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PRELIMINARY PLANNING OF PART MANUFACTURING PROCESS

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Abstract

The solution of manufacturing process planning is a complicated and combined problem therefore it is necessary to divide the tasks into hierarchical levels. The first level of this hierarchy is called preliminary process planning, which is the conceptual level of the planning process.

The most important tasks of preliminary process planning are (1) the preparation of process planning of blank manufacturing, the part manufacturing and the assembly; (2) correction of the design documents in the view point of manufacturability and assemblebility; (3) selection of manufacturing system; (4) analysis of the manufacturing tasks and estimation of manufacturing cost and time data.

The aim of this article is to define these tasks, the connections and a possible process of preliminary manufacturing process planning.

Keywords: manufacturing process planning, preliminary process planning, CAPP, manufacturability analysis, blank type selection, cost and time estimation.

1. Introduction

The production process of a new product consists of two main steps. The first is the design process, when the construction of the product is developed by satisfaction of the functional expectations, the material restrictions and other guidelines. The second step is the manufacturing process planning, when the processes, which are necessary for the manufacturing, are determined.

The manufacturing process planning is a complicated and combined problem therefore it is necessary to divide the tasks into hierarchical levels (HORVÁTH [3], TÓTH [9], ELMARAGHY [1]). In this manner the process plan is defined successively, step by step, up to down. The 'up to down' term means that the planning process progresses from the complex tasks to the simpler and the process plan becomes more detailed and concrete.

In technical literature there is no unified standpoint about the number and the tasks of these planning levels. The five level model of HORVÁTH divides the whole process planning as follows: (1) preliminary process planning, (2) planning the sequence of operations, (3) operations planning, (4) operation elements planning and (5) post processing (*Fig. 1*). The preliminary process planning is a less-researched field and our article tries to summarise the tasks and connections of this planning level and define a possible process of preliminary process planning.

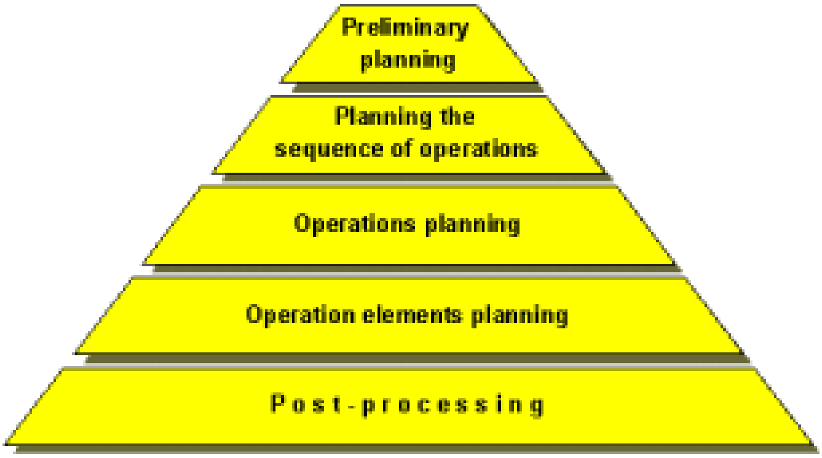

Fig. 1. Levels of manufacturing process planning

2. The Tasks of Preliminary Process Planning

The preliminary process planning is the highest level of manufacturing process planning, the strategy of the manufacturing (SZEGH [8]). In this stage we have to make many decisions which have essential role in the point of view of tasks of lower levels, so these decisions determine the quality of the final plan.

The preliminary process planning is different from other levels in many aspects. The most important difference is that some tasks regard the assembled product as a basic unit instead of part. In other words the preliminary planning examines in the same time every part of the product and their influences whereas the object of other levels is only one part.

The tasks of the preliminary process planning are as follows:

- Collecting the technological data for the process planning of the blank manufacturing, the part manufacturing and the assembly; rationalising of manufacturing process; preparing of manufacturability and assemblebility correct part, assembly and blank design documentation.
- Determining the strategy of process planning which means the selection of manufacturing systems and actual manufacturing variant.
- Analysing the manufacturing tasks, estimation of manufacturing cost and time data.

The validity of the mentioned tasks is the function of actual manufacturing task. The planning task is different if the manufacturing task is part or product manufacturing, or it is a new or a returning order.

