

AUTOMATED SYSTEM OF TECHNOLOGICAL PREPARATION OF PRODUCTION

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Technological preparation of production is one of the main stages of creation of industrial products. The level of the TPP today determines the timing of new products, its quality and competitiveness. Therefore, the issues of TPP automation become especially relevant. The analysis of the general principles of the organization of technological process of manufacturing of a product is carried out. The basic requirements to the uniform information space of technological preparation of production are defined. The software architecture was developed and its operation was simulated using UML language. Established the main set of data that requires storage and processing: inventory, part, process operation card, part manufacturing technology, specification. The basic requirements to software means of automation of technological preparation of production are formulated.

Introduction

The need to improve the efficiency of the CCI is explained by the fact that the design of technological documentation in most cases significantly (from two to five times) exceeds the complexity of the development of design documentation. A tangible increase in the efficiency of the CCI in comparison with its existing level is possible only if the following conditions are met:

- availability of a single information space for specialists of the design and technological services of the enterprise;
- increasing the speed of development and validity of the plans of the Chamber of Commerce and Industry, continuous monitoring of their implementation;
- meaningful assistance to employees of the technological service of the enterprise during all stages of the development of technological documentation based on the use of mathematical methods and ideas of artificial intelligence, the use of modern computer technology.

These conditions are implemented in the automated system of technological preparation of production (ASTPP). ASTPP is a hardware-software system, but its hardware and software parts are not equivalent. The core of any enterprise's ASTPP is the software of this system. First of all, it ensures the fulfillment of these conditions. This circumstance is explained by the fact that the software accumulates the knowledge of the most experienced specialists and scientists in the field of mechanical engineering technology. First of all, the use of such knowledge also provides the required increase in the efficiency of TPP.

The purpose of this work is to describe the methodology of software development for automation of creation, analysis and accounting of design and technological documentation at the production plant.

1. Analysis of the general principles of technological preparation of production

Technological process (TP) is a complex relationship of different mechanisms, resources, characteristics and indicators. For the most efficient work of the production enterprise it is necessary to organize the technological process in such a way as to obtain a rational combination of labor of workers with the material elements of production.

The division of labor necessarily presupposes its connection, since each partial work acquires a certain meaning only in combination with other partial works (fig. 1). Therefore, the specialization of labor is complemented by its cooperation.

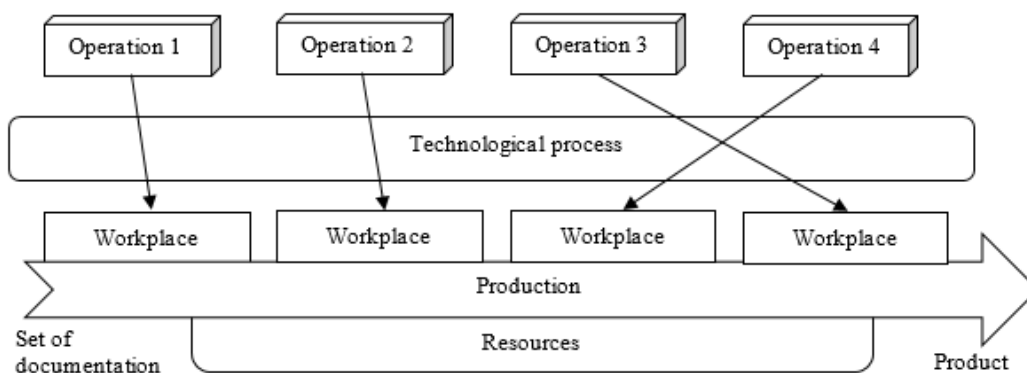


Fig. 1. Production of products at enterprises

Technological design consists, first of all, in choosing the most economical method for obtaining blanks and parts for given specific conditions, establishing a rational sequence of processing operations, assigning the necessary production tools and regulating their use, as well as determining the labor intensity and cost of the manufactured product. The technological process should be designed so that equipment, tools, fixtures, raw materials, production areas are used most fully, correctly and rationally, which, accordingly, will allow the production plan to be fulfilled at the lowest material costs.

In industrial enterprises, the basis for the production of certain products is a production line, which is a combination of machine (machines, devices, devices) and human (labor) resources. Raw materials and materials enter the entrance, and then, by performing certain operations using the existing equipment, the finished product is obtained at the exit, i.e. such products and materials, the process of work on which in this production cycle is fully completed (fig. 1).

The production line has a sequential structure for the placement of its elements, so the failure of one of them entails a failure of the entire system. This leads to production downtime and unforeseen economic losses, as well as a shift in the lead time, which negatively affects the company's reputation and can lead to a decrease in the competitiveness of the product.

In the technological process, all its constituent operations are located in time space, i.e. a strictly defined amount of time is allocated for the performance of each individual work. Accordingly, the time intervals between the execution of operations ($T_1, T_2, T_3 \dots T_n$) also differ from each other (see fig. 2).

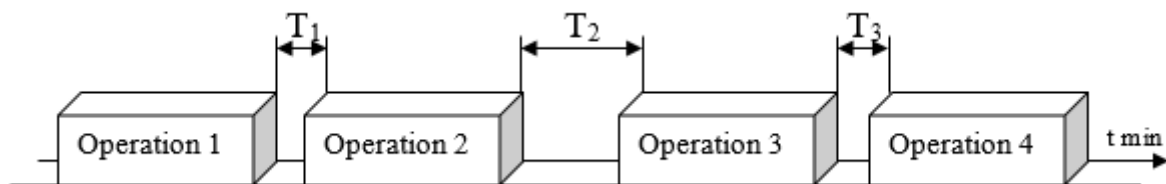


Fig. 2. Time distribution of technological process operations

The entire life cycle of any manufactured product is accompanied by a wide variety of information. To improve the efficiency of production management, the integration of automated processes and related data is necessary. The issues of integrating information resources, without the solution of which effective preparation of production is impossible, are very important in creating a single information space for an enterprise. Note that most often this integration is based on the parallel use of PDM (Product Data management) and ERP (Enterprise Resource Planning) systems, simultaneously with external corporate directories and classifiers.

