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DEVELOPMENT OF THE COMPUTER-AIDED PROCESS PLANNING (CAPP) SYSTEM FOR POLYMER INJECTION MOLDS MANUFACTURING

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Beginning of production and selling of polymer products largely depends on mold manufacturing. The costs of mold manufacturing have significant share in the final price of a product. The best way to improve and rationalize polymer injection molds production process is by doing mold design automation and manufacturing process planning automation. This paper reviews development of a dedicated process planning system for manufacturing of the mold for injection molding, which integrates computer-aided design (CAD), computer-aided process planning (CAPP) and computer-aided manufacturing (CAM) technologies.

Key words: process plans, CAPP, polymer injection molds, materials

Razvoj CAPP sustava za izradu kalupa za injekcijsko prešanje polimera. Početak proizvodnje i plasmana polimernih proizvoda u velikoj mjeri ovisi od vremena izrade odgovarajućeg kalupa, čiji troškovi čine veliki udio u ukupnoj cjeni proizvoda. Osnovni pravac unapređenja i racionalizacije procesa proizvodnje kalupa za injekcijsko prešanje polimera usmjeren je na automatizaciju projektiranja kalupa i tehnoloških procesa njihove izrade. U radu je prikazan razvoj specijaliziranog programskog sustava za automatizirano projektiranje tehnoloških procesa izrade kalupa za injekcijsko prešanje polimera, zasnovanog na integraciji CAD, CAPP i CAM aktivnosti.

Ključne riječi: tehnološki procesi, CAPP/RPPP (Računalno podržan proces planiranja), kalupi za injekcijsko prešanje polimera, materijali

INTRODUCTION

Modern organization of manufacturing, featuring novel design and manufacturing technologies, with emphasis on flexible automation and extensive application of computers. Automation of manufacturing systems is primarily focused on product design, process planning, production planning and control, as well as manufacturing. Design automation is successfully solved using CAD/CAE systems, manufacturing is automated using CAM and NC (numerical control) systems, production control is solved using MRP and ERP (enterprise resource planning) systems, while the process planning is solved by CAPP systems [1]. Due to a relatively low level of CAPP systems, process planning activities represent a significant problem in integration of manufacturing. To corroborate this claim, Figure 1 shows application of CIM elements in small and medium-sized enterprizes (SMEs).

Certain terms in Figure 1 are: concurrent engineering (CE), automated guided vehicle (AGV), flexible manufacturing systems (FMS), group technology (GT), multimedia (MM), electronic data interchange (EDI), material requirements planning (MRP).

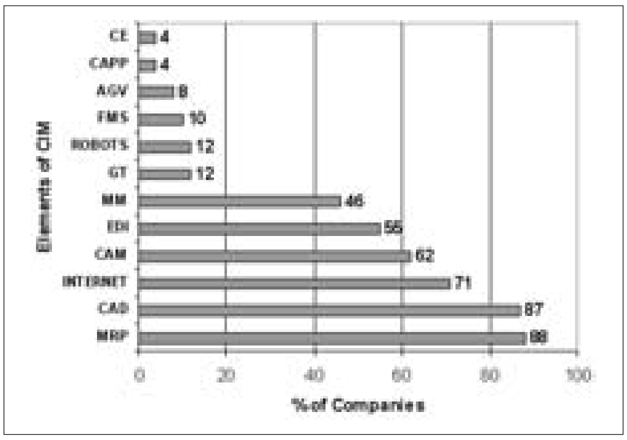

Figure 1 Application of CIM elements in SMEs [2]

Process planning is mostly based on the know-how and experience of engineers. Intensive use of computers has allowed significant advances, resulting in a number of CAPP systems. The basic goal of developmental activities in manufacturing technologies is the integration of all segments of manufacturing and a set up of computer integrated manufacturing (CIM). CAPP systems have key role in the integration of design and manufacturing, i.e. they are a bridge between CAD and CAM systems [3, 4].

