FUNCTIONAL APPROACH FOR STRUCTURING OF THE MACHINING PROCESS

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Обосновано применение функционального подхода в структуризации технологических операций и процессов механической обработки деталей тяжелого машиностроения. Рассмотрены вопросы выбора и обоснования комплексного критерия оптимальности технологической операции механической обработки, учитывающего влияние на эффективность технологической операции детерминированных и стохастических факторов. Предложена форма комплексного критерия оптимальности, представляющего собой аддитивную свертку частных критериев снабженных весовыми коэффициентами. Обоснованы требования, предъявляемые к выбору комплексного критерия.

Обґрунтовано застосування функціонального підходу в структуризації технологічних операцій і процесів механічної обробки деталей важкого машинобудування. Розглянуто питання вибору й обґрунтування комплексного критерію оптимальності технологічної операції механічного оброблення, що враховує вплив на ефективність технологічної операції детермінованих і стохастичних факторів. Запропоновано форму комплексного критерію оптимальності, що представляє собою адитивну згортку окремих критеріїв постачених ваговими коефіцієнтами. Обґрунтовано вимоги, пропоновані до вибору комплексного критерію.

Is justified the application of the functional approach in structuring of the process steps and processes of machining parts heavy machinery. The question of choice ground of optimum complex criterion of machining technological operation is considered. It takes into account influence on efficiency of technological operation of the determined and stochastic factors. The form of optimum complex criterion founded on the additive furl of separate criteria of supplied by weighed coefficients is offered. The requirements offered to the choice of complex criterion are grounded.

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The most important problem of modern engineering production is the promotion of competitiveness of products. One way to solve it is the refinements of standard production methods, allowing to increase of them efficiency.

At present are known and developed various methods for the design styles of the production methods. The researches [1, 2, 3] show that for the current system of industrial relations their benefits are undeniable. However, their use in the increasing demands of competitiveness does not always provide the necessary efficiency of the process. For this reason, at this stage of production development, when the demands to the quality and competitiveness of products are changing rapidly, it is necessary the new approaches of the methods of the technological process.

The paradigm of engineering technology has changed. At that, the content of the technological process is determined not only by the level of scientific and technological progress, but also the requirements of the producer and the consumer [2]. In general terms, this problem is the complex problem, when the content of technological operations and of the whole process is formed from a set of requirements (criteria) of different nature.

In this regard, measures are proposed to improve the structure of typical technological process based on the use of method of cognitive structuring. The ideology included in the technology of cognitive modeling is based on the use of structural models that combine the deterministic (technical) and stochastic (economic, social) factors – the components of the technological process [1, 3].

In our view, this decision is relevant and has both scientific and practical meaning for production.

With the development of information technologies, on the one hand, and on the beginning resource crisis, on the other hand, to solution to the questions the optimal allocation of resources in the production and effective establishment of standard technological processes, that are taken into account the rate of change of the manufacturing process, is given a little attention. Therefore, the aim of this research will be to study the effect of factors stochastic nature on the optimization of standard technological processes of mechanical operation of heavy machinery pieces.

This methodological approach provides the real opportunity of parameterization of machining by definition of technological regimes, sound equally from both a technical and from a production point, ensuring the achievement of the required ratio of processing quality, productivity and costs.

The research showed that for the solution of the problem required the application of the principles of systematic approach, first of all, integrity, since the manufacturing operation is a complex integrated system of interacting elements. On this basis, it is proposed to use a complex criterion that takes into account such stochastic factors such as the level of organization of the workplace, the discharge of machine operator, the satisfaction with the process of the work, the level of corporate culture, the strength and safety of work of the machine operator, etc. In this case, the criterion of structuring the F will be the additive convolution of the normalized values of the individual criteria K_i endowed with weights coefficient f_i.

$$F = \sum_{i=1}^{n} f_i K_i \,, \tag{1}$$

where n – the number of individual criteria.

In addition scheme was used a weighted sum of ratings, the weighting coefficient which determines the weight of the term in the sum. Thus:

$$\sum_{i=1}^{n} f_i = 1, \qquad (2)$$

For the i transition of the technological operation (process step) the value of the F complex criterion of the sum total indicators of technological operation is determined by the relation:

$$Fi = f_1 k_1^* + f_2 k_2^* + \ldots + f_n k_n^*, \qquad (3)$$

Where k_i^* – the normalized values of the criteria for the i transition operation; $f_1;f_n$ – positive numbers that characterize the relative importance of the criteria, the sum of which is determined as:

$$f_1,+f_2,+\ldots\ldots+f_n=1, \qquad (4)$$

The normalization of the criteria, h.e., the bringing them to a dimensionless form, is practiced by the formula:

$$K_i^* = \frac{K_i - K_{\min}}{K_{\max} - K_{\min}}, \qquad (5)$$

Where $K_{\min}$ and $K_{\max}$ – the minimum and maximum values of the criterion K on the set of solutions;

K_i and K_i^* – respectively the current and the normalized value of the criterion K for the i– transition of the operation.

