

New Generation Design System of Technological Processes

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Abstract—The paper considers the issues of creating a web-based CAD of technological processes (CAD TP), based on the creation of parametric models of parts and operational blanks, operating in a common information space (CIS) of computer aided technological preparation of production (CAPP). CIS is based on a dictionary system that allows you to overcome the barrier of interoperability between the components of CAD TP. The formation of models of operational blanks is based on the “added bodies” method. The technologist forms a model of the operational blank in parallel with the automatic solution of technological problems. The life cycle of received technological documents is monitored by the PDM system.

I. INTRODUCTION

Digitalization of production is the factor requiring radical transformation of technological preparation of production that in the current industrial production is very difficult to perform. However, intense competition is forcing humanity to improve the preparation of production, as an important stage in the product life cycle, affecting the cost and labor intensity of manufactured products. In paper [1] the main principles of Computer-Aided Process Planning (CAPP) system design and further ways of it's improvement are considered:

- CAPP system is being created as a corporate web-oriented system functioning within the framework of a virtual (extended) enterprise
- Tracking the product life cycle at the stage of the product planning is carried out on the basis of PDM system using the technology "workflow"
- Interaction efficiency of CAPP system components is based on multi-agent technologies
- A consistent increase in the intellectual level of CAPP subsystems is achieved through the creation and accumulation of knowledge bases
- Information interoperability (compatibility) between the CAPP subsystems and enterprise management subsystems is achieved by creating a single information space (Collaborative Workspace)

During the time that has elapsed since the publication of work [1], new directions for improving preparation of production have been developed and implemented in new systems. Systems have been developed for the development and analysis of polymeric materials with specified characteristics (Ophelia CAD, etc.).

The main system of CAPP is the system of designing

technological processes (CAD TP). Therefore, in this paper, approaches to creating a new generation CAD / CAM system within the framework of the above areas of preparation of production improvement are considered:

- CAD TP is developed as a complex of interacting web services and functioning as a multi-user system
- CAD TP operates within the framework of a single information space to ensure interoperability with other CAPP systems
- The life cycle of the developed technological documents (development, approval, adjustment) is supported using the PDM system
- CAD TP is focused on the use of annotated 3D models of parts called electronic models of parts (EMD) [3] and containing the entirety of information about the part

However, the existing CAD TPs have a number of disadvantages, the main of which is the relatively low level of automation of solving technological problems. This is primarily caused due to the presence of a barrier to information interoperability between CAD and CAD software. The technologist is forced to analyze the EMDs and enter the information necessary for the design of technological processes. Analysis of the possibility of transmitting information using neutral formats showed that STEP can be used to the greatest extent for CAD / CAM. The simultaneous level of its development does not allow its effective use in solving technological problems.

II. DEFINITION OF CAD TP STRUCTURE

The modern approach to CCI automation is based on the transition to a web-oriented and multi-agent CAPP system, which allows the implementation of the teamwork of technologists in an extended enterprise [6], [7]. Therefore, CAD TP is created as a set of weakly interconnected functional components (FC) designed as web services as shown at Fig. 1.

System users (technologists and specialists in maintaining databases and knowledge bases) work directly with control components (CC). Access to the FC from the CC and back is carried out using a message broker. In the experiments, Beanstalkd was chosen as a broker, which allows processing asynchronous queues for FCs and CCs, which usually do not require an immediate response as shown at Fig. 2.

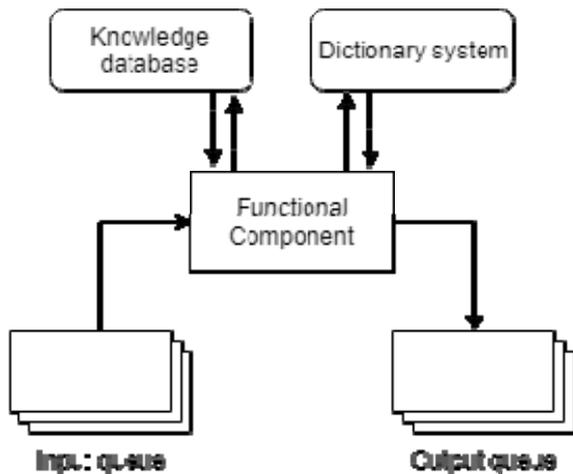


Fig. 1. Functional component environment

Each FC solves technological problems in a multi-user mode, therefore it has input and output queues. In addition, the FC can have its own databases and knowledge bases. Databases are maintained by the MongoDB, a document-oriented database, because the stored information has a variable length and structure. FC receives the initial data from the input queue, and enters the results into the output queue. If the input queue is empty, then FC "falls asleep".