At present, a fairly large number of various systems of this kind have been developed, and powerful means of integrating these systems, including with computer-aided design systems, make it possible to meet the requirements of enterprises. These systems allow:

- to manage the storage of data and documents (organization of electronic data storages, management of version levels and changes);
- to manage workflows and processes, as well as the product structure (defining and modifying the structure, supporting versions and design options);
- to automate the generation of samples and reports, the ability to display messages about any information contained in the database;
- to provide secure access to information, defining the rights of individual users or their groups.

Unified Information Space (UIS) of TPP is implemented by means of a PDM system and uses a network of automated workstations as a platform. It allows:

- to accept and store the product design in electronic form; effectively monitor the current state of TPP products; to ensure the integrity, consistency and absence of duplication of data; to organize quick authorized viewing of all models and documents; to ensure the prompt exchange of information between ASTPP users; to ensure the rapid passage of design and technological changes; automate the processes of workflow management in the TPP area; ensure informational consistency of all ASTPP subsystems; maintain openness of ASTPP, ease of adaptation to changing

production conditions; provide information exchange with systems that support various stages of the product life cycle.

UIS TPP contains:

- information about parts and assembly units of the product;
- information on the technological processes of manufacturing the product;
- information about equipment and means of technological equipment;
- normative and reference information;
- planning and accounting information.

Fig. 3 shows the product life cycle.

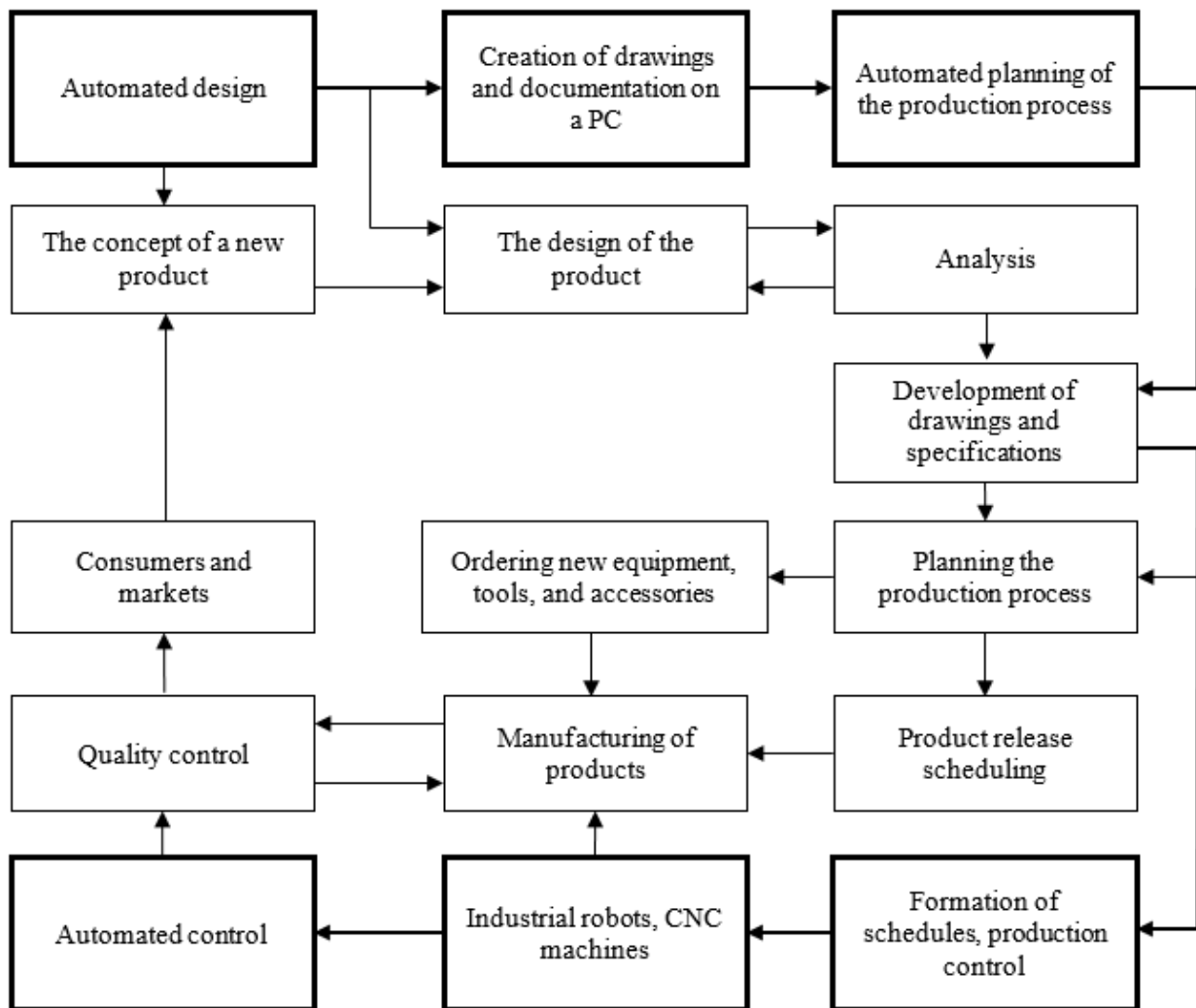


Fig. 3. Product life cycle

UIS is the basis of ASTPP, since both target and native ASTPP functions are implemented in its environment (target functions correspond to the tasks for which ASTPP is created, and its own functions correspond to the tasks that must be solved in ASTPP to ensure target functions)

