COMPUTER AIDED SEMI-PRODUCT SELECTION AND DESIGN

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SUMMARY: *The selection and design of a semi-product are an essential element of a really complicated and multistage operation of process planning designing. The choice of the correct form of a semi-product, its design, selection, andfinally its production depend on many factors. This paper presents factors which are influence the selection and design of semi-products and trends of semi-product design automation. The paper also presents a test of the expert system used for computer aided semi-products design and selection.*

1 Introduction

Fast technological progress and industrial development cause continual improvement of constructional solution and introduction of changes into production technology. New materials and their practical application induce continuous development of construction, which, in turn, leads to technological progress. The introduction of a new material is often connected with a change of the semi-product and of the way it is produced. Changes of the semi-product forms and of the ways of their production are necessary to reduce manufacturing costs while maintaining at least the same quality of the product. Correct form of the semi-product has a significant influence on costs of production and operating costs. Proper choice of the semi-product and production methods and correctly designed allowances are essential problems in industry. These problems require new and better solutions. The automation of computer aided semi-product selection and design is becoming of great importance.

2 Semi-product planning

Starting materials (raw materials) are materials in such a form, in which one they leave ironworks' and other works' departments of raw material. They are for instance steel bars and metal plates, chemical materials, etc.; they are further converted in the manufacturing process.

Semi-products [5],[1] (*blanks, semi-manufactures*) are starting materials, which have been converted in the manufacturing process of preparatory departments. They are casts, forgings, drawpieces and die stampings. Semi-products are also half-finished products, which undergo further change of the form, dimension, the state of surface and/or mechanical properties. Thus the required part is obtained.

The choice of starting materials can be divided into two phases [11]:

a) choice of a semi-product's form, e.g. castings, forgings, drawpieces, die stampings, starting materials from metallurgic materials, sheared blanks, welded semi-products, etc,
b) choice of the production method, e.g. forging or die forging, etc.

One can split the factors, which are necessary to make a design of semi-product correct, into three main groups:

1) constructional - the material must be compatible with technological circumstances,
2) technological - labour consumption ought to be minimal,
3) economical - the cost of production ought to be minimal.

The main factors, which have an influence on selection of the form of a semi-product, are [2], [7]:

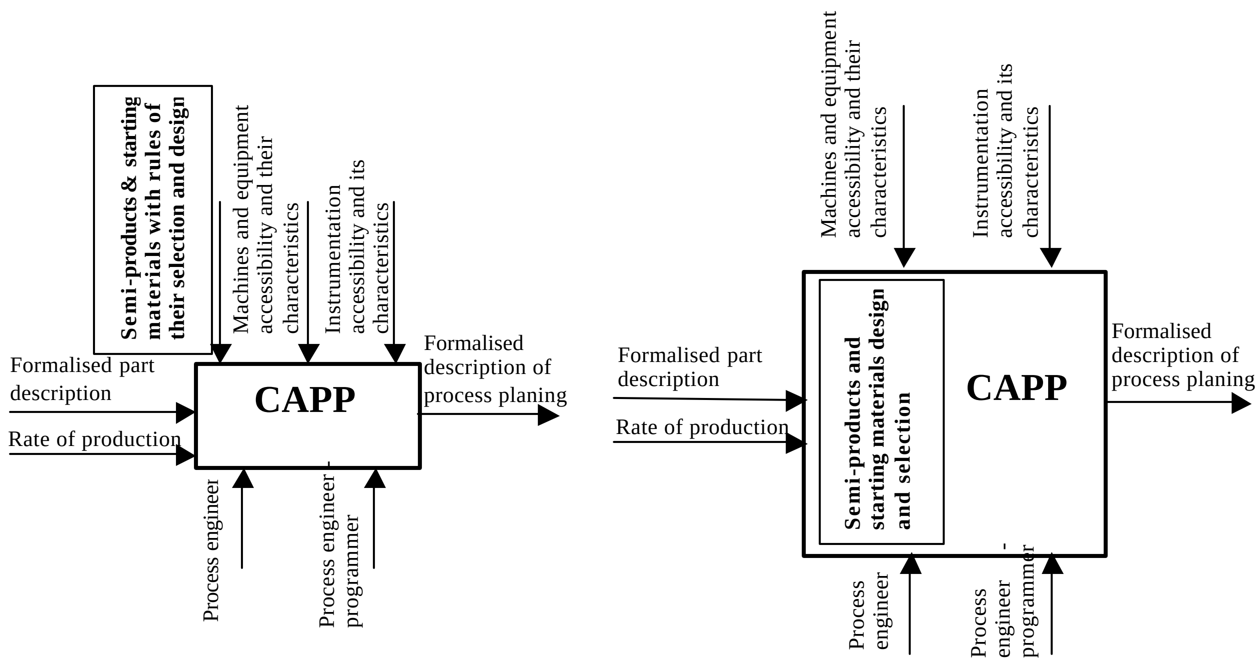
– the rate of production,
– the form of a workpiece,
– the material of workpiece or special recommendation for technical specifications.

