Computer Aided Process Planning System Based on Modular Approach

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***Abstract*— The main problem which was discussed in this article is to increase the efficiency of machining process planning. To solve this problem authors proposed the way to design CAPP system based on modular approach. The first task consisted of changing the subject of production and use special features classification, called a surface module. It is assumed that it is possible to decompose any part into such elements. The second problem was to choose main parameters for checking the most efficiently technological operation. As a result of this work we got automatized machining process system for producing features.**

***Keywords*— CAPP; modular approach; module of surfaces; features; manufacturing; machining; expert system**

I. INTRODUCTION

Nowadays process of technological preparation of manufacturing takes about 50-70% of entire product production cycle length. This large time costs caused by a high level of labour consumption and low level of manufacturing processes planning automation. The first reason is a big diversity of means of technological support, parts and others units in the current engineering industry and duplication of work. The absence of a single classification, which makes it possible to uniquely identify and systematize work with these elements leads to a significant duplication of operations. Such overlap of work in the manufacturing is observed very often. Despite this fact a manufacturing preparation is still considered as a part of the whole system and is not studin-depth and in detail. The market lacks a solid solution, which would allow to optimize the preparation process, reduce time costs for this technological preparation stage several times and increase the automation level. This is also related primarily to a large amount of unstructured information stored in handbooks, supplier's databases, state and industry technical standards and other regulatory documents. Existing attempts to convert this information in electronic databases don't provide some visible results, technologists still should take their own decisions based on their personal experience. Furthermore, it is reasonable that the CAPP system should be multipurpose and not dependent on the manufacture specialization.

The preproduction engineering process can be divided into five stages. The overall level of automation does not currently exceed 20%. [1] There is no doubt that the laboriousness and time of technological preparation of production can be reduced. One of the modern approaches to decide this issue is based on principles of the modular technology. The basis of the technology is a representation of the product as a combination of surface modules (SM). The fundamental idea of this method consists of the classification and the possibility of decomposition each part by a combination of surfaces. Such classification involves three different categories: basic, working and linking combination of surfaces. [2] This approach allows companies to organize the element database of technological passes, processing methods, equipment and tools at the module level and combine these elements to develop technological operations and processes. The modular machining operations integrate the advantages of a single, typical and group technology considering all the features of a particular product as well as a single process. [3] The idea of typification is implemented at the level of manufacturing modules and combining products in groups by common modules, as in the group technology.

The computer-aided process planning (CAPP) system is a link between computer-aided design (CAD – Computer-Aided Design) and compiles the code for machines with CNC (CAM – Computer-Aided Manufacturing). [4] In this software we should choose the most suitable machine tools, cutting conditions and other necessary information for technological processes and operations. Decisions made on this step have a great impact on the cost, quality and efficiency of workpiece processing. Most of the work to date has not been automated and is performed manually by an engineer. For instance, technological analysis of part and determination of the possibility of processing items based on parameters like part geometry, dimensions, tolerances, and etc.

The idea of creating software to automatically developing technological processes and plan production tried for a long time. But as it was said earlier, the solution of this problem is due to some difficulties. One of them is a large variety of parts. There is not possible to build a database for all parts, so their unlimited amount. The obvious way out is to go to the level of the features, which are clearly structured, limited and do not change over time. The result was a large amount of data that must be taken into account when developing the technological process. To handle and analysis all conditions, the authors used the basic principles of artificial intelligence and expert systems. This was one of the major problems that did not allow implementing the modular approach. Time of development of technological processes for the manufacture of parts can be reduced from several months to several hours and minutes,

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there will be the opportunity to create an enterprise knowledge base.

II. TECHNOLOGY DESCRIPTION

A. CAPP system approaches

It should be noted that there are different approaches to the method of designing the technological process. In particular, there are significant differences between Russian and foreign standards for document processing. In Russia, these standards are fixed in the corresponding GOST – at the federal level and OST – at the enterprise level. The input parameters are information about the detail, production volume, available equipment in the enterprise. There are three ways to obtain the source data:

- DBF – Design by feature method.
- IFR – Interactive design feature recognition.
- AFR – Automated design feature recognition. [5]

Based on these data, the matrix is formed with information about items parameters. Then a library of materials with known data on the hardness and brittleness of materials is loaded. The next stage is the formation of operations, cutting conditions, machines and machine tools for operations are selected. To determine the most effective combinations, the authors developed an expert system with predefined rules.