ASTPP includes:

- software component - includes the supply of CAD / CAM, CAE and PDM systems, application development, database configuration, etc. This also includes the supply of tools for visual modeling of TIP business processes;

- technical component - includes the supply of tools that form the ASTPP technical platform (servers, AWP computers, computer networks). This support can be resolved by the engineering firm through partnerships with computer hardware vendors;

- information component - provides the enterprise with the information necessary for making organizational and technical decisions of the project (comparative characteristics of various systems, information on the progress of ASTPP projects at other enterprises, etc.);

- methodological component - includes the transfer to the enterprise of various methodological materials for the implementation of the project (for example, the methodology for using the UML language for modeling business processes, methods for solving various TIP problems using CAD/CAM and SAE systems, a method for building a single TIP database, etc.) and conducting appropriate training;

- the engineering component - helps the enterprise to more quickly implement the ASTPP components by directly solving individual TIP tasks by the engineering firm using the supplied software systems (for example, designing a specific mold in a CAD/CAM system, modeling the hot stamping process of a given part in the CAE system, etc.);

- personnel component - assistance to the enterprise in filling the gap in specialists required to participate in the ASTPP project. Such assistance can be carried out by an engineering firm, in particular, through close contact (partnership)

with the departments of universities that provide training for students in the necessary specialities.

The main task of PDM is to support an electronic description of a product (product) at all stages of its life cycle. This support should ensure the solution of the following tasks:

- project management: management of work, procedures and documents within the project, control over the implementation of the project;

- planning and scheduling of works;

- distribution of access rights to information between individual project participants or their groups;

- organization and maintenance of distributed archives of design, technological and management documentation (electronic archives);

- management of changes in documentation: control over versions of documents, keeping records of work with documents, registration sheets of changes and notifications;

- fixing the standard stages of the passage of documents, control over the passage of documents by stages;

- integration with CAD/CAM systems and their applications used in the design;

- project integrity control;

- search for the necessary information in the project based on requests.

A large number of different types of data used in ASTPP require the definition of some general criteria that all these data must satisfy. In other words, you need to define the underlying data model. Only in this case it will be possible to build unified and efficient mechanisms for storing and processing information. Consider the following when choosing a basic data model.

ASTPP is created and used by a large number of specialists who solve various problems. Therefore, the data model should be organized so that all specialists can

effectively use the results of each other's work and, if necessary, make their own changes to the model.

The ASTPP creation process is iterative, so the model should, on the one hand, allow for consistent refinements, and on the other, be resistant to changes in the subject area. This means that when modifying the subject area, only a certain minimum required set of model elements should change.

2. Development of architecture and simulation of the program

Three groups of functions can be seen in the software systems in the boundaries of the architecture of the architecture, which are organized for the latest development:

- the function of the introduction and presentation of the gifts (you will not be able to communicate with the user);
- applied functions, characteristic for a given subject area;
- functions of resource management (file system, base of data, etc.).

Execution of these functions is mainly provided by software, which can be represented as interconnected components, where:

- the graphical component is responsible for the user interface;
- the application component implements the algorithm for solving a specific problem;
- resource management component provides access to the necessary resources.

The client-server architecture defines the general principles of organization of interaction in the network, where there are servers, nodes-providers of some specific functions (services) and clients, consumers of these functions.

The two-tier architecture is used in client-server systems, where the server responds to client requests directly and in full, using only its own resources. That is, the server does not call third-party network applications and does not access third-

party resources to execute any part of the request. Fig. 4 shows the architecture of the software system being developed.

This architecture assumes that a graphical shell with a set of required functions (client process) is loaded on one or more computers, and the server process on another. We will use a separate computer with the Linux operating system and the Postgresql database management system as a server.

It is recommended to use a computer network to exchange information between the components of the architecture. In this model, one process can work independently of another, perform certain tasks and share the computational load. At the same time, each of the clients can handle different tasks or perform different functions. For example, on one PC the function of formation of the specification can be loaded, on the second the operator can fill directories with new details, and on the third - to create technologies of manufacturing of details.

Thus, the general architecture of interaction between the components of the software system can be represented in fig. 4.

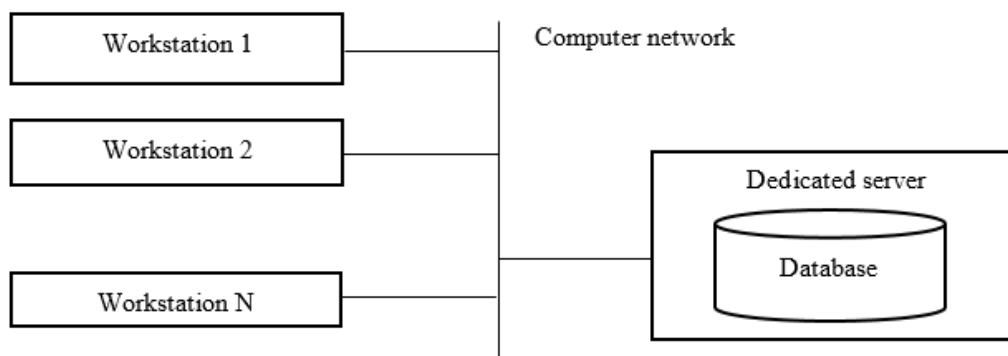


Fig. 4. General architecture of interaction between components of the software system

We will use UML diagrams to model the behavior of the software system. To model the behavior of the software system at the logical level in the UML language can be used several canonical diagrams: states, activities, sequences and cooperation, each of which focuses on a particular aspect of the system.