In the case of returning order the task of preliminary planning is, depending on the load capacity of manufacturing systems and the batch quantity, the selection of the optimal manufacturing variant and estimation of manufacturing cost and time data.

In the case of new order the process of preliminary planning is more complicated. The necessary steps are the following:

– Preparation of manufacturability and assemblebility correct design documentation.
– Selection of blank types and design of blank parts.
– Analysis of manufacturing tasks.
– Assigning the manufacturing system.
– Selection of the optimal manufacturing variant.
– Estimation of manufacturing cost and time data.

The connection between the preliminary planning and other areas is determined by these planning tasks. Briefly the data flow between the preliminary planning and the management, the design engineering unit and the production planning unit is bi-directional, but the connection to fields of process planning is just data supply (*Fig. 2*).

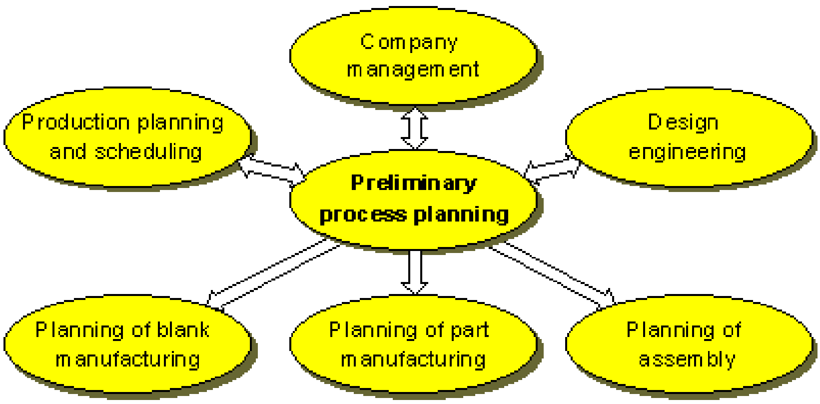

Fig. 2. The connection between the preliminary planning and other areas

The preliminary planning is a complicated process therefore its internal and external data flow is complicated, too. Follow the data flow for understanding it.

3. The Process of Preliminary Planning

The aim of manufacturing process planning is to generate the manufacturing documentation for fulfilling of planned production projects by production unit considering the financial aims of the company management. Therefore one of the basic item of information of preliminary planning is the long terminate production plan.

The actual design documentation, which consists of assembly drawings, detailed drawings, BOM lists and other descriptions, is provided by the design engineering unit.

3.1. Design Analysis

The first step of preliminary planning is the design analysis (*Fig. 3*).

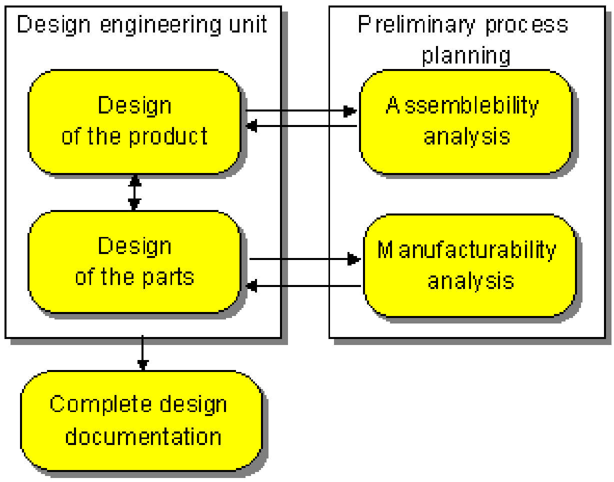

Fig. 3. Design analysis

The aim of design analysis is rationalising of manufacturing process, lowering costs by analysing the product from the viewpoint of manufacturing. The design analysis indicates a feedback to the design engineering unit and it assures the correct and complete design documentation. The design analysis consists of two main tasks: the analysis of assemblebility and the analysis of manufacturability.

The purpose of analysis of assemblebility is to study the existence of topological conditions of assembly. This is a complicated problem, which is hard to automate and it needs the detailed understanding of the functional connection of the product. The assemblebility analysis contains the measurement chain analysis, which is an exact mathematical problem. During the calculation of tolerances each part is controlled and/or determined considering the number of series, the process of assembly and the condition of manufacturing equipment. The result of assembleblility analysis indicates design modification demands to design engineering unit.

