Edward GAWLIK
Cracow University of Technology, Cracow, Poland

THE ANALYSIS OF METHODS FOR COMPUTER AIDED PROCESS PLANNING

Summary: This paper presents the analysis of most important methods for computer aided process pla ning and application possibilities in practice.

1. Introduction

Process planning can be defined as the function which establishes the sequence of the manufacturing processes to be used in order to convert a part from an initial to a final form, where the process sequence incorporates process description, the parameters for the process and possibly equipment and/or machine tool selection.

The planned process should be optimum, that is production based on this process, final part should be realized with a specified time and the lowest production cost. All this leads to the need for computerized systems that will allow the process planning function to be performed either totally or partially by a computer, providing the user with optimum process plans in a quick consistent fashion.

Input data information for computer aided process planning system will be formalized part description (half-finished product description and finished part description) and production size. Whereas output data information is a formalized description of planned process. First of all this description should contain:

- general information about: part name, part class, drawing of part and its number (code symbol),
- technological process structure including its elements (technological operations, set-ups, positions, cuts),
- information for every operation: operation name (string description), operation number (code symbol), production department name (code symbol), work (machining) station name and type (code symbol of work station), part drawing before and after carrying of operation, specification of part fixtures, specification of tool fixtures, kinds and sequence of technological cuts, technical standard operationtime, control program,
- information for every technological cut: word description of cut, its number, kind and type of tool and its characteristic (code symbol), machining parameters for example: speed of cutting – v, rotational speed – n, feed – p), main time of cut (machine time). Components taken into consideration in computer aided process planning are shown on Fig. 1.

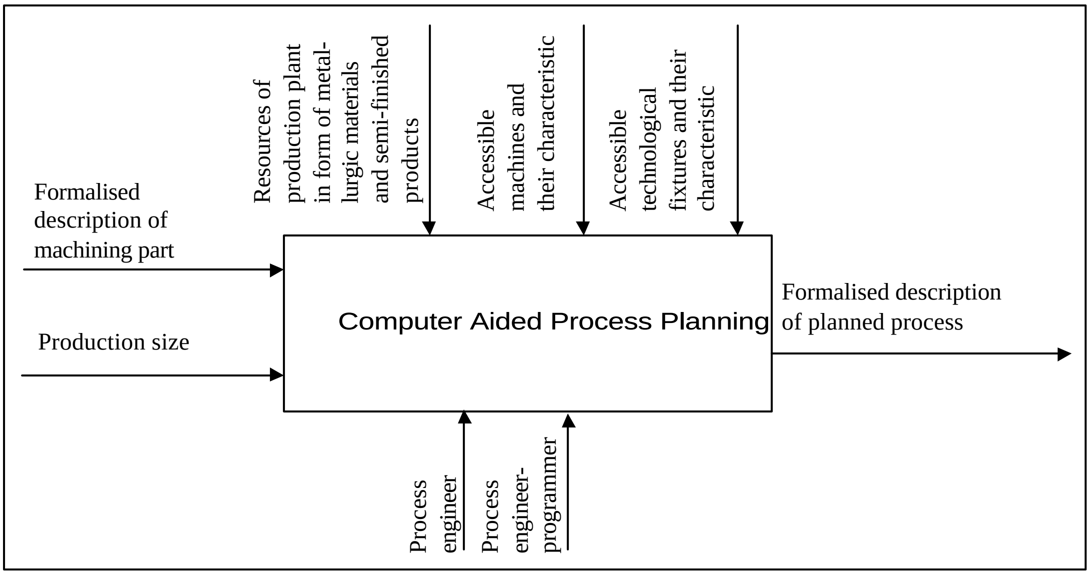

Fig. 1. Components taken into consideration in computer aided process planning

2. Characteristic of methods to computer aided process planning

Computer aided process planning is carried out with utilisation of two major methods:
- variant method,
- generative method.

A number of computer aided process planning systems combine both methods, so that a third category is now recognised, the semi-generative method. It is an interim method to the time of complex development generative method.

2.1. Variant method

The variant method of computer aided process planning is comparable with the traditional manual method where a process plan for a new part is created by identifying and retrieving an existing plan for a similar part (sometimes called a master part) and making the necessary modifications for the new part. According to applied master for identification and retrieval of process plan the following versions of computer aided process planning are used:
- planning on the basis of a set of individual processes,
- planning on the basis of a typical process model,
- planning on the basis of a group process model.