Unlike other diagrams, a state diagram describes the process of changing the states of only one class, or more precisely, one instance of a certain class, that is, it simulates all possible changes in the state of a particular object. In this case, the change in the state of the object can be caused by external influences from other objects or from outside. State diagrams are used to describe the object's response to such external influences.

Fig. 5 shows a state diagram for modeling the program.

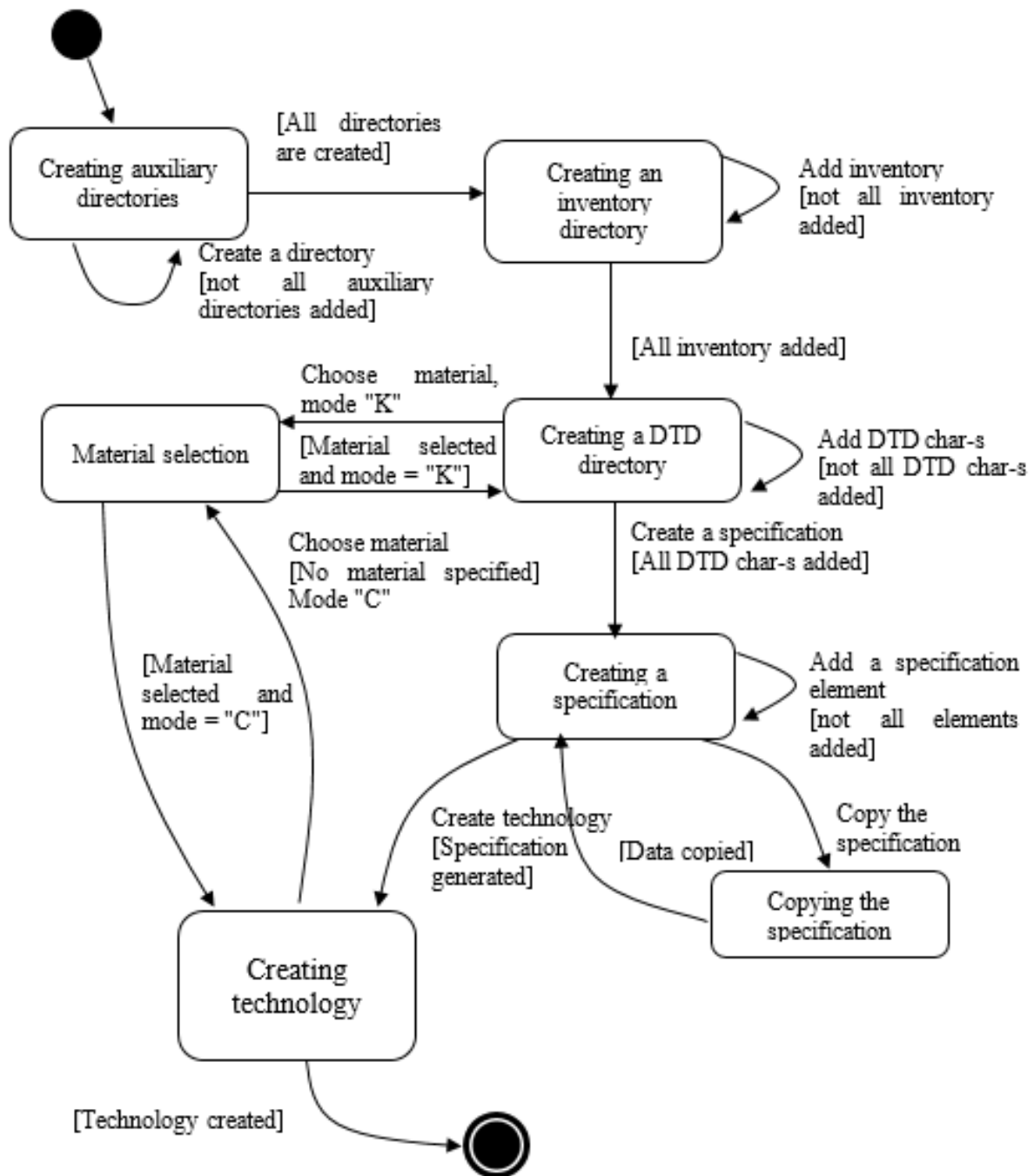


Fig. 5. State diagram for modeling the program

As can be seen from Fig. 5 in order to develop the technology of manufacturing parts it is necessary to go through the following stages:

- creation of auxiliary directories;
- creation of an inventory directory;
- creation of the DTD directory;
- creation of a specification directory;
- creation of technology.

The transition from stage to stage can be carried out only after the completion of all established operations at each stage.

Consider the order of all stages.

At the first stage it is necessary to create all auxiliary directories.

Only when all of them are ready you can move on to creating a directory of goods and materials. As mentioned earlier, a complete description of each material should be added to the goods directory.

