METHODOLOGY OF PREPARATION TO MANUFACTURE ORIENTED ON GEOMETRICALLY AND TECHNOLOGICALLY SIMILAR ELEMENTS

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Abstract: The paper presents the stages of creating technoology and use in practice a methodological approach to the process of preparation of manufacture of machinery elements designed as series of types and modular systems of constructions. The methodology covers stages of the process (in this case manufacture preparation process) and methods aiding these stages. Two new methods of selection of technological data were developed for geometrically similar elements. Technological similarity method and algorithmic method.The established methods and algorithms are the basis to generate series of types of technologies of elements that are technologically similar. At the same time, the determined similarity conditions and relations in the area of design and technology are the basis to create technological databases that might, in the process of developing a technology, be oriented towards productive capacity meeting the criteria of repeatability, modular structurization and efficiency.
Key words: methodology, similarity, technology, modular systems, manufacturing

1. INTRODUCTION

Requirements of the industrial production over years have shaped models that one should follow when designing technological processes. It is very common that these models are burdened with the necessity of designing a complex production process despite the fact of just minor changes introduced in a given construction. Therefore, it entails additional effort and time. In today's market economy time and financial resources are factors that mean 'to be or not to be' for a given company. With this in mind, research has been carried out for a long time now that aims to develop the methodology of designing production process and that would enable reducing time needed to design and modify processes in companies. It is particularly important in the areas of aiding the production of geometrically and technologically similar elements [9].
Contemporary ideas of creating designs, and then preparing process documentation based on them, with the help of the advanced graphic software assume that the emerging technologies for specific machinery elements must be able to live up to intense international competition [1, 2]. A particular machining process must be executed fast and efficiently, according to assumed data from the design and construction process. It is justified to standardize these processes, which is often a basis to create standards, guidelines and technological standards. It is particularly important to standardize geometrically similar elements, such as series of types, which enables reducing production costs and specializing means of production. From this perspective, it seems justified to develop methods aiding the processes of preparation of manufacturing.
For economic reasons, standardization and unification in machinery construction calls for using typical and verified design solutions. It is, at the same time, supposed to ensure fungibility of using. It is therefore essential to possess fast and verified tools to achieve this, [7-9].
The activities focus on assuring rapid and automated record of technology for a specific group of technical means. This particularly applies to:

- development of the technological structure
- selection of a blank and machine tools,
- selection of machining tools and equipment,
- calculation of optimal machining parameters.

2. DESIGN AND CONSTRUCTION PROCESS

The methodological approach facilitates establishing stages of the process and methods aiding these stages. This process, as shown with the example of a design and construction process, is presented on a diagram, as in Figure 1.
In the cycle of publications [3-6], were presented stages of the process of preparation of manufacture for geometrically similar constructions (series of types and modular systems) and methods aiding these stages, based on the developed theory of technological similarity. These stages mainly concern converting design features into technological features in the following areas: technological structure and the choice of machine tools, the selection of semi-finished products, machine tools and additional equipment, calculation of optimal machining parameters.

