Development of methodology for formalized selection of technological operations when designing technological process manufacturing of machinery

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Abstract. This article presents the possibility of automating a formalized selection of technological operations by interconnecting dependencies between all the component components of the technological process. It is shown that the dependencies are folded, including the specifics of working with an enterprise or an enterprise. The study demonstrates the nuances that make it difficult for production and law to affect the approach to selecting a tool and equipment for performing one or one technological operation. An example of a technological process forming for manufacturing a detail in the example of an aviation part of the profile type is given.

1. Introduction
Currently, under conditions of fierce competition, it is significant for the enterprise, whether it is a machine-building or any other, to be customer-oriented. This concept means that the company must be able to quickly and efficiently prepare and re-arrange its production, adapting itself to the needs of another client and his requests.

Automated pre-production systems are aimed at solving the problem of efficient use of time. The first, undoubtedly, an essential step in the process formation is the technical evaluation of the part. Now many enterprises "evaluate" products manually, which significantly affects the speed and effectiveness of the company in the preparation of production and its further readjustment.

2. Tools and Methods
However, some special programs and modules can analyze a three-dimensional model of the part. They help to significantly reduce the time for the design of the construction of the geometry, and again we make it. Even after the analysis of the finished model, the technology is completed, and the technology is different.

Consider a few examples of such software.

2.1. Sprut-TP.
This software allows applying the technological process to the details of the assembly of the mini cots, on which the technological process has already been designed.
So the repeated formation of the technological process is excluded. The functionality of the system allows copying the technological process or parts of the technological process to the newly developed part from other completed projects. At the same time, several types of technological process variants can be fixed.

The whole system of document blanks is linked with the tables of the corresponding resources of the database from which the data can be filled in. Contextual tabs are dynamically selected when the document is filled out. They contain the corresponding tables to fill in the given field [9].

2.2. ADEM-VX
The main features of the CAPP module of the ADEM system include:

1. Obtaining the necessary information from the electronic design view (drawing, 3D model).
2. Designing a production route (dialogue, semi-automatic or automatic), presenting it in the form of a structured hierarchical tree and in the form of a formatted text (the displayed information is divided by font colour, indentation).
3. Calculation of the central processing modes, automation of routine calculations.
4. Material and labour regulation.
5. The formation of all necessary documentation under the requirement of uniform technological standards of the enterprise.
6. The ability to work with normative and reference information as supplied with the ADEM system, as well as the database of these users.
7. Organization of parallel work of the technological process.
8. Organization of the transfer of information on the technological process to the enterprise management system (MES / ERP).

The creation of a technological process in the ADEM system is carried out in two stages. The first stage is the water accumulation of data, in fact, in the self-design process. In this case, information is entered only once, and in the future, it can fall into various documents. Depending on the serialization of production, the development of technological processes is limited to route technology (in individual small-scale production), and more detailed operational technology (medium-sized and large-scale production) is being developed. At the second stage, the formation of output documents is carried out. This stage is performed in batch mode without the participation of a technologist [10].

2.3. ARM Technology
At the moment, the APM Technology module provides the ability to develop technological processes for machining using reference data, databases of equipment, devices, cutting and auxiliary tools, measuring instruments; to draw up technological documentation (routing and operational maps, technological process maps) under the standards of the Unified System for Technical Documentation. The result of the module is a project that includes design documentation (a part drawing created in the APM Graph module), a process tree, and a set of technological documentation [11].

The basis of any preparation of the production process is the formation of the manufacturing process of the part. This part of the production process is one of the most time-consuming in preparation for production or its conversion. Today, process engineers spend quite a lot of time on the formation, development of the most advanced process adjustment. By and large, the formation of a new technological process takes place by way of working with the existing previous technological processes of a typical (similar) part. However, this part of the production preparation, as well as the technical evaluation of the part, can be automated, which can reduce the total labour costs for the formation of the technological process.

3. Results and Discussion
One of the tasks is the necessary settings formation for the design of the optimal technological process for the manufacture of this part. An analysis of the manufacturability of the part model allows getting a list of the necessary technological operations, equipment, tools and accessories. The possibility of
the formation of such dependencies (rules) between them is based on the database, which includes the same technological process components as

- structural elements;
- technological operations;
- tool;
- technological equipment;
- equipment.

For instance, after analysis of the evidence (Fig. 1), we have a list of structural elements of which it consists. Further, following the rules, the system will formulate a list of technological operations for the implementation of the same structural element.

Next is the selection of equipment, tools and accessories. Naturally, the selection takes place based on dependencies between the components of the technological process and the conditions set at the very beginning. For example, the lead time of the part, the complexity, cost, set cost, and other indicators of manufacturability are taken into account.

