Methods to create series of technology

R. Rząsiński *, P. Gendarz

Institute of Engineering Processes Automation and Integrated Manufacturing Systems,
Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: rafal.rzasinski@polsl.pl

Analysis and modelling

ABSTRACT

Purpose: The main reason to commence research concerning new methods of transformation technology into structure was introduced in the process of creating ordered technologies on the basis of series of structure. The worked out datum for these methods is as elaborated ordered families of structure in the form of series of types or modular series of elements structure.

Design/methodology/approach: This paper shows algorithmic understanding to get input data in the process of technology creation based on data of structure. Basic tool to realize data selection for the process of manufacture is the theory of technological similarity, algorithmic method and use of advanced graphic programme.

Findings: The basic result of the analyzed problem is to realize relations between structure and technology for specified series of machine engines elements types. Moreover, the theory of technological similarity with its essential constituents which determine input date for selection processes algorythmisation of technological features on the basis of constructional features was introduced.

Research limitations/implications: Analyzed methods develop algorythmisation of designing environment and support integration with the process preparing production. Further analyses will be carried out on in order to specify the theory of technological similarity in new forms of computer-aided (relational databases, theory of automatic classification).

Practical implications: Described methods were developed based on practical examples of the technological module systems creation for hydraulic cylinders used in mining, slag cars used in metallurgy and series of gears types. The represented methods are applied to the unit's types of hydraulic servo-motors used in mining.

Originality/value: Method of the technological similarity, the algorithmic method and CAM method are the basis for selection of technological features in the process, which creates the as ordered technology families (types and module systems of constructions). This method is characterized by a possibility to shorten time related to production preparation and series production increase.

Keywords: Technological design; Series of type; Technology

1. Introduction

This paper represents a method of transition from series of construction to technological ones through transformation of selected constructional features. New requirements related to the constructional process assume that the project has to be executed quickly and adapted to user's demands.

The basic tools for creating series of technology on the basis of series of construction are:
- knowledge acquisition in the range of construction and technology,
- methods application: technological, algorithmic and CAM similarity,

- methods application: construction with preparation of production database created out of technological working plan components.

All operations mentioned above, related to methods description of integrated transformations of constructional features into technological ones, create a methodological approach in the process of series of technology for series of construction. Elaborated methods are oriented on processes of machining: turning, drilling and milling.

Undertaken tasks are susceptible to algorythmisation and computer aid. Moreover, it concerns both the methods of quantitative selection and qualitative technological features. Working on defined reports between construction and technology, the row of applications and computational programmes were elaborated. Visual BASIC programming language as well as AutoLISP used in AutoCAD programme were applied in preparing computational programmes. Access and I-DEAS programmes were applied to create the databases of tools and instrumentations.

The possibility to create technology series was also verified with the use of graphic programmes of CAD and CAM ranks as working conditions for small and average productive institutions..

2. The area of construction and technology

In the forming process of series of technology, there is transformation of features required (mainly qualitative) in the area of the constructions ks_k and technology te_k (Fig. 1).
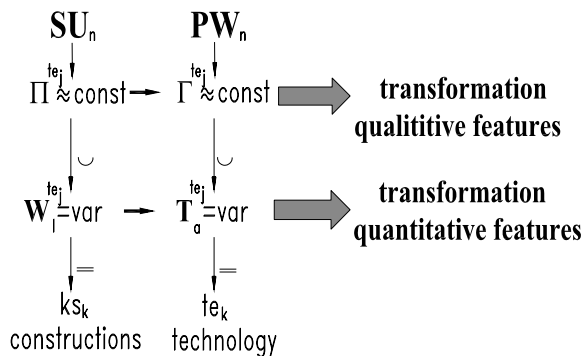

Fig. 1. Interdependencies between models considered in the paper

The constructed element is defined by constructional features: geometrical features (C_g) and materials features (C_t) [1, 2, 9,10]. Each technological process is defined by the process structure (Γ), that consists of: processing parameters, tool dimensions and tooling-up. Computer aid used at this process may be improved thoroughly applying transformations of quantitative features to prepare series of technology (creating databases and computational programmes).

Construction and technology are being examined as *ordered family of construction* RK_n (Equation 1) *and ordered family of technology* RT_n (Equation 2) [2, 8, 11].

$$RK_n = Ks_n^u \left\{ (ks_k; (k=1, kz) \right\} <=$$
$$<= Po_n^u \left\{ (po_i; (i=1, iz) \right\} \tag{1}$$

$$RT_n = Te_n^u \left\{ te_k^{ej}; (k=1, kz)(j=1, jz) \right\} <=$$
$$<= Ks_n^u \left\{ (ks_k; (k=1, kz) \right\} \tag{2}$$

2.1. Construction

Construction is a set of structures and product conditions, described by design features CK [1,2,7,10]. Structures and conditions states are properties of product formulated by design engineer. Design features are modified in a way to enable qualification of basic components of technological documentation on their basis.