The second step is the manufacturability analysis of the parts, which may indicate design modification demands, too. The analysis of manufacturability can be executed in two levels. The global level concentrates on the theoretical manufacturability of each feature, in fact it is an aspect of the design process which is the problem of design of manufacturing (e.g. design for casting). The other level is called local level and it studies the possibility of manufacturing considering the available manufacturing equipment. The necessary data of this analysis is the manufacturing capacity (list of manufacturing methods, accuracy, size of workspace, etc.) of manufacturing environment (machine tools, tools, jigs and fixtures, etc.).

The analysis can be made on two approaches (GUPTA et al. [2]).

In the case of rule-base approach (*Fig. 4a*) the analysis is executed directly on geometrical data by rules. The rules are domain and environment specific, because the general solution of the problem is impossible or it needs so large a set of rules, which can be unmanageable and unutilizable.

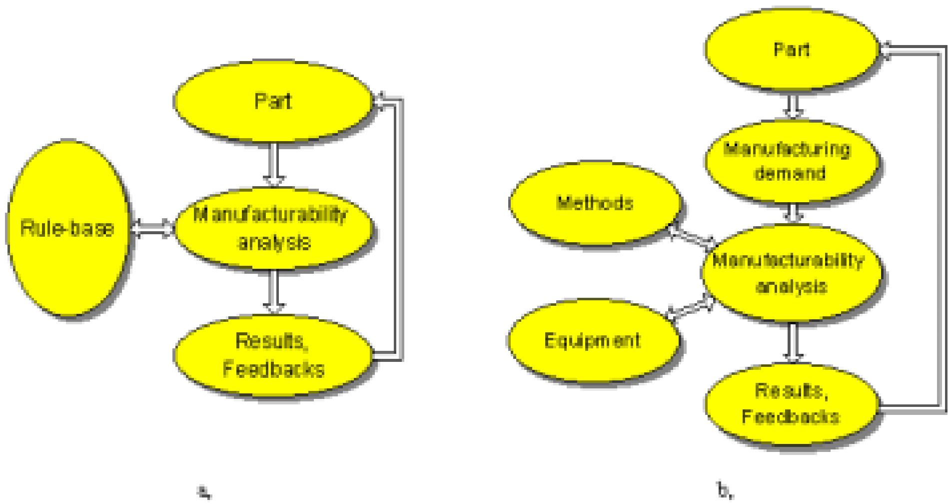

Fig. 4. a) Rule-base approach of manufacturability analysis; *b)* Plan-base approach of manufacturability analysis

When we apply the plan-base approach, the base of the analysis is a skeletal process plan (*Fig. 4b*). On the strength of geometrical data of the part the manufacturing demands are detected, and manufacturing sub-processes can be assigned. Considering the characteristic of the potential manufacturing systems, the analysis is executed. The analysis is suitable if the required manufacturing demands can be satisfied on the potential manufacturing system. If it is not possible the reasons of failure must be disclosed.

There are many methods for measure of manufacturability (GUPTA et al. [2]).

The most basic and the simplest method is the binary method which simply reports whether a part can be manufactured or not.

During the qualitative measure qualitative grades are assigned to manufacturability, like ‘poor’, ‘average’, ‘good’, ‘excellent’. The weakness of this method is that it is hard to interpret these categories, especially the assemblebility and the manufacturability have to be measured together.

The abstract quantitative method assigns numerical ratings along some abstract scale. As qualitative measuring scheme, it can be difficult to interpret such measures or to compare and combine them.

The manufacturability can be characterised by cost and time data, which provide an easy interpretation and comparison.

At the end of design analysis the correct design documentatio of the product and its parts are provided.

3.2. Preparation of Sub-processes of Planning

The manufacturing process planning consists of three planning fields (*Fig. 5*): the planning of blank manufacturing, part manufacturing and the assembly. The aim of these stages are to define the manufacturing process of blanks and parts, and the process of assembly.

The first task is to define the interfaces between these sub-processes, which means definition of intermediate states of parts.