B. Part decomposition by features

Big diversity of parts does not allow creating a good and stable classification. We may see different ways to classify parts and features, but most of them depend on the time. It means they will change in a time. If we look through the surface elements we see the huge different composition of them. It is worth noting some approaches to automating works with such elements:

- Professor BMSTU A. Kondakov works on the hybrid CAPP for constructions (CAD) and processes (CAM) which will be able to reduce the duration of the technological preparation of parts production. The essence of the study is in identifying the links between design and technological solutions and in combining these steps. The subject of production is so-called "T-complex" – a complex of surfaces, united by common shaping technology. [8]
- Professor Y. Bochkarev carries out research on the creation of an automated system for multi nomenclature processes planning, the main principles of which are the complete formalization of design procedures, parallel technological processes design for all parts planned for processing. According to this method processing of individual surfaces is going to be parallel.
- Professor O. Novikov carries out scientific research for a system of complex automation of the TP design. The system is based on a formalization of parts description by building the structural models of elementary, complex, aggregated groups of surfaces.

Among the international scientists and developers, the most advanced works are from countries such as China and the United States. There were published more than 30 000 papers, describing various approaches to a possible solution to the problem during 2014–2017. But none of them makes it possible to exclude human involvement in the technological process design. [6, 7, 9, 10, 11, 12, 13, 14]

One of the main reasons is an unlimited number of design and technological elements. This problem can be solved by using modular technology in which there are a limited number of combinations of such surfaces and the structure is defined at the upper level: based, working and linking.

The modular approach to manufacturing preproduction was run by Institute of Mechanical Engineering of the Russian Academy of Sciences. Currently, it's carried out in cooperation with the researchers from the Moscow State Technical University named after N.E. Bauman and Moscow State Technical University “Stankin”. An example of decomposition of part is shown in Fig. 1.

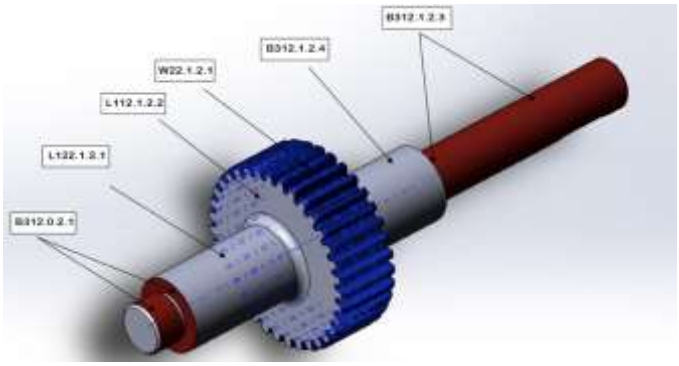

Fig. 1. Three-dimensional model of the pinion shaft decomposed by modular approach

Choosing module of surfaces as a primary element of the part, caused by that:

- MSs are "elementary particles" of which consists any part;
- MS is not dependent on the purpose and construction of part;
- MS has a limited variety.

III. CAPP SYSTEM BASED ON MODULAR APPROACH

In the manufacturing operations planning at the unit level, we use module of surfaces as the subject of production, instead of a part. In this case, for the development of technological operation, we need to decompose detail on many elements. Each element is assigned its processing technology. To identify this term will use the expression: modular processing technology (MPT). For the automation of selection MPT, the engineer is proposed to use developed expert system based on modular technology. The expert system allows designing a modular process by choosing the most suitable MPT based on

several criteria. This approach allows significantly reducing the stage of designing the technological process.

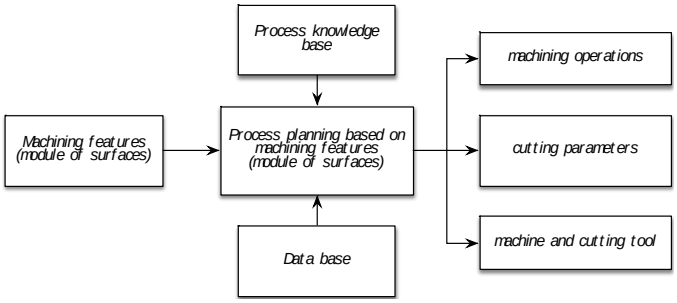

Fig. 2. Scheme of the expert system

The general algorithm of the expert system is shown in Fig. 2. In the first step, we need to get information about the details and recognize the existing features (module of surfaces) according to the developed classifier. In the case of an interactive input, technologist works with the CAPP system interface and enters data via the keyboard and computer mouse. Sometimes data can be entered is not correct. For instances, it may be a result of human error. To solve this problem, necessary checks have been added in the system. Also, the technologist must be well-versed in the modular technology and be able to properly decompose features in part. Unfortunately, it's hard to imagine, since you need to manually process a large amount of information and need additional training. To accelerate this process, the program interface has been simplified and divided into several steps. The interface for selecting the design features is shown in Fig. 3.