One of disadvantages of variant method is that the quality of the process plan still depends on the knowledge background of a process planer. The computer is just a tool to assist in manual process planning activities. However, the variant method is still popular. The main reasons probably are:
- the investment in hardware and software is less. Vendors for variant systems are more available now as compared with generative systems,
- the development time is shorter and manpower consumption is lower. Installation is easier than for generative systems,
- in the current situation, the variant system is somewhat more reliable for use in real production environments, so it is reasonable for current production environments, especially for small and medium sized companies.

2.1.1. Planning on the basis of a set of individual processes

This method of computer aided process planning provides process plan selection for a given part from the set of individual process plans existing in database. Database should be organized in a manner allowing to retrieve it on given set of part features basis (for example specified feature code). The flowchart for process planning procedure on the basis of a set of individual processes is shown in Fig. 2.

2.1.2. Planning on the basis of a typical process model

Typical process plan is a single common process for the part family, substituting planning of individual processes for every part separately. Part family, for which the typical plan is established, belongs to the *parts technological type.*

The parts technological type results from choosen coding and classification system [1],[3],[4],[5],[6]. Part family consist of the different parts, because the criterions of classification specify only general similarity features.

The flowchart for a procedure of typical process planning is shown in Fig. 3. It was developed on the assumption that specified set of parts exist, but process plans for this parts don't exist. Creation of typical process plans database is the result of designing activities.

