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MACHINING PROCESS PLANNING IN PLM ENVIRONMENT

PROJEKTOWANIE PROCESÓW TECHNOLOGICZNYCH OBRÓBKI W ŚRODOWISKU PLM

A b s t r a c t

The paper presents the characteristics of planning actions on the stage of conceptual and detailed manufacturing process planning in an integrated PLM environment. The functionality of the available solutions is discussed in details. Based on these analysis, the directions for the future development of the machining process planning systems to increase the automation level are presented.

Keywords: *CAD/CAPP/CAM integration*, *production preparation*, *manufacturing knowledge data bases*

S t r e s z c z e n i e

Artykuł przedstawia charakterystykę działań projektowych na etapie koncepcyjnego i szczegółowego projektowania technologicznego w zintegrowanym środowisku PLM. Szczegółowo przeanalizowano funkcjonalność dostępnych rozwiązań. Bazując na tej analizie, zaproponowano kierunki dalszego rozwoju komputerowo wspomaganego rozwoju procesów technologicznych obróbki, w celu zwiększenia stopnia automatyzacji prac projektowych.

Słowa kluczowe: *integracja CAD/CAPP/CAM*, *przygotowanie produkcji*, *bazy wiedzy technologicznej*

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1. Introduction

The growing competition on the market enforces the introduction of new methods and approaches both in the preparation and the realization of production processes. Competition on the market enforces several changes, including the extensive use of computer systems to shorten the development of product and production processes and the use of modern development methodologies like CE.

There is a lot of research works on modern manufacturing production preparation approaches [1, 5, 10]. A number of both Polish as well as international works on particular product lifecycle phases, as for example design [1], computer aided process planning [4, 5, 9], assembly process planning and the advanced production organization methods are available. On the other hand, the number of works characterising the use of computer systems in the particular product development phases (as for example CAD, CAPP, CAAP, DFM, DFA, CAS, etc.) and integrated design with the use of PLM applications [6, 7, 8] and modern development strategies is limited. To fill this gap, the methodology of using such systems in the manufacturing preparation phase in the Concurrent Engineering environment was developed. This papers presents the part of this methodology related to the machining process planning and discusses the functionality of the available commercial solutions. At the end, the directions for the future development are presented.

2. Integrated process and system development in PLM environment

Features of modern development strategies indicate the need for product development phase integration.

Integration and parallel execution of activities were received through the separation of the conceptual design stages, allowing for the creation of the variant solutions. Variants are then evaluated in the view of the requirements of the next development phase [5].

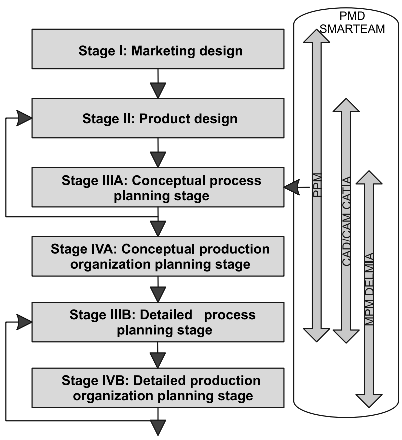

Fig. 1. Parallel execution of product development phases

Rys. 1. Równoległa realizacja faz rozwoju produktu

The integration of design and manufacturing product development suggests the separation of the following phases (Fig. 1):
- conceptual process planning phase (STAGE III A),
- detailed process planning phase (STAGE III B).

The integration of manufacturing and organizational product development suggests the separation of the following phases:
- conceptual organization process planning phase (STAGE IV A),
- detailed organizational process planning phase (STAGE IV B).

The selected variant fulfilling the established criteria is next further developed in the detail design stage (Fig. 1). The concurrent execution of selected product development phases within the scope machining process planning is presented in the following points.

3. Formal representation of machining process planning

Manufacturing process is the ordered series of discrete events occurring in the manufacturing system in relation to the product [2]. It was found, that during the manufacturing process, the product goes through several states from the initial one (raw material) to the finish state (machined product). It was also assumed that the machining process executed in manufacturing systems is described by the series of actions $\{E_0\}$ executed by the manufacturing system elements causing the discrete change of the product characteristics, from the initial state to the final state and the structure SPO describing the order of the process plan actions.

$$\mathrm{PTO} = \{E_0\},\ \mathrm{SPO} \tag{1}$$

where:

$\{E_0\}$ – set of machining actions,

SPO – structure of machining process plan.

Based on the analysis of the machining processes, three types of actions were distinguished:
- E_{TRO} – actions changing the state of the machined part,
- E_{OPO} – actions changing the location of the object in the system (as the object the tool (N), machined part (PO) or exchangeable equipment (ZPW /ZNW) can be taken),
- E_{IDO} – actions comparing the present characteristics of the machined part with the requirements given in the manufacturing process documentation.

So:

$$\mathrm{PTO} = \{E_{\mathrm{TRO}}, E_{\mathrm{OPO}}, E_{\mathrm{IDO}}\},\ \mathrm{SPO} \tag{2}$$

Machining process planning for the given input data: production program and characteristics of the machined part:

$$\mathrm{POW} = \{C_W, W_W, \Psi_W\} \tag{3}$$

is the creative decision process aimed to determine the shape of the raw material POP based on the technical and economical assumptions and the series of actions executed in manufacturing system, transforming the raw material POP into the machined part with the given characteristics of POW.