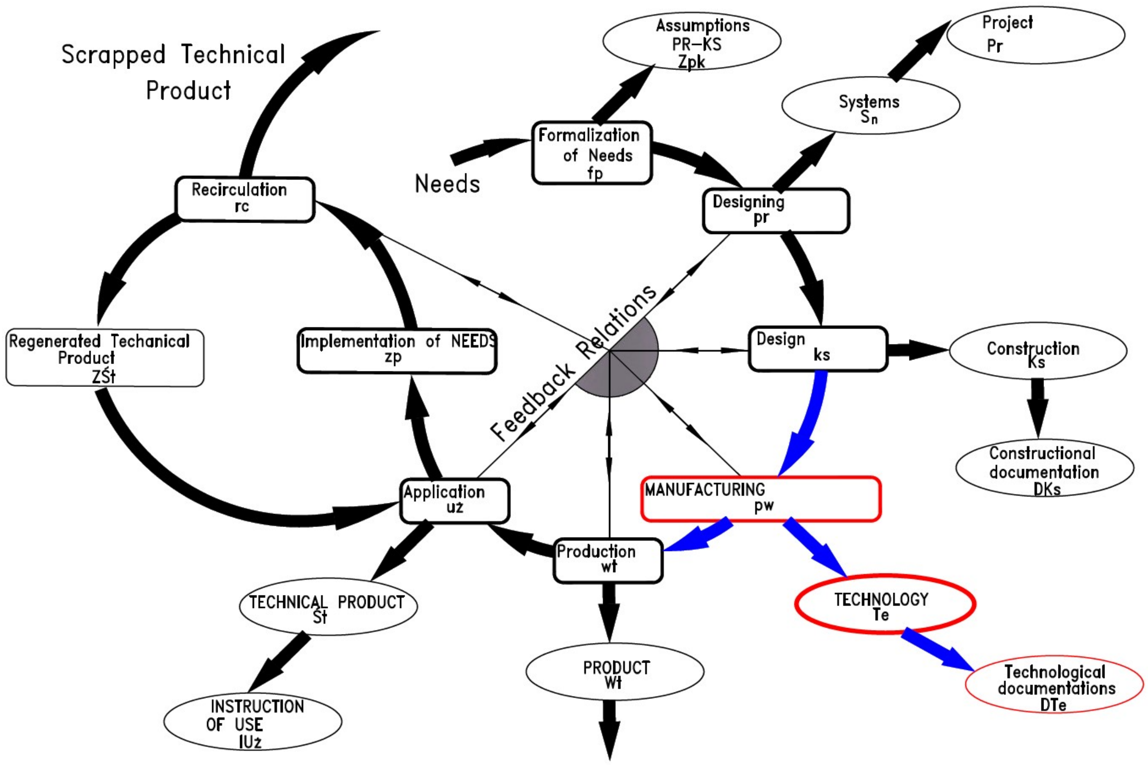

Fig. 1. Diagram of the design-construction process

Conversion of design features into technological features requires introducing and using many repeated and standardized stages, which makes the process susceptible to algorithmization. The key tools to create series of types of technologies are:

- aggregation of knowledge in the field of construction and technology;
- application of the developed theory of technological similarity, and the algorithmic method;
- application of integration methods of construction with preparation of production;
- creation of databases of technological documentation components.

The key methodological assumption in creating series of types of element's technology is a fixed or slightly diversified structure of technology Γ^{tej} and changeability of quantitative technology components T_a^{tej} referred to as technological parameters [5]. Computer-aided conversion of design features into technological features enables semi-automatic generation of particular components of the considered technology (e.g. machining parameters). Methodological approach to the process of creating series of technology types for series of construction types of machines requires an integral (comprehensive) understanding of preparing series of types of technologies, Figure 1. The approach provokes that for the specific series of construction types k_{si} (i= -n, …., 0,…., n) a series of technology types is created t_{ei} (i= -n, …., 0,…., n) retaining the fixed (or slightly diversified) technological structure Γ=const and variable (resulting from the conversion of design features using the developed methods) technological dimensions T=var. This process is symbolically represented on a diagram in Figure 2, where a specific design *MDU_...* corresponds to a specific technology *Te_DU_...* defined with the used of the developed methods.

In case of individual approach, one receives a wide variety of technological processes and their components. Each design may have different, independently developed manufacturing technology.

Additionally, a lack of methodological approach to preparation of manufacture may lead to situation as in Figure 3. The process of defining technologies lengthens considerably and in consequence there is no certainty that choosing it is the best possible option.

Following this assumption, resulting from the relations as in Figure 2, have been developed mathematical relationships, whose aim was to identify the value of technological process components, based on construction similarity of the elements. A possibility of assigning a construction with technology was mostly the effect of the possibility of conversion in the area of quantitative design features, i.e. geometric dimensions.