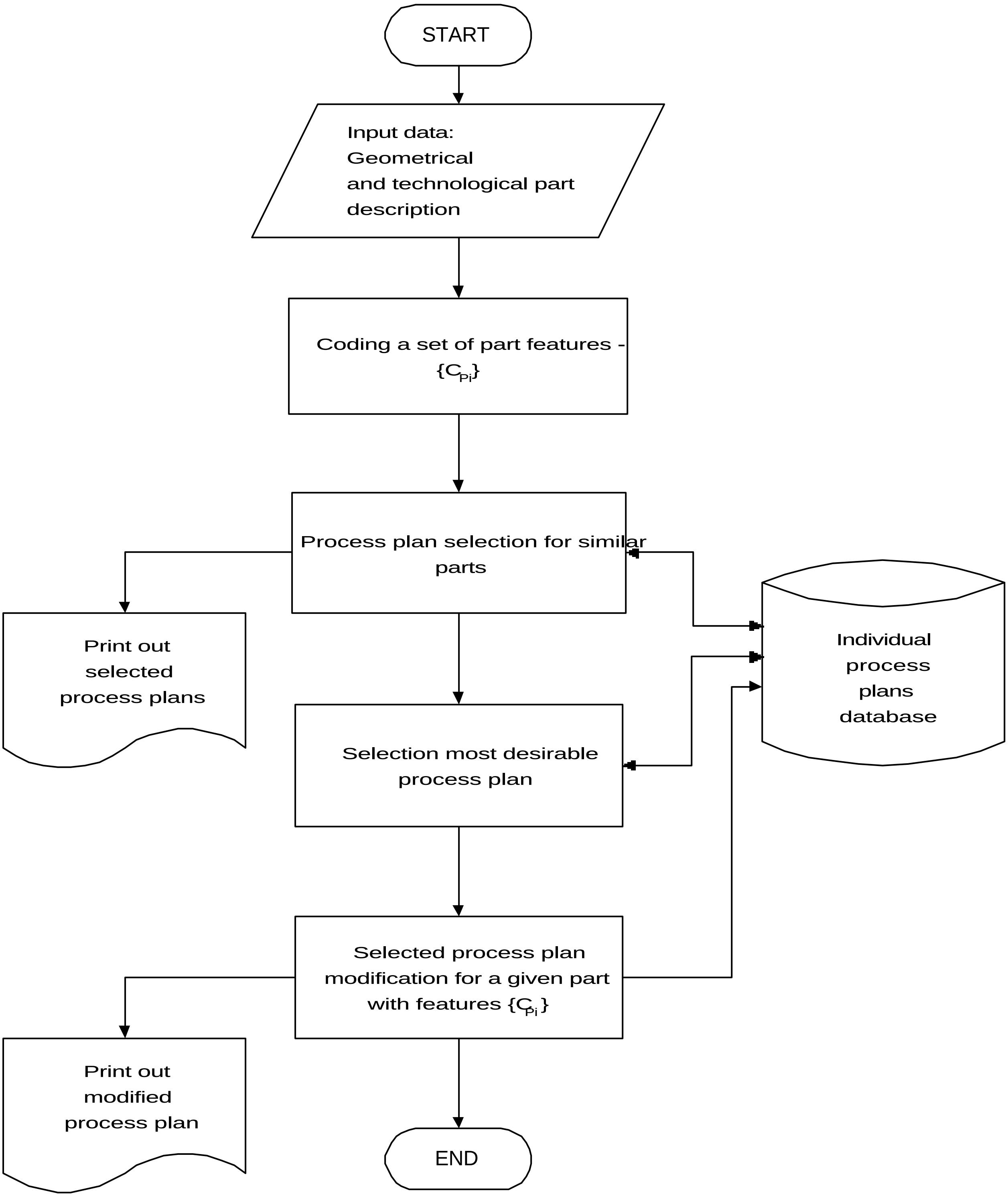

Fig. 2. The flowchart for process planning procedure on the basis of a set of individual processes