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This paper shall review the development and application of a dedicated CAPP system for molds for injection moldings of polymers (in further text molds), which is custom-made for a specific manufacturing environment.

DEVELOPMENT OF A INTEGRATED CAPP SYSTEM

Production process of polymer products depends significantly on cost of quality, time to market and cost to produce appropriate molds.

Previously, the design and manufacturing of molds largely based on individual approach, with unfavourable techno-economic effects. It has been noted that the majority of parts, i.e. mold parts, can be standardized, which allows the concept of group technology to be applied on mold design and manufacturing. As a result, mold standardization and batch manufacturing were introduced, allowing shorter lead times and delivery, high quality, low manufacturing costs, etc [5, 6].

The ever-intensive application of polymer products has, in the last decade, inspired CAx manufacturers to develop systems which allow improvement of design and manufacturing of polymer products and molds. A significant advancement has been made considering the development of CAD systems dedicated to mold design, as well as the special CAE systems dedicated to simulation and analysis of polymer injection moldings [7]. The manufacturing process planning domain has become a bottleneck in the overall system for manufacture of molds.

In order to rationalize and advance the manufacture of mold, a model is proposed and the system for automated process planning for mold manufacturing is developed. The basic algorithmic structure of the proposed system comprizes three distinctive modules according to Figure 2 [8, 9]:

– Input data,
– Mold design (CAD module) and
– Process planning for mold parts manufacturing (CAPP/CAM module).

The system relies on available commercial software systems to complete particular stages: the systems for: product design and NC programming, development and management of relational data bases, development of knowledge base and system integration.

The input into this system are polymer products and the data on particular manufacturing conditions. Within the first step, the CAD module can be used for mold design. To support mold design, the system allows selection of standard mold parts, as well as the selection of the type of blank and material for particular mold parts. The second CAPP/CAM module is dedicated to automation of process planning for manufacture of mold parts, including the generation of NC part programs.

Within the proposed system, process planning can be performed for:

