https://doi.org/10.26552/com.C.2000.1.10-16

KOMUNIKÁCIE
COMMUNICATIONS

Jan Duda *

GENERATÍVNY SYSTÉM PRE NAVRHOVANIE TECHNOLOGICKÝCH POSTUPOV

GENERATIVE SYSTEM FOR MANUFACTURING PROCESS PLANNING

Článok prezentuje generatívnu metódu ako základný prístup pre expertné navrhovanie technologických postupov. Metodológia navrhovania technologického postupu, štruktúra technologických operácií a modelovanie postupov sú základné úlohy pre exaktné generatívne metódy tvorby technologických postupov. Záver článku opisuje expertný systém EXSYS ako základný nástroj pre vývoj systému generatívneho navrhovania technologických postupov.

V článku je predstavená architektúra expertného systému, pričom veľký dôraz sa kladie na kontrolný mechanizmus. Procedurálne kódovaný kontrolný mechanizmus je riadený pomocou deklaratívnych vedomostí, ktoré opisujú ako použiť vedomosti pre plánovanie technologických postupov. Vedomosti sú reprezentované pomocou produkčných pravidiel. Na základe reprezentácie výrobných vedomostí boli špecifikované tri úrovne: výber všeobecnej štruktúry technologických operácií, reverzibilný návrh medzitvarov a prechodových tvarov; generovanie procesu technologických operácií. Prezentuje sa tu aj prototyp expertného systému. Navrhnutý systém, ktorý využíva na reprezentáciu vedomostí produkčné pravidlá a rámce, bol vyvinutý pomocou prázdneho expertného systému EXSYS PROFESSIONAL. Systém bol verifikovaný v obrábacom centre CPTOR 1, pre ktorý bol generovaný technologický postup.

The paper presents the basic approach for the expert process planning - generative method for planning of the manufacturing processes. The methodology of process plan, structure of manufacturing processes, modelling of processes are key tasks of exact generative methods of creation of process plans. Conclusion of papers describes the expert system EXSYS as a basic tool for development of generative process planning system.

In this paper a domain - specific expert system architecture with special emphases put on the control mechanism is presented. Procedurally encoded control mechanism is driven by explicitly represented declarative control knowledge, describing how to use the planning knowledge represented as production rules. On the basis of such knowledge representation three stages were specified: selection of the generalised structure of manufacturing process, reversible design of the semi finished product and intermediate shapes, and generating the machining process. The prototype of an expert system is also presented in this paper. The system combines the rule and frame technique to represent the knowledge and is built using the expert system EXSYS PROFESSIONAL as the shell. It has been verified by building the system which generates process plans for rational parts, manufactured in the CPTOR 1 machining centre.

1. Introduction

The generative method is a subject of theoretical and experimental research, and difficulties with its implementation are connected with the lack of formal description of the synthesis of activities constituting the manufacturing process. To overcome the difficulties while developing the huge technological knowledge base, a semi-generative method is often used [3].

Computer-aided process planning systems may operate in several modes. The main modes of CAPP are as follows[1]:

- *pattern generation mode* - involves the generation of system resources, such as process patterns on which the process planning is based. This mode comprises the archiving of individual processes, the generation of group representatives, development of group processes, and the development of planning principles and rules (the design of the knowledge basis).
- *process planning mode* - involves the utilisation of system resources by planning real manufacturing processes,
- *data base management mode* - involves the generation and updating of data bases available in the system.

In semi-generative method the pattern is characterised by changeable process structure. It gives more freedom to create the various manufacturing process for a given workpiece. The pattern of the process structure is determined on the basis of technological knowledge and analysis of manufacturing processes for a given set of workpiece belonging to defined class of workpiece.

On the basis pattern, after analysis assigning the workpiece to the one of the workpiece classes, manufacturing process is generated.

* **Dr. Ing. Jan Duda**
Institute of Production Engineering, Cracow University of Technology, Al. Jana Pawla II 37, PL-31 - 864 Cracow, Poland,
E-mail: duda@mech.pk.edu.pl

2. Pattern generation mode

For a given set of similar (by processing characteristics) objects the structure of the process indicates some kind of processing order owing to increasing accuracy of surfaces being machined and also to the shape and mechanical properties of the workpiece. In this phase the structure of processes is shown.

This structure defines the sequence of activities models. Hierarchical decision nets are defined by:

- connection of activities models into a sequence of activities of higher level,
- development of decision making rules for all levels of hierarchy.