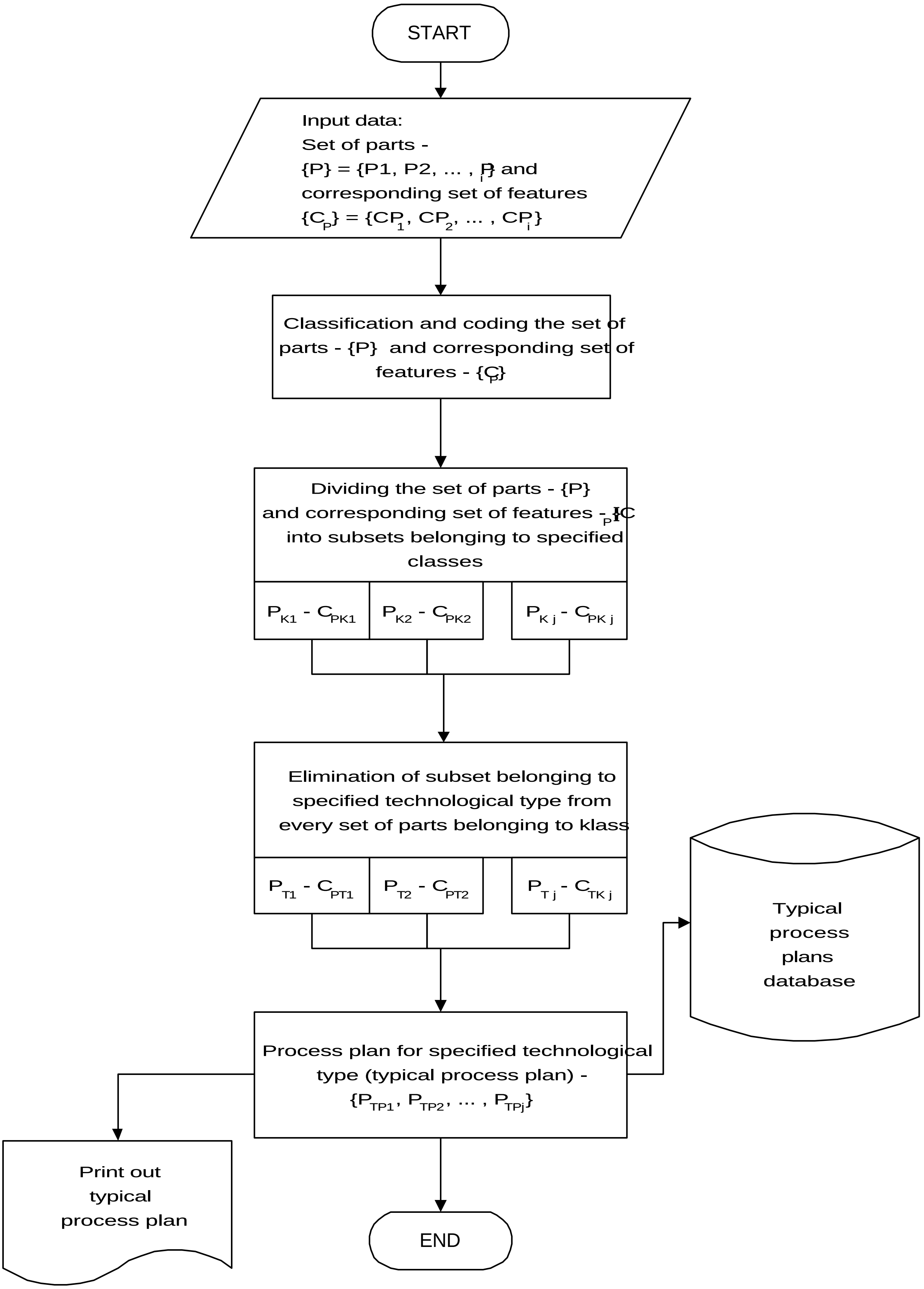

Fig. 3. The flowchart for procedure of standard process planning

If it is necessary to develop technological process which does not belong to the set of parts, one should make an assumption that typical process plan database exist. In this case, procedure

of selection typical process from existing database should be realized . The flowchart for this procedure is shown on Fig. 4.
One should give attention to correct understanding of typical process plan and its realization in production process that is typical process. Although the process plan is typical, practical realization can be different.