At the end of the inventory description, proceed to the creation of the DTD directory. At this stage it is necessary to fill in all the characteristics of the part or assembly unit. If the designer has not yet been able to choose the material for the manufacture of the part, it can be omitted, but it will not be possible to create the technology of manufacturing this part without it.

Next, when all the characteristics of the part are specified, you can proceed to create a specification. At this stage, you can copy a previously created specification, or add all items yourself.

With the addition of all positions, you can proceed to the creation of technology. At this stage, it is necessary to specify all manufacturing operations, and specify the necessary coefficients and parameters. Also, to complete the creation of technology, it is necessary to finally specify the material of manufacture of the part. After completing all these stages, we can assume that the technology is created.

3. Development of a program for automation of accounting of design and technological documentation

The main objects, the characteristics of which must be described: inventory; detail; technological operation card; part manufacturing technology; specification.

Each entity has a set of fields associated with an object.

The general structure of the database is presented in fig. 6. As you can see from this figure, the database structure includes 31 tables.

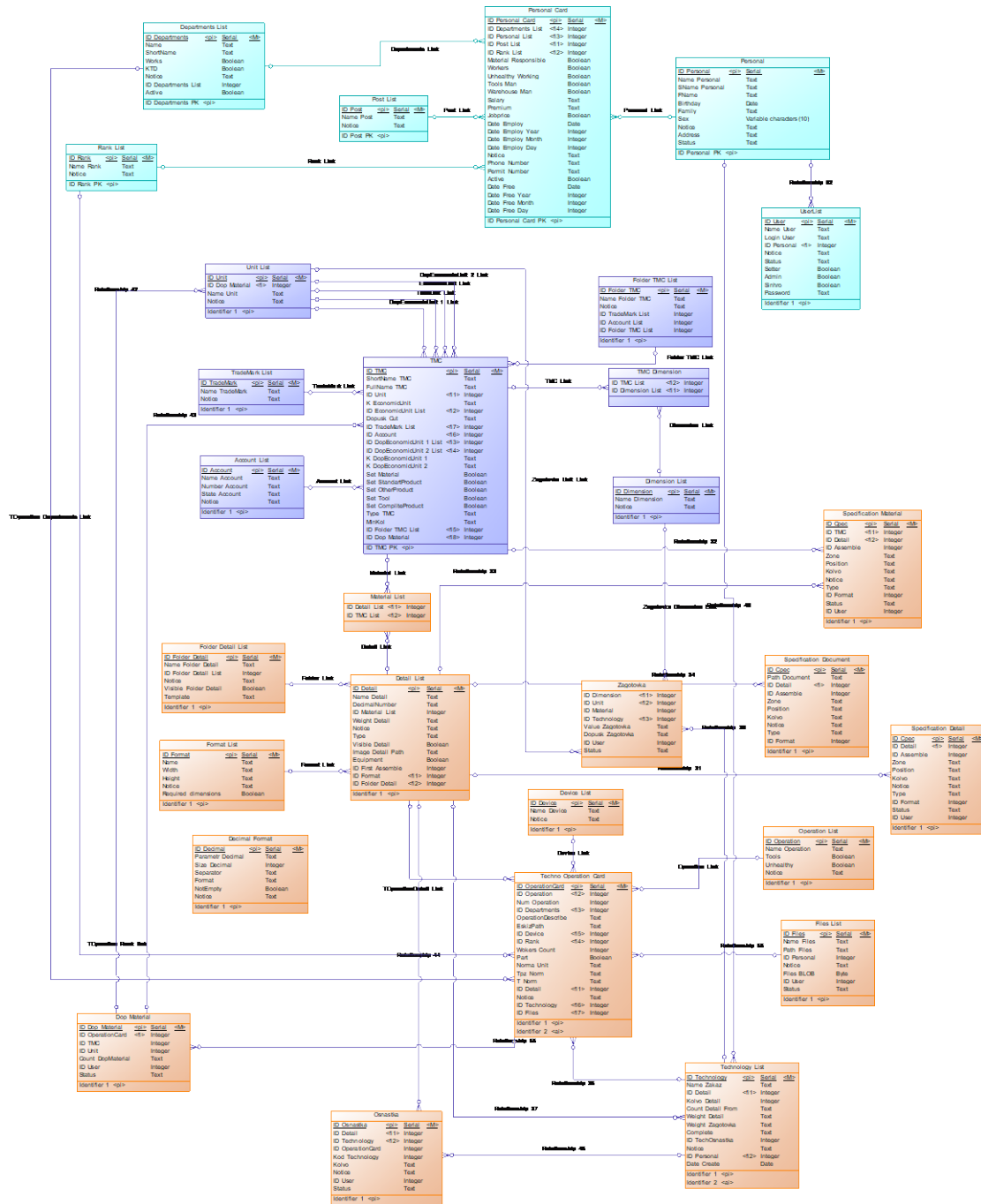


Fig. 6. General structure of the database

Data structure modeling was performed in an automated PowerDesigner environment. PowerDesigner allows you to model the data structure at the design stage, offers metadata management techniques and contains a unique technology for analyzing the relationships of models. While supporting leading modeling and metadata management techniques, PowerDesigner also lets you work with any type of model in a single integrated environment, and the PowerDesigner metadata repository helps interact with all company stakeholders for faster response to changes in the existing business environment.

The program must have the necessary forms to work with the data presented in the design section of the DBMS structure. Fig. 7 shows an example of a form for displaying data from the inventory directory.

