the expense of wages but as a consequence of production process optimization by introduction of new modern production technologies, modern production preparation and management methods, by increase of production quality and flexibility.

The target of the project is to build up a flexible manufacturing system with robotized operation enabling a drawing-free production. That means, the product will be

simulated by PC in a suitable 3D CAD program, thereafter a control program necessary for production of the component will be generated and this program will be then started up in a flexible manufacturing system that will physically produce that component. In this way it would be possible to produce all necessary components for a specific product that will be assembled in the final phase.

During production, all components made will be subjected to checking operations, consequently, in the final assembly the faulty piece rate of finished products will be considerably reduced.

This prototype facility can also examine impact of various manufacturing strategies on production costs, time necessary for production of required product quantity and other important parameters of production efficiency. Next, it will be possible to explore and present advantages of drawing-free production and impact of this production method on efficiency of the whole process before and during production.

All information and knowledge acquired will be presented at inland and also international level via scientific and technical journals as well as via scientific conferences and workshops.

We are going to address also representatives of inland industry and present them this prototype, demonstrate its potentiality and ask them for cooperation within other projects so that results of theoretical and practical research can be integrated into industrial production and utilized in efforts to keep competitiveness of the Slovak industry.

### III. DEMANDS ON FLEXIBLE MANUFACTURING SYSTEM WITH ROBOTIZED OPERATION

A flexible manufacturing system (FMS) is a group of numerically controlled machine tools, interconnected by a central control system. The various machining cells are interconnected, via loading and unloading stations, by an automated transport system. Operational flexibility is enhanced by the ability to execute all manufacturing tasks on numerous product designs in small quantities and with faster delivery. It has been described as an automated job shop and as a miniature automated factory. Simply stated, it is an automated production system that produces one or more families of parts in a flexible manner. Today, this prospect of automation and flexibility presents the possibility of producing nonstandard parts to create a competitive advantage. [2]

The concept of flexible manufacturing systems evolved during the 1960s when robots, programmable controllers, and computerized numerical controls brought a controlled environment to the factory floor in the form of numerically controlled and direct numerically controlled machines.

For the most part, FMS is limited to firms involved in small batch production or job shop environments. Normally, small batch producers have two kinds of equipment from which to choose: dedicated machinery or unautomated, general purpose tools. Dedicated machinery results in cost savings but lacks flexibility. General purpose machines such as lathes, milling machines, or drill presses are all costly, and may not reach full capacity. Flexible manufacturing systems provide the small

batch manufacturer with another option one that can make small batch manufacturing just as efficient and productive as mass production.

Flexible manufacturing system with robot operation for environment of drawing-free production (therein after only FMS) will be represented by the model CIM (Computer Integrated Manufacturing) in conditions of UVSM MTF. It is a systemic approach to planning, management and production itself. The target is to gain experience in these fields at the level of a manufacturing system as a unit. [1], [3]

In practice, these experiences, if accepted, can considerably increase competitiveness of industrial companies. Such a competitiveness increase will result from higher efficiency in planning, management and production. Higher efficiency will be seen in shorter production time, higher utilization of machines and tools, higher production flexibility what all together means production cost saving.

Production flexibility increase and cost reduction is strongly influenced by strict observance of applied data structures in communication between individual workplaces in the whole production chain from designing individual components via designing a product, and production preparation up to programming individual manufacturing and handling devices and finally the production itself.

The whole FMS (all manufacturing and handling devices) must therefore contain a communication structure based on modern industrial standard that is compatible also with other industrial facilities to enable trouble free data transfer. One of marginal conditions for definition of FMS characteristics is the ability to cooperate with CAD system CATIA available in our institute. In addition, this system will also have to cooperate with other CAD software systems. This cooperation is extremely important in a term of final project objective: „drawing-free production“. The block diagram of such a modular system is in the Fig.1.

The principal philosophy of the system is based on theoretical knowledge and practical experience in the area of production planning, management and implementation of small batch and piece manufacturers. At present, these production areas are the ones with the most dynamic development.