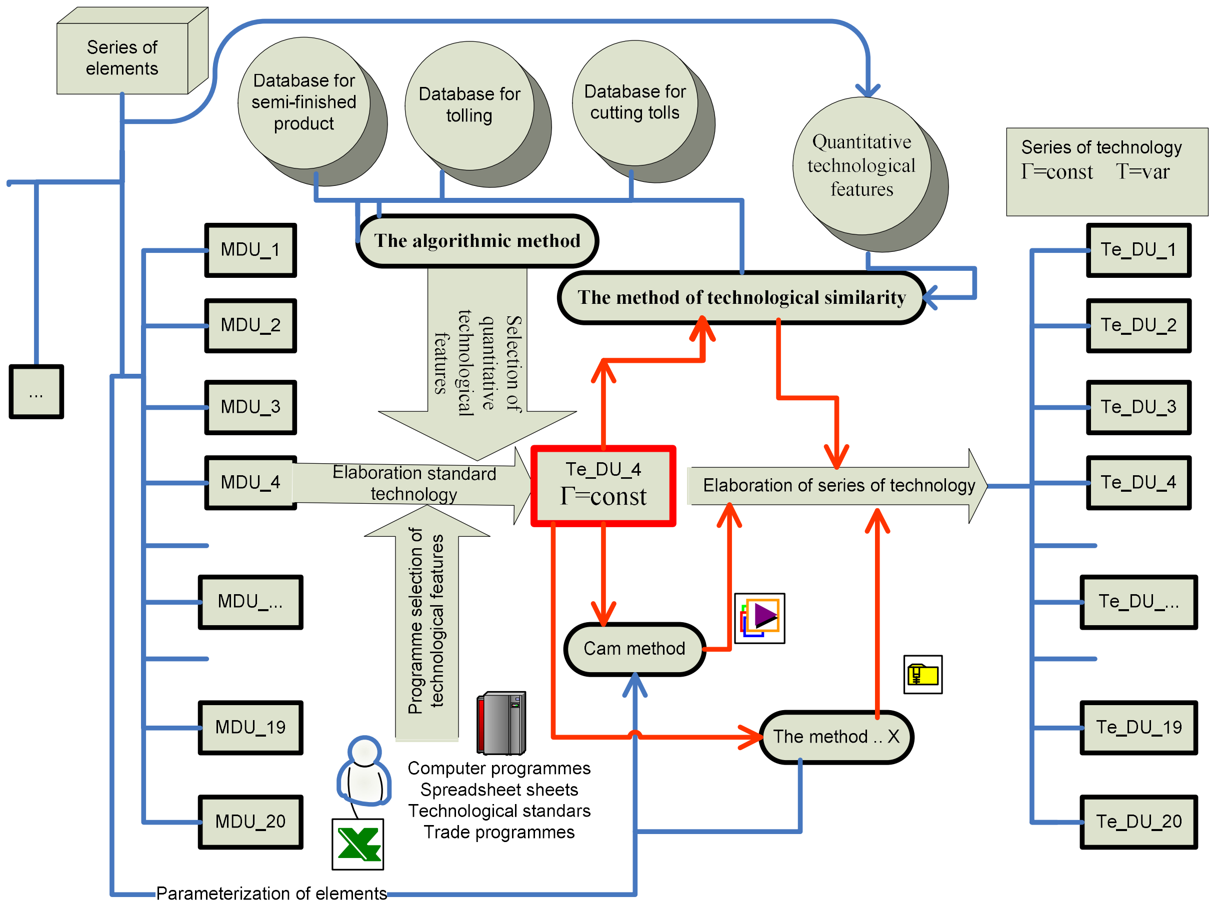

Fig. 2. Integral approach the creation series of types of technology

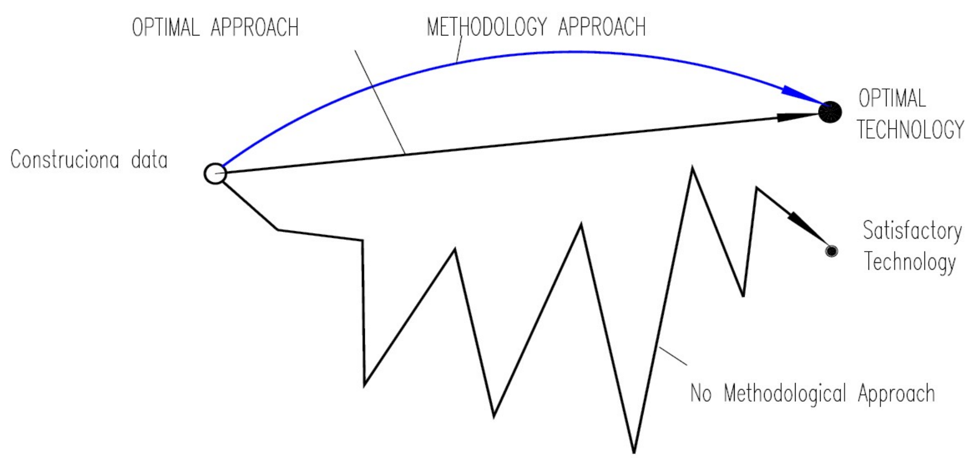

Fig. 3. Individual approach the creation series of types of technology

Taking as a base variability of dimensions in a series of construction types, it was possible to determine:

- tool dimensions,
- dimensions of semi-finished products,
- dimensions of tooling,
- machining parameters.

The major problem was algorithmization in the area of qualitative data, in other words a method of selecting a technological process resulting mostly from the variability of design form of the element. In fact, it required the creation of extensive databases. It is undoubtedly very time-consuming. The alternative was suggesting the solution by means of creating so called model manufacturing technologies [4]. Model technology was determined for a given element from series of construction types and was taken as a base for conversion to determine technologies for other elements of series of types. At the same time, when determining technological process, this assumption enabled considering the most verified and typical methods of manufacturing a particular class of elements. In order for the process of assigning particular stages of creating designs and technologies to effectively contribute to determine dependencies and mathematical relationships, the following assumptions were considered:

- sorting constructional data (constructional features) making up the basis to create technological components of the ordered technology,
- transferring from construction the greatest number of data to the process of production,
- maximum connection of constructional features with manufacturing technology,
- minimisation of information redundancy,
- development of the relational database,
- minimization of variety of construction and technological processes particularly along with constructors and technologists' subjective feelings,
- developing computer programmes and their application in order to integrate the working environment process engineers and design engineers,
- typical constructional solutions and technological processes, which modules computational programmes should be presented.

