

# The New Approach to Solving Technological Problems in A Common Information Space

Dmitry Kulikov<sup>[0000-0003-0600-2587]</sup> [ddkulikov@mail.ru](mailto:ddkulikov@mail.ru), Artem Vostropyatov<sup>[0000-0002-6930-1771]</sup> [art-em39@mail.ru](mailto:art-em39@mail.ru), and Kamo Abramyan<sup>[0000-0002-4518-6756]</sup> [vostar93@yandex.ru](mailto:vostar93@yandex.ru)

ITMO University, 197101 Saint-Petersburg, Russian Federation

**Abstract.** A modern approach to the automation of the design of technological processes is to create a complex of web services that perform a variety of technological tasks. The paper shows the organization of the functioning of web services, which is based on the creation of a single information space and knowledge bases. For this, an ontology of technological preparation of production and a vocabulary system are developed. Information about the relationships between services is also stored in knowledge bases, which allows you to create an adaptive management environment between services and consistently increase the level of automation of design of technological processes.

**Keywords:** Technological preparation of production · Design of technological processes · Common information space · Vocabulary system · Web services · Knowledge databases · Information management environment.

## 1 Introduction

The design of technological processes can be presented as a sequential solution to a complex of technological problems. These include tasks:

- determining the structure of the process;
- selection of allowances;
- calculation of cutting modes;
- selection of technological equipment;
- calculation of operating sizes;
- formation of technological maps, etc.

This approach to the creation of CAD of technological processes (CAD TP) allows you to create a multi-user system in which the interaction between components (web services) is based on multi-agent technology [1].

---

Copyright © 2019 for this paper by its authors. Use permitted under Creative Commons License Attribution 4.0 International (CC BY 4.0).

## 2 Methodology

### 2.1 Common Information Space

Overcoming the barrier of interoperability between components is achieved by creating a common information space (CIP) [2, 3]. The CIP is based on the creation of an ontology of technological preparation of production (TPP) and a vocabulary system containing the attributes of the concepts used. TPP is characterized by the presence of a large amount of normative and reference information and, therefore, requires the creation of a large number of databases, which requires the organization of an effective system escorting these bases. Otherwise, the quality of the tasks being solved will gradually decrease due to outdated databases.

### 2.2 Knowledge Databases

To improve the adaptive properties of CAD TP, many algorithms that solve technological problems can be expressed in a declarative form and placed in knowledge bases for which support systems are also created [3]. In existing CAD TPs, the sequence of solving technological problems is controlled by the technologist, which indicates an insufficiently high level of automation of these systems.

In our opinion, the main drawback of existing CAD TP systems is the presence of an interoperability barrier between CAD systems and CAD TPs. Modern CAD systems allow using annotations to express in the 3D model of a part all the information necessary to create a drawing of the part. However, it is very difficult to transfer this information in a form convenient for computer-aided design TP, even using neutral formats such as STEP. It was shown in [4, 5] that a solution to this problem can be achieved by creating parametric models of parts formed in parallel with creating an electronic geometric model of a part (EGM) in accordance with GOST 2.052 2006. The formation of electronic geometric models of operating blanks and their parametric models can be performed by the method of adding bodies, information about which can be expressed both in graphical form and in parametric form. This approach opens up the possibility of increasing the level of CAD TPs automation. Automated control of the sequence of execution of components is achieved by indicating links in the knowledge bases to the next task that needs to be performed. Thus, the control environment for designing TP is realized. Such an environment is adaptive, because it makes it easy to make links to knowledge bases as they are formed and improved.

### 2.3 Creation of Parametric Models of the Part and Operational Blanks

Research on the creation of a new generation of CAD TP systems at ITMO University has allowed the development of a method for forming a parametric model of a part, which is being created in parallel with the creation of EGMs in the CAD system "CATIA". For this, a library of structural elements (SE)

of parts was created and a set of macros was developed to display tables with SE parameters. Enter information about FE as follows. The required element is selected from the SE catalog and a table with its parameters is displayed. Next, the table is filled with the values of the element's parameters (dimensions and their accuracy, surface roughness, deviation from the shape of the element's surfaces, etc.). After that, using macros, the EGM of the element is displayed on the screen, i.e. a three-dimensional image of the element with all that allows you to create its parametric model (PM) in parallel with the receipt of the EGM part. Graphic and parametric models are entered into the current database (CDB). Based on the DBMS "MongoDB". Thus, the barrier of interoperability between the CAD system and CAD TP is overcome. This approach allowed us to develop a set of procedures for selecting the necessary information from PM during the design of the technological process.