The first two factors mentioned above have a crucial influence on the selection of a semi-product. The rate of production and the form of a workpiece are the factors, which should be considered together. Often the material of a workpiece established by the designer has a decisive influence on the choice of a semi-product. It would mean that the process engineer's potential, as far as the choice of a semi-product is concerned, has been strongly limited, because the decision is made by the designer who designs a certain part and works out technical specifications. It seems that the best solution to this problem is a continuous co-operation between process engineers and design engineers starting from the early stages of design. The application of Concurrent Engineering rules enables the proper choice of the semi-product. It also enables taking into consideration the demands of specified technology according to which this semi-product will be manufactured.

2.1 The place of the process of semi-product selection in the CAPP

The choice of an optimum manufacturing process is really complicated. To solve this problem it is necessary to make advanced projects of manufacturing process automation and the automation of design process. There is a high correlation between a semi-product and the manufacturing process, especially when the potential of industrial plants, plants equipment, instrumentation, the state of technology and organisation, and staff experience are taken into consideration.

If a design engineer has not imposed the form of a semi-product, it means that the material, its shape and manufacturing process have not bee stated. In this case a process engineer can choose the most popular form of the semi-product - black rolled bars or bright ground bars. It mainly concerns round bars, which are delivered by steelworks in the ready-made form of normalised measurement [6], [7]. The solutions, which have been used so far, treated semi-products, starting materials and rules of selection and design as one of elements (data, information) delivered to the CAPP system. Because of that the process of semi-product selection and design has not been automated; moreover, it has been frequently ignored. In the proposed system of the computer aided semi-product selection and design the process of semi-products design and selection is the integral part of the CAPP system (fig.1).



(a) (b)

Fig.1. Computer aided semi-product selection and design position in the CAPP process currently applied [10] (a) and in the proposed system (b).

2.2 Computer aided semi-products design

Since the choice of a semi-product form the calculation its weight, the choice of the production method and material consumption standards are require many laborious calculations and analyses, the use of computers and computer programs seems especially justified. It is necessary to make databases, which will contain allowances, tolerances and standards of manufactured casts, forgings, drawpieces and die stampings. It is also necessary to build a computer program, which can manage these data and use the knowledge needed to select and design a semi-product. The expert system can serve as this program. Additionally the expert system can carry out the cost analysis of alternative projects (Design for Assembly and Manufacturing) and the analysis of alternative projects, which take the potential of industrial plants into consideration. Depending on the detail level, the computer aided design solves the following problems [9]:

– defining basic dimensions of a designed semi-product; these dimensions are necessary for correct designing of workpiece process planing,
– determining design and construction data, such as: forging drafts, casts' edges roundings, parting lines, etc.,
– defining dimensions which are necessary to design the semi-product process planning with needed tools specified.

The role part of a design engineer in the computer aided semi-product selection and design does not change. However, the process engineer is aided by the computer or he can even be replacet by the computer during the process of designing. So, all algorithms on the basis of which a computer program works must include all possible decisions, which could be made by the process engineer designing a semi-product. These algorithms must be additionally supplemented with appropriate databases containing data necessary to design a semi-product, for example: a database of allowances, a database of casts, forgings, drawpieces and die stampings standards.