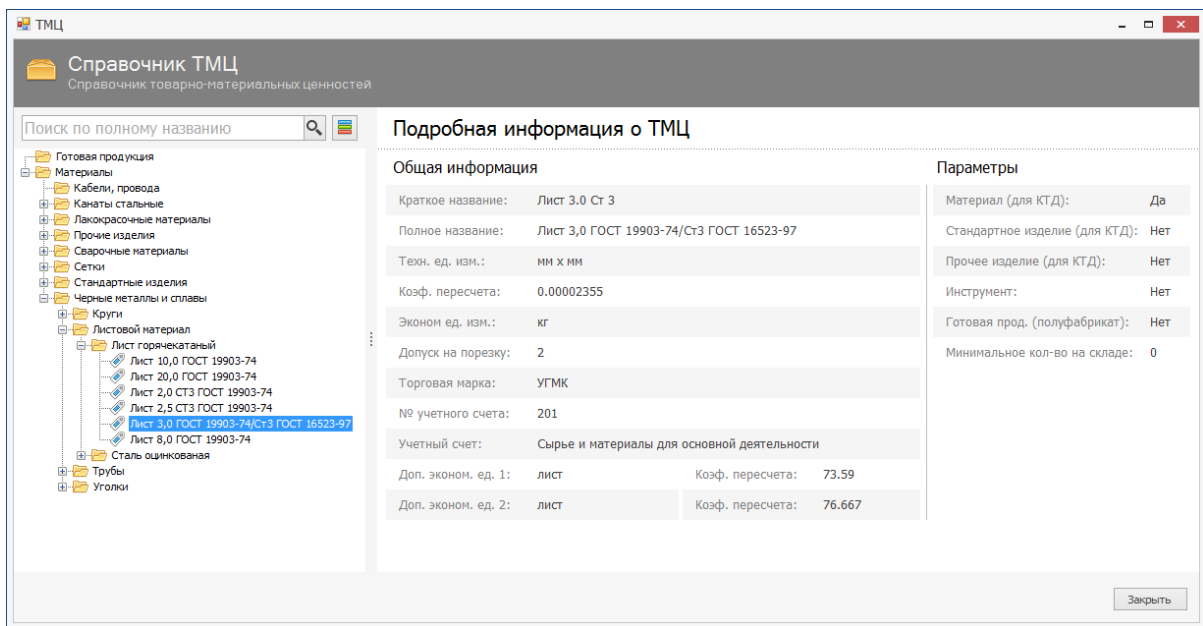


Fig. 7. Form for displaying data from the inventory directory

Fig. 7 shows that the form has two areas: an area with a list of inventory in the form of a tree; area displaying the characteristics of the selected inventory. In the

inventory list area, the data search interface in the inventory table by short or full name is implemented.

Fig. 8 shows a form for adding and editing inventory characteristics.

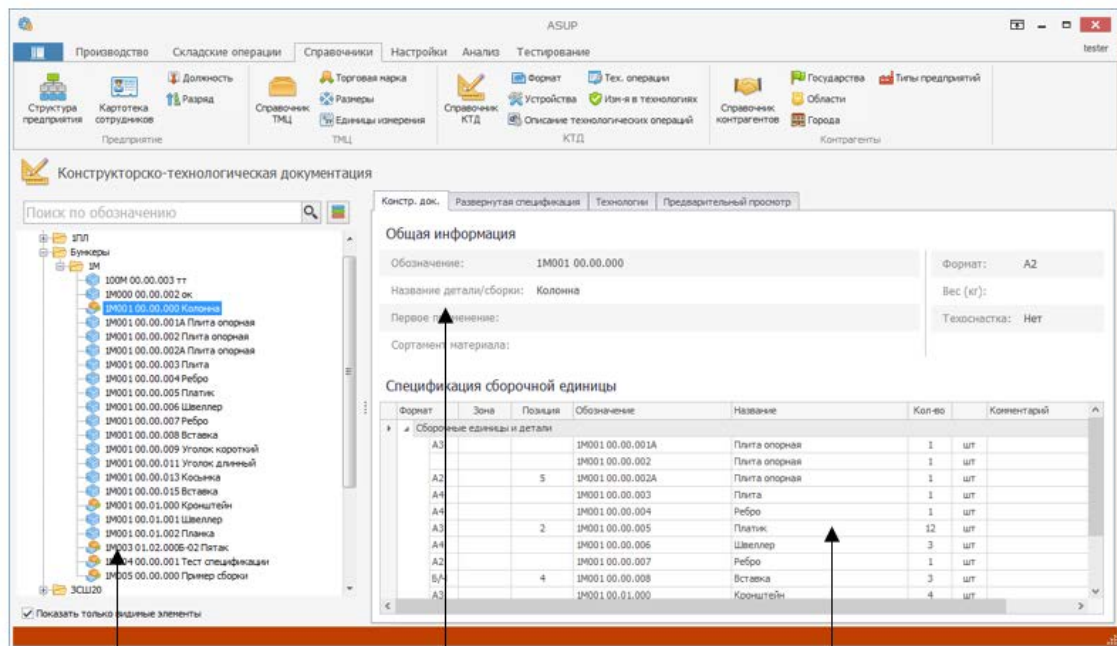
| Общая информация | Техническая размерность | Настройки |
|----------------------------------------------------------------------------------------|--------------------------------------------|--------------------------------------------------------------|
| Краткое название: <input type="text" value="Лист 3,0 Ст. 3"/> | <input type="checkbox"/> Высота | <input checked="" type="checkbox"/> Материал (для КТД) |
| Полное название: <input type="text" value="Лист 3,0 ГОСТ 19903-74/Ст3 ГОСТ 16523-97"/> | <input checked="" type="checkbox"/> Длина | <input type="checkbox"/> Стандартные изделия (для КТД) |
| Техн. ед. изм.: <input type="text" value="мм"/> | <input type="checkbox"/> Количество | <input type="checkbox"/> Прочие изделия (для КТД) |
| Коэф. пересчета: <input type="text" value="0.00002355"/> | <input checked="" type="checkbox"/> Ширина | <input type="checkbox"/> Инструмент |
| Эконом ед. изм.: <input type="text" value="кг"/> | | <input type="checkbox"/> Готовая продукция (полуфабрикат) |
| Допуск на порезку: <input type="text" value="2"/> | | Минимальное кол-во на складе: <input type="text" value="0"/> |
| Торговая марка: <input type="text" value="УГМК"/> | | |
| Учетный счет: <input type="text" value="Сырье и материалы для основной деятельности"/> | | |
| Доп. эконом. ед. 1: <input type="text" value="лист"/> | | |
| Коэф. пересчета: <input type="text" value="73.59"/> | | |
| Доп. эконом. ед. 2: <input type="text" value="лист"/> | | |
| Коэф. пересчета: <input type="text" value="76.667"/> | | |