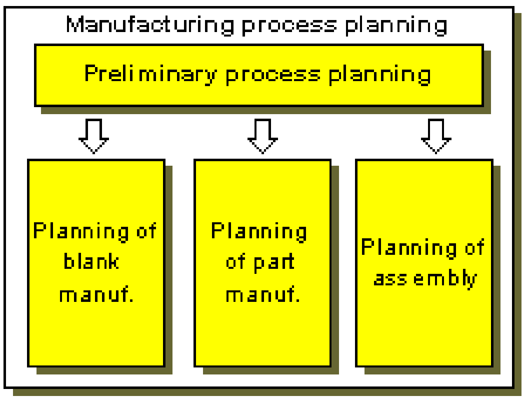

Fig. 5. Sub-processes of planning

The source of parts has to be decided to define the interface between assembly and part manufacturing. We have to decide which parts have to be manufactured in our workshop or in an other factory and which parts can be considered as commercial parts. The solution of this problem requires close cooperation between process planning unit, logistic unit and management, whether it is solved as an optimization problem or by simple management decision. The manufacturing task is indispensable information to the planning of part manufacturing.

The interface between part manufacturing and blank manufacturing is the blank (*Fig. 6*). We have to define two properties of it: the type of blank (like cast, forged, rolled etc.) and the allowances for machining. The type of blank depends on many conditions. The most important are: material, geometry, size and mass of the part, the batch quantity, deadlines and set of potential blank manufacturing technologies. We have to strive to realise the minimal summarised cost of blank and part manufacturing. The exact definition of the geometry of the blank is a design task. That is why we have to cooperate with design engineering unit.

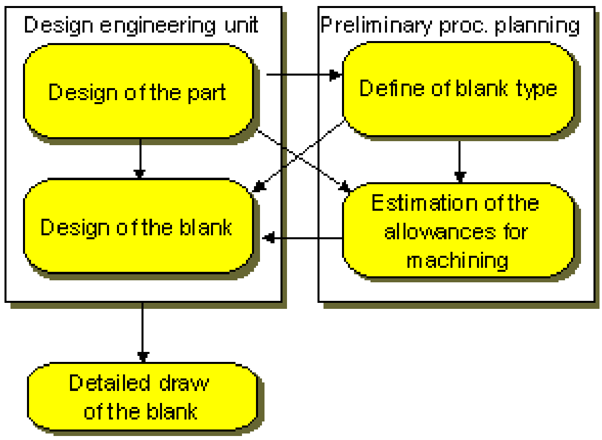

Fig. 6. Blank type selection

On the base of the manufacturing equipment the manufacturing task analysis produces the skeletal process plans for each manufacturing process (*Fig. 8*). These plans can be used as concept or strategy during the other levels of process planning.

Skeletal process plans have important role in solving of other planning tasks, too, like in manufacturability analysis (see above). *Fig. 7* shows additional possibilities.

The optimal manufacturing system can be selected on the base of the results of this session.

3.3. *Time and Cost Estimation*

The role of time and cost estimation is to supply some indispensable information to the production planning and scheduling unit and the company management. The aim of the estimation is to determine the deadlines of purchases and to check the capacity of manufacturing system. This task can be solved by two methods (PAPSTEL – SAKS [7]).

Taking the case-base approach previous cases are stored in the data-base and the most similar one is retrieved by an appropriate classification system. More accurate result is generated if the case-base consists of data of features of the parts instead of data of parts.

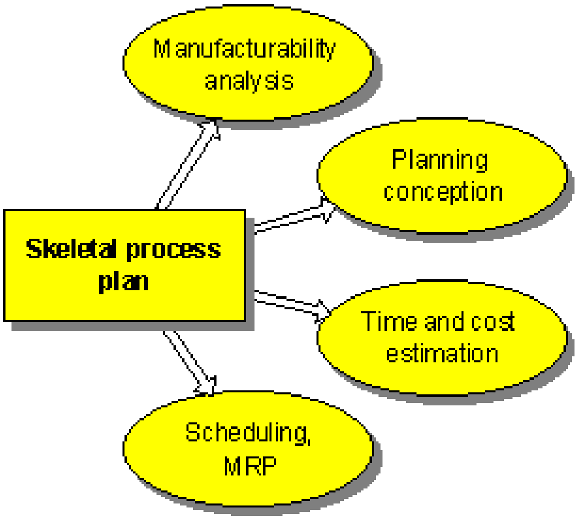

Fig. 7. Utilisation of skeletal process plan

During plan-base approach skeletal process plan has to be generated and the cost and time data can be derived from the evaluation of this process plan.