The nature of the decision process in planning is represented by the knowledge model. The decision problems are solved on several different levels and the number of level depends on the complexity of the problem. Each I-th level of details can be described by nets [2]:

$$S_I = [D_I, T_I, R_I] \qquad (1)$$

where: D_I - a set of planning decision determining the rules for selection of activity models for i-th level,
T_I - a set of activities models or transition to the other planning decision for i-th level,
R_I - relations defined on the set of planning decisions $d_I, d_{I2}, d_{I3} ... \in D_I$ and activities $t_{I1}, t_{I2}, t_{I3} ... \in T_I$ for the i-th level,
I - = 1 ... N, N - number of levels

Each operation model $t_{I1}, t_{I2} ... \in T_I$ can be described using the net of the lower level.

The knowledge base has N level of details:

LEVEL I - comprises the manufacturing knowledge determining the rules for assigning the workpiece the knowledge concerning the planning of the generalised structure of the machining process.

LEVEL II - N-1 comprises the manufacturing knowledge determining the rules of the planning of the generalised structure of the process for a given object. For a given set of similar (by processing characteristics) objects the structure of the process indicates some kind of order. Phases and stages are the basis for the separation of the parts of the process structure, where the machining of the object surface subsets should be executed with the determined accuracy.

LEVEL N - comprises the manufacturing knowledge determining the rules for the planning of the structure of the manufacturing process for the range of a particular stage and phase of the process. The manufacturing knowledge on such level allows to select an appropriate model of activity, suitable for the requirements concerning the workpiece and taking into account the constraints of the manufacturing system capabilities.

The knowledge for I-th level contains:

- relations between decision nodes and activities model,
- set of decision trees for selection of the activities model,

The rules for the selection of the activities can be presented as a decision tree. The decision tree is a graph-tree, the root of which is created by the selected attribute Q of the planning task, and the particular branches represents the values of this attribute q. The graph nodes on the higher levels of the tree have assigned further attributes occurring in the classification task, whereas the nodes on the lowest level describe the corresponding activities. The actions can be described by means of the net of the lower level.

On the basis of the model presented above, two principal types of knowledge can be distinguished [2]:

- control knowledge
- classification knowledge.

The control knowledge determines the set of activities adequate to the current planning context, so it is used to determine the possible sequence of activities. Thus the role of the control knowledge is supervisory - it controls the rule-based knowledge database, applied to solve the classification task.

The control knowledge is represented by means of frames. Each net of the I-th-level is described by the frame. The frame has three columns where the first one gives the start decision nodes, the second gives the activities models and the third the end decision nodes. There are also pointers which connect frames together.

The classification knowledge can be presented in the form of a decision tree. On the basis of the decision tree $d_{I1}, d_{I2}, d_{I3} ... \in D_I$, a set of rules (IF...THEN) defining the principles for the selection of planning actions can be determined.

In the THEN part of the rule values are assigned to parameters of the procedure related with the selected activity models and the procedure is called.

The following planning actions are subsequently realised in the pattern generation mode:

- the classification of the workpiece,
- the division of workpieces into subset of workpieces types,
- the generation of manufacturing process structures for the subset of similar workpiece,
- the development of decision- making rules for process structure selection,
- the development of decision- making rules for semi-finished product design,
- the development of decision- making rules for machining process generation,

3. Process planning mode

Taking the nature of the decision process into account, the problems solved in the decision process create a multi-level decision system which can be divided into several planning subsystems. On one hand, planning because of its complexity is made in stages, from general solution concept to particular solutions by iterative actions. On the other hand, some order can be established on each level of detail because of the characteristics of the planning task.

In the process planning mode it is possible to select the appropriate variant of the machining process by defining the structure of process components and by the parametrisation of these components.

The following process planning activities are subsequently realised in this mode:

- Selection of a generalised structure of the manufacturing process
- Reversible planning of the semi-finished product and intermediate shapes of the product
- Generating the machining process

3.1 Selection of a generalised structure of the manufacturing process

The generalised structure of the manufacturing process is selected based on the processing and geometrical characteristics of the product (Fig. 1). The product is evaluated taking into consideration the values of its attributes, according to the sequence resulting from the structure of decision tree. Using such a reasoning the activity (which means the selection and transition to manufacturing process planning on the basis of the chosen structure) can be determined.