#### A. Flexibility of Manufacturing Systems

There are various approaches to the term flexibility of manufacturing systems. The most frequent meaning of this term is described as follows:

- Possibility of production program change without any significant alteration of machinery (new NC program, eventual tool change),
- Speed of production program change from previous product line to new products,
- Possibility to change production program at level of individual products.[2]

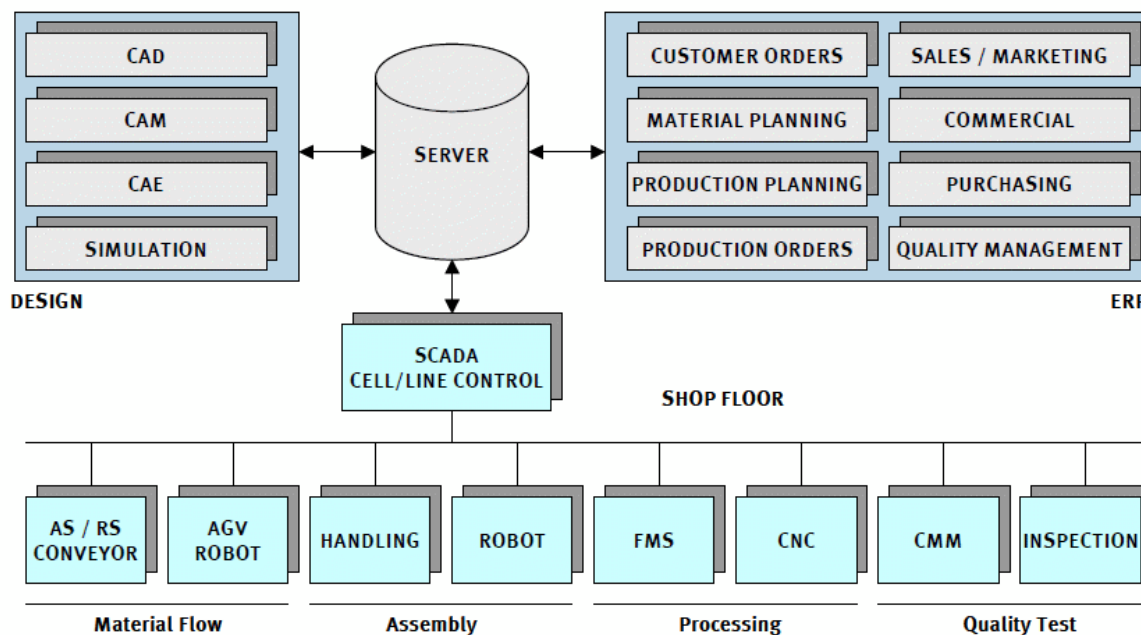


Fig. 1 Modular flexible manufacturing system block diagram

#### IV. FMS FUNCTION ALGORITHM

We want to produce (simulate production) various components of shaft, flange, bracket and box shape in this system. Each component made will represent piece production that means only one piece of this component will be made. Variability (dimensions and shape versions for each component) will be relatively wide. Planning and management of the production process in FMS must be adapted to that fact. Method of ground plan designing is described e.g. in references [1], [6], [7].

The whole process starting with design up to storage of final component must run automatically without human intervention. That means, material in the FMS storage system will be automatically taken out of store, transported to individual machines according to program, put in operating area by a handling device (industrial robot). Machine will execute individual technological operations to reach final properties (shape and dimension) of the component. Simple components can be worked by one machine only but in case of more complicated parts, the component will have to be handled in the machine (e.g. turned to another position) or relocated to another machine so that other necessary technological operations can be realized (sometimes this relocation between individual machines needs to be repeated several times).

After completion of all necessary technological operations the component made will be relocated to checking station for quality control and if quality control is successful, the finished and checked component will be automatically transferred to FMS storage system. If the quality control is not successful,

the component is also transferred to the storage system, however to the part where faulty products are stored.

Function graph of the whole flexible manufacturing system is showed in Fig. 2. Material flow in flexible manufacturing systems is described in [4], [5], [11].

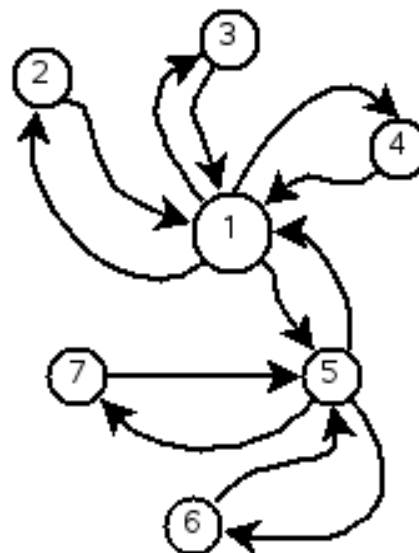


Fig. 2 Function graph of flexible manufacturing system  
1 – conveyor, 2 – storage, 3 – pallet handling and quality station, 4 – robot vision and assembly station, 5 – robot feeder of machine tools, 6 – CNC lathe, 7 – CNC milling machine

### A. FMS Structure

In a term of FMS structure (selection of manufacturing and handling devices) it is necessary to define a general characteristics of products to be produced and of technologies applied.