Among design features CK, here we have:
- geometrical design features C_g
- material design features C_t
- assembly design features C_m

$$CK = C_g \text{ u } C_t \text{ u } C_m \tag{3}$$

Geometrical design features C_g describe external structure and macrostructure of the technical mean [2,9]. Among geometrical design features here we have:
- qualitative geometrical design features $\prod_g$
- quantitative geometrical design features $|W_g|$

$$C_g = \prod_g \text{ u } |W_g| \tag{4}$$

Qualitative geometrical design features $\prod_g$ describe geometrical form of technical mean, external and internal surfaces.

Quantitative geometrical design features $|W_g|$ are considered as a set of dimensions describing geometry of technical mean and dimensions describing macrostructure (surface roughness, tolerance form, position tolerance etc.).

$$|W_g| = N \text{ u } |T| \tag{5}$$

N – nominal value of dimension,
$|T|$ – dimensional tolerance with tolerance range.

2.2. Technology

Technology is a state of product manufacturing, described by technological features.

Among technological features C_{Te} here we have (Fig. 2):
- qualitative technological features Γ_g,
- quantitative technological features $|T_g|$.

Qualitative technological features describe:
- technological structure of manufactured element,
- form of semi-finished product ,
- form of cutting tools,
- form of tooling.

All these features are named a technological form. Technological structure depends on form of series of construction.
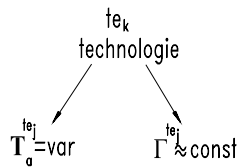
Fig. 2. The area of technology

$$C_{Te} = \Gamma^{tej} \bigcup |T|^{tej} \qquad (6)$$

Γ^{tej} =const - technological form,
T^{tej} =var - technological parameters.

Equation 7 presents all technological features:

$$C_{Te} = (\Gamma_s \bigcup \Gamma_p \bigcup \Gamma_n \bigcup \Gamma_o) \bigcup$$

$$\bigcup (T_{pf} \bigcup T_{ps} \bigcup T_n \bigcup T_o) \qquad (7)$$

where:
Γ_s – technological structure

Γ_{pf} – form of semi-finished product

Γ_n – form of cutting tools

Γ_o – form of tooling

T_{pf} – dimensions of semi-finished product

T_n – dimensions of cutting tools

T_o – dimensions of tooling

T_{ps} - parameters of processing

Quantitative technological features describe: dimensions of a semi-finished product, dimensions of cutting tools (inserts shape, dimension of holder), dimensions of tooling and parameters of processing (feeds, depth of cut, cutting speed).

All these features are called technological parameters.

2.3. The traditional method creating of the ordered families of technology

In aspect of constructions investigations of hydraulic servomotors, the consecutive methods to create the ordered families of technology are distinguished as:
1) method of ordered technologies creation Te_n, based on universally applied constructional form of units (shafts, targets, muffs) [5, 11],
2) method of group processing for technologically similar elements [6, 8, 9, 13],
3) methods oriented on elementary objects (the postal entire) with parts of elements (the hole, threads, grooves) [7,11,12],
4) method of ordered technologies creation te_k on the basis of ordered constructions ks_m^{te}, elements [10].

The work is oriented on ordered technologies creation on the basis of ordered constructions $ks_{m \, te}$, elements. In this method, on the level of required elements construction, the ordered technology can be assigned (Equation 8).

$$ks_m^{te_j} \rightarrow te_n^{te_j} \qquad (8)$$

The process of technology ordering is realized for series (Equation 9) or module series (Equation 10), applying them in identical possible operations, cuts, parameters of processing, seizing, tools, gears.

$$ts_m^{te_j};(m = 1, mz_j) \qquad (9)$$

$$mk_m^{rwe_j};(m = 1, mz_j) \qquad (10)$$

The basic methodological assumption to create ordered technology of manufactured element (the hydraulic servo-motors) is constant or the imperceptibly differential structure of technology Γ^{tej} and the variation of technological parameters T_a^{tej} (Equation 11).

$$te_n^{te_j} = (\Gamma^{te_j})_{const} \cup (T_a^{te_j})_{var} \qquad (11)$$

This problem is analysed in later part of the paper. In order to obtain the most effective integration of process creating series of technology including a process creating the ordered construction performance under-mentioned standards, the following must be required:
1) sorting constructional data (constructional features) making up the basis to create technological components of the ordered technology,
2) transferring from construction the greatest number of data to the process of production,
3) maximum connection of constructional features with manufacturing technology,
4) minimisation of information redundancy,
5) development of the relational database,
6) minimization of variety of construction and technological processes particularly along with constructors and technologists' subjective feelings,
7) developing computer programmes and their application in order to integrate the working environment process engineers and design engineers [13],
8) typical constructional solutions and technological processes, which modules computational programmes should be presented.

3. Methods to create series of technology

In the process of creation the ordered families of technology, two basic areas of the transformations, in set of construction and technology are as follows:
- ε_j – subordinating between constructional forms and components of production process structure,
- ε_i – subordinating between constructional features and values of technological parameters,

Integration of this environment has the purpose in finding the connection between individual areas of sets, Fig. 3.