#### 2.4 Design Scheme of Technological Processes

It should be noted that the design scheme of TP changes radically. The technologist is primarily involved in the formation in CAD of systemographic models of operational blanks using the method of added bodies.

Parametric models of operational blanks are obtained automatically, similar to the creation of PMD and are recorded in the current database. Most of the technological problems are solved automatically on the basis of a selection from the CDB of the necessary information about the parametric models of operational blanks. This gives rise to a very important feature of the proposed design scheme for TP. While the technologist forms another annotated model of the operational workpiece in the CAD system, the tasks of designing the technological operation for this workpiece in parallel using the control environment are automatically started.

The method of adding bodies, considered in the above works, is based on the formation of operational blanks, starting from the last operation, because the output blank for this operation is a finished part, information about which is known to the technologist. After setting up the technological bases and technological dimensions in the CAD system, the technologist synthesizes the shape of the input operational billet by logically adding the EGM of the output billet to the EGM of the added body (DT) selected from the library of structural elements of the CAD system (see Fig.1). As can be seen from this figure, two options for adding bodies are possible to close the gearing. The body DT1 is a complex of added bodies, conventionally regarded as one body, obtained by copying the space between the teeth, which is quite laborious. The DT2 body is based on the use of a typical "Disk" type structural element. The result of using both bodies is the same and obtained by the logical addition operation (eq. (1)):

$$D \oplus DT_1 \Rightarrow OZ \text{ OR } D \oplus DT_2 \Rightarrow OZ \quad (1)$$

However, the use of the DT2 body requires an order of magnitude less time compared to DT1 for the formation of the input billet model.

Information on the results of the design of the operating workpiece (OW) is supplied to the calculated components of the system for selecting allowances, calculating cutting conditions, choosing technological equipment and calculating operating sizes. The technologist has the ability to control the decision process, to form and adjust the content of technological transitions. If the calculation of the operating dimensions was unsuccessful, a new installation of the technological bases is carried out and the design of the technological operation is repeated.

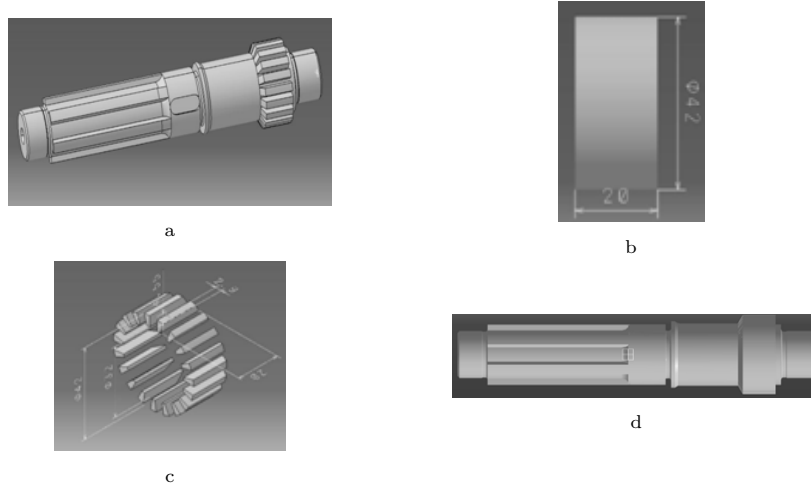


Fig. 1: An example of the use of added bodies to obtain an input model of an operational workpiece for a gear milling operation. a) Model D of the output workpiece after the milling operation. b) Body DT1. c) Body DT2. d) Model of the input workpiece received for gear milling operation OZ.

