DESIGN PRINCIPLES OF FLEXIBLE MANUFACTURING SYSTEMS

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Abstract: Flexible Manufacturing Systems (FMS) has been used already for a long time. Due to increasing competition among companies, use of different kind of flexible production systems is also increasing. The main objectives to implement the FMS in the company are to produce different parts or part families more efficiently. Efficiency in FMS means minimizing system unbalance and maximizing system throughput, while satisfying the technological constraint. Selection of rational FMS layout and system components in preliminary design stage is one the most difficult problem. This paper gives an overview of basic principles and criteria of selecting rational FMS layout and structure.

Key words: Flexible Manufacturing System, design principles of FMS.

1. INTRODUCTION

Production system is a structural integrated complex of manufacturing equipment, special fixtures and tools; processes and products with the objective to fulfil a production tasks. Production tasks are directly related to the nomenclature of the products. Production system capacity is directly related to the technological possibilities of the equipment and competence of the workers [1].

Customer oriented flexible production management has led to the extensive use of various types of flexible manufacturing systems. Systems development is based on systems engineering [2]. Systems engineering is an interdisciplinary process ensures that the customers’ needs are satisfied throughout a systems entire life cycle.

Flexible manufacturing system (FMS) is an automated manufacturing system consisting of multiple CNC machining centres and workstations, automated material handling and storage system and distributed computer system that is interfaced with all components in the system [3].

The FMS automatically transfers pallets between workstations, storage system and loading/unloading system. The core of FMS system is sophisticated control software that can schedule production, manage and transfer programs, and run unmanned production [4]. Installation of an FMS is usually a significant capital investment for the company but there are also many benefits: increased machine utilization, reduced factory floor space, lower manufacturing lead times and high labour productivity [5]. Managing and planning the production in the FMS is very complicated task because each machine can perform many different operations and several part types simultaneously, and each part may have alternative routes [6].

Every single flexible manufacturing system is basically unique and specially made for specific company. During the design process of flexible manufacturing system, the most complicated task is to find most rational structure for FMS and effective way to produce different parts according to the company’s production needs and product types [7]. The main criteria to consider are cost of the FMS, payback
period, throughput time, utilization rate, quality of results, etc. Example of typical in-line layout FMS is shown in “Fig. 1”.

Most of the published works in this research area focuses on determination of the position of facilities or efficient layout arrangement of FMS cells or machine tools [8,9]. This research focuses on selection principles of rational FMS structure, by defining the criteria for system design, including data about machines (quantity, main specification), material handling system (type and layout) and storage system (type and size).

2. REPRESENTATION OF PRODUCTION SYSTEM

A production system configuration can be understood as a design task which system components are selected and arranged to form a system. The production system carries out a transformation process for changing the input into determined (task correspondent) output. However, whatever the nature of the business is, the main objective is looking for new ways of adding value either by providing benefits and products that customers are willing to pay more or by combining resources more efficiently to reduce costs. The basic for this task is the manufacturing system engineering (MSE) ontology, what was presented in [10].

For fulfilling a production task, there is necessary to have a production system which formal description is as following [11]:

\[ T = \{N, A, S, F, P\}, \]

Where,
\( T \) – production system;
\( N \) – components of the system (e.g. 5-axes machining centre, 7-axes machining centre, washing machine, measuring machine);
\( A \) – a set of parameters, describing the system and determining the technological capabilities of the system [1];
\( S \) – structure of the system (location of equipment’s of the system and the connections between machine tools and storage, see Fig. 2);
\( F \) – number of functional connections between the elements of the system (depends of the ontology of manufacturing and defines the essence of single events, see Fig. 3). The number and essence of events depends on used technology, rate of automation and organization of production.
\( P \) – number of machining operations, taking place in the system, \( p_1, p_2, ..., p_n \) (e.g. \( p_1 \) – milling, \( p_2 \) - turning, \( p_3 \) – boring, etc.), depends of technological possibilities of the system.

Fig. 2. From abstract description of FMS to its realization.

Fig. 3. Manufacturing alternatives
certain type of orders (the volume of order, delivery time, special type of manufactured products, features, etc.). Technological possibilities determine the diversity and complexity of the products the system can produce, and also determines the cost of the system.