The methods of selection of quantitative and qualitative technological features are as follows:
- technological similarity,
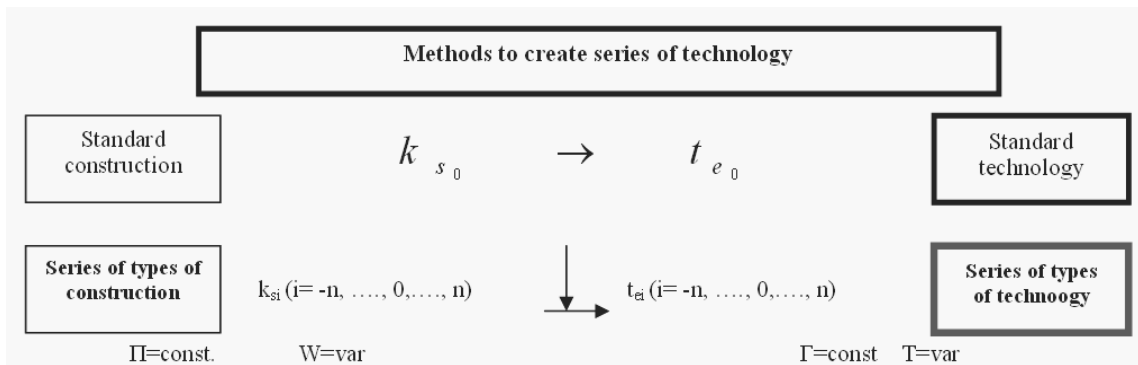- algorithmic method,
- CAM method.

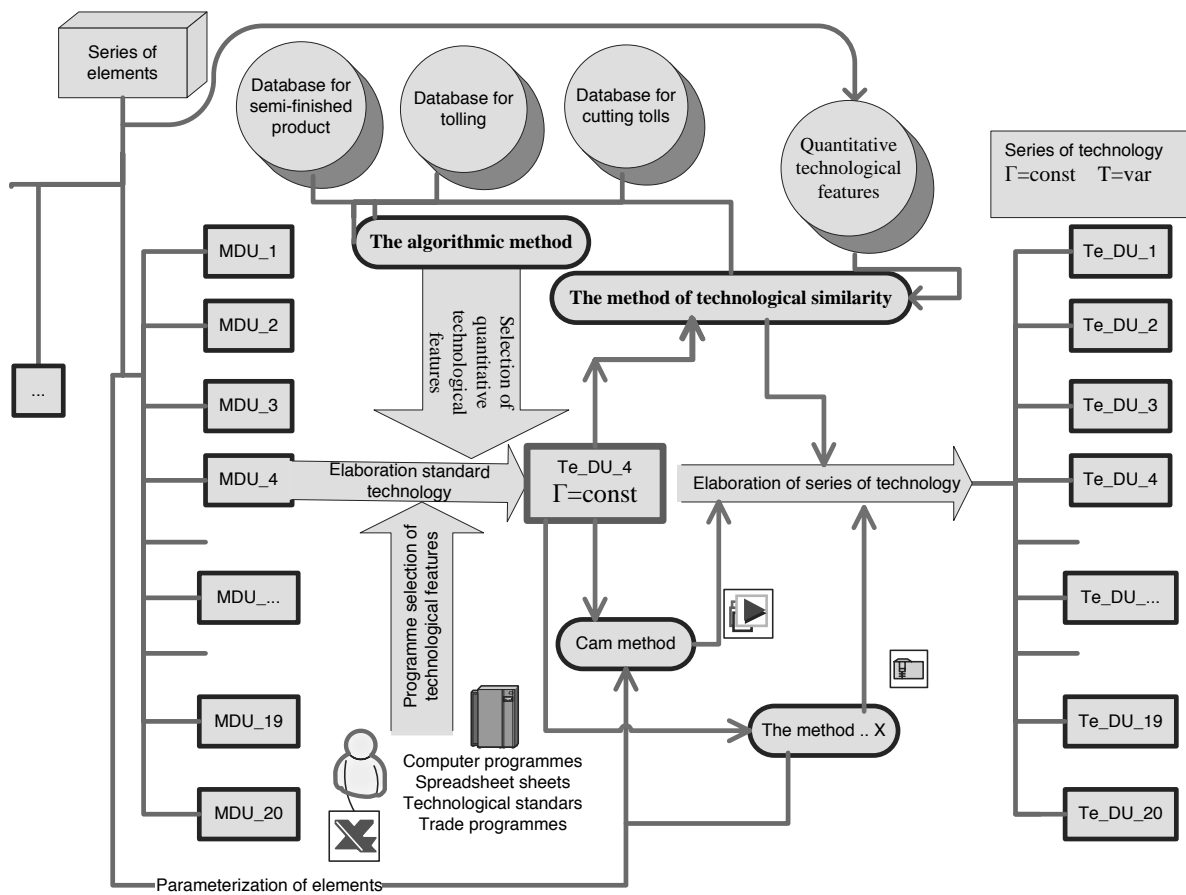Fig. 3. Creating series type of technology

Fig. 4. Integral conception of process creating series of technology

Worked out methods represent integral (general) the conception of preparation series of technology (Fig. 4). The approach causes that for specified series of construction k_{si} (i= -n, …., 0,…., n) the series of technology create t_{ei} (i= -n, …., 0,…., n) with maintenance constant (or imperceptibly differential) technological structure Γ=const and variables (resulting from transformations of constructional features using worked out methods) the technological dimensions T=var. This process is presented in Fig. 4, where definite construction MTU_... definite technology belongs Te_MTU_… defined with the use of worked out methods.

