Using group technology in flexible manufacturing

P Kostal

Slovak University of Technology
Faculty of Material Science and Technology
J. Bottu 25, 91724 Trnava
Slovak Republic
peter.kostal@stuba.sk,

Abstract: Current engineering production is characterised by rapid changes. These changes arise due to the shortening of product life cycles. Manufacturers are forced to introduce upgraded products at shorter intervals based on customer requirements. In this paper, we focus on the possibilities of production upgrading by using a group technology in the flexible manufacturing system. The production capabilities of one of the production machines in the manufacturing system will be analysed. This production machine is a lathe that produces one of the essential parts of a finished product. Determine what variations of this part can be produced without changing the physical configuration of the machine.

1. Introduction

Today's trend in manufacturing is characterised by expanding production, shortening the innovation cycle and products with new shapes, materials and functions. A time-oriented manufacturing strategy must change from the traditional functional production structure to manufacturing with flexible production cells and lines. Manufacturing using an automated manufacturing system (AMS) is the most critical case of manufacturing in recent years. The development of engineering products is supported by CAD software; these systems are mainly used for product design. Product designers use different types of CAD systems, which may be incompatible. To introduce a new product, it is usually necessary to transform the CAD data and re-enter the manufacturing data into the manufacturing system used by the manufacturer.

A possible solution is to generate production data directly from the CAD model and place it in the model in a generic format. Manufacturers can transform this data from the 3D CAD model into a format specific to their facility and upload it into the control system of a flexible manufacturing system.

The need for flexible manufacturing systems (FMS) has become particularly important in recent years due to fierce competition in the manufacturing industry. These systems allow us to react quickly to change, but this flexibility costs time and money.

Flexible Manufacturing Systems (FMS) has been developed with the hope that they will be able to address these new challenges and strike a balance between product standardisation and production flexibility. A competitive FMS is expected to be flexible enough to respond to small batches of customer demand. Given that the construction of each new production line represents a significant investment, existing production lines must be able to be reconfigured to keep pace with the increased frequency of new product introductions. This new kind of system we must study in a formal framework, which is a challenge if we consider that in each FMS, we find important characteristics that we must model: sequential relationships and concurrent relationships, events that must occur asynchronously and others that require synchronisation, as well as resources that we must use in mutual exclusion to avoid conflicts, such as a robot. We must also ensure that deadlocks are not created. [1]

A possible solution to this problem is integrating flexible manufacturing systems, product design and engineering. Integration is possible through the implementation of CIM systems. Such an explanation and finding a link between CAD and the iCIM 3000 manufacturing system from Festo Co. is the focus of the research project and this paper. [2]

2. Flexible production system

In 2008, our institute started to develop a project called "Flexible Manufacturing Systems Laboratory with Robotic Manipulation for a Drawing-Free Environment".
The main objective of this project is to build a laboratory equipped with a flexible manufacturing system that will be directly connected to our CAD laboratory. The direct link between the two laboratories will allow the implementation of a coupled design and manufacturing system. The main benefit of this system is the possibility of rapid production response to design changes without paper-based production documentation. This is a model for new 'digital' manufacturing.
The iCIM 3000 is one of the latest relevant solutions designed by Festo Didactic for the education of students and the scientific needs of research centres in manufacturing research. It is expected to play an important role in illustrating complex topics such as manufacturing logistics and sequence planning in flexible manufacturing systems (FMS), material supply and disposal, scheduling algorithms for automated production lines, and many more. [7]
The system consists of a CNC turning machine tool: CONCEPT TURN 105, a milling machine: CONCEPT MILL 105, and a flexible robotic assembly cell. Two industrial robots operate the machine tools. The production system also includes a quality control station with pallet handling equipment. At this station, the base plates are checked for the diameter of the milled holes. In Fig. 1 configuration of this FMS system is shown.

Fig. 1: The flexible production system iCIM3000 from Festo

The transport system is the central unit of flexible production systems. It connects the individual workplaces by a conveyor. Its task is to transport the pallet carriers on which our palettes with the workpieces (semi-finished products) are transported between the individual workplaces of the production system. The pallet carriers are encoded with RFID chips read at the individual workplaces' handover points. Each carrier is stopped and read at each handover point.

Lathe machine and manufacturing process.

The EMCO Concept TURN 105 lathe (Fig. 2) is part of our laboratory's flexible manufacturing system (FMS). It will represent the CIM (Computer Integrated Manufacturing) model in the conditions of our institute. It is a systems approach to planning, control and actual production. We aim to gain experience in these areas at the level of the production system as a whole.