The result of the design of the operation are:

1. An annotated graphical model of the output operational workpiece with affixed technological bases and operational dimensions (EGMOZvy).
2. The parametric model of the output operational workpiece (PMOZvy).
3. A graphical model of the input operational blank (EGMOZvh).
4. The parametric model of the input operational blank (PMOZvh).
5. The parametric model of the technological operation (PMTO).

After the transition to the previous operation, the technologist copies EGMOZvh and PMOZvh and forms the output blank from them for the previous operation (eqs. (2) and (3)):

$$EGMOZvh_i \Rightarrow EGMOZvy_{i+1} \quad (2)$$

$$PMOZvh_i \Rightarrow PMOZvy_{i+1} \quad (3)$$

On this information base, the technologist designs the previous operation. For the first operation, the input blank model is already the initial blank.

### 3 Structure

#### 3.1 Web-Oriented CAD TP

The modern approach to the automation of TPP, as mentioned above, is based on the transition to a web-oriented and multi-agent TPP, which allows for the implementation of the teamwork of technologists in an extended enterprise [1]. Therefore, CAD TP is created as a set of weakly interconnected functional components (FCs) designed as web services. Each FC solves technological problems in a multi-user mode, therefore it has input and output queues. Technologists work with the control component (CC) and put tasks in the output queue of the CC to solve specific technological problems. In turn, the postman agent (AP) selects the task, determines which FC to transfer the task to, and puts the task in the input queue of the found FC. The postman agent sends the results of solving the technological problem from the output queue either to the control unit, or, if necessary, to the next FC. In this way, the external control loop functions.

CAD TP is characterized by a large amount of reference information (RI). For example, only in the reference manual on cutting conditions there are more than 200 tables [6]. The obtained solutions for one table can be refined with corrective coefficients 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 [7]. 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, solved on the basis of the internal control loop. Only the availability of parametric models of the part stored in the CDB, operational blanks and the technological process allows replacing manual data entry with automatic data entry from the indicated parametric models! This is a fundamental feature of the proposed approach to the design of TP.

As mentioned above, the principal feature of the applied approach to designing TP is the work of the technologist in the CAD system environment for the design of EGM operational blanks. If necessary, he can turn to the control component to control and analyze the results of designing TP. Using CC, a task is formed to solve a technological problem, and then the task is queued. If the FC is a tabular processor, then the process of obtaining the initial data is performed according to the following chain:

$$Z \rightarrow Kbz \rightarrow Cd \rightarrow Vd \rightarrow Kvd \quad (4)$$

The postman agent picks up the task  $Z$  and puts it in the queue for the given FC. If the FC is a table processor, then the FC selects a task from the queue and searches the knowledge base in the  $Kbz$  directory and selects the  $Cd$  data scheme

for the found knowledge block. The agent, the postman, using the technological components database (TCB) complements the data scheme with the values of the parameters specified in the scheme. The received data packet is processed by the FC. After receiving the decision, the postman selects the results from the output queue, enters the results into the current database, and reports to CC. The interaction scheme is shown in Fig.2. Thus, the internal control loop is implemented.

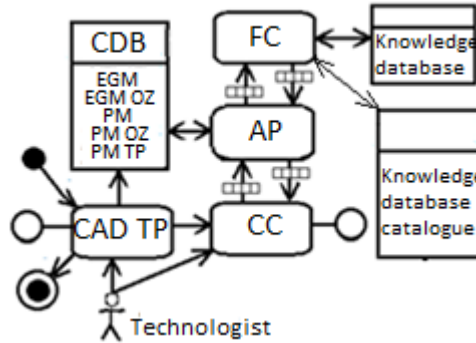


Fig. 2: The scheme of interaction of components in the design of TP.