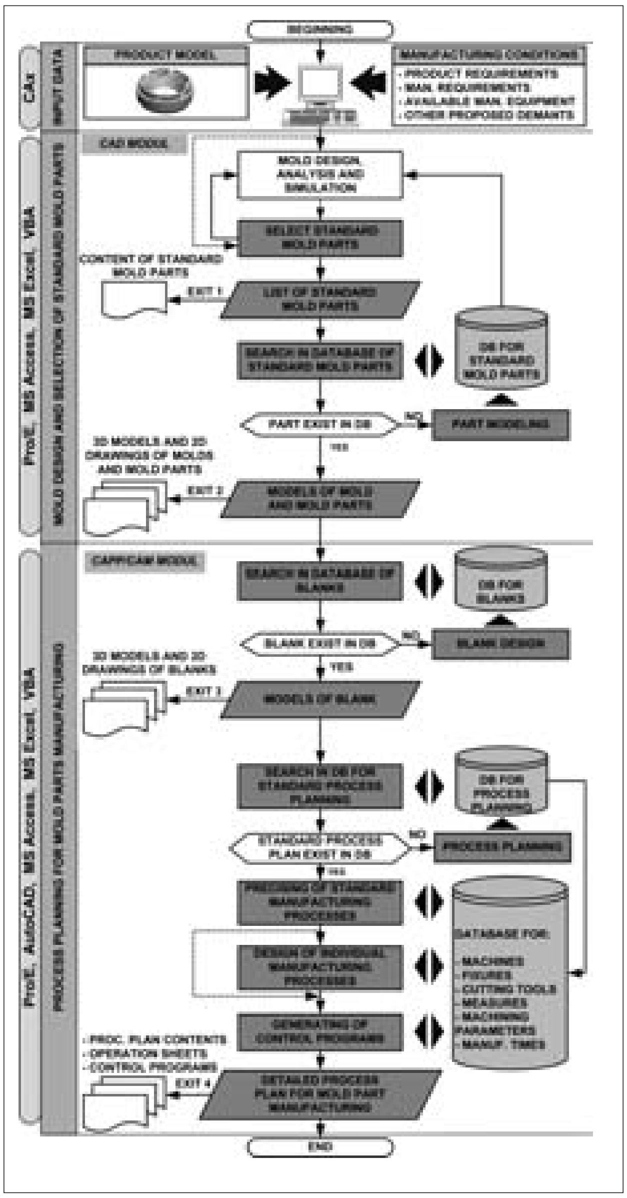

Figure 2 A diagram to determine reaction forces and moments of the slide

– Typical, i.e. standard mold parts (the dotted line in Figure 2 algorithm) for standard machining processes and operations and/or
– Parts of a specific mold, which require particular machining processes and operations such as engraving, etc.

For the purpose of this review, prismatic parts of mold be considered, together with the adequate process plans for their manufacture under particular machining conditions.

In order to clearly define the processes which take place within this dedicated CAPP system according to algorithm goven in Figure 2, the diagrams of basic activities shall be explained in detail by IDEFO methodology. Figure 3 shows the diagram of basic activities within the system: A1-Mold design, and A2-Process planning for mold parts manufacturing.

Organization and management of data is based on a relational data model, i.e. on a relational database. The integrated knowledge base (KB) within this system was developed by combining the data structure stored in the database, and the VBA (Visual Basic for Applications) procedures, using production rules technique. Within the data base, there are distinguishable classes or parts of database which allow decision-making [8, 10]:

- Knowledge base for mold part selection,
- Knowledge base for material selection,
- Knowledge base for blank selection,
- Knowledge base for manufacturing features determination,
- Knowledge base for standard process planning (process sequences, standard processes, operation group, standard operations),
- Knowledge base for machining resources selection (machine tools, fixtures, modular cutting tools, measuring devices), and
- Knowledge base for selection of machining parameters.

In the following paragraphs we will briefly present the background for the development of a mold base parts' materials selection knowledge database.

DEVELOPMENT KNOWLEDGE BASE FOR MOLD PARTS MATERIAL SELECTION

Molds are generally intended mass-production of polymer products. That is why the molds quality and durability greatly depend on particular mold parts' material selection. Mold base consists of a number of pieces of rectangular or circular plate shape, or plate parts. These parts form basic or support structure of molds.

Fixed and movable mold parts represents the most important parts for molds, because they form mold cavities, which are in direct contact with polymer melt. The quality of mold manufacturing is directly reflected to the quality of molding process and to the quality of produced polymer parts.

In order to make an optimal selection of steel for molds, it is necessary to consider the following requirements [5]:

- The behavior during mold exploitation,
- Sufficient resilience,
- Consistency of dimensions during exploitation,
- Allowed tensile strength and yield strength,
- Resistance to the creation of surface cracks,
- Resistance to chemical influence, etc.

According to the type of steel that are most often used for molds, they can be divided into: steel for hardening, steel for improvement, steel for nitration, conventional high strength tool steels, stainless steel.

With respect to the applied polymer material, mold materials (steel) can be divided into the following groups:

- Steel for chemical non aggresive polymers,
- Steel for chemical aggresive polymers,
- Steel for glassy polymers and polymers with other admixtures.

Certain type of polymers have agreesive impact on the mold's parts, for example: aminoplastics, PVC, and others. During the polymer injection process, chemical byproducts such as amino acids are created. They affect the surface of mold cavities by creating cracks and therefore they have significant influence on the mold parts wear. When glassy polymers are used, mold materials must have high hardness and high wear resistance, due to the effects of glassy particles on the surface of mold cavity sprue and runner channels.

Table 1 presents a base for the development of a knowledge database for suitable type of steel for the mold base parts selection.