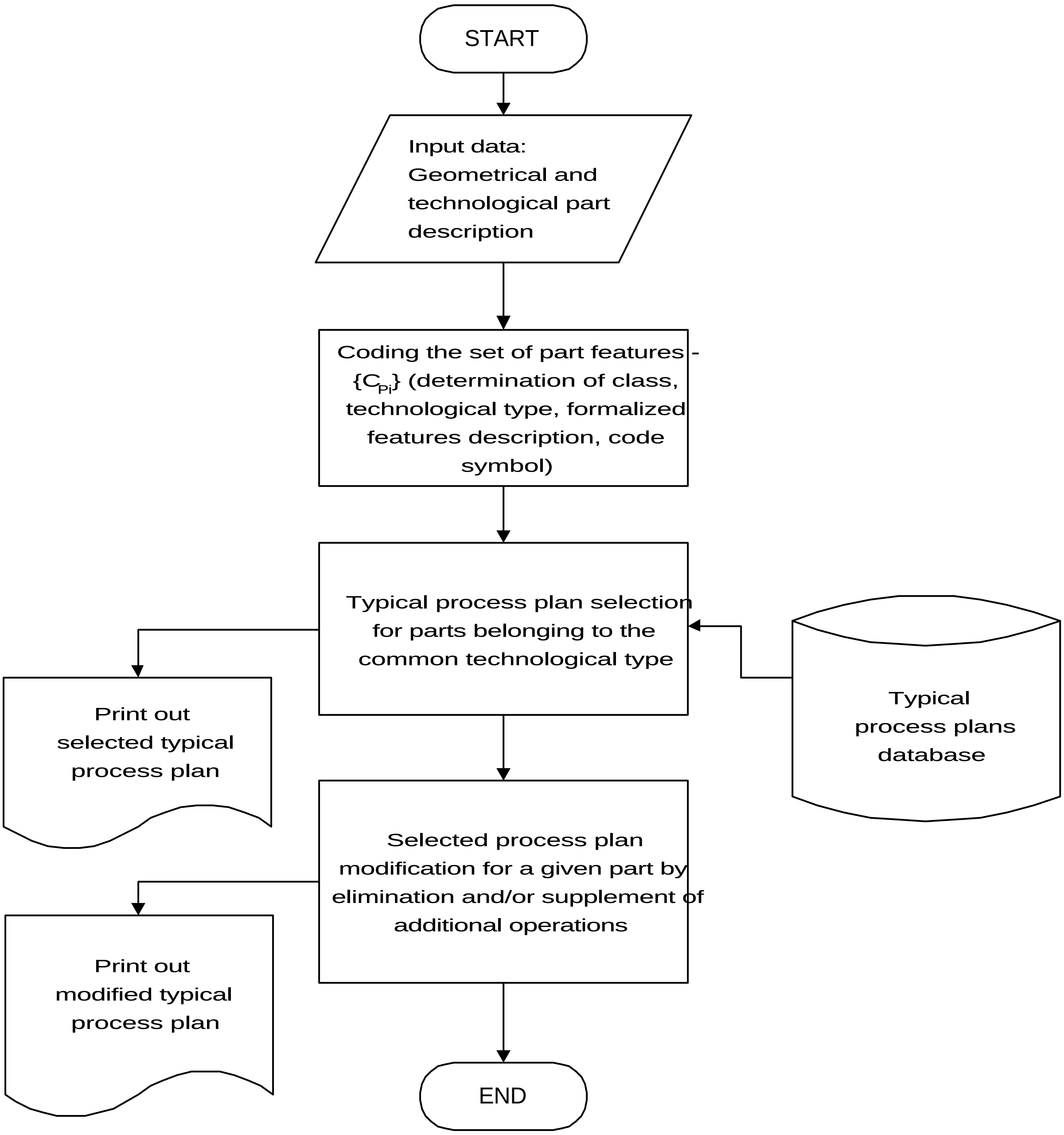

Fig.4. The flowchart for typical process plan selection

Case I

Plans of so-called *typical basic processes* for the specified part technological type are developed. Process plans consist of general data as a framework. Sets of parts that belong to the given technological type are relatively large. After selection of typical process plan for the specified part from database it is necessary to make its modification by elimination and/or supplement of additional operations. Process realization for every part that belongs to the given technological type has individual character.

Case II

Plans of so-called *typical operative processes* for specified part technological type are developed. In this case, process plan contains the most essential details concerning specified operations. Process plan concern technological type of parts with considerable similarity, that is part which are manufactured with the use of the same basic operations.

There are two kinds of typical operative process plans:

– plan of typical operative process with homogeneous course,
– plan of typical operative process with homogeneous course and witch inclusion of additional operations,

The first kind of typical operative process plan can be applied to a not large set of parts that belong to specified technological type and with complete similarity that is parts which are manufactured with the use of the same operations. Process realization can be realized on separate workstands and without time relation (scheduling) for every part.

The latter kind of typical process plan allows to increase the number of parts that belong to the given technological type. Their complete similarity it is not required. Process plan as well as its realization can be supplemented by additional operations for some parts.

2.1.3. Planning on the basis of a group process model

In the planning on the basis of a group process model, the set of parts {P} intended for machining and corresponding set of features $\{C_P\}$ are divided into groups of technologically similar parts. Synthetic (hypothetical) representative for every technological group is created, that is part that possesses all features of parts which belong to the given technological group. Group process plan for synthetic representative of group is developed. The flowchart for procedure of group process planning is illustrated on Fig. 5. If it is necessary to develop process plan for specified part, problem is reduced to selection of suitable group process plan from existing database (Fig. 6). That requires classification and coding of a given part features and assignment to the specified technological group, for which group process plan exist in database.

After selection of group process plan the next step is its modification by elimination of specified activities (for example cuts).

Course of group process, except operations uniformity, is characterized by operations synchronization, that is part series, that belong to the given technological group, can be machined directly one after another on the same workstands equipped with suitable technological tooling.

Computer aided process planning procedures take also advantage of mixed models as master:

– model of individual process with group operations,
– model of typical process with group operations.

In those cases, courses of technological processes for specified parts must be the same, so as to get to workstands realization of group operations in a specified time.

2.2. Generative method

The generative method process plans are generated by means of decision logic, formulae, technology algorithms and geometry based data. Generally, format of input to CAPP systems can be divided in two categories: as a text input, where the user answers a number of questions (defined as interactive input), or as graphic input, where the part data is gathered from a CAD module (defined as interface input).

Some alternative approaches to generative process planning are used [1]:

– decision trees,
– decision tables,
– axiomatic approach,
– artificial intelligence-based approach and expert systems.