Publication [3] presents design and technological features that the conversion was based on. Its specific division into quantitative and qualitative features is included in publication [4]. An approach to creating series of types of technologies refers to determining a technology that is described by technological features. Qualitative and quantitative technological features have been distinguished. Qualitative technological features Γ^{tej} describe technological structure of manufacturing the element, form of the semi-finished product, form of the tool and forms of other equipment. All these features are called qualitative technological features. Technological structure Γ^{tej} and the remaining qualitative technological features are mostly affected by design form of series of construction types $\prod^{tej}$.

- ε_j, assignment between constructional forms and components of the manufacturing process structure
- ε_i assignment between constructional features and values of technological parameters.

Quantitative technological features called technological parameters T^{tej} concern: blank dimensions T_{pf}, tool dimensions T_n (e.g: plate size, toll holder dimensions), clamping dimensions T_o and paremeters of cut T_{ps} (feed rate, cutting speed, depth of cut).

3. METHODS

The presented assignments have been the basic stages of converting design features into components of the technological process. Two methods have been developed for these stages:

- algorithmic,
- technological similarity.

An algorithmic method enables determining technological features for series of types of constructions by means of using technological operators. Technological operators convert quantitative and qualitative design features into sets of qualitative and quantitative technological features. Determining technological features, with the use of operators, concerns the quantitative aspect in case of the selection of machining parameters, tool dimensions etc. However, in case of selecting the type of machine tool, semi-finished products or tools, it is a qualitative aspect. The following types of operators have been identified:

- selection of semi-finished product,
- selection of machine tool type,
- selection of cutting tools,
- selection of parameters of a cut.