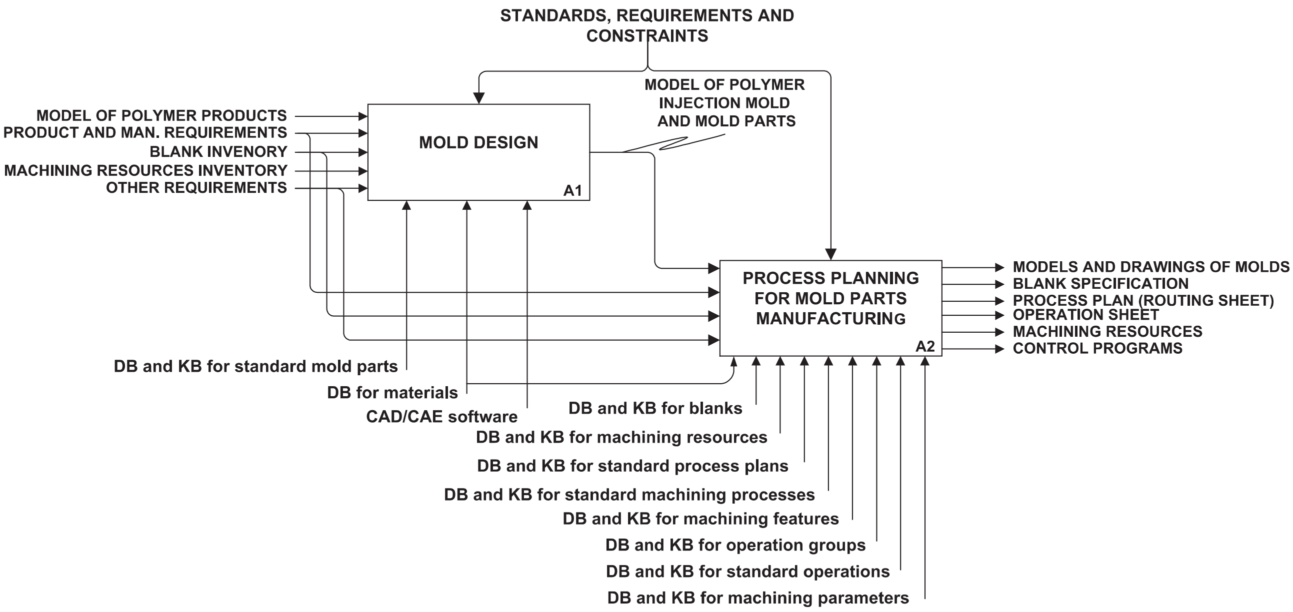

Figure 3 Activity diagram for the dedicated CAPP system

Table 1 The distribution of certain types of steel for making mold plates

Polymer material	Type of steel and delivery condition	Material (steel) code		
non aggresive	Low alloy Cr-Mo steel for improvement (termally unthreated)	1.7218	Č.4730	25CrMo4
		1.7220	Č.4731	34CrMo4
		1.7225	Č.4732	42CrMo4
	Low alloy tool steel (improved)	1.2311		40CrMnMo7
		1.2312	Č.4742	40CrMnMoS86
		1.2738		40CrMnNiMo7
aggresive	High alloy Cr-Mo steel (termally unthreated)	1.4110	Č.4770	X55CrMo4
	High alloy Cr stainless steel (normalized)	1.2083	Č.4175	X43Cr13

Selected types of materials plays a significant role in manufacturing process planing, as well as for the selection of appropriate resources and parameters.

APPLICATION OF THE DEVELOPED SOFTWARE SOLUTION -A CASE STUDY

The developed CAPP system shall be verified on a study case dealing with the manufacture of an fixed mold plate which is a constituent part of the mold of a multi socket body (Figure 4).

Based on the input data, the selection of standard mold parts (Figure 5) was performed within the CAD module at the previous stage, and used as a prerequisite for the design of the mold assembly, the selection of the blank material for the fixed mold plate (Figure 6).

Based on the developed production rules shown in table 1, the contents of the standard process plan, coded TTP11A, for the manufacturing of the fixed mold plate for the selected mold (Figure 7).