The limited accuracy of these methods satisfies the requirements of preliminary process planning.

The abovementioned subprocesses of the preliminary process planning are not succeeded in this sequence. Certain subprocesses can be executed in parallel or the execution of one of them can interrupt the execution of an other one. For example we have to identify the blank type just of those parts which are selected for manufacturing.

4. Implementation

On the base of overview of tasks and relations of preliminary process planning it can be proved that the preliminary process planning is a complicated and complex planning level which requires many different solving methods and its output influences decisively the success of subsequent planning levels, the efficiency of the process plan and the strategic decisions of the management.

During our research we developed many methods and procedures for the automation of tasks of preliminary process planning. As we see above several tasks can be solved on the base of the skeletal process plan so our research interest focused on the generation of it.

The developed process planning system applies case-based reasoning method, namely the suitable process plan can be generated on the base of process plan of

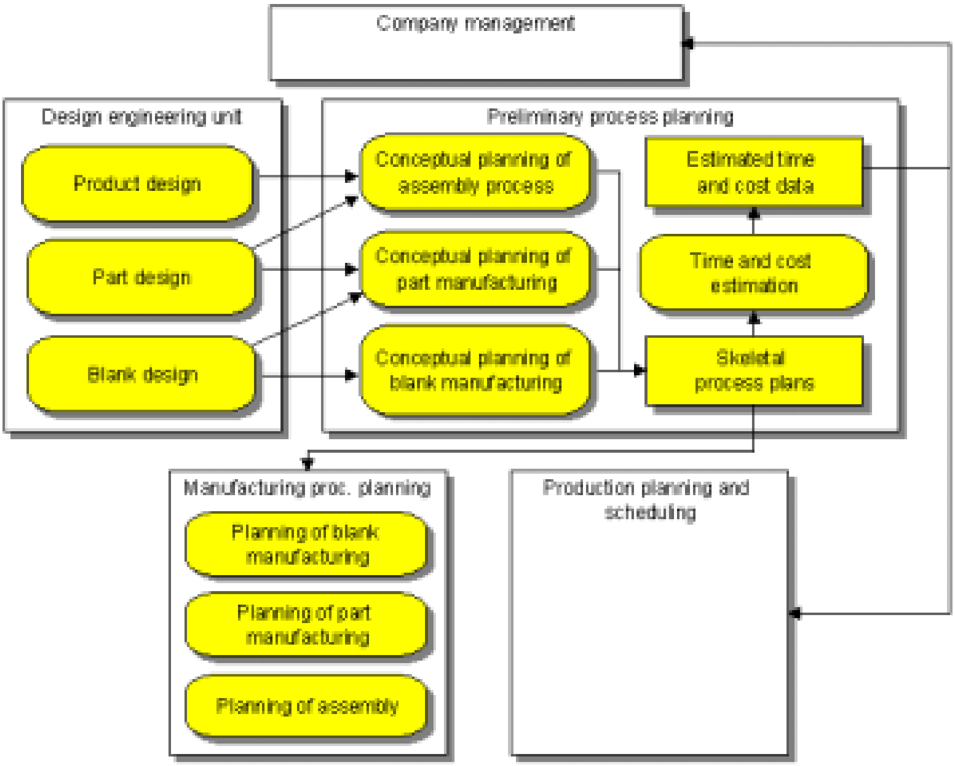

Fig. 8. Skeletal process planning and time and cost estimation

a stored appropriate part. The description of parts is realised by a free structure question graph, which is easy to adapt to an application environment (MIKÓ – KUTROVÁC – SZEGH [4]). The estimation of similarity is helped by an artificial neural network (MIKÓ – SZEGH – KUTROVÁC [5]). The structural adaptation of process plan can be managed by a user-friendly plan editor or a rule-based expert system depending on the content of case-base (particular process plan/group technology), while parameter estimation is done by a genetic algorithm based optimisation method (MIKÓ – SZEGH – KUTROVÁC [6]).

Another important task of preliminary process planning is the blank type selection and identification of allowances for machining. For this task we have developed a rule-based expert system which determines the blank manufacturing technology and the allowances on the base of general data (material, mass, batch quantity, etc.) and geometry of the part and then selects the best variant on the point of view of total cost.

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