![Figure 1. Structural and technological analysis of the part](image)

Now we turn to the question of the rules formalized in the enterprise database. Assume that the technological analysis revealed the structural element “hole” in part. The drilling equipment and the drill tool can be used for the drilling operation depending on the geometrical dimensions of this FE (diameter, depth) and the required roughness of its surface. In parallel with this, based on the dimensions of the part, technological equipment is selected; for example, a workbench (Fig. 2). However, there are probabilities of a hole, deviations from perpendicularity. Traces may remain worn because the drill “moved” from its original position.
All this is folding up, and it is more and more logical to use a drilling machine. However, here it is necessary to take into account the dimensions of the part because it can only be larger than the
equipment available at the enterprise. Alternatively, they may not issue technical revolutions or pressure, which is necessary for the material and its condition.

Other structural elements of the part must also be considered. After all, if there is a groove, pocket, a milled board or some other element that needs to be milled, then it is correct to do all this in a milling machine in one installation of the part. However, this process is not simple. After all, the customer, on the other hand, lays down a certain cost, and a milling machine cannot "fit in" into the budget or use it merely if it is a single-piece production.

It is also important to take into account the enterprise itself, and what type of production it is aimed at. Let us clarify this factor a bit. Different plants operate differently. Somewhere manual labour is used, and the enterprise takes pride in releasing ten products a year, but each screw is fitted manually and with maximum thrill. Somewhere on the contrary, 110 products a year are produced, and everything is as automated as possible. Moreover, this singularity is not taken into account in any existing programs for the formation of technological production.

Moreover, in the end, after going through all the rules, the system gives us several possible technological productions that satisfy the initial requirements, from which the technologist himself chooses the optimal one.

4. Conclusion
An example of only one FE – "hole" was considered.

Thus, it can be argued that the formation of only such dependencies is very diverse and it is necessary to take into account not only what relates directly to the part, but also more narrowly targeted very specific factors of production.

The hypothesis in this work is that the possibility of a formalized choice of technological operations when designing the technological process of manufacturing a part will help to reduce the time for its design by at least 20–30 per cent.

The purpose of this work is to develop a methodology (algorithm) by which the selection of necessary technological operations will take place, and several different ready-made process variants will be formed.

Tasks that must be completed to achieve the intended purposeful work:
1. On the example of an existing part, it is necessary to form dependencies between the various components of the technological process. The issue is conditions and parameters based on which the material of the part and the size of the hole for the drilling operation, a drill and a drill are selected. Based on the dimensions of the part, what equipment should be used for drilling this hole? Alternatively, maybe the person does not need to use any equipment and drills, it may be more logical and less expensive to install the CNC machine part and combine the cutting of holes and milling of the part wall.

In other words, it is necessary to formulate the rules, following which the technological process will be formed. It is necessary to imagine how various structural elements correlate with certain technological operations, equipment and other components of the technological process. Thus, the diameter and length of the milling cutter in which milling machine will depend on the dimensions, shape and material. For example, it will be possible to install this milling cutter, which machine can produce the required number of revolutions for working with this material, or in which machine we can install the part to be manufactured. Moreover, if the result is several possible options, then what combination will be the most effective or the most typical for this enterprise. It is also necessary to trace the effect of the conditions at the time of cost. After all, the customer can request, for example, the cheapest option.

2. Further from a particular example of the dependencies of a real part, it is necessary to pass to general. That is, in various ways to expand the "area" of action of these dependencies. For example, to increase the range of overall dimensions of structural elements and the part itself, add various materials and properties so that it is possible to use other machines and cast mills. Add other factors that can influence the choice of one or another component of the technological process. For example,
when milling a wall with a length of 30 mm and a length of 40 mm of an aluminium part on an FPX-20E hand milling machine, the reject percentage is 15% higher than on the Cuter ST series CNC machine. However, with a single technological process, the fulfilment of the given part will be justified by the fact that for the sake of two or three parts it does not need to write a program for the CNC machine.

To date, there are identified a little more than hundreds of such generalized dependencies (without reference to specific sizes and specific features of various parts). Since at this stage only one real part is considered, not many specific rules are formed (for example, if the diameter holes less than 5 mm, it is necessary to use this tool and this equipment).

Next, it is necessary to experiment on another part that also really exists. Isolation and elimination of problem areas are supposed through moving towards the universality of rules and algorithm and not to rebuild everything from a "new" part.

The practical value of this work is as follows:
1. As a result of the work done, the direction of science in the field of automation and control of technological processes and production and the field of machine building, automation of technological preparation of production will be further developed.
2. On the basis of the studied methodology, as well as the existing systems for the technological evaluation of the part, a higher customer focus will be achieved due to the formation of several possible options for the manufacturing process of the part (for example: expensive, quick, cheap, lengthy, one that will be the maximum type of the given enterprise) offered by the system, and as a result, the user selects the most optimal/profitable option based on the source/target indicators.
3. The overall result will be observed:
   - increase in efficiency, reduction of cyclotechnological preparation of production;
   - increase in production manufacturability of the product and individual adjustment (customization) of production.

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