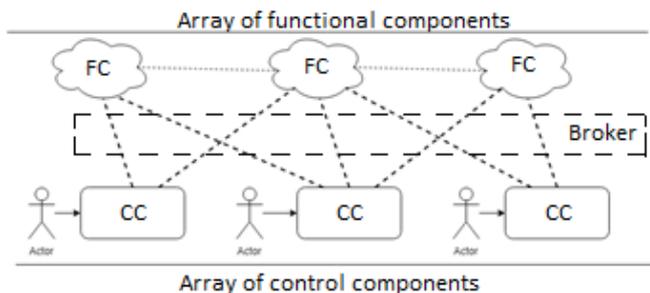


Fig. 2. Common system structure

Users work with the control component and pass the message to the input queue. It indicates the given FC, the code of the problem to be solved, and the initial data for the task. After solving the problem, the resulting data FC places in the input queue of the CC. Each CC contains a current database (CDB) containing files with the current EMD and its parametric model. As the design of the technological process, electronic models of operational blanks and their parametric models are being accumulated in it. In addition, the parameters of the developed operations are being sequentially written to it. At the final stage, using the appropriate FC, a set of flow charts is printed from the CDB and the process model is entered into an electronic archive and registered in the PDM system.

III. KNOWLEDGE BASE METHODOLOGY

CAD TP is characterized by a large amount of reference information (RI). It includes information about the range of materials, cutting conditions, about tools, equipment, etc. For

example, only in the reference manual on cutting modes there are more than 200 tables, each of which contains its own data scheme [8]. The obtained solutions for one table can be refined with correction factors for another table. The functioning of many FCs working with RIs is based on the use of table processors that contain a software shell that makes decisions based on processing the knowledge base [9]. With the autonomous functioning of the table processor, the technologist enters the initial data and transfers the result to the model of the technological process. To increase the level of automation, it is necessary to form the initial data for the FC automatically, which is a non-trivial task.

A new scheme for working with a table processor is proposed, in which the functions of the FC are expanded and the process of obtaining source data is performed according to the following scheme (1):

$$Z \rightarrow Kbz \rightarrow Cd \rightarrow Vd \rightarrow Kvd \tag{1}$$

FC selects task Z from the queue and searches the directory of the knowledge base Kbz. From the found block of knowledge, a data scheme Cd is allocated and put in the output queue. FC, playing the role of a postman agent (AP), selects Cd from the output queue and starts working with the current database. The AP supplies the FC with the information that it receives by searching among the parametric models of blanks, blanks and the process. In this case, the AP selects from the CDB the values of parameters Vd according to a given data scheme. Parameter values are returned to the table processor for decision making. The resulting solution is returned to the CDB's model of the projected operation or transition. This approach significantly speeds up the design process, but complicates the CAD software TP.

IV. COMMON INFORMATION SPACE

A large number of object models circulate in the CAPP, some of which are graphic (2D or 3D models of parts and blanks), and others are parametric models in which parameters can be organized into objects with a complex structure.

Some objects can have both graphical models and parametric ones. Parametric models include models of tools, fixtures and equipment. The volume of these objects can be tens of thousands, or even hundreds of thousands of units. When designing technological processes, information from graphic models is transferred by the technologist to the TP. With transfer automation, a barrier to interoperability (compatibility) arises. In article [2], it is noted that this barrier arises primarily due to the lack of consistency (correctness) of the attributes of the parameters of the transmitted models. First of all, the consistency of the concepts assigned to the parameters of the model transmitted from the FC should be fulfilled. For this, these components must have a single ontology.

It should be noted that the parameters of the models are transmitted without their concepts to reduce the amount of information transmitted. Now consider the consistency of the designation of parameters. Their important feature is the variety of designations of parameters and their repeatability

for different concepts. For many objects there are standardized designations of parameters, which are undesirable to change. Many objects that have the same designation but different concepts can be divided into classes: parts and blanks, tools, equipment, devices, etc. Each class has its own notation area (domain). Thus, the attributes of the parameter can be supplemented by the attribute "domain".

An important feature of the designations of parameters is their diversity and repeatability. For example, the designation "d" may mean: "drill diameter", "hole diameter", "spindle diameter", etc. In addition, many notations are supplied with indices, for example, "dmin" or "Vn", etc. For many objects there are standardized designations of parameters, which are undesirable to change. To separate parameters that have the same designation, but different concepts, many objects can be divided into classes: parts and blanks, tools, equipment, devices, etc. Each class has its own notation area (domain). Thus, the main attributes of the parameter can be supplemented with the attribute "domain" (for example, "det" - domain "parts", "inst" - domain "tool", etc.). If you need to narrow multiple domains, they can be divided into subclasses. The latter case is the most common, since the role of a subclass is played by models of a given type. Each type of model has its own set of parameters and, therefore, its own set of concepts and designations of parameters. If systems exchange only models of the same type, the parameter indicating the type of the transmitted model can be omitted.