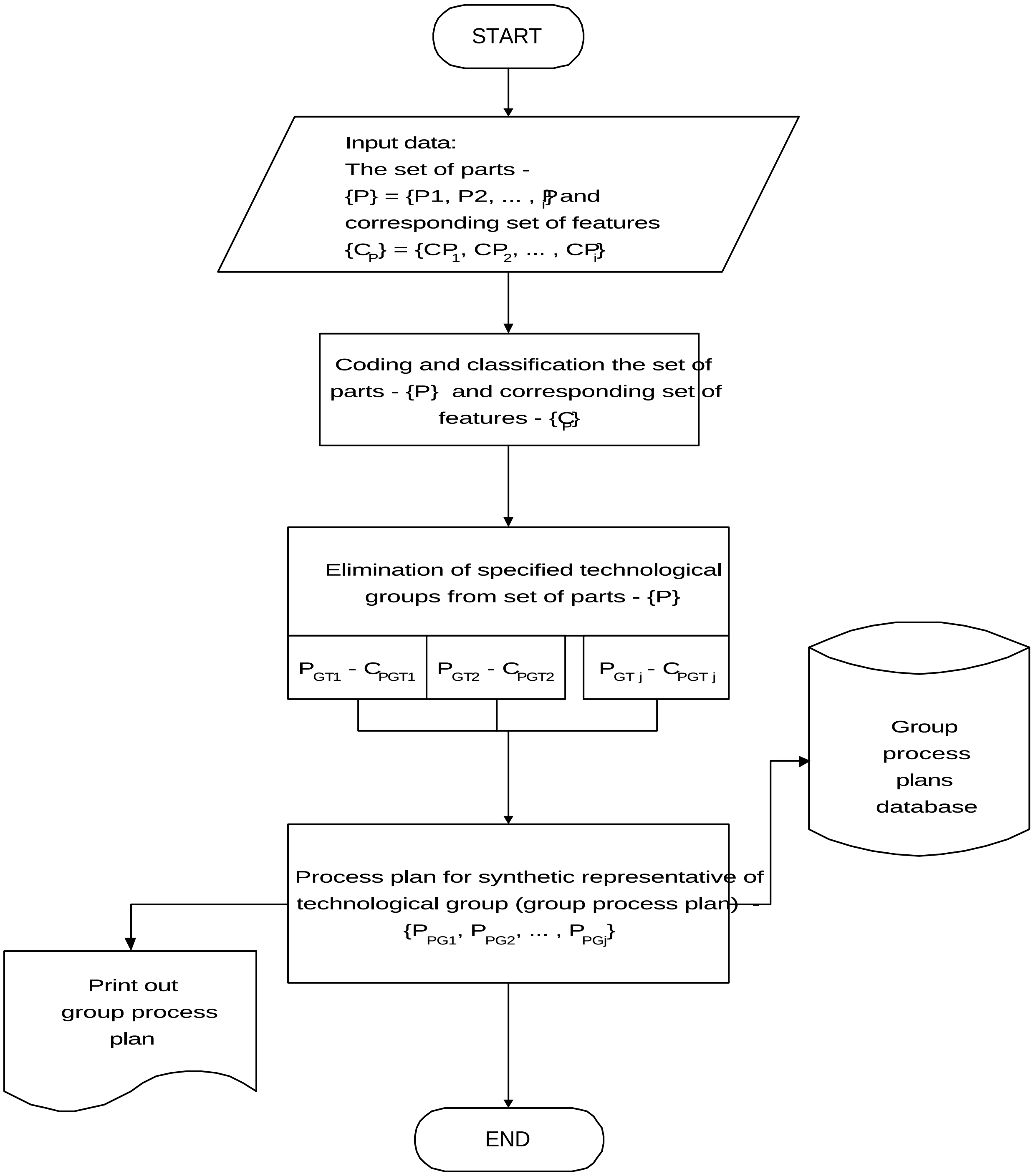

Fig. 5. The flowchart for procedure of group process planning

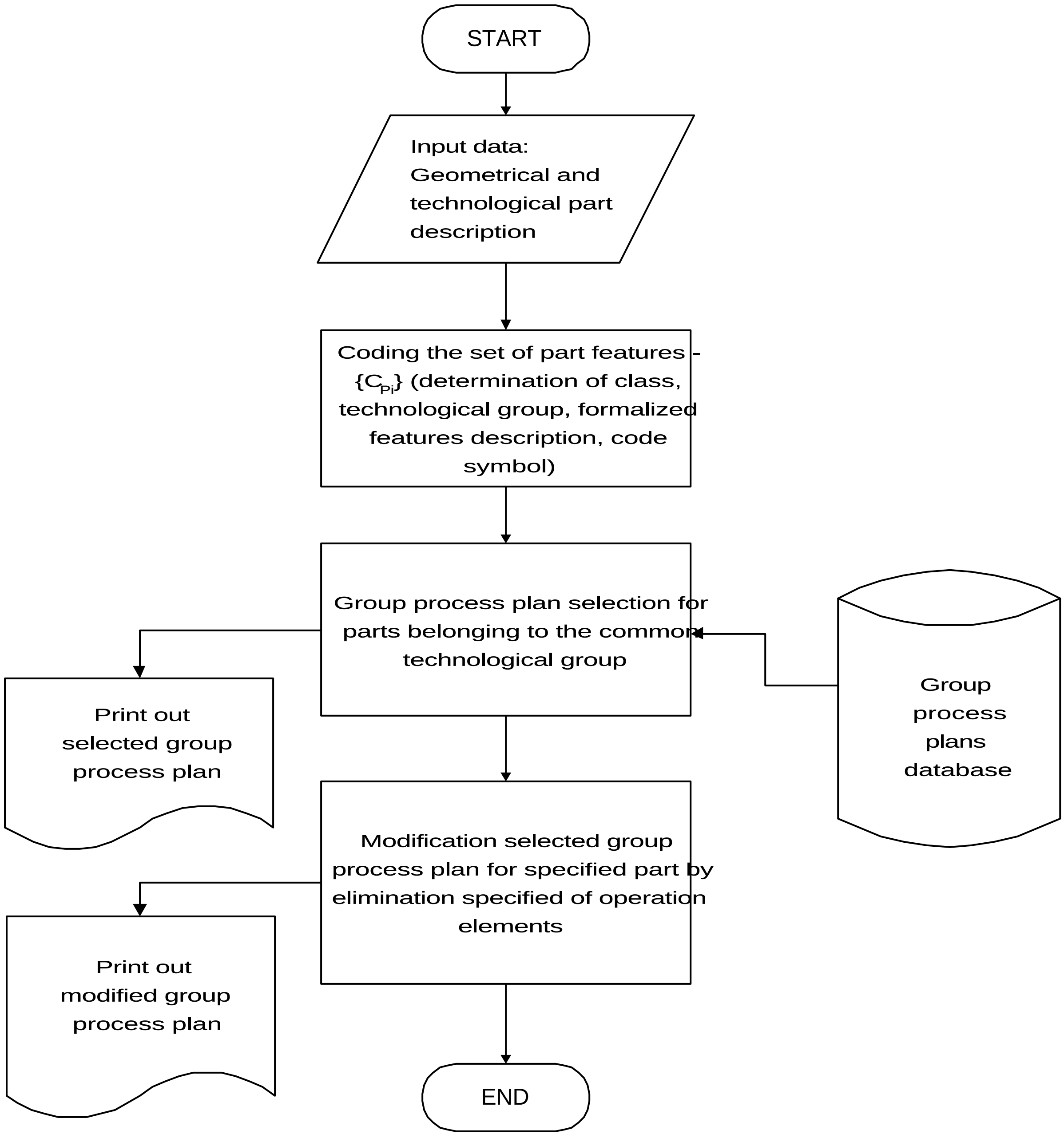

Fig. 6. The flowchart for select procedure of group process plan

2.2.1. Decision trees

A decision tree is comprised of a root and a set of branches originating from the root. In this way paths between alternate courses of action are established. Branches are connected to each other by nodes, which contain a logic operation such as an “and” or “or” statement. When a branch is true, travelling along the branch is allowed until the next node is reached, where another operation is assigned or an action is executed. Decision trees can call another sub-tree, for example DCLASS, a typical visible tree structure system [1], [7], [8]. Sub-tree can call up to 25 additional sub-trees. Decision trees can either be used as computer or represented as data. As a computer code, the tree is converted to a flowchart. The starting node is root and every branch represents a decision statement which is either false or true. Decision trees have certain definite benefits over decision tables:

– trees can be updated and maintained more easily than can decision tables,

- selected branches of the decision tree may be extended to a considerable depth if necessary, while other branches may be quite short, which is more difficult to do with decision tables,
- some branches of the decision tree may be used to define TYPE, and others ATTRIBUTES, which results in relatively small trees,
- trees are easy to customize, visualize, develop and debug.