The objective function F, presented a complex task structuring criteria will be as follows:

$$F_i(X) = f_1 K_1^* + f_2 K_2^* + \ldots + f_n K_n^* \to \max, \qquad (6)$$

Where X – the set of attributes that describe the system; Ki * – the normalized value of the private criterion K; fn – the coefficients of significance of individual optimality criteria.

The delimitations:

- the minimum and maximum values of the attributes defined by the training sample and describe the manufacturing operation;
- conditions of infeasibility of sequential execution of the options of the transition in technological operation, if they are not related to each other.

The main requirements to the choice of the individual criteria, is their completeness, minimum, operational functionality, measurable and cost-effectiveness. These requirements are met such criteria: quality and precision of machining, durability of the cutting tool, the complexity of manufacturing of machine parts, processing power , the costs for operation, the intensity of work of the machine operator, the level of organization of the workplace, the level of motivation of the machine operator.

The taking researches helped to formulate the basic principle of modeling technology of machining operation – the principle of structural minimization and to identify the factors influencing its synthesis: technical, that is characterized the work of the technological systems and the factors that is characterized the influence of the external (relative to the system «machine – device – tool – part») environment.

It is provided the use of the method of structuring for production processes (Fig. 1), which it is based on the laws of the origin and development needs, process stages of technology development, the evolution of technical systems, the correspondence between the functions and structure of technical systems. The theory of sequential decision analysis in the process of design and optimization of production processes in machine building manufacture in general form can be represented by six main stages. The first stage is the choice and justification of the object, purposes and objectives of the research. The second stage – the choice and substantiation of optimum quality criteria for optimized production system. The third – the most rational choice for the functional structure that describes the optimized technological system. For the fourth – the choice of the most effective principle of operation for the realization of functional structure, reasoning for the choice of optimization method. For the fifth stage – the choice of the best technical solutions, realizing the principle of action, the reasoning of the device software research. The sixth step – determining the optimum settings for the selected technical (technological) solution.

At each stage for decision making it is advisable to use the automation of search projecting and construction, the technological knowledge base and data banks. The efficiency of decision of tasks increases from 6-th to the 1-st level. Thus, the main difference of this method is the systematic and methodological principles for the development and creation of competitiveness products of heavy machinery.

Just to solve this problem it is advisable to use a method of neural network programming, that allows to solve the problems, to carry out comprehensive structuring with the set of input data and with taking into account the stochastic parameters of products production based on the use of artificial neural network of Hopfield, the distinguishing feature of which is the presence of feedbacks, ensuring the quality of its setting and operation.

Accordingly, the method of structuring machining operations based on the use of neural networks technologies will consist of the following stages:

1. The identification (based on expert analysis) the best group of criteria of structuring of technological operation.

2. The preliminary processing of the factors deterministic and stochastic character by the networks with the homogeneous structure. Screenings of factors and use in further work only those, which have the value coefficient 0,5 or greater than 0,5.

3. The realization of complex structuring of technological operation based on expert weighting values of each of the criteria.

4. The formation of new variant of the technological process of mechanical processing with the taking into account the optimal process conditions and requirements to the factors stochastic nature.

The proposed method allows you to:

– consider the impact on the comprehensive test of deterministic and stochastic factors of technological operations of parts group and to correct any distortions of input data;

– integrate into the models the accumulated production and technological experience, taking into account the specific production conditions, the characteristic of equipment and the like;

– solve the actual problem for engineering plants of work productivity or reduce the cost of operations with a given level of quality, installing the rational connection for these conditions of technological mode of operation and the conditions of working operation;

– reduce the time and improve the effectiveness of the technological solutions, put into practice rational the organization of production.

The universality of the proposed approach can be it easily adapted to other stages of the process of production.

It has been realized the testing of the proposed method of structuring the heavy lathe operation of machining of rolls for cold rolling production. It has been determined the complex of mathematical models presented to the technological limitations of the system operation. It has been defined the input and output parameters, it was illustrated the functional interpreters and forms for after work of normalized values of researching criteria: $C_н$, $Q_н$, $IT_н$., $Ra_н$, $t_{шт}$-$к_н$, $PM_н$, $MT_н$, $KK_н$, $HT_н$, t_o, $T_н$,.

For process of the roll body by the cold rolling after hot metal working by the currents industrial frequency is recommended for use four separate criteria: the specific cost of technological operation C, UAH/min, the productivity of technological operation Q, p/min, the intensity of the work of machine operator *HT* and the level of motivation of work of machine operator *MT*. Accuracy and quality of as-machined surface, which are characterized by the indexes of precision quality *IT* and roughness *Ra*, are the main delimitations.

In this case, the complex criterion will be the