Algorithmic method is considered in context of three basic ways defining technological features on basis of constructional features with the operators' use resulting from, Figure 4:

- mathematical dependence,
- the table of data,
- the decision boards (choice).

Technological operators, resulting from mathematical relationships, help assign quantitative design features and qualitative technological features, with the use of mathematical relationships adjusted to standards and catalogs.

The essential forms of using operators are decision tables. They are used to present a decision that needs to be made given the circumstances. They are independent of the remaining elements of the decision process (they do not define the method or the addressee of the decision, nor do they influence the process of entering and deriving data). Their structure basis is causation (if…, then). Extended entry tables and limited entry tables have been taken into consideration. Extended entry tables are more concise and easier to use in a specific programming language. In algorithmic method, this type of tables has been mainly used to determine quantitative technological features due to simpler relationships between particular conditions. Limited entry tables have been used mostly to note qualitative and quantitative technological features. This method was used mostly to create relational databases.

Design and technological features in relation to creating series of types and modular systems have also been determined using the method of technological similarity. The theory of technological similarity is strictly associated with the theory of construction similarity.

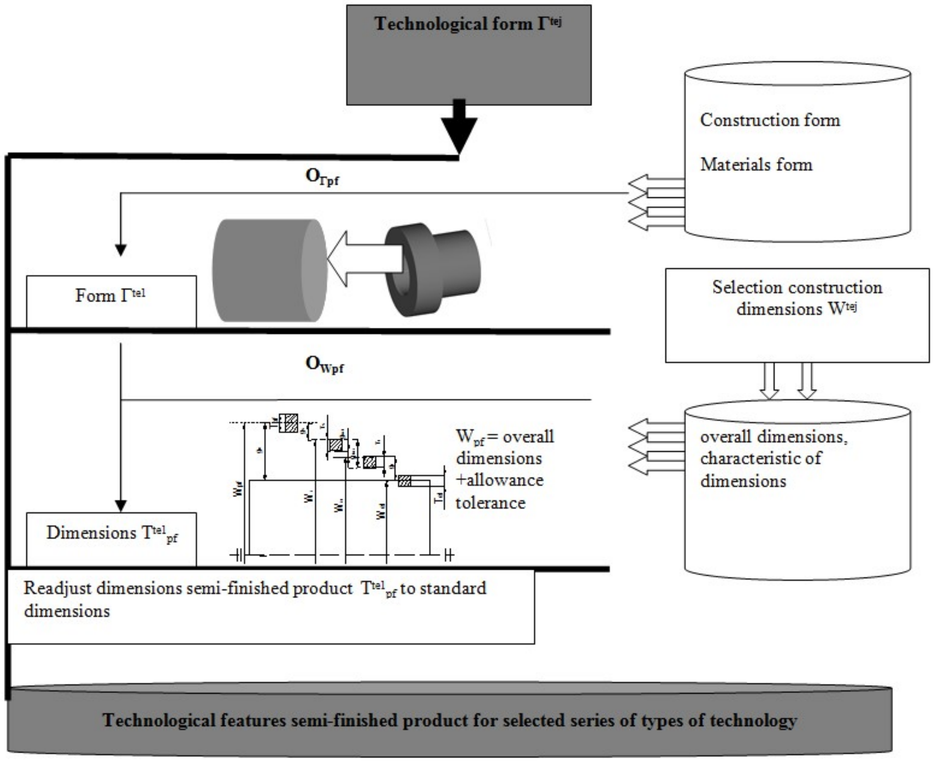

Fig. 4. Diagram of selection of semi-finished features with the use of operators

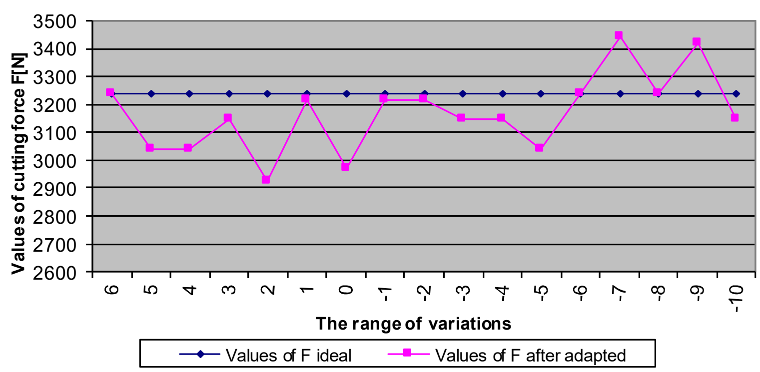

Fig. 5. The distribution of cutting force values, (ideal and after adapted)

Similarity between particular classes of technical means has for a long time been used in different fields of science.

No matter how it is defined and what aspects it concerns, it is always associated with comparing and specifying certain new values based on the known ones, considering the similarity conditions. The model of conversion in the theory of construction similarity and technological similarity is based on the creation of a model construction and technology. Determining design features of newly constructed technical means results from obtaining identical physical, stereomechanical and simple states. This assumption was used with respect to technological similarity, where one aims at obtaining identical technological states such as: machining power, forces and capacity, as well as durability of tools as in model technology. Figure 5 shows the results of the selection of machining parameters based on the constant cutting force for the series. This assumption enables algorithmization of the selection of quantitative technological features (machining parameters). The entire technological structure (machining type, operations, procedures, stages) remains constant (or slightly diversified) for all elements of series of types. Due to a large number of variables and relationships between dimensions and technological features, technological similarity has been identified according to the type of technological operations. It has been limited to similarity in the area of turning, milling and drilling operations.