3.1. The method of technological similarity

The similarity between specified classes of technical means is applied in different fields of science [6, 9, 11,]. This paper presents a model of construction ordered families transition into ordered families of technologies with the use of theory of technological similarity [9, 11].

The method of similarity is applied in the process of technological features definition to generate the parameters of processing.

Those parameters concern the processes of machining: turning, drilling, and milling. For series of technology for one selected technology, the parameters of process are calculated. They are calculated by: algorithms, analytical programmes, norms. The parameters defined as standard parameters (technological features) are selected on the basis of constructional features [10, 11].

The theory of technological similarity is applied for elements characterized by constant constructional form and variational values of dimensions, Fig. 5. Technological working plan is created by advanced graphic programmes according to traditional methods using program and relation parameterization.
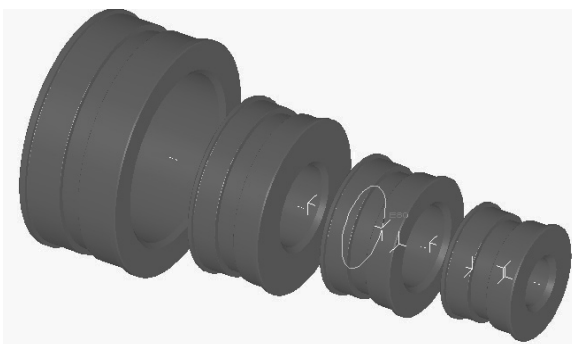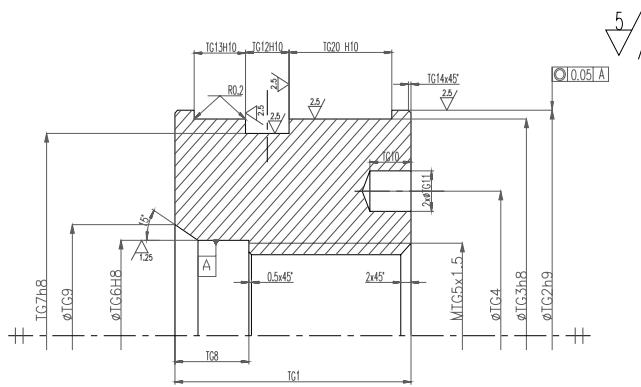

Fig. 5. Constructional form of servo-motor element

Standard structure is used to generate further technological structures by modification of chosen parameters. The selection and transformation of parameters is realized after having defined the system of relations and the system of connections and transformations between individual features. It is important that this method is applied to create technological documentation for series of elements. It is characteristic for all series of elements to have constant constructional form of all elements. Constructional features (dimensions) are variable.

This assumption allows for algorythmisation of quantitative technological features selection (parameter of processing).

Entire technological structure (processing type, operations, cuts, transition) remains constant for all elements of series.

The values of processing parameters define standard values of technological conditions. Then, for constant technological conditions with the use of measures of technological similarity the processing parameters are generated for next elements of the series.

The number of similarities define the digitization level of a calculated value of technological parameters.

They refer to transformation features assigned to standard technological process. Their value is chosen according to the type of machining and similarity of constructional features. Their final is in accordance with the series of normal numbers (e.s. R20).

This paper analyzes the similarity of constructional parameter (entrance data presenting constructional quantitative feature, marked as pi) and the similarity of parameter of processing (exit data presenting the quantitative parameter of process, marked as wi).

- similarity of constructional parameter

$$\varphi_{ik} = \frac{p_{ik}}{p_{0k}},$$

- similarity of parameters of processing

$$\varphi_{it} = \frac{w_{ik}}{w_{0k}}$$

The model of transformation of selected constructional features (quantitative):

1. Mathematical functions describing technological conditions

$$Q = v_c * a_p * f \qquad F_c = R_m *$$
$$A_w \qquad P_c = \frac{v_c * a_p * f_n * k_{c0,4}}{240 * 10^3}$$

2. Similarity conditions resulting from assumed technological conditions

$$\varphi_{Pc} = \frac{P_{ci}}{P_{c0}} \quad > \quad \varphi_{Pc} = \varphi_{V_i} * \varphi_{a_{pi}} * \varphi_{f_{ni}} * \varphi_{k_{c0,4i}}$$

$$\varphi_{Q_c} = \frac{Q_{ci}}{Q_{c0}} \qquad \varphi_{Q_c} = \varphi_{R_m} * \varphi_{a_p} * \varphi_{f_n}$$

$$\varphi_{Pc} = 1 \quad \varphi_Q = 1 \quad \varphi_{Fc} = 1$$

process of transformation……..
equation of similarity

$$\varphi_{V_i} * \varphi_{a_{pi}} * \varphi_{f_{ni}} * \varphi_{k_{c0,4i}} = 1$$

3. The conditions of similarity describing dimensions of similarity for parameters of processing

$$v_{\ i} = v_0 * \varphi^i \qquad pa_{a_p i} = pa_{a_p 0} * \left(\frac{1}{\varphi^2}\right)^i \quad f_{n\ i} = f_{n0} * \varphi^i$$

for i = -7,-6,...,0,...,6,7

where: i – number of element of series of type, φ- number of similarities.