The automated design of a semi-product can be realised as an independent system or as part of a larger system of the computer aided process planning. In both cases a formal description is necessary, thus for the whole system unified representation must be worked out. To recapitulate, data needed to design a semi-product can be defined:

1) manually, i.e. the project is made by the process engineer on the bases of his own experience and data stored in books, tables and standards; the result is loaded in the computer for the needs of manufacturing process designing,
2) with partial automation of calculation; the process engineer selects the form of a semi-product, e.g. steel bars, forgings or cast, and dimensions are calculated by the program created on the basis of algorithms, databases and data delivered by the user,
3) with full automation; the computer automatically selects the form of a semi-product, calculates its dimensions, conducts economical analysis, makes the optimum choice and, as final result, delivers the ready project of the semi-product in the form of numerical technical documentation. This documentation makes the instant production of a semi-product possible. The obtained result may be also used to the automated designing of process planning.

Depending on the detail level, the computer aided semi-product selection and design can be divided into:

1) determining basic dimensions, which are needed to design the manufacturing process,
2) determining all of the more important dimensions, which are needed to design the manufacturing process and tools necessary to make a semi-product,
3) determining all constructional data for a semi-product, e.g. for a cast the data are: dimensions, drafts, parting lines, a gating system, etc.

It is also possible to design collective semi-products. The correct semi-product is selected from a group of similar parts. This procedure concerns mainly small lot production and it can be realised in the following ways:

1) by the automated analysis of database of similar parts, and then designing one common semi-product for these parts,

2) by the automated analysis of database of semi-products, which are applied in an industrial plant or in the entire branch and by choosing this semi-product whose dimensions are equal or bigger in specified limits (this approach is applied mainly with reference to various kinds of forgings).

2.3 The economical basics of semi-product selection.

A significant number of methods and manners of semi-product manufacturing together with diversity of applied materials cause problems in the correct selection of a semi-product. The cost of the manufacturing process depends, among other things, on the material of a semi-product and production accuracy. Therefore it is necessary to take into consideration the entire issue during the choice of a semi-product or material. One has to consider not only the cost of a semi-product but also the costs of further machining in the conditions of the proper rate of production. The total cost of making a workpiece is the basis of economical analysis. The economical analysis of semi-product selection can cause many difficulties, but it can be crucial especially in questionable cases.