3.2 Reversible planning of the semi-finished product and intermediate shapes of the product

The elements of the generalised structure, i.e. stages and phases, are the basis for determining the so called intermediate states describing the shape and processing properties of the workpiece, which are to be achieved as the result of an appropriate (i.e. consistent with assumed phase-stage structure, see description of the Level II ÷ N-1 manufacturing knowledge) execution of the machining process. On the basis of geometrical and processing characteristics of the product and the manufacturing knowledge the intermediate shapes and the semifinished product may be determined by using the reversible (from the product to the semifinished product) method.

This stage is realised in the following steps (Fig. 2):

- determination of the type of the semi-finished product,
- planning of the intermediate shapes of the product.

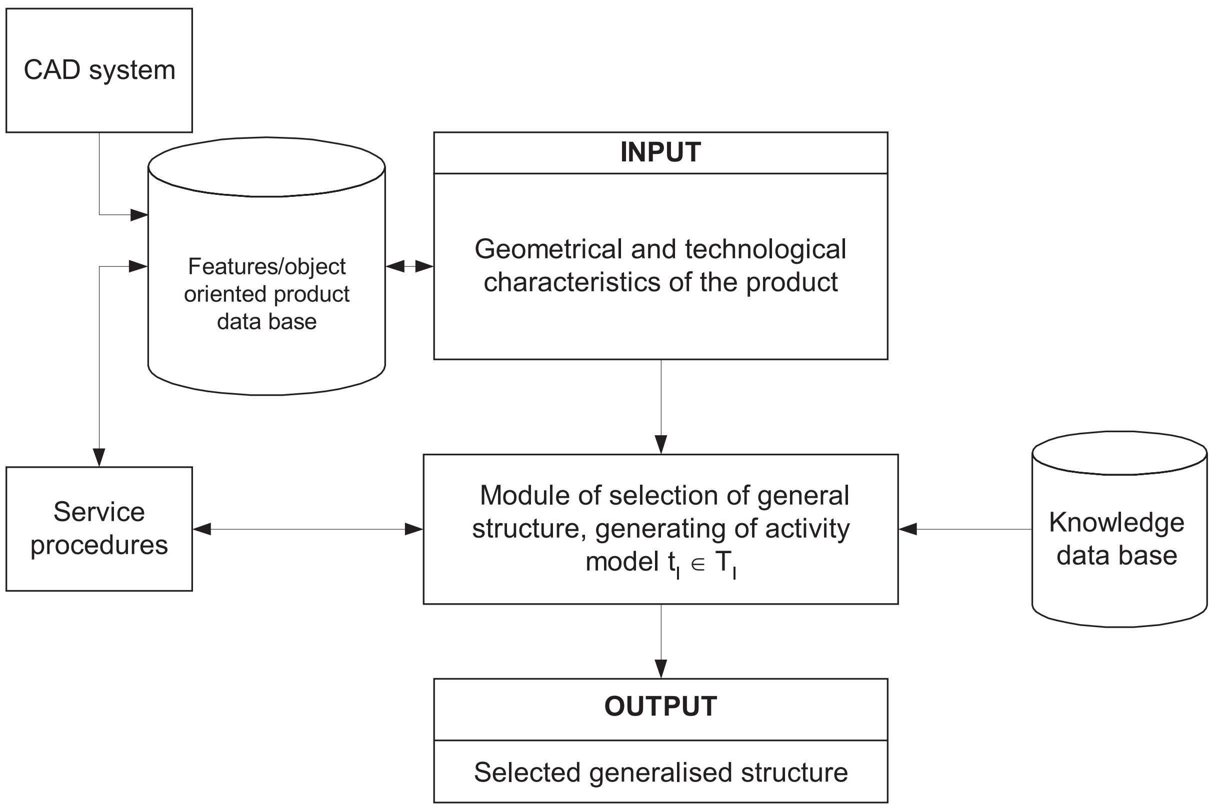

Fig. 1 Stage I- selection of a generalised structure of the manufacturing process.