One of the main conditions for defining FMS characteristics is the ability to work with the CAD system CATIA, which is available at our institute. This cooperation is crucial given the final objective of the project: 'manufacturing without drawings'. [8]

Fig. 2: The lathe machinetool EMCO ConceptTURN 105

An industrial robot operates the lathe. It removes the pallet with the semi-finished product from the conveyor belt, transfers the pallet into the hopper and inserts the semi-finished product into the lathe chuck. After the semi-finish product is processed into the final product, this product is removed from the lathe chucking belt, placed on a pallet in the hopper, and transferred to the pallet carrier on the conveyor. A hydropneumatic chuck with a clamping diameter of 28-31 mm is used as a clamping fixture. This lathe is equipped with an 8-position turret head for tool changing. The maximum turning length is 240 mm, but the actual length is smaller, only (121 mm), because the turret head must also be able to change axial tools (drill bits). The maximum turning diameter is 140 mm.

These physical constraints of the machine must be kept in mind when preparing a process plan for a real manufactured part. Another constraint is the tools that the turret head is equipped with. Fig. 3

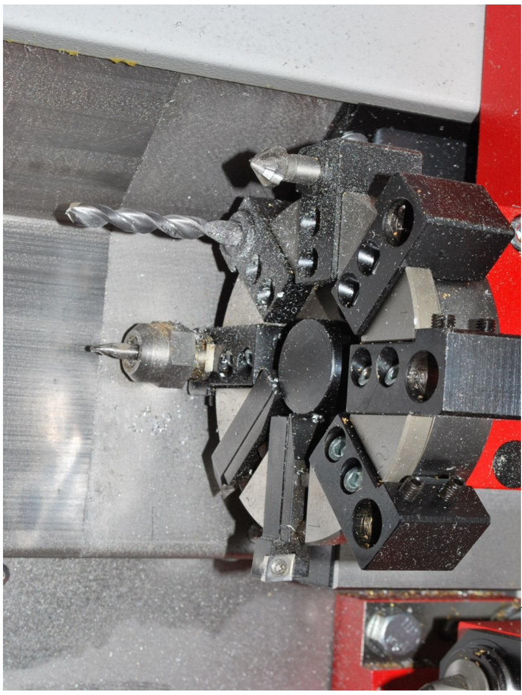


Fig. 3: The lathe machine tool's tool holder equipped by cutting tools

3. Group technology.

The lathe machine allows production only for a limited range of parts (several variants of one part), so it is advisable to group them and produce on the principle of group technology. We take advantage of the repeatability characteristics of production.

Already developed and proven technological processes are often used in the production of parts. Group technology has long proven to be a suitable tool for improving existing technical documentation in a plant with repeatable production characteristics. [9]

One of the first steps in grouping technology is grouping similar items. This clustering can be done based on various parameters. It can be:

- The geometric similarity is based on the size and shape of the component.
- The technological similarity is based on the number and order of operations.
- Possible additional parameters.

Proper grouping of items is the key to successfully implementing group technology. Group technology is implemented in several sequential steps:

- Classification of components into technology groups,
- Analysis of technological aspects of design and manufacturing processes of individual components,
- Representative group design (the most complex part can only be imaginary)
- Processing of the technological process of the group,
- Design of group equipment (tools, jigs, etc.)
- Development of technological documentation for group technology.

4. Actual production.

Currently, the iCIM FMS is programmed to produce a set of table sets (Fig. 4). The set consists of products produced by the production system and products supplied by an external manufacturer.

The production parts produced by the manufacturing system are:

- Pen holder (turning)
- Base plate (milling)

Parts supplied by external suppliers are (assembly only):

- Thermometer
- hygrometer
- ballpoint pen

Fig. 4: The final product - desk set

Scraps from a 30 mm diameter bar are used as a semi-finished product. Pen holders are produced in various modifications. They can be made of Al alloy or brass in different shapes (Fig. 5, Fig. 6).
The blank is clamped in a hydropneumatic chuck. All the necessary manufacturing operations are carried out using the tools clamped in the turret holder. When machining is complete, the product has the desired dimensions, shape and surface quality.

Fig. 5: Penholder from Al aloy

Fig. 6: Penholder from brass

4.1. Manufacturable shapes

All parts consist of a finite number of defined areas. To produce a specific part, we need to consider the appropriate combination of machine tools - motion and cutting. In some cases of surfaces, it is necessary to modify an additional surface (for example, thread cutting). It is therefore essential to pay close attention to the order of surface production in the manufacturing process.

There are three ways to create surfaces on a part by turning: [12]

- Point + motion - usually longitudinal rotation of rotating surfaces, transverse rotation of directional surfaces
- edge + movement - usually rotation of the groove
- surface + movement - drilling in general

Table 1 gives general examples of surface forming by turning using a given combination of machines and tools.

The first tool can only create surfaces as point (tooltip) + movement. This tool is used for longitudinal turning or face turning.

The second tool can create a surface, usually as point+motion. This case applies to longitudinal turning, but this tool can also use groove turning. In this case, it is an edge+motion, and the final surface is the impressions of the edge shape. In this case, it is a V groove. This means that the geometric characteristics of the tool are partially copied into the geometric features of the workpiece.

The third, fourth and fiftieth tools are drilling tools, creating a new surface using the surface+motion method. This means that the geometric characteristics of the tool are almost entirely copied into the geometric features of the surface being created. (Table 1.)