Considering the values of the parameters, it is necessary to note a wide variety of ways to set them:

- Parameter is set by the exact value (for example, "d = 20")
- Parameter value is set by the interval
- Parameter value is set by a list of possible values

Parameter values can be set syntactically in different ways. For example, the interval from 10 to 40 mm is written: "1-40" or "1.4 ... 5.3". The maximum cutting depth of the cutter can be set as "up to 4". Relationships of order can be used, for example, " $k > 3$ ", " $t \geq 3$ ", " $p < 5.4$ ", " $s \leq 5.4$ ", etc. Dimensions can be specified with an indication of their accuracy, for example, "20H14" or " 30 ± 0.3 " or " $40 + 0.12$ ", etc. In many cases, accuracy is specified by a separate parameter, for example, "IT = H14" or "BO = 0.12" and "HO = -0.3". The system receiving the message must perform an analysis of the values of the parameters of the objects, methods for setting them and respond accordingly. In this case, all types of consistency are ensured by the value of the parameter.

An analysis of the attributes of the parameters will not be complete if the attributes of the constraints of the parameter value (CPV) are not taken into account. For example, the value of a parameter is 45, but is this value the size in millimeters or inches, or degrees?

The attributes of the CPV include:

- Dimension of the parameter
- Parameter type (numeric, text, logical)
- Length of the field allocated to the parameter value

- Number of decimal places for the real numerical value of the parameter
- Minimum and maximum value when numerically setting the parameter value

Some of these attributes are usually used in relational DBMSs to form the data schema when creating the database. If the parameter value meets these restrictions, then there is consistency in the OZP. Thus, it can be argued that the parameter is generally correct if there is consistency in all attributes of the transmitted parameter.

A functional component containing a dictionary system makes it possible to check the consistency of transmitted messages. The creation of the CIS is a complex, laborious and long-term process carried out with the help of the FC to accompany the vocabulary system, but without it it is impossible to organize the effective implementation of the tasks of the CAPP system.

V. FUNCTIONAL COMPONENT INTERACTION

As mentioned above, the fundamental approach to the design of technological processes is the organization of the joint functioning of the CAD system and CAD TP. CAD system CATIAv5 is used for designing operational blanks. The technologist uses two terminals. At the first, he works with a CAD system, and at the second, he manages the design process, looks at the results of the operation design, tracks and corrects the created technological process.

In the beginning, with the help of CAD TP, the technologist determines the composition and sequence of operations and proceeds to the formation of the output operational blank for the last operation using the CAD system. To do this, by disabling all annotations, the technologist on the 3D model of the part puts down the operational dimensions, roughness of the machined surfaces, technological bases, etc.

After forming the model of the output blank, the technologist saves it in the CDB and transfers the task to the appropriate FC to check the correctness of the setting of the operating dimensions. FC based on the parametric model of the output billet makes dimensional chains and determines whether all operational dimensions are maintained. Dimensions for which verification has not been performed (the so-called "deferred" dimensions) will be checked during the design of previous operations [10]. If some sizes cannot be maintained, the technological bases are changed and the calculations are repeated. In the case of a positive calculation of the operational dimensions, the values of the operational dimensions and their accuracy are put down on the model of the output blank as shown at Fig. 3. This approach allows us to detect the incorrect installation of technological bases in time without designing previous operations, which significantly reduces the design time of TP.

Next, the technologist proceeds to the formation of the input blank, i.e., the blank received for the operation. To do this, it disables all annotations and starts working according to the method of "adding bodies" [4,5]. To do this, from the graphic library of typical elements, the necessary elements are

selected and configured and added to the output blank by the logical addition operation, the process is shown at Fig. 4. Information about the added body is entered in the parametric model of the output blank. After that, it becomes possible to issue a task to select equipment for the projected operation. Adding bodies ends when the input blank is fully completed. Next, the verification of the results of the formation of the operational blank begins by disabling the added bodies and turning on the necessary annotations. The reverse process begins of sequentially disabling the added bodies and enabling the necessary annotations. Such actions simulate the removal of material when performing a technological transition and make it possible to select a transition text for a given type of operation. Further, the technologist gives tasks to the functional components to select a tool and calculate cutting conditions. These tasks, as shown above, are performed using the "Table Processor" FC. This FC can generate computational chains when the decision by the table processor results in the determination, for example, of not only the feed, but also the issuance of a task to calculate the cutting speed with retransmission of control to the table processor. Thus, while the technologist is building a model of the operational blank, the system solves technological problems, which significantly reduces the overall design time of the TP. This approach significantly reduces the design time of TP due to the fact that the necessary information is not taken from graphic models, but is automatically selected from parametric models of the part and blanks.