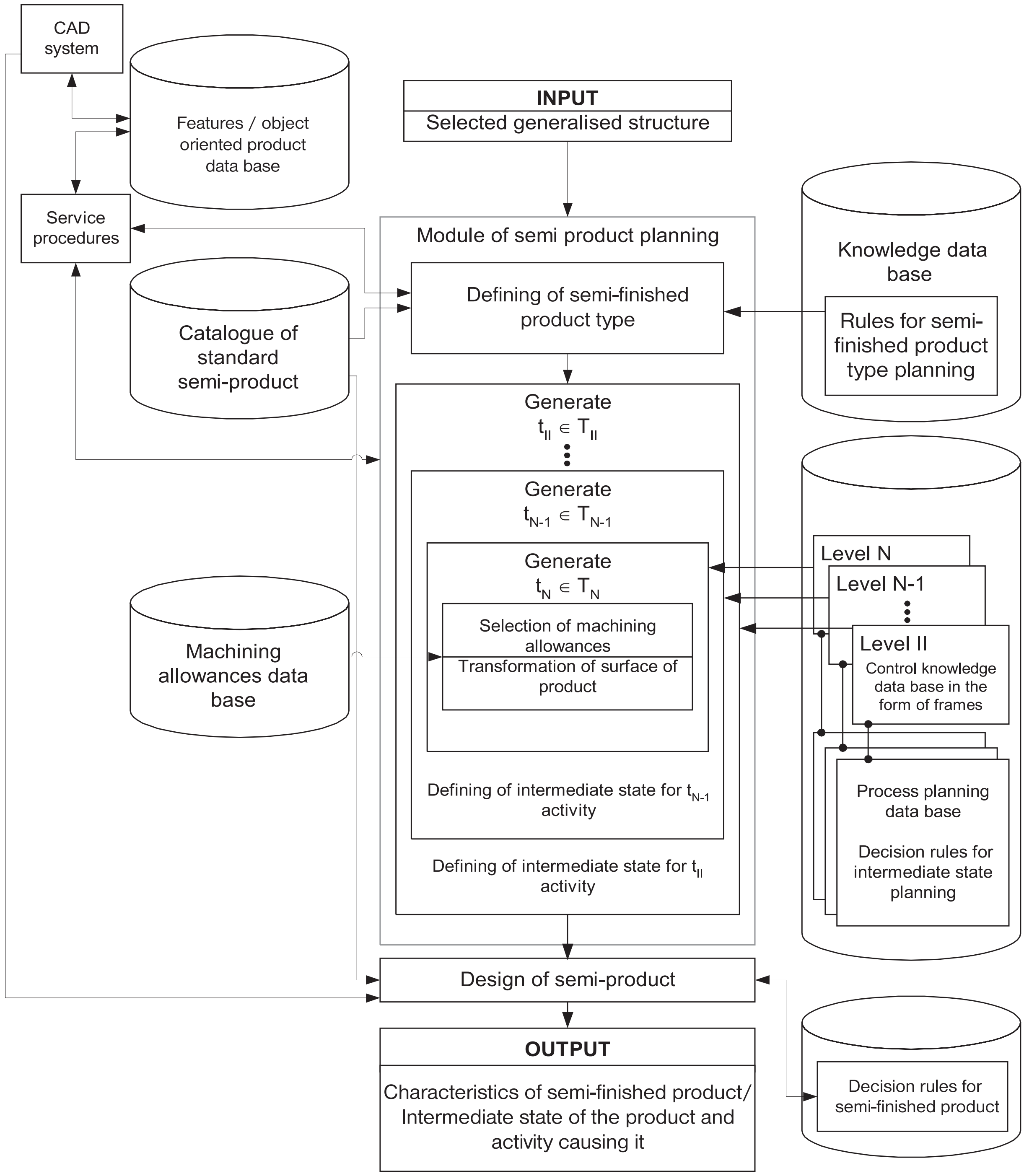

Fig. 2 Stage II -reversible planning of the semi-finished product and intermediate shapes of the product

3.3 Generating the machining process

For each step determined in the previous planning planning objective the task can be formulated in the following way: Choose the methods and means leading to an intermediate state for a given stage and phase.