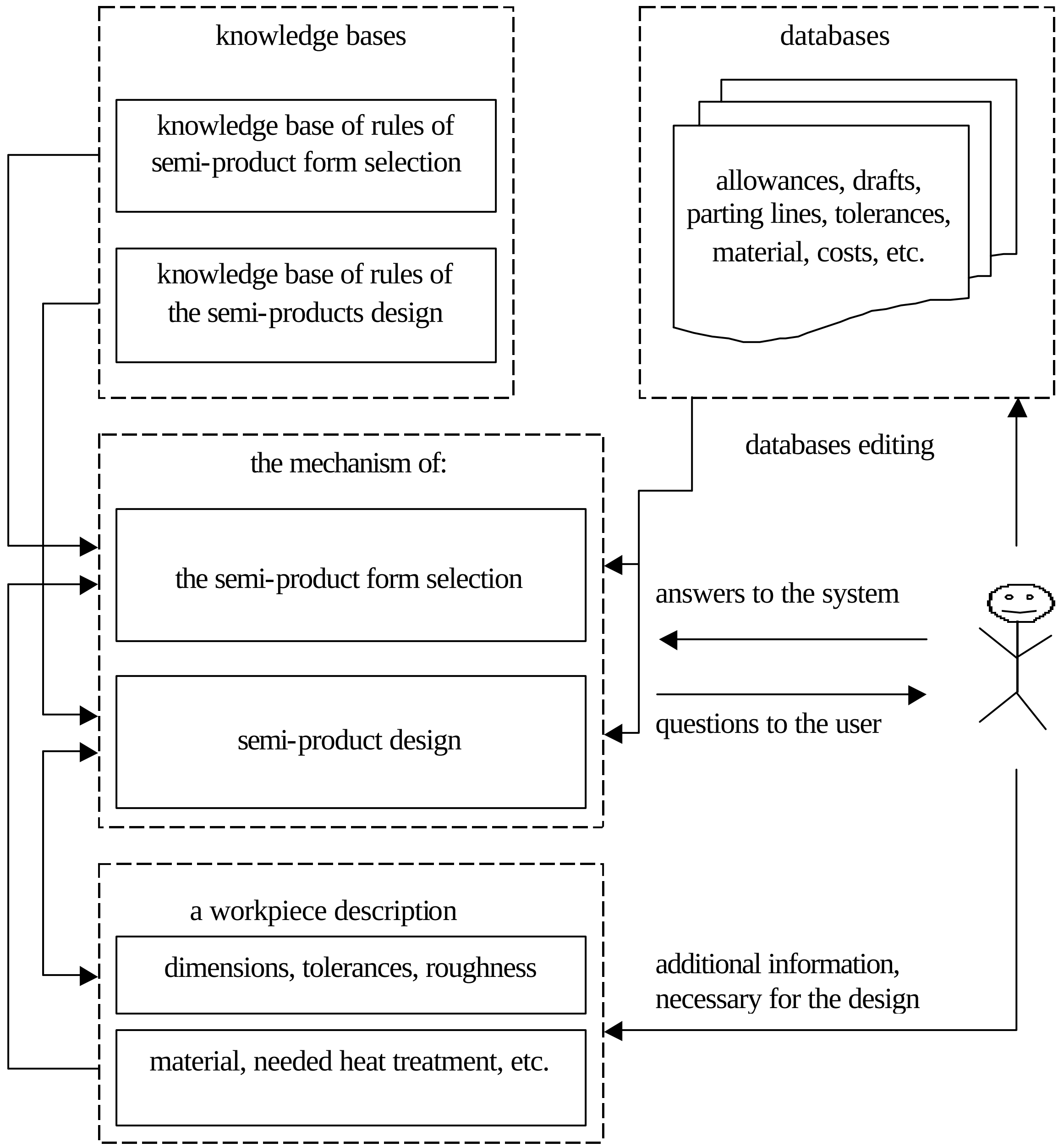


Fig.2. Diagram of the conception of the computer aided semi-products selection and design system.

This analysis is particularly useful when a few solutions are possible, the rate of production is significant and other methods do not give clear-cut answers [8]. There is currently a trend to select such a semi-product whose shape is similar to the workpiece's shape, or the semi-product has even finished same surfaces. It results in lower machining costs, but the costs of semi-product production are definitely higher. In that case the economical analysis of semi-product production and workpiece machining should be decisive.

3 Conception of solution [3]

As a solution the following computer aided semi-product selection and design system has been proposed (fig.2)

3.1 Knowledge bases

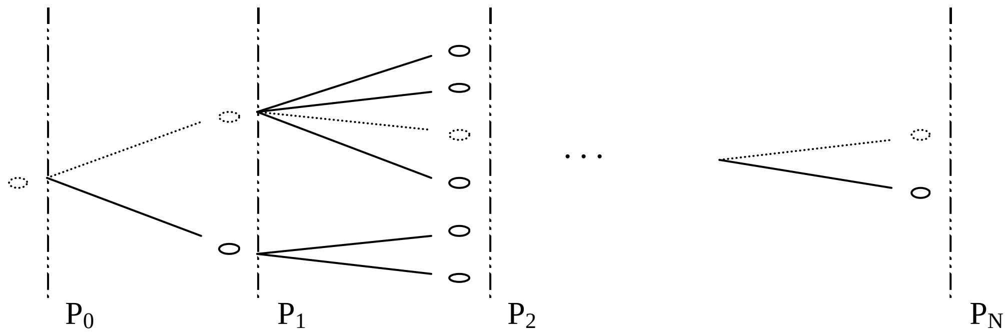


Fig.3. Diagram of the structure of the knowledge base in the form of the decisive tree.