MCP. (Fig. 7). By combining all the areas producible from the table, we create a representative for a given product group - the complex part. Fig. 7 This part contains all the possible surfaces that can be realised with a given machine and tools. This part does not have to be physically made real, it can be only imaginary, but all real products will contain only a subset of the surfaces from this imaginary part.

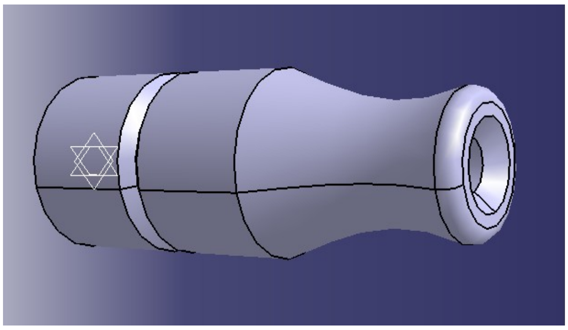
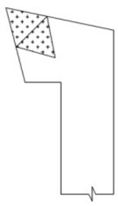
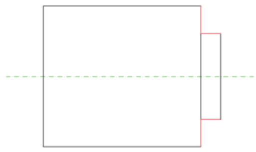
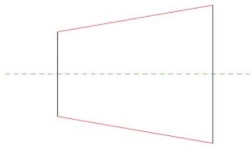
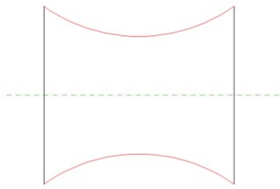
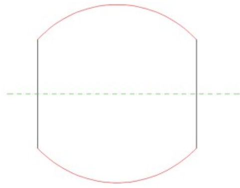
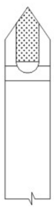
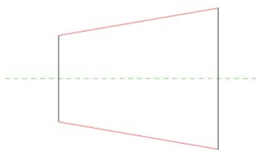
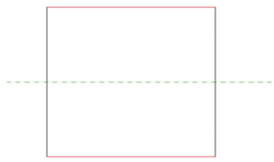
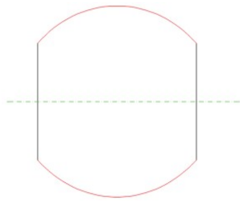
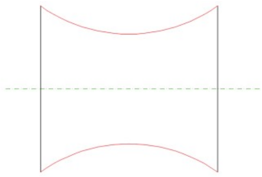
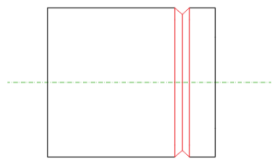
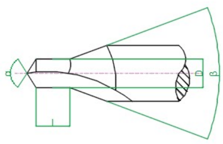
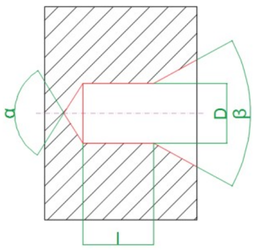
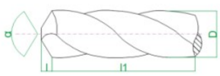
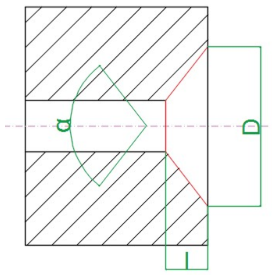
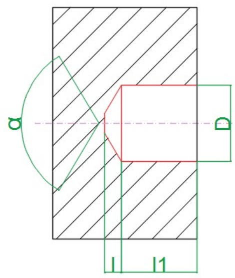
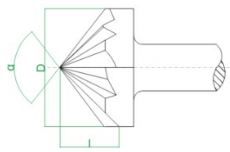
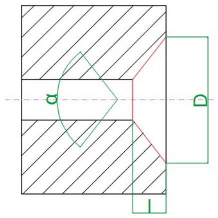


Fig. 7: The 3D model of a Complex Part

Based on the producible surfaces, new shape variants of the pen holders were designed, as shown in the figures (Fig. 4, first from the left, Fig. 5, second from the left). The models of these new pen holders were created in CATIA CAD. The NC code for their manufacture was also created in this program. These new pen holder variants were successfully implemented in the system.

Table 1. *Surfacing with some tools on the lathe*

Tool	Surfaces		
			
			
			
			
			
			

5. Conclusion

Nowadays, as a result of dynamically changing customer requirements, companies are forced to gradually rebuild the nature of their production from mass production to piece and small batch production and substantially expand the range of products. Many problems are connected with this phenomenon, especially inventory planning, production organisation, and work rationalisation. This approach also corresponds to the idea of lean production.

Despite developments in engineering systems and advances in information and communication technologies, current (manufacturing) engineering systems cannot address the needs of today's manufacturing enterprises.

This article provides a very brief insight into the possibilities of applying the theoretical foundations of surface formation by cutting and the idea of group technology in modern, flexible manufacturing systems. The article lays the groundwork for a broader research project that involves the transition to smarter manufacturing systems and smarter manufacturing preparation in these systems. Other research ideas are related to but are not limited to refining what has been described here and using simulation to explore different scenarios.

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