The results of solving such technological problems are recorded in the CDB. After completing the design of the current operation, the technologist proceeds to the previous operation. The input blank is copied and becomes the output blank for the previous operation. Further, the above algorithm is repeated until a procurement operation is formed and the initial blank is designed.

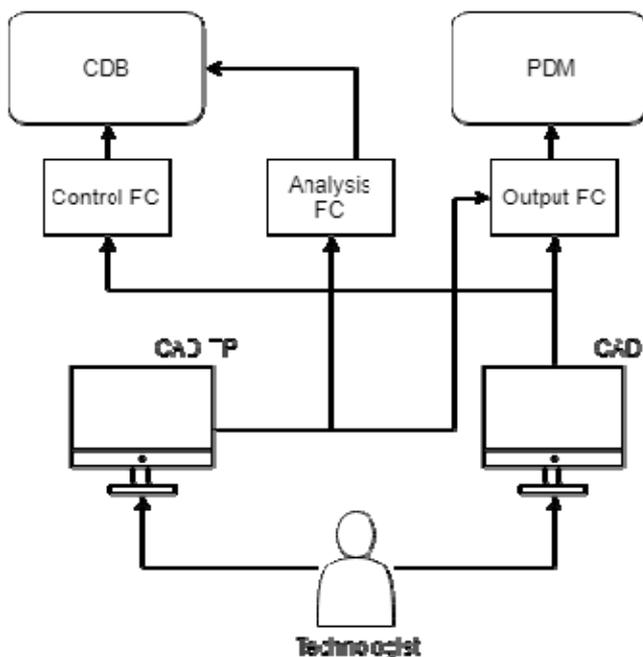


Fig. 3. Design process scheme

To control the design process, the technologist has the opportunity at any time to use FC "Results", which works with the current database and allows the technologist to display the results of designing the TP at the current time to evaluate them and make the necessary adjustments.

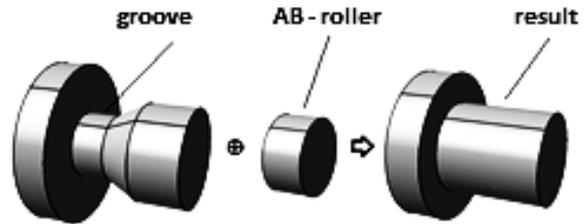


Fig. 4. Body «roller» adding for groove filling

The resulting process version is processed by the appropriate FC and converted into a set of process cards for further storage in the SMARTEAM PDM system. Tracking the life cycle of a flowchart kit is already performed using the PDM system, while the approval of the kit in technology bureaus can be controlled using "workflow" diagrams and "redline" technology.

The concept of the proposed campaign can be seen at Fig.2 and based on the consistent development of CAD TP taking into account the specifics of a particular enterprise. For this, a tracking system is used, with the help of which an analysis of the nomenclature of the enterprise is performed to replenish the library of typical structural elements and macros for the CAD system for newly introduced standard elements are developed. Databases and knowledge bases are analyzed. For them, a schedule of their adjustment and additions is drawn up. In connection with the digitalization of production, it is necessary that all changes in the tool economy are reflected in databases and knowledge bases. Thus, the tracking system plays an important role in the consistent development of CAD TP.

VI. CONCLUSION

Designing blanks with use of the method of added bodies with a parallel automated solution of technological problems opens the way to creating web-based multi-user CAD TP with a high level of automation. Not all problems in creating such a system are satisfactorily resolved. However, this approach is very promising for the further improvement and creation of a new generation of CAD TP systems.

The advantages of the proposed approach are as follows:

- The use of the library of structural elements and their macros to display the structural elements in a three-dimensional image along with annotations and tuned by the parameters introduced by the technologist, which significantly reduces the time of formation of the part model
- The automatic creation of a parametric model of the part in parallel with the formation of its graphic model allows you to overcome the barrier of interoperability between CAD and CAPP systems and greatly facilitates

access to information about the part when designing technological processes

- The total amount of information about the geometric models of the part and the operational blanks is reduced, since the model parts and the added bodies are stored in one file
- Reducing the time it takes to create a technological process by combining the time of forming operational blanks and solving technological problems (calculation of cutting conditions, allowances, etc.)

In general, the total time for creating a geometric model of a part with annotations and designing a process can be reduced by 3-5 times.

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