For each machining process by given program system is able to obtain the content of proces, i.e. specified operation and appropirate machining tools, cutting tools, fixtures, measuring devices and machining parameters. For typical machining proces that performed on NC machining systems enables generation a control program, using parametric programming by Pro/E [8, 9].

CONCLUSIONS

Application of general-purpose CAD/CAM/CAE software systems, the systems for database developments, and systems for development of software applications, allows development of software solutions for automation of design and manufacture.

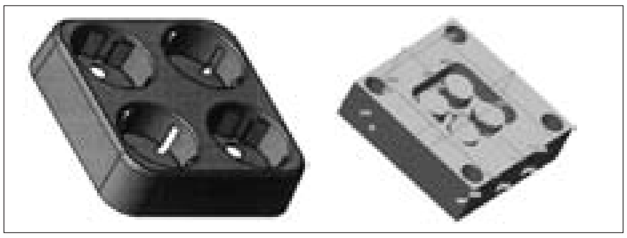

Figure 4 A 3D model of the multi socket body and the appropriate fixed mold plate

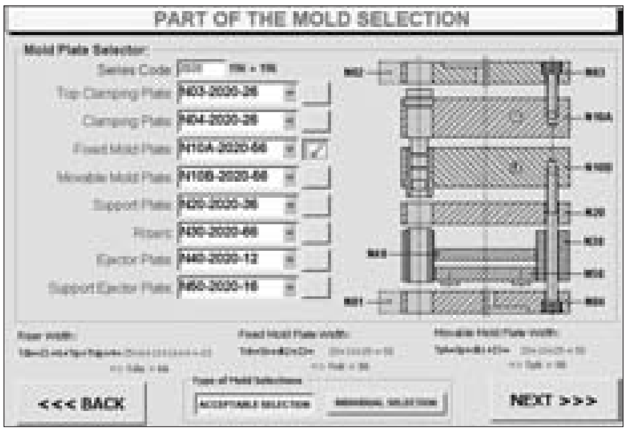

Figure 5 Selection standard mold plates

Figure 6 Selection of fixed mold plate material

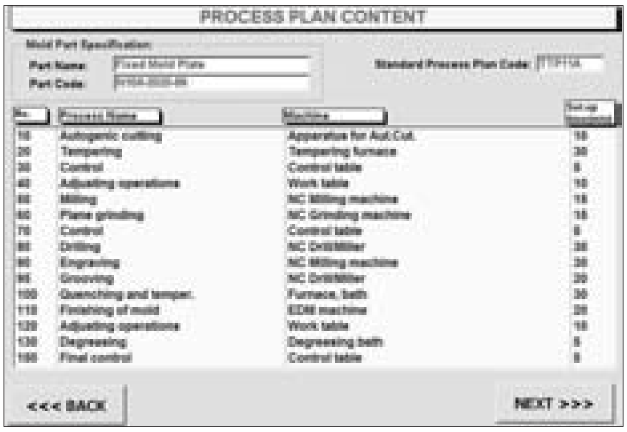

Figure 7 Generated process plan for the manufacturing of the fixed mold plate

The dedicated software solution developed in this work, i.e. the integrated CAPP system, allows automation of a significant number of activities in the process of mold design and manufacturing process planning, which contributes to rationalization of activities proceeding the manufacturing process.

In the future period, one should expect a significant advancement in the development of a universal platform for CAPP systems and their further integration with various CIM-related activities, as well as other activities related to product lifecycle. This integration means easier sharing of product model data, which is already supported by a number of specifications for product data exchange, among which ISO 10303 (STEP) and ISO 14649 (STEP NC) is most prominent. Internet technologies are also increasingly used as support for integration processes. Globally available data bases are used to support concurrent and collaborative engineering, as well as in the development of digital factories and E-manufacturing.

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Note: The responsible translator for English language is J. Bajkin, Faculty of Technical Science, Novi Sad, Serbia