Fig. 8. Form for adding and editing inventory characteristics

Three areas are organized on this form: the area of editing the main characteristics; area for editing the technical dimension; inventory area. In the first area, you can use the text input fields to add the required inventory characteristic. In the area of editing the technical dimension with the help of marks, you can specify which parameters are used to measure the inventory.

For example, in fig. 8 sheet steel is measured using the parameters length and width. To protect against incorrect data entry, as well as possible avoidance of filling in some fields, the OK button appears only after entering all the necessary data and the fields that have not yet been filled in are highlighted in red.

Fig. 9 shows a form for working with the directory of design and technological information.



List of DTD in the form of a tree

Details information

Collection unit specification

Fig. 9. Form for working with the directory of design and technological information.

In this form, you can see three main areas: a list of DTDs in the form of a tree; detail information; collection unit specification. There are also four bookmarks on the form: design documentation; detailed specification; technology; preview thumbnail details. The view of the "Technology" tab is shown in fig. 10. In this figure you can see that the tab "Technology" contains the following areas: a list of technologies; list of orders; list of operations for the selected technology; list of performers for the selected operation.

When adding a new operation, you must fill in the following fields:

– general information about the transaction, which includes: transaction number; the name of the site; the name of the operation; name of equipment.

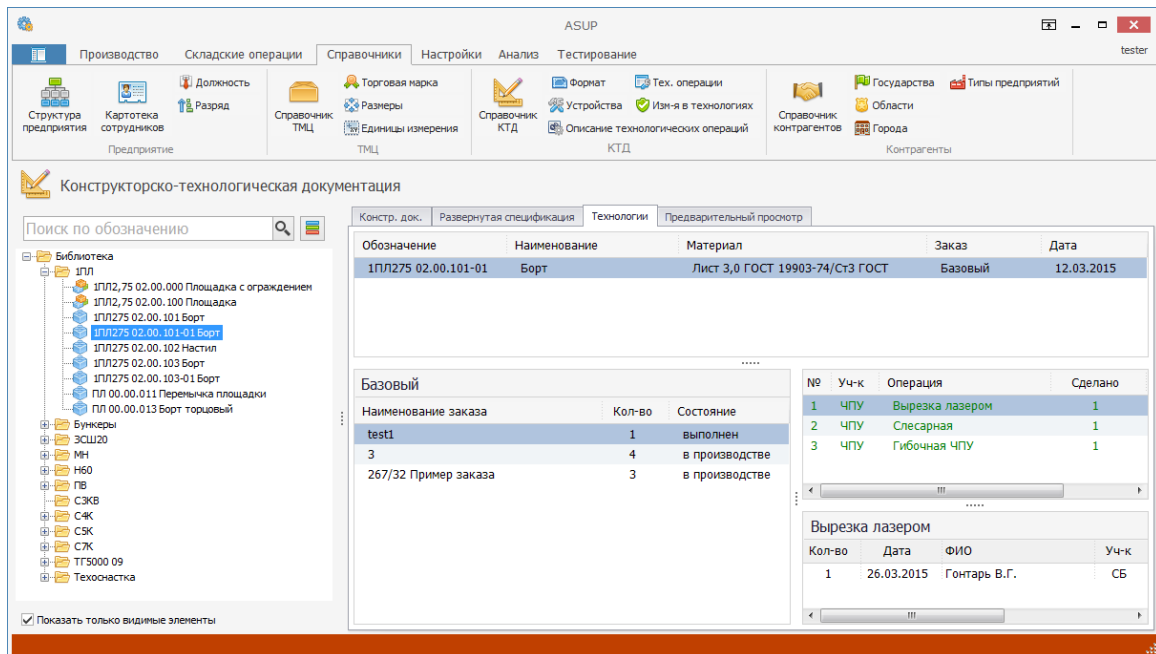
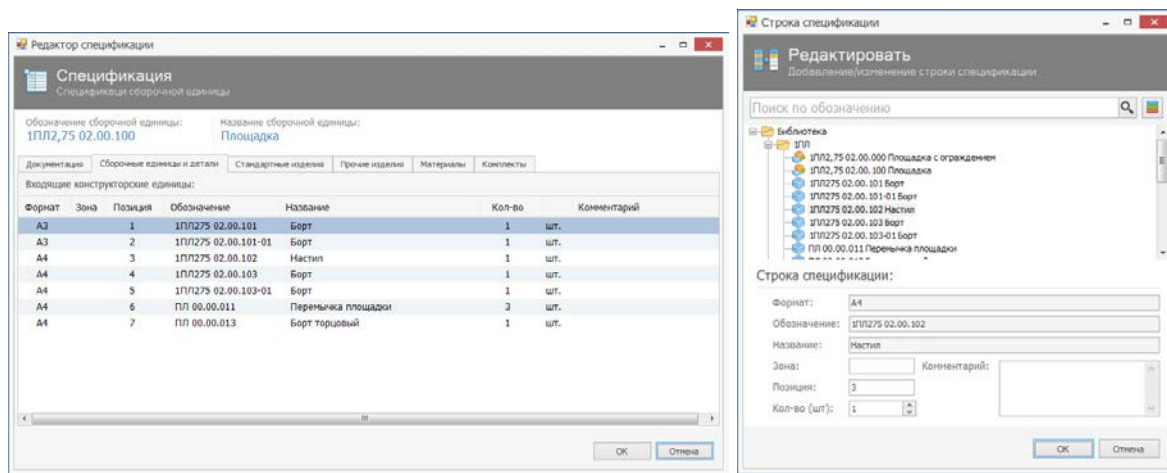