So, machining process planning covers:
- selection and design of the raw material,
- development of machining plan,
- development of the structure of machining process by the selection of the methods and technical means for the machining process execution,
- development of machining process documentation.

The structural elements and their order in the machining process structure depend on:
- geometry characteristics, and physical and mechanical properties of the machined part,
- dimensional and shape accuracy increasing together with the machining process realization.

The analysis of the degree of automation of computer aided process planning in the CAD/CAM and MPM ((Manufacturing Process Management) systems being the component of PLM applications is presented below.

4. Machining process planning in CAD/CAM and MPM systems

CAD/CAM and MPM systems are used for the machining process planning in PLM environment. The analysis of the machining process in PLM environment (Fig. 2) show that the level of automation is very low. Most of the planning actions still require the participation of the manufacturing engineer.

CAM system does not assist the manufacturing engineer during the raw material selection. The only available assisting function is the automatic generation of the box including the machined part. Because there is no links to the steel product database, there are just simple geometric calculations.

CAM system also does not help to select the machine tool. The machine tool selection is one of the first decisions taken by the manufacturing engineer during the machining process development. Very often, CAM system are equipped with the machine tool database and the tools for development of machine tool models. These tools allows to define the kinematics of machine tool, the range of axis movements, max. rotational and linear speed, geometry of particular machine tool elements, tool magazines, part mounting point and tool mounting point. These tasks are executed in PLM environment by MPM systems allowing to define and simulate the machining stands and systems. Nevertheless, there is no systems for selection of machine tool based on such data. These data are used only for control program simulation (Fig. 3).

In the development of machine operation contents, which covers selection of appropriate cycles, their parameters and ordering, the automatic assignment of machining cycles to recognised manufacturing features is widely used. Unfortunately, such solutions have several limitations mainly due to the limited functionality of feature recognition modules. There is no commercial solutions capable to copy with the problem of intersecting manufacturing features, i.e. features for which the common volume in 3D space is not null. As the result, the hole intersecting with the slot is recognised as two pockets, and the slot as two independent slots which influence the process of machining cycles selection. The machining selection process can be modified by the development of the simple conditions using the parameters of the recognised manufacturing feature (Fig. 4). It should be noted that there is no basic parameters important from the manufacturing process planning view.

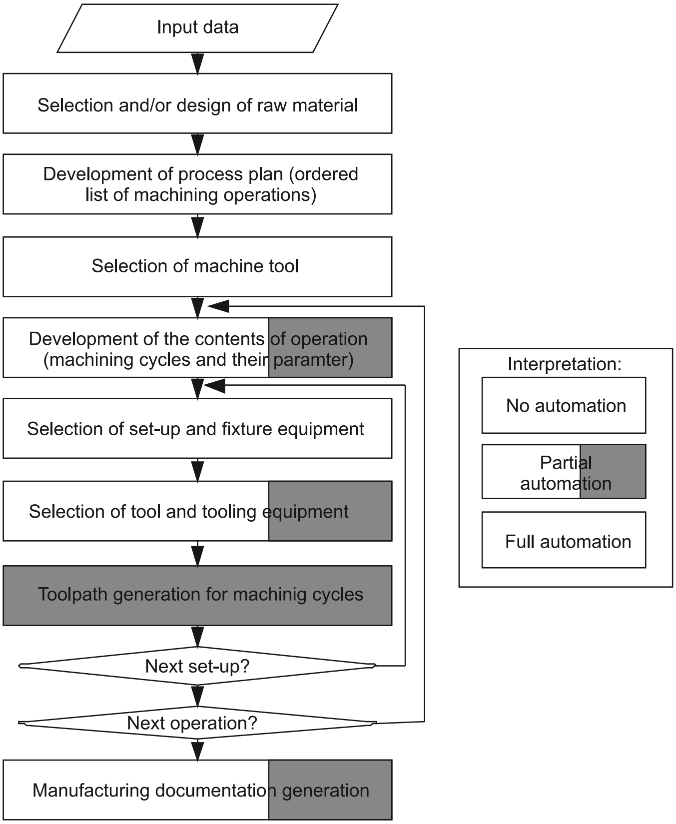

Fig. 2. Machinig process planning in CAD/CAM system - estimation of the degree of automation
Rys. 2. Przebieg projektowania procesów technologicznych obróbki w systemie CAD/CAM – ocena stopnia automatyzacji zadań składowych

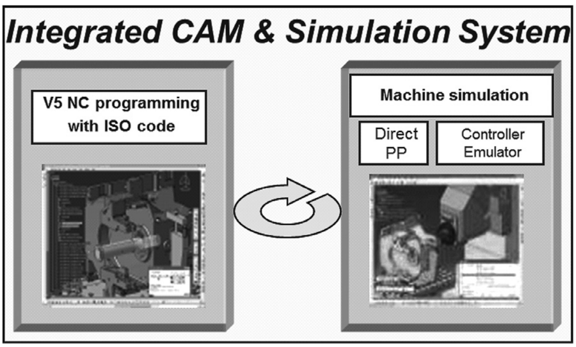

Fig. 3. Machine tool and its model for program simulation in MPM system
Rys. 3. Obrabiarka i jej model do symulacji programów w systemie MPM