In the proposed system of the computer aided semi-product selection and design the knowledge necessary to solve the task is stored in knowledge bases. It is suggested to show the structure of the knowledge base in the form of the decisive tree (fig.3). Colon dotted lines mean successive decision layers P_0, P_1, ..., P_{N+1}. Transition from P_i to P_{i+1} layer means transition from the state of knowledge W_{i-1} to the state of knowledge W_i, that is enriching W_{i-1} knowledge from P_{i-1} layer with the partial information q_i included in the layer P_i. The foregoing is shown by the formula (1).

$$P_i \rightarrow P_{i+1} \Rightarrow W_{i-1} \xrightarrow{q_i} W_i \tag{1}$$

Finally, in the layer P_{N+1} the entire knowledge W is accumulated; it is necessary to solve the task. This knowledge is the sum of all partial information q_i according to the formula (2).

$$W = \sum_{i=1}^{N} q_i \tag{2}$$

Partial information q_i can come from three various sources: from databases, from the user or can be a result of different computer programs. The information stored in the knowledge base concerns the choice of:

1) the form of a semi-product; a cast, forging or a die forging, a bar (peeled, black rolled, etc.), a drawpiece and die stamping, others like: a double extra strong pipe, a welded semi-product, etc.,
2) semi-product allowances which are estimated using the computational-analytic method

3.2 Databases

The automation degree depends on the amount of data, which are stored in databases. Accumulating a significant number of data in databases enables acceleration of the design process and relives the process engineer from the necessity of manual searching for data in tables and standard brochures. Because the relation database has been built, a huge number of data has been arranged in the proper order and the stored data are simple in editing. A diagram of the suggested database is shown in fig.4.