In spite of significant expansion of plastics application in machine industry, metal remains to be the basic material. By this reason we decided that this FMS will produce (simulate production) components made especially from metal eventually another material that can be processed by the same technologies as metal components. The areas for application of flexible manufacturing systems are described in [9] and [10].

Of course, components must be limited in dimensions and weight. This limitation is needed by several reasons:

Economical – bigger components consume more material, bigger and more expensive machines, higher demands on energy, etc.

Spatial – bigger machines require more places.

With respect to relatively small space available for FMS we must choose to manufacture and handling devices of small dimensions and that means the size of individual components will also be limited.

As upper limit for box component size we determined 120x120x120 mm.

For cylindrical components we defined the maximum size  $\phi 75 \times 120$  mm. The maximum component weight should be 5 kgs.

Technologies that can be used for processing basic metal material into a finished component can be divided as follows. Basic division of machine technologies is in Fig.3.

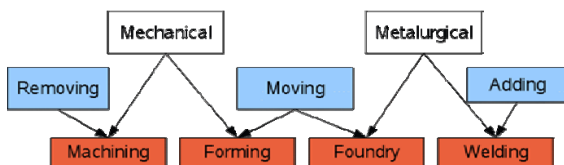


Fig. 3 Basic division of technologies

Both metallurgical and mechanical production technologies are energy demanding, cause environmental contamination and require rather big production facilities. This was one of reasons to focus on machining technologies in our FMS.

Another reason for choice of machining technology for our FMS was that more than 80% of all components are machined in their final phase and other technologies actually produce only a suitable semi product for machining and ultimately are not suitable for piece production.

For production of rotary components, turning operations are used most frequently and milling operations are most frequently used for production of non-rotary components. Accordingly, also our FMS will include production facilities that are able to execute these technological operations (lathe and milling machine).

As we need a fully automated FMS function, production facilities (machining devices) must be CNC controlled what

will enable their integration with other devices of one system (Fig. 4 - 6,7).

Robotized attendance within FMS will be provided for by industrial robots which will load the semi product into the operating area of individual machining devices or into the operating area of the checking station and unload machined eventually checked components from these devices. (Fig. 4 - 5)

FMS must also include an automatic storage facility where various types of semi products as well as finished products will be stored. This storage system must be operated by a feeding device that will take out individual semi products from the storage system and store in finished components. (Fig. 4 - 2)

The checking station will check real dimensions and shape of individual components made. This station will also be robotized. (Fig. 4 - 4)

All mentioned devices must be linked with the transport system which will ensure transport of semi products and finished components to necessary place to be in operating area of individual industrial robots. (Fig. 4 - 1)

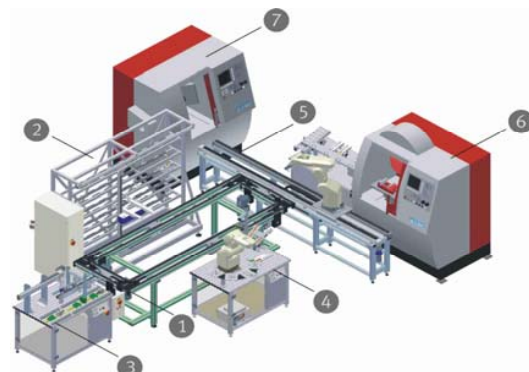


Fig. 4 Flexible manufacturing system

1 – conveyor, 2 – storage, 3 – pallet handling and quality station, 4 – robot vision and assembly station, 5 – robot feeder of machine tools, 6 – CNC lathe, 7 – CNC milling machine

### V. CONCLUSION

Currently, due to shortened product life cycle, market liberalization, a great competitive pressures and constantly dynamically changing demands of customers, enterprises are forced to gradually rebuilding the nature of its production to mass production and small series with a wide range of products. This phenomenon relates with many problems especially with inventory planning, organization of production, rationalization of work. In particular, large enterprises have adapted the nature of their production to mass production, what creates a huge problem with optimization of inventory both in storage and manufacturing, production optimization problems with frequent alterations of machinery and related timing, capacity and economic losses. The Institute of Production Systems and Applied Mechanics applies to designing flexible manufacturing system principles including rational and efficient manufacturing and assembly ways and basic intelligence principles.

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