For example, the pocket has no parameters describing the occurring of concave sub--profiles, requiring to the tool with the smaller diameter. No possibility to use in the selection conditions the non-geometric information of features like surface roughness or tolerance class (with some exceptions for holes) is another serious limitation. Because of this, the automatic selection of final machining cycles is not possible. Also feature recognition does not take the raw material into account. The order of machining cycles is determined base of the types of cycle, i.e. first all pocket milling cycle are executed, then drilling, reaming, etc. or the type of the tool. CAD/CAM system are not equipped with the meta-knowledge allowing to select the order of machining cycles based on the common manufacturing rules, represented for example in the form of multi-level, hierarchical decision nets [2].

Without discussion, the most important advantage of CAD/CAM system is the ability to generate the toolpaths for the defined machining cycles and their parameters. The toolpaths are generated taking onto the account the selected movement scheme and the tool dimensions. Nevertheless, the supervision of manufacturing engineer is still necessary, because CAD/CAM systems are not able to determine the appropriate approach, retract or linking motions, which results very often in the collisions between the tool and the machined part or machine tool elements.

To document the program and deliver the information necessary for its runs, the manufacturing documentation must be also developed. Not all CAM systems have such functionality. The systems having such functions are not able to save a number of important data like for example part clamping scheme in the documentation. Once more, the help of manufacturing engineer is necessary.

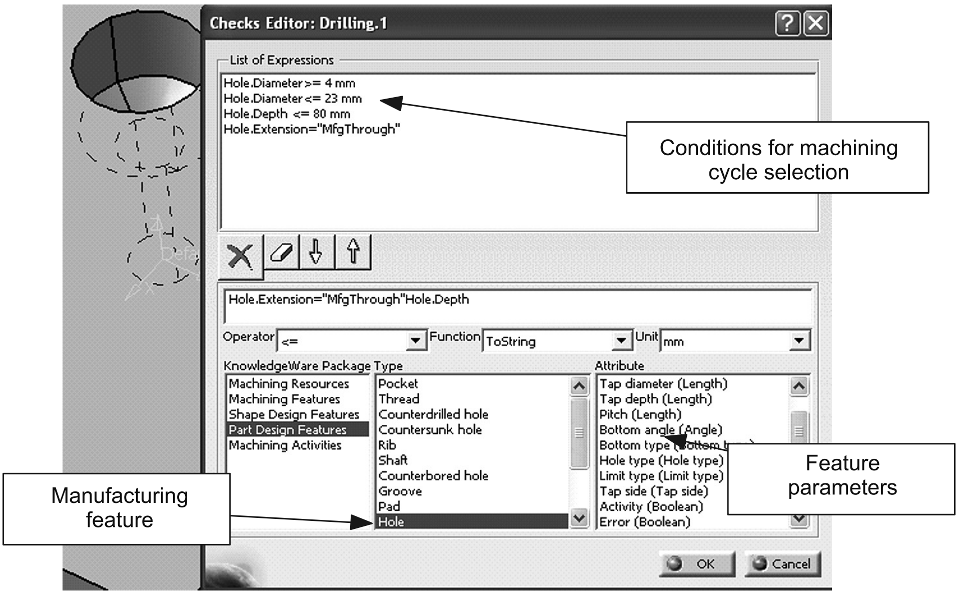

Fig. 4. The conditions for drilling cycle selection

Rys. 4. Warunki wyboru cyklu wiercenia

The increase of the functionality of the integrated systems for the process and manufacturing system development should be carried out through the development of the modules for assisting and/or automation of the particular planning tasks. The high level of integration of such systems is obtained through the use of common data model PPR (Product, Process, Resources), securing the exchange of information between the modules used in the planning actions and the development of systems based on the knowledge, using the artificial intelligence (AI) tools.

5. Conclusion – perspectives for the machining process planning automation

The analysis presented above indicate that the level of automation of CAD/CAM components of PLM applications is relatively low. The main factor deciding about the efficiency of machining process is the structure of the process plan. This function is performed by CAPP system, establishing the contents and the sequence of operations using generative and semi-generative methods. The prototype of such system is under the development in Production Engineering Institute, Cracow University of Technology. It allows for:

– storage, modification and processing of manufacturing knowledge (knowledge repositories),
– storage of characteristics of manufacturing systems in the view of manufacturing process planning,
– generation of solutions on the different degree of details.

Such system integrated with other modules of PLM application should increase the level of automation of computer aided process planning and shorten the production preparation time.

The key elements still requiring the research works are:

– development of the model of manufacturing process planning in the integrated development of the products, processes and manufacturing systems,
– development of the knowledge databases with the special attention on meta-knowledge,
– improvement of the algorithms for manufacturing feature recognition.

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