The processes of turning have been considered in terms of the selection of proper machining parameters for its different variations. The theory of technological similarity applied for these issues enabled identifying technological features for series of the machined diameters (shafts or holes). It has been verified in preparation of manufacture of series of types of cylinders and hydraulic systems (piston, piston rod, gland). It has been achieved by means of mathematical estimation of similarity numbers of the certain machining parameter for the operation of rough and precise turning and groove turning.

Having identified model technological features (resulting from model technology for one element from the series of types) it was possible to determine similarity conditions. Similarity conditions have been identified considering three technological states. These were states concerning machining forces F, machining power P and machining capacity Q. An additional requirement has been introduced connected with maintaining maximum durability of tools. The results concerning maintaining identical technological states in turning operations have been presented in publication [6].

Subsequently been developed mathematical relationships concerning technological similarity in drilling operations. Drilling holes is connected with selecting certain machining parameters of the tool itself and the machine tool. The theory of technological similarity applied for these aspects enables identification of machining parameters of series of drilled holes. Technological features are determined based on design features of the series of types, as well as on technological features of the previous operations. Both drilling into solid material and boring have been considered. In order to calculate a technological feature, the following input data has been adopted: hole diameter, hole length, tolerance, material type. Output data of a given technology, processed with the use of similarity conditions, then define for example: feed, machining speed, machining depth, rotational speed. Here, just as with similarity in turning operations, the conditions have been derived based on machining power, machining forces and machining capacity.

4. CONCLUSIONS

Created programs require analysis and optimization of large amounts of data. The values of technological parameters should meet additional criteria such as adaptation to:

- normal numbers series;
- recommended technological parameters for tools;
- recommended technological parameters for a machine tool;
- technological norms.

This criteria is a cause of the deviation from the full technological similarity, as a result of which one obtains revised values of technological parameters and values describing technological states. However, these adjustments are inconsiderable. The maximum deviation for the entire series of holes was up to 10%. Figure 5 presents this process with the example of machining force in turning operations. The conditions have been verified to identify technological features for series of types of hydraulic systems and cylinders. Testing methods using the developed approach, it can be stated that machining power, force and capacity for specific technological similarity conditions enable identification of machining parameters for a given series of types.

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