2.2.2. Decision tables

Decision tables organize conditions, actions and decision rules in tabular form. Conditions and actions are placed in rows while decision rules are identified in columns. The upper part of the table includes the conditions that must be met in order for the actions (represented in the lower part of the table) to be taken. Decision table should contain the actual rules conditions specified in the design. According to the rule representation, decision tables can be classified as follows:

- limited entry decision tables that represent the exact conditions (input values) as true or false entries,
- extended entry decision tables that specify the condition but not the value,
- mixed entry decision tables whereby sequenced and unsequenced actions can be entered. Sequenced actions rate a sequence number while unsequenced actions do not rate one.

2.2.3. Axiomatic approach

Its intention is to provide a logical framework for designing products and processes. A set of desired characteristics of the design, known as *functional requirements* (FRs), must be defined to establish a *design range*. A set of *design parameters* (DPs) must also be identified so that the system range can be defined. Axiomatic approach to process planning is used to define and simplify the relation between the FRs and DPs through a set of axioms. The entire framework is based on two axioms:

- Axiom 1 – The independence axiom - *Maintain the independence of functional requirements,*
- Axiom 2 – The information axiom – *Minimize the information content.*

To implement axiomatic design in process planning, the following steps are applied:

1) List all the design (or production) parameters to be evaluated,
2) Divide the surfaces to be produced into surface groups, each of which is to be machined by a single machine,
3) List candidate machines for each surface group,
4) Evaluate all alternatives for the production and machine parameters,
5) Obtain the total information content and select the best machine combination based on the information content.

2.2.4. Artificial intelligence technique and expert systems

Artificial intelligence techniques like formal logic, describing components and expert systems for codifying human processing knowledge are also applicable to process planning problems.

Due to the rapid development artificial intelligence techniques, generative process planning systems are built as expert systems with technological knowledge representation, which specifies general and detailed rules of process planning. They have involved object-orientated programming techniques and virtual single manufacturing database techniques. Some new generation systems have employed fuzzy logic and neural network techniques and machine learning approach [2].

The major areas of activities in generative approach to process planning are:

- determination of part characteristic,
- semi-product designing,
- elementary activities selection,

– machine selection,
– technological instrumentation selection,
– technological operation sequencing,
– tool selection,
– machining parameters selection,
– time and cost calculation.

Examples of developed generative process planning systems are APPAS, CMPP, EXCAP, XPLAN.

2.3. Semi-generative method

Semi-generative method is interim approach used when problems is building purely generative process planning system have occurred. The semi-generative method can be characterized as an advanced application of variant technology employing generative type features. Systems utilized semi-generative method to process planning should co-operate with planner, who posses technological knowledge. The planner's responsibility is the interpretation of decision data and/or working drawing. There are following ways of this method:

– the variant method can be used to develop the general process plan, then the generative method can be used to modify,
– generative method can be used to create as much of the process plan as possible then the variant method can be used to fill in the details,
– process planner can select either generative mode for complicated part features or variant mode for fast process plan generation.

3. Conclusion

To summarize, the advantages of computer aided process planning are typical of those accrued when any procedure is automated via computers. A brief list of these advantages are: reduced clerical effort, fewer calculations, fewer oversights in logic, immediate access to up-to-date information, consistent information, faster response to engineering or production changes, use of latest revisions, more detailed and uniform planning, more efficient use of resources.

Literature

[1] Zhang H. C., Alting L.: Computerised Manufacturing Process Planning Systems. Chapman & Hall, 1994.
[2] Lu S.C.-Y., Zhang G.: A combined inductive learning and experimental design approach to manufacturing operation planning. Journal of Manufacturing Systems, 9(2) 1990.
[3] Houtzeel A.: The MICLASS System. Proceedings of CAM-I's Executive Seminar-Coding, Classification and Group Technology for Automated Planning, CAM-I, Arlington, Texas. 1976.
[4] Feld M.: Planning and automation of technological processes of machine elements. WN-T Warszawa, 1994 (in polish).
[5] Collective work: Uniform design-technological classifier of production parts. Standard Publications, Warszawa, 1977 (in polish).
[6] Opitz H.: A Classification System to Describe Workpieces, Part I, Pergamon Press, UK, 1970.
[7] CAM Software Inc. DCLASS Technical and System Manual, CAM Software Inc., Provo, Utah, USA, 1985.
[8] DCLASS Technical Manual, CAM Software Research Laboratory, Brigham Young University, Provo, Utah, USA, 1985.