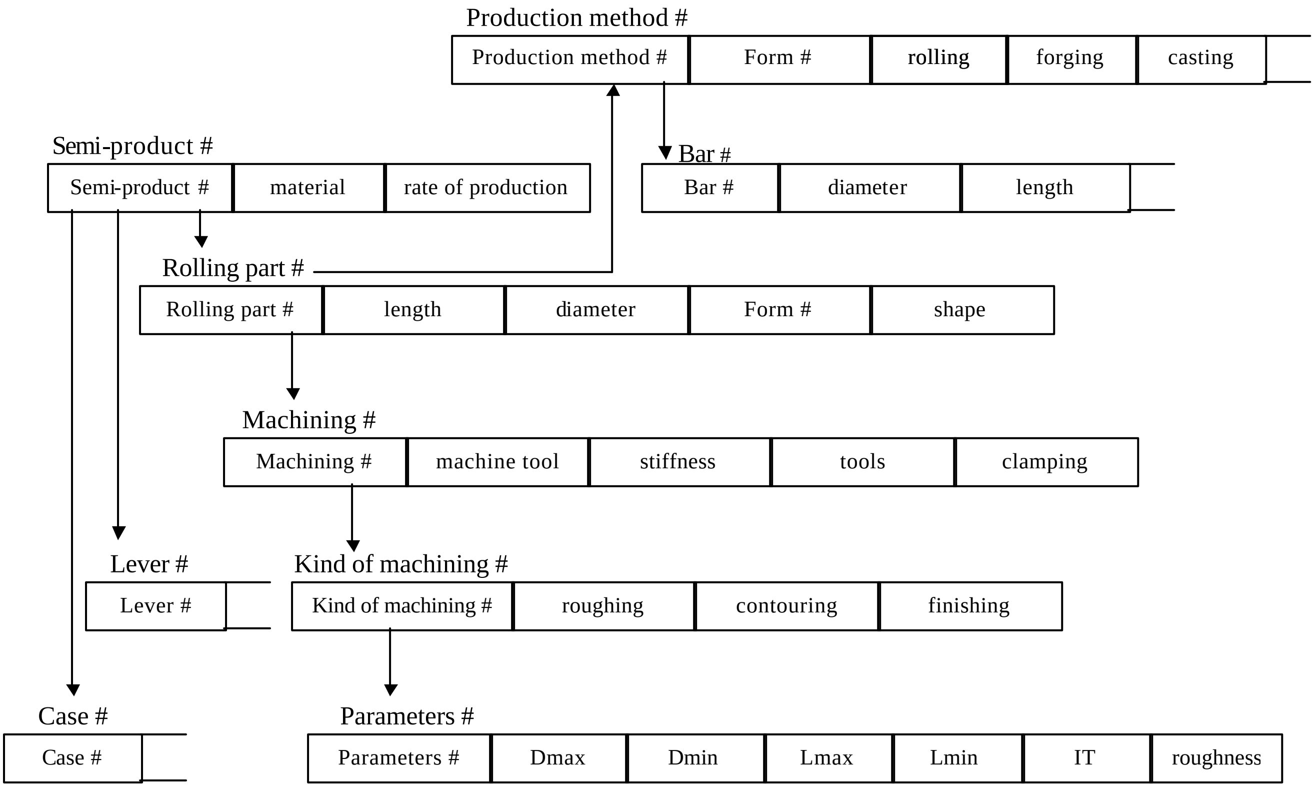


Fig.4. Diagram of the database.

As a result of selection, the data needed for transition to the state of knowledge W_i are extracted from the database. It is shown in formula (3).

$$R(A_1, A_2, ..., A_m) \xrightarrow{selection} (d_1, d_2, ..., d_p) \equiv q_i \tag{3}$$

$R(A_1, A_2, ..., A_m)$ - attributes $A_1, A_2, ..., A_m$ of relation R,
$d_1, d_2, ..., d_p$ - extracted data.

3.3 Mechanism of making a decision

The computer aided semi-product selection and design system must be equipped with the mechanism of decision making. This mechanism has to fulfill two tasks:

– processing the knowledge collected in knowledge bases; collecting data from databases and answering the question of what is the proposed form of a semi-product on the basis of given algorithms,

– designing the semi-product, i.e. allowances calculation, and selection of other quantities, which are necessary to make, for example, the engineering drawing of a semi-product or digital technical documentation.

To fulfil these aims one can build a big independent computer program of semi-product selection and design using a computer program language. Unfortunately, due to the high degree of complication, such execution of the program requires a lot of work and programming knowledge.

Since the system, which consists of the mechanism of decision making and data and knowledge bases, is similar to the expert system structure, the other way of solving the task is to use a frame expert system. The frame expert system is a computer application enabling making an expert system by storing the dcision rules in this system [4].

3.4 A workpiece description

The proposed system is open to co-operation with the external computer aided design (CAD) program. To make this co-operation possible it is necessary to use the proper interface between the system and CAD program. This interface should allow sending data from CAD program to the computer aided selection and design system and in the opposite direction. This kind of communication enables immediately and automated introduction of changes into the project. It is necessary to mention a formalised of description a workpiece. This description allows a univocal interpretation of data, which are sent from the system to CAD program and in the opposite direction. Missing information is completed by the user. Additionally the information which is obtained through the interface can be used in other programs, for example in those oriented towards producibility, assembly, disassembly, recycling, costs, environmental protection, and others included in concurrent engineering.

A lot of these problems are the subject of study at the Cracow University of Technology, in the Production Engineering Institute.

4 Conclusion

1) The realisation of the computer aided semi-product selection and design system is possible with the use of existing and accessible software; this realisation depends on programming skill and available computer programs.
2) The application of the expert system allows unification of the semi-product form selection; it leads to such simplification of decision process that the experience of the process engineer is not necessary and the significant part of technological knowledge is stored in knowledge bases. This fact causes that using of data is simple and all the rules are applied.
3) If usually a computational-analytic method of allowance estimating is used in industry in large-lot and mass production, then in the piece and small lot production it is different. The computational-analytic method is rather rarely used in small plants because of the high complication level and complex algorithms, especially when time is limited. In these cases the values of allowances are approximated and then are often much too big. The use of the proposed computer aided semi-product selection and design system is instrumental in small plants because it enables fast and correct designing of the semi-product form and dimensions.

5 Literature

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