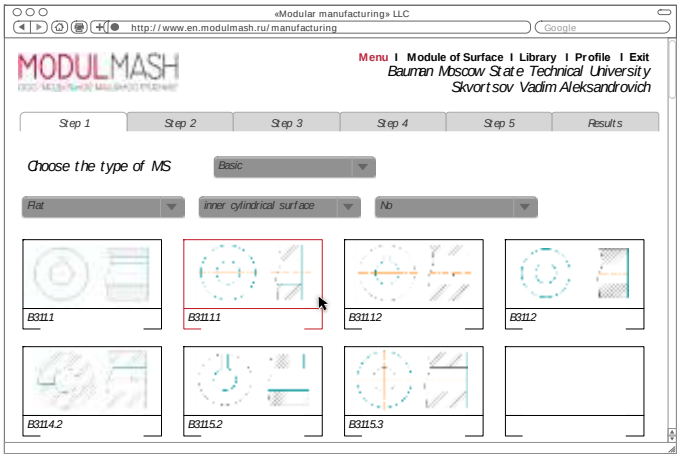

Fig. 3. Interface of the expert system for choosing design features

When the technologist has entered the initial data on the module of surfaces, the system carries out a search on the available options and offers various designs. The number of surface types in the basic modules can be from one to three. For example, choose two surfaces. There are inner cylindrical and flat surface. Consider for instance the module B311.1.1. The modular technology means that we assign for each feature a code. Numbers are limited by points for easier perception. Fig. 3 shows us the software interface where the user selects this feature type.

In operation, with the knowledge base, the number of modules will be increased. It was calculated that the approximate number of possible subtypes of the modules of surfaces for each type of MS would be about 8 million characteristics. Next, we ask user about dimensions, tolerances, and roughness for each surface. It is important to set the cutting conditions, tool selection, and surface treatment technology. Next step, we add the other necessary information, such as a volume of production, material of part and etc.

The expert system stores the information about the tools, machine tools, and other equipment. For this aim, we have already given information about the machine tools, its cost and the method of calculating depreciation.

IV. Advantages of the Developed CAPP System

The main advantage of the developed CAPP system is an automation of the decision-making during the technological process designing. The modular approach allows reducing the time required to search for technological solutions, technological process development complexity by several times comparing with other existing technologies, and also it allows improving a quality of technological preparation of production by using technological solutions that are tested practically. Thus, the "repository" for all technological solutions is being developed that allows saving it and spread widely at the enterprises.

Another application of CAPP system is a work with suppliers of equipment – machines, tools, equipment (sales, advertising, and promotion).

Designed expert system has the knowledge in the field of processing each module of surfaces, where each module corresponds to the several options surface processing modules. The reason for this is a large number of machining operations that you can use to produce the part.

Another advantage of using the CAPP system is a training program that allows young technologists to gain the necessary knowledge and experience of previous generations of existing technologies, equipment, tools and processes that have ever been used.

V. Work Results

The modular technology has appeared in the early 80s, and the theoretical principles of it still evolve. Despite the rather long existence of technology, the possibility of its application has appeared only in recent years since the software has reached a required level and allows integrating the CAPP system.

The task of the designed expert system is to simplify the technologist work and hide the complex information system for the calculation of the internal algorithm. The interface of the developed CAPP system shows us the different combination of machine tools and other equipment like geometric characteristics of the cutting insert, the cutting insert material and recommended cutting conditions. But most of the information stored in enclosed in the base of knowledge.

It was noticed, that we need to include a lot of input parameters to get more practical figures. In some cases, we work with inaccuracy of data in the directories. For instance, we noticed differences between the steel produced in Russia and other countries. They are characterized by the chemical composition of which is specified in the regulations. Permissible limits of these elements in different countries are different. But these boundaries within one percent can change the hardness of the material, and it will affect the tool life. To solve this problem, it was proposed the solution to create the database with recommended, permissible and actual cutting conditions. Using the actual parameters of the cutting, we can gather information from the manufacturers.

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