Therefore, while the technologist closes the machined surfaces (OP) with the added bodies in the CAD system, the design system “plows” and solves the technological problems, while it is possible to repeatedly switch from one FC to another using the links that may be parameters in the solutions found. Thus, the control environment of the system is realized. When the design of the input blank for this operation is completed, then the dimension chains are calculated, which can show that the technological bases for the designed operation are chosen incorrectly and the technological process needs to be adjusted. With this approach, it is not necessary to wait for the completion of the design of all OZs and immediately begin to correct the developed operations, which can significantly reduce the overall design time of the TP. Some operational dimensions for the planned operation cannot be determined. These are the so-called “deferred” sizes, which will be determined in previous operations, which may require a further return to already designed operations to carry out appropriate adjustments [8].

To control the design process, the technologist has the opportunity at any moment to go to viewing the TCB to evaluate the results of designing the TP at the current time and to correct the received FC decisions.

The resulting process option 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 set of technological maps is already carried

out using the PDM system, while the approval of the set in technology bureaus can be controlled using workflow diagrams and redline technology.

The introduction of a new generation of CAD TP systems is a complex and time-consuming process. Adaptation of the system to the conditions of a specific industrial enterprise is based on the consecutive (evolutionary) TPP reengineering. A system implementation and maintenance team is being created. A “road map” of implementation is being developed, in which the composition and sequence of work performed is fixed. The regular use of simulation modeling of business processes of implementation with their consistent detailing will allow us to constantly evaluate the effectiveness of the results of reengineering. The following areas of reengineering are highlighted:

1. Organization of a single information space based on the creation of the ontology of the TPP and the vocabulary system.
2. Analysis and adjustment of databases and knowledge bases on equipment, fixtures and tools, cutting conditions, assortment of materials, etc.
3. Analysis and adjustment of the library of structural elements for the CAD system, as well as analysis and adjustment of the macro package for working with graphic models of structural elements and the package for parametric models of structural elements.
4. Training of technologists and regular verification with their help of the next stages of improvement of CAD TP.
5. Integration of CAD TP based on the use of PDM - system with related departments of the enterprise.
6. Consistent crowding out of existing CAD TP as it captures the ever-increasing scope of next-generation CAD TP. It is necessary to take into account the difficulties that arise with the help of simulation of simultaneously functioning systems.

## 4 Conclusion

Designing operational workpieces by the method of adding bodies with a parallel automated solution of technological problems opens the way to the creation of web-based multi-user CAD systems with a high level of automation, which will reduce the design process time by 2–3 times. Not all problems in creating such a system have been satisfactorily resolved. However, this approach is very promising for the further improvement and creation of a new generation of CAD systems.

## References

1. Yablochnikov, E.I., Kulikov D.D.: Technological preparation of production as a multi-agent system. 5th Russian multiconference on management issues. In: Materials of the conference “Information Technologies in Management” (ITU 2012), 444–450. Moscow (2012).

2. Kulikov, D.D.: Integration of pre-production systems. In: Modern Engineering: Science and Education: Materials of the 7th International Scientific and Practical Conference, 749–759. Saint-Petersburg (2018).
3. Oleynikov, A.Ya.: Ensuring the interoperability of information systems, <https://www.itweek.ru/upload/iblock/6c4/oleynikov.pdf>.
4. Kulikov, D.D., Babanin V.S.: Automation of the formation of models of operational blanks. Scientific and Technical Bulletin of the St. Petersburg State University of Information Technologies, Mechanics and Optics, vol. 57, №8, 26–29. Saint-Petersburg (2014).
5. Kulikov, D.D., Vostropyatov, A.I., Arnst, A.A.: Synthesis of operational blanks in the design of technological processes. In: Proceedings of the international conference "Systems for design, technological preparation of production and management of the stages of the life cycle of an industrial product (CAD / CAM / PDM - 2017)", 390–395. Moscow (2012).
6. Guzeev, V.I., Batuev, V.A., Surkov, I.V.: Cutting modes for turning and boring-milling machines with numerical control: Reference. Mashinostroenie, Moscow (2005).
7. Kulikov, D.D., Nosov, S.O.: The use of a table processor to solve technological problems. Higher Education News, vol. 59, №10, 874–879. Priborostryenie, Saint-Petersburg (2016).
8. Kulikov, D.D.: Calculation of operational dimensions in CAD TPs. Higher Education News (1991).