In the process of manufacturing system engineering, the two key questions at the first stage are existing:

- manufacturing alternatives:
  - one-level manufacturing;
  - multi-level manufacturing.
- loading-unloading organisation:
  - automated loading,
  - duo-block automated loading,
  - robot-based loading.

On the basis of Fig. 2 and Fig. 3, it is possible to determine the functionality and technological possibilities of FMS.

3. PROBLEM STATEMENT

Increasing competition is forcing production companies to implement new flexible technologies and increase their automation level. The main problem in automation process is to find most rational and suitable type and structure of flexible manufacturing system for specific company, as every company has different production requirements, production equipment and products.

The design of flexible manufacturing system consists of selecting the best set of resources to satisfy the production requirements during the whole system lifecycle with the maximum expected profit [13].

Design of FMS is complicated and time consuming process, consisting of several stages. The basic problem in the preliminary design stage is to understand, what kind of FMS structure suits the best to manufacture the set of parts or products \{D_i\}, described by the basic characteristics:

- Dimensions,
- Accuracy,
- Production volume,
- Production cycle time,
- Nomenclature (i = 1, 2,...,n).

The goal of this research is to analyse relation principles between products criteria and FMS structure.

4. DESIGN PRINCIPLES OF FMS

The design of FMS focuses on making decisions about system specification for automation of production [13].

The necessary input information for design process of flexible manufacturing system is [14]:

- Technological characteristics of the product family – material, volume, tolerances, type (prismatic, rotational), dimensions, and weight.
- Machining information of the product family – operation type, machining times, required power, required spindle speed, tool life, tool type, tool number.
- Clamping information of the product family – fixture type, fixture size, number of faces on the fixture, number of parts on the fixture.

The main output information of the design process according to the input is:

- Machine type - work cube dimension, loading weight, positioning accuracy, spindle power and speed, tool magazine capacity and type, number of controlled axes, pallet changing system.
- Machine number - number of machines for each machine type in the system.
- Material handling system - rail-guided vehicles, automated guided vehicles (AGV), industrial robots.
- Storage system – dimensions, number of sides, number of levels, number of material pallet places.
• Loading and unloading stations – type of the stations, number of the loading/unloading stations
• System type and layout – layout type, system type

During the design process, different decisions about system configuration has to be made according to the information available as the input. Generally, design of the flexible manufacturing system consists of the following steps:
• Selection of machine type
• Selection of machine number
• Selection of material handling system
• Selection of storage system
• Selection of type and layout of FMS

To make these selections, some kind of decision making model is needed. Many different FMS decision support system for design process can be found in literature [15], but the output of these systems are not specific type or structure of FMS. In this research generally, database will be created for the decision making. By analysing a variety of existing flexible manufacturing systems (built by FASTEMS) and products they produce, we can generate a database that will help to make above mentioned selections. This database contains information about different system configurations and product specifications. Therefore, it is possible to make relations between products and systems. In configuration design task, the alternative design solutions are concentrated into the special database and the selection criteria lead us to the possible, most suitable and rational solutions.

5. RELATION PRINCIPLES

Relation principles between system and product parameters are as following:

• Machine working cube dimensions depends on part dimensions and fixture dimensions.
• Machine loading weight depends on part weight, fixture weight and pallet weight.
• Machine positioning accuracy depends on dimensional tolerances of part.
• Machine spindle power and speed depends on cutting parameters.
• Tool type depends on part and operation type.
• Tool magazine capacity and type depends on part material, tool life and operation type.
• Number of controlled axes depends on operation type, part type and fixture type.
• Machine pallet changing system depends on material handling system type.
• Number of the machines in the system largely depends on the number of the parts that will be produced per time unit.
• Material handling system depends on part type, dimensions and weight, fixture type, pallet changing system and storage system.
• Storage system depends on type of the material handling system, number of part types, dimensions of the parts, number of machine types; size of the storage system must ensure the unmanned production of a given period.
• The layout and type of flexible manufacturing system depends on number of machines, type of material handling system, type of storage system.

These relation principles are used in the framework of the database to analyse how the product parameters affect the system structure. This information is used for
selection process of most suitable and rational structure of FMS.

6. CONCLUSION

Design principles and relation principles of flexible manufacturing system was described to find most rational FMS structure according to given product family specification. Further research work is related to the creation of a database and analysis of relation principles to develop a decision model for design of flexible manufacturing system.

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7. REFERENCES


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