In the paper the transformation of the quantitative constructions features (dimension) into quantitative features of technology (technological parameters) with the assumption of constant qualitative features in considered domain is proposed. On the basis of elaborated technological processes the following stages of creating the ordered family of technology on the basis of ordered construction.

According to defined measures of similarity value of parameters of processing are specified according to constant technological conditions.

The values of parameters are generated one after another using the following elements: constant power machining, solid efficiency of processing or strength of cutting.

The obtained values of parameters should be optimized into the range of applicable values.

In accordance with the chosen machine tool and productive possibilities the value of a given parameter should be adapted to definite series of value.

3.2. The algorithmic method

Algorithmic method realizes subordination between elements of series of technology and elements of constructions types on the basis of plan of production with operators use (Equation 6). Technological operators transform quantitative and qualitative constructional features $x_{mi}^{e_j}; (l = 1, lv_j)$ in sets of quantitative and qualitative technological features xt_{ia}^{tt} in family of technology described by technological structures $\Gamma_{rw}^{te_j}; (j = 1, \dots, jz)$

$$CK^{te_j} \xrightarrow{operator} CTe^{tej}, (j = 1, \dots, jz) \qquad (12)$$

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

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

The example of operator mathematical dependence selection of rotational speed and operator selection of feeds presented in Equation 13 and Equation 14, where:
d_i, R_z- constructional features,
v_i, n_i, f_i-technological features.

$$CK^{te_j}(d_i) \xrightarrow{operators \ of \ n} CTe^{tej}\left(n_i = \frac{1000v_i}{\pi d_i}\right) \qquad (13)$$

$$CK^{te_j}(R_{zi}) \xrightarrow{operators \ of \ f} CTe^{tej}\left(f_i = \sqrt{\frac{8R_z r_\varepsilon}{1000}}\right) \qquad (14)$$

The decision boards are the basic form of applying the operators. They are examined and apply decision board with limited record and decision board with extended record. Example of decision board with extended record is presented on Fig. 6. The specified rule is applicable e.g.: R1, when the range of feature d_i comprises in range ck_i^{te1} (50)i ck_i^{te2} (60), and value ck_i^{te3} (Ra$_i$) = 5, then are defined technological features as cte_i^{te1} (f$_i$)=0,3, cte_i^{te2} (n$_i$)=1500, cte_i^{te3} (a$_{pi}$)=1.

	R1	R2	R3	R4	Rn
Range of feature ck_i^{te1} >(d$_i$)	50	60	70	90	-
Range of feature ck_i^{te2} <(d$_i$)	60	70	90	100	-
Range of feature ck_i^{te3} (Ra$_i$)	5	1,5	2,5	1,25	-
Value of feature cte_i^{te1} (f$_i$)	0,3	0,2	0,1	0,15	-
Value of feature cte_i^{te2} (n$_i$)	1500	1300	1400	1220	-
Value of feature cte_i^{te3} (a$_{pi}$)	1	0,5	0,3	0,1	-

Fig. 6. Example of decision board with extended record used in application

Defining with the operators' use the technological features concerns quantitative questions in case of selection of parameters processing. In case of selection of machine tool, cutting tools and the semi-finished product at this point is qualitatively-quantitative.

The technological operators invest the qualifications of individual components of technology. Among those technological operators are::

- selection of semi-finished product O$_{pf}$,
- selection of machine tool type O$_o$,
- selection of cutting tools O$_n$,
- selection of parameters of a cut O$_{ps}$.

Scheme of the operators' use in the process of series of technology creation is presented on Fig. 7. The plans of production on basis of constructional form of unit are created. Plans can be presented in form of variants of solutions plan production (VPW_1^{el1}, VPW_0^{el2}, VPW_i^{el1}). These plans of production are also the object of optimization for each series of construction, and the typical plans of production are the final result PW_0^{te1}.

The computational programme for creating series of technology is a result of applying the operators for series of specified construction, Fig. 8.

In order to obtain the most effective integration of technologies process forming along with formation of the ordered construction performance process, the following under-mentioned standards are required:

1) sorting constructional data (constructional features) making up the basis to create technological components of ordered technology [9,10],
2) maximum connection of constructional features with manufacturing technology,
3) minimisation of redundancy of information,
4) development of relational database [14],
5) minimization of variety of construction and technological processes particularly consequential with constructors and technologists' subjective feelings,
6) development of computer programmes and their application in order to integrate the working environment process engineers and design engineers.
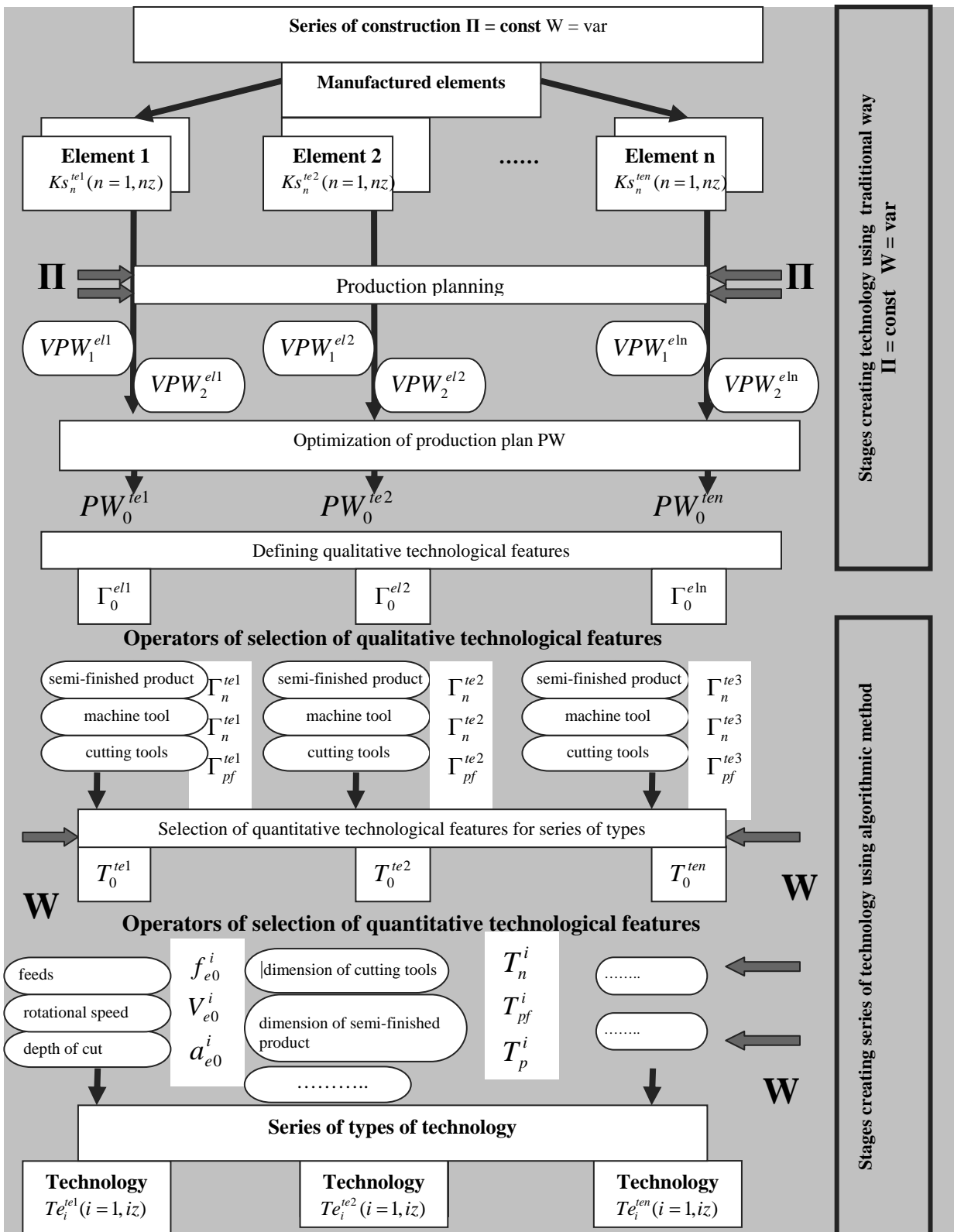
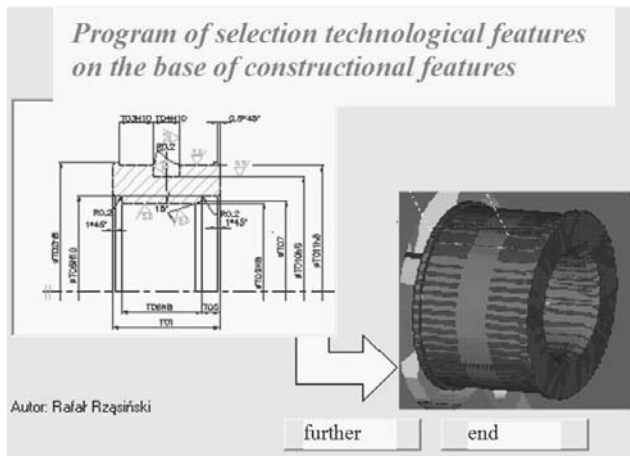Fig. 7. General model of series of element constructions covering into series of technology

Fig. 8. Created series of type of technology

For determination of the parameters of processing, the parameters selection programme was created for basic processes of machine cutting. "Parameters" programme worked out adaptation to necessary data for defining the parameters in advanced graphic programme I-DEAS for processes machining: turning, milling, drilling. "Parameters" programme was made in Visual Basic programming language. All data of programme came from with norm [6].

3.3. CAM method

The basic tool of the ordered technologies created (Te_n) on the basis of ordered constructions is the CAM method and CAD/CAM integration [3,4]. For this purpose the advanced graphic programme I-DEAS was applied.

Integration of the advanced graphic programme is the most advanced and effective method of the CAD/CAM integration. The advanced graphic programme is based on the uniform patternel of data. The comparability of data between the constructional patternel and technological one occurs there. To present this standard technology with the base of tools, tooling-up and the programme correcting the processing parameters was created.

The associativeness creating of the technology consists in exchange of 3D model element and semi finished product and renewed execution of the processing simulation with all settings of the standard technology (Fig.4).

Standard created technology can fit to proper ordered constructions as long as the mistake of technological process regularity will appear (the irregularly chosen tool, the collision of movements). After changes introduction this technology can be recorded as a newly ordered technology. The structure of the technology Γ^{tej} is constant, but in some cases (that is: necessity of greater number of passages in hole drilling) it can be slightly modified and the new variant of technological structure is created.

The whole process of construction formation and technology families is based on construction and technology parameterization (Fig. 9). The parameterizations is a form of construction and technology record where the constructional figure ($\prod^{tej}$) and the structure of element manufacturing technology (Γ^{tej}) are recorded in the operational computer memory. However, variable value of dimensions (WV_1^{tej}) and technological parameters variables T_a^{ej} are taken from outside.

On the basis of elaborated technological processes the following stages of creating the ordered family of technology on the basis of ordered construction are distinguished, (Fig. 10):
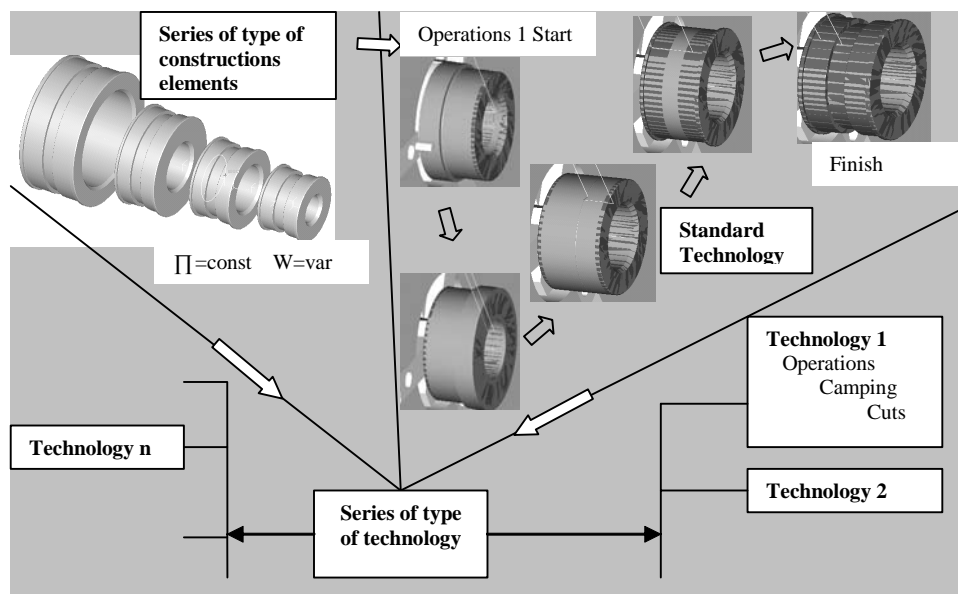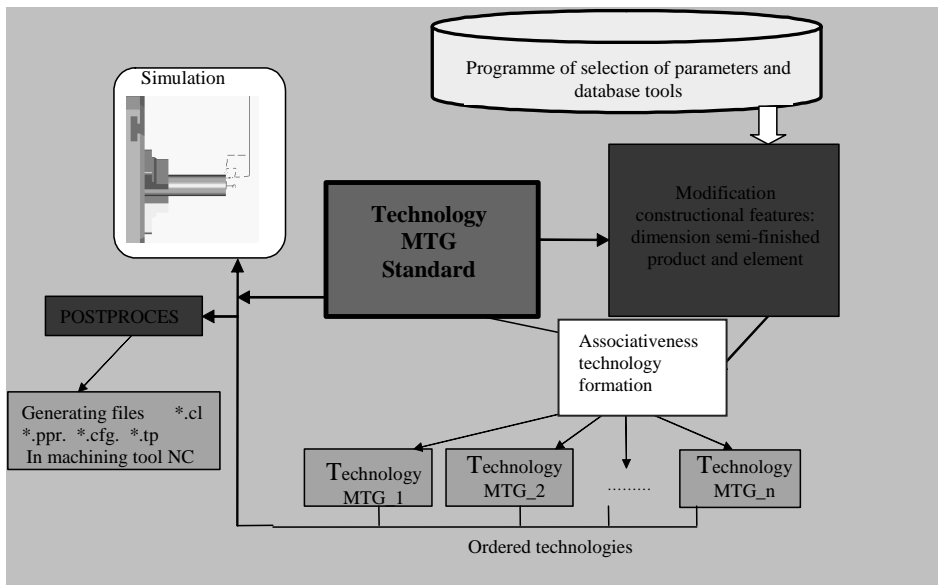

Fig. 9. Created series of type of technology

Fig. 10. Associativeness technology formation

1) assumption of essential constructional features with regard to the technological process (material features, geometrical features concerning macrostructure),
2) assigning the typical constructional form ($\prod$tej), to the semi-finished product ($\prod$pf),
3) assigning the ordered constructions of the constant form of elements constructions ($\prod$tej=const) to the same or slight diverse structures of technological processes (Γtej=const),
4) assumption of the technological process structure: operations, clamping, groups of cuts,
5) algorithmic selection of parameters of processing,
6) simulation of element processing which result in the production technology,
7) associativeness of technology created for other geometrically similar constructions.

Fig. 11. Example of the catalogue of tools

Adaptation is necessary in order to improve process of creating series of types of technology using CAM method for tooling, cutting tools for all operations of individual elements. In this destination for changing conditions of processing (e.g.: processing of the roller 30 mm for element 1, processing of the roller 300 mm for element 20) datum features of generally applied cutting tools and tooling were carried out (Fig. 11, Fig. 12).
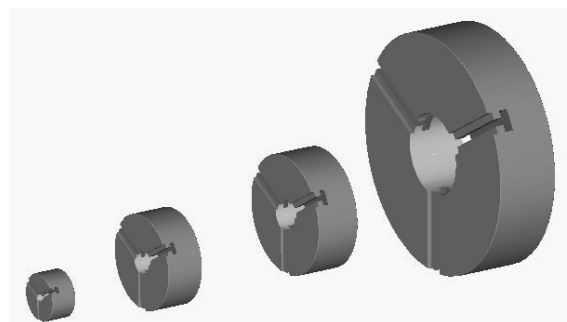

Fig. 12. The picture of parameterized three-jaw chuck with appropriate table of parameters

Depending on variables of conditions of processing (the constructional features), it is possible to take the definite tooling and a required cutting tool. The simple drops of screens of executed models on Fig. 12 were introduced with parameterization tables of parameters.

4. Conclusions

The result of this paper is to verify the established model of relation between constructional features (C_k) and technological features (C_t) and elaboration of methodological approach in the light of relation between the construction and technology.

The methods formation as well as their application concern the machining processes:

- turning,
- milling,
- drilling.

Main conclusions from elaboration methods are the following:

- the division of constructional features and technological ones on qualitative and quantitative features introduces the order among the definitions and notions as well as the worked out methods,
- qualitative technological features defined in the paper depending on qualitative constructional features allow for elaborations methods of their transformations,
- the distinguished quantitative technological features are the basis for algorythmisation and elaborations of computational programmes supporting the process of creating the series of types of technology,
- the conditions of technological similarity are oriented on operations and cuts, only for processes of processing the turning, drilling and milling,
- elaboration of standard technology which is the basis for creating the series of types of technology seems to be of vital importance as far as methods of technological similarity and CAM are taken under consideration,
- the distinguished technological operators allowed to create technology oriented on series of families types of construction,
- computational programmes used to select quantitative, technological feature are the result of algorithmic method.

References

[1] J. Dietrych, System and construction, WNT, Warsaw, 1985 (in Polish).

[2] P. Gendarz, Methodology of creating of ordered sets of construction of machine engines, The Scientific Exercise book of Silesian University of Technology: Mechanics z. 141, Silesian University of Technology Publishing House, Gliwice, 2002 (in Polish).

[3] Z. Adamczyk, K. Kociolek, CAD/CAM technological environment creation as an interactive application on the Web, Journal of Materials Processing Technology 109/3 (2001) 222-228.

[4] F. Gabryelewicz, Typification of production in engineering industry, WNT, Warsaw, 1976 (in Polish).

[5] C. Grabowik, R. Knosala, The method of knowledge representation for a CAPP system, Journal of Materials Processing Technology 133/1-2 (2003) 90-98.

[6] J. Świder, K. Herbuś, P. Ociepka, The application of object methods for functional features representation, Proceedings of the 13th International Scientific Conference "Achievements in Mechanical and Materials Engineering" AMME'2005, Gliwice − Wisła, 2005, 655-658.

[7] G. Pahl, W. Beitz, Science of construction, WNT, Warsaw, 1984 (in Polish).

[8] Z. Siuzdak, J. Wisniewski, Group processing, Warsaw, 1964 (in Polish).

[9] P. Gendarz, P. Chyra, R. Rząsiński, Constructional similarity in process of ordered construction families creating, Proceedings of the 16th International Scientific Conference "Achievements in Mechanical and Materials Engineering" AMME'2008, Gliwice − Ryn, 2008 (CD-ROM).

[10] R. Rzasinski, P. Gendarz, The creation of ordered technologies on the basic of ordered constructions of machines, Proceedings of the 3rd Scientific Conference "Materials, Mechanical and Manufacturing Engineering" MMME'2005, Gliwice − Wisła, 2005, 203-207.

[11] A. Baier, Aiding of design, virtual creation and investigation of machine elements and group of elements, Proceedings of the 3rd Scientific Conference "Materials, Mechanical and Manufacturing Engineering" MMME'2005, Gliwice − Wisła, 2005, 639-644.

[12] A. Buchacz, Modelling of robots by means the hypergraphs method, Proceedings of the 9th International Scientific Conference "Achievements in Mechanical and Materials Engineering" AMME'2000", Gliwice − Sopot − Gdańsk, 2000, 63-66.

[13] S. Tkaczyk, M. Skucha, The application of the Balanced Scorecard Method in Organization Management, Proceedings of the 9th International Scientific Conference "Achievements in Mechanical and Materials Engineering" AMME'2000", Gliwice − Sopot − Gdańsk, 2000, 549-552.

[14] F. Čus, B. Mursec, Databases for technological information systems, Journal of Materials Processing Technology 157-158 (2004) 75-81.