Fig. 10. "Technology" tab view

Data on rationing, which include: discharge; number of workers; preparatory and final time of technological operation; rationing unit; artificial time of technological operation (Tpc); formula for calculating Tpc; additional data included in the formula; list of additional materials; sketch details.

An appropriate form was developed to create the specification.



a)

b)

Fig. 11. Form for creating specification (a) and example of giving a new position to specification (b)

Fig. 11a shows the appearance of this form. As can be seen from fig. 11a, this form allows the designer to see all items of the specification in the form of a list. All positions are divided into groups, each of which is in the appropriate tab. There are six such tabs: documentation; assembly units and parts; standard products; other products; materials; components.

When adding a new item to the specification, a special dialog box is used, which is shown in fig. 11b. The following interface components are present in this form: DTD list; field for displaying the format of the drawing of the part (not editable); field for displaying decimal number (not editable); field for displaying the name of the part (not editable); field for entering the zone; position input field; field for entering the number of parts; comment input field.

Conclusions

The proposed method of creating an automated production management system reduces the time to perform operations on inventory accounting and design documentation. Due to the creation of a single information space of technological preparation of production, all documentation is within the scope of operational access and can be used to manage the product life cycle.

The software architecture was developed and its operation was modeled using the UML language on the example of a state diagram. As a result of preliminary analysis and modeling of the software system, established the main set of data that requires storage and processing: inventory, part, process operation card, part manufacturing technology, specification.

It is proposed to use the automated PowerDesigner environment to model the data structure. The paper shows an example of a database structure and the necessary set of tables for storing information. The program is written in the C # programming language using Microsoft Visual Studio. The program has eight main forms for working with data, which are presented in the section of designing the DBMS structure.

Thus, we can conclude that a single information space creates the basis for the successful operation of ASTPP, for the effective organization of joint, coordinated work of designers, technologists and other specialists of TPP enterprise. As a result, the following are provided:

- acceleration of TPP processes due to parallel work and electronic data exchange between specialists;
- improving the quality and reliability of information due to the transparency of the system and mutual control of participants in the design process;
- accumulation and storage of information in electronic form;
- no unnecessary duplication of information;
- flexibility of the created ASTPP, convenience of its development and adaptation to changing production conditions.

REFERENCES

1. Yablochnikov, E. I. (2005), *Methodological foundations for the construction of ASTPP* [*Metodologicheskiye osnovy postroyeniya ASTPP*], SPb, SPbSU ITMO, 84 p.
2. Yablochnikov, E. I. (2002), *Automation of technological preparation of production in instrument making* [*Avtomatizatsiya tekhnologicheskoy podgotovki proizvodstva v priborostroyenii*] : Textbook, SPb, SPbGITMO (TU), 92 p.
3. Zilberburg, L. I., Molochnik, V. I., Yablochnikov, Ye. I. (2003), *Reengineering and automation of technological preparation of production in mechanical engineering* [*Reinzhiniring i avtomatizatsiya tekhnologicheskoy podgotovki proizvodstva v mashinostroyenii*], SPb, Computerburg, 152 p.
4. Ksenofontov, D. V., Ivaschenko, A. V. (2004), "Implementation of information support systems for a product when organizing a single information space at an enterprise" ["Vnedreniye sistem informatsionnoy podderzhki izdeliya pri organizatsii yedinogo informatsionnogo prostranstva na predpriyatii"], *Proceedings of the International Symposium*, Penza, Publishing House of Penz. state un-ta, p. 203–205.
5. Kolchin, A. F., Ovsyannikov, M. V., Strekalov, A. F., Sumarokov, S. V. (2002), *Product life cycle management* [*Upravleniye zhiznennym tsiklom produktsii*], Moscow, Akharsis, 304 p.
6. Ivaschenko, A. V. (2004), *Object-oriented management of engineering data* [*Ob'yektno-oriyentirovannoye upravleniye inzhenernymi dannymi*], Samara, SNTs RAN, 111 p.
7. Schuh, G., Millarg, K., Goransson, A. (1998), *Virtuelle Fabrik: neue Marktchancen durch dynamische Netzwerke*, München, Wien, Carl Hauser Verlag.
8. Product Lifecycle Management, "Empowering the Future of Business", CIMdata, available at : http://www.acuityinc.com/News/articles/PLM_defmed_CIMdata