For the planning objective the decision-making process will be realised in an iterative way. The process is generated in the following steps:

- identification of allowances,
- selection of the range of machining,
- selection of the workpiece fixture variant,

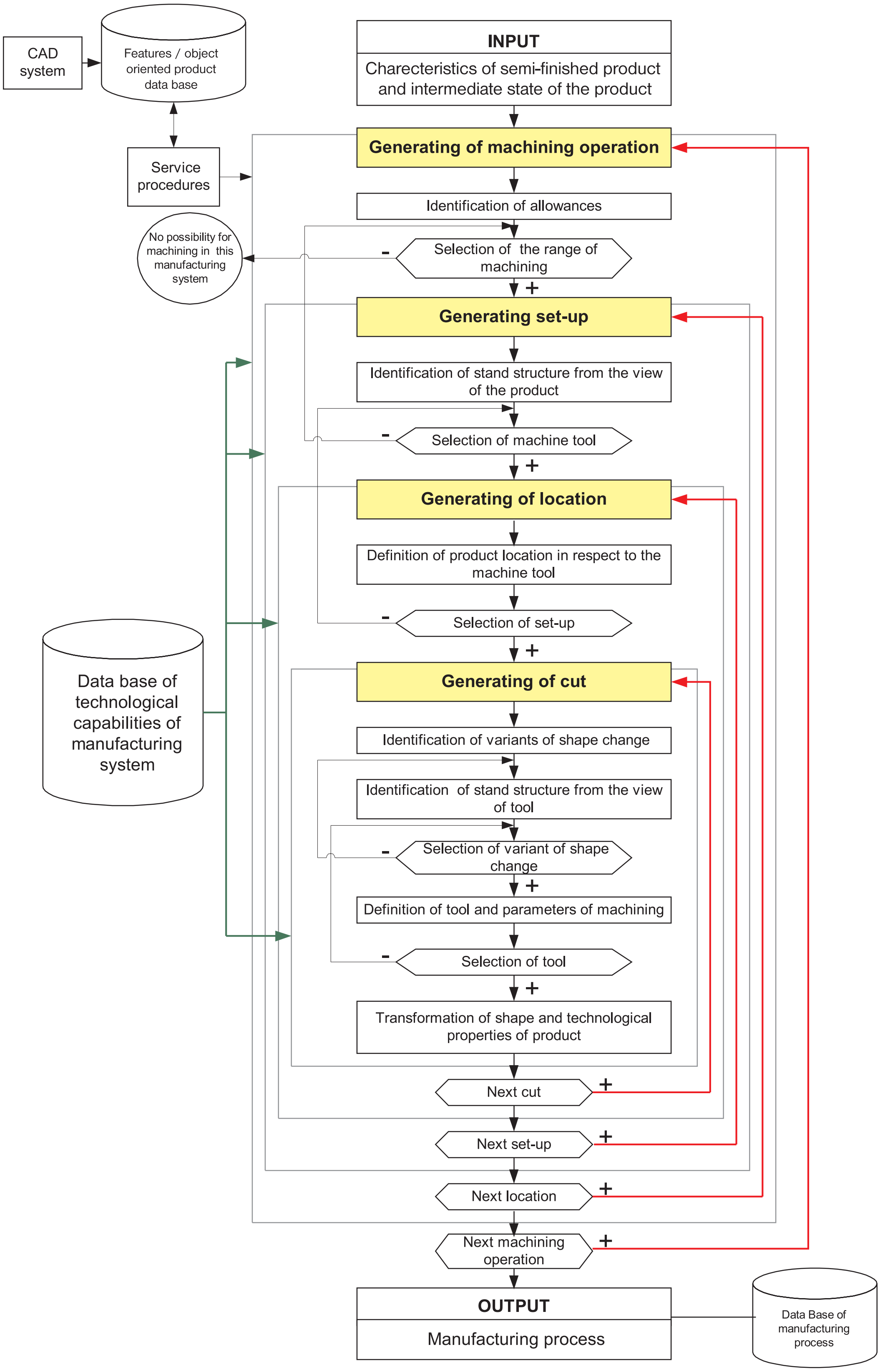

Fig. 3 Stage III- generating the machining process

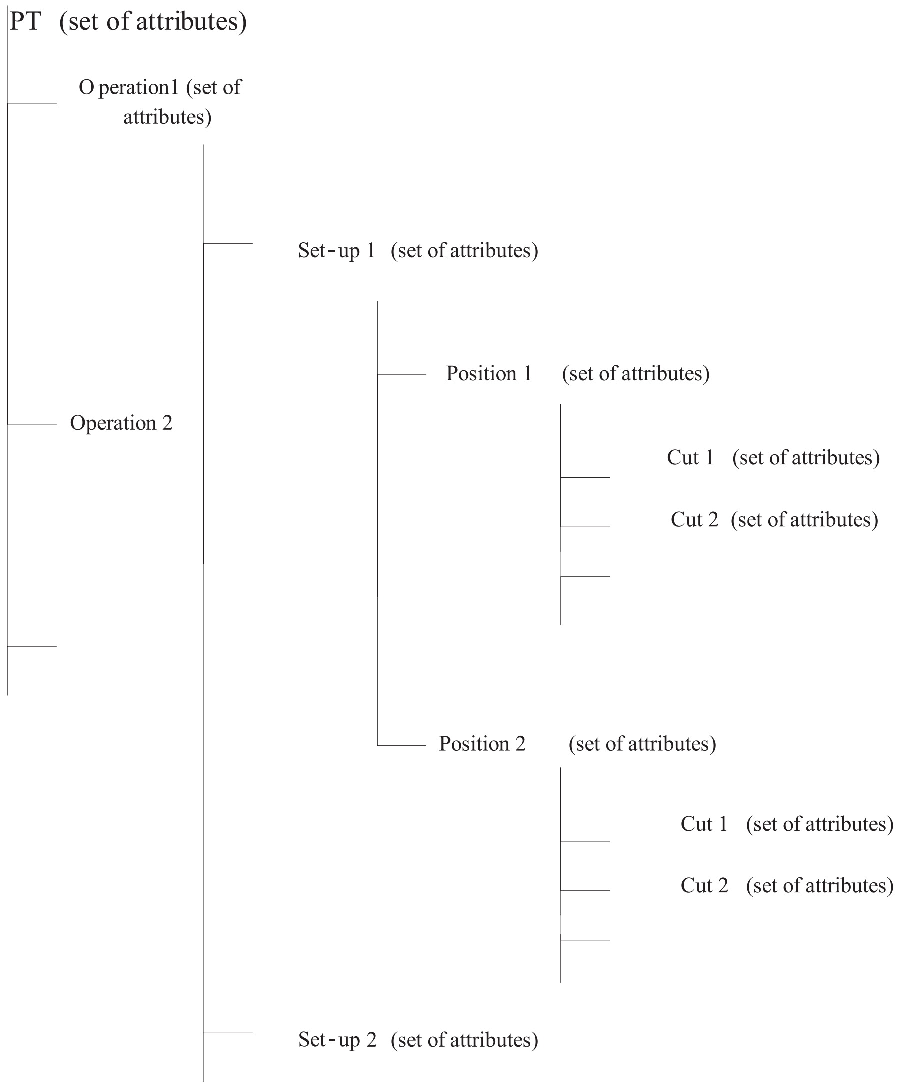

Fig. 4. The hierarchical structures of the machining process plan.

- identification of the stand structure from the view of the product,
- selection of machine tool,
- definition of product location,
- selection of set-up
- identification of stand structure from the view of tools,
- selection of variants of shape change,
- selection of parameters for the machining variant,
- selection of tool.

After defining the model of shape change and the way, in which it is obtained, the transformation of the workpiece shape and processing properties is carried out. The process will be repeated until the intermediate shape, which corresponds to the realised goal, is obtained.

In this way the process plan in the form of tree Fig. 4 for the given product is generated.

$$PT = [Operation[Set-up[Position[Cut[Pathway]]]]]$$

4. Implementation aspects

The diagram of the computer aided process planning system operation presented above was implemented using the internal programming language of EXSYS PROFESSIONAL v.4.0 shell expert system. The mechanisms for running external programs (written for the WINDOWS environment) and for the data exchange between the EXSYS and external programs were utilised. It has been verified by building the expert system for process planning for rational parts manufactured in the CPTORl machining center.

Reviewed by: J. Peterka, I. Kuric

5. References

[1] Duda J. Kwatera M. Architektura systemów komputerowego wspomagania projektowania procesów technologicznych, International DAAAM Workshop CA Systems and Tehchnologies, 29-30 September 1998, Kraków, Polska

[2] SAMEK, A., DUDA, J., POBOŻNIAK, J.: Reasoning in Expert System For Machining Process Planning In Concurrent Engineering Environment, Proceedings of the CIRP International Seminar On Intelligent Computation in Manufacturing Engineering, 1-3 July 1998, Capri, Italy

[3] SAMEK, A., DUDA, J. Sformalizowany opis metod projektowania procesów technologicznych, Konferencja Naukowo- techniczna Projektowanie Procesów Technologicznych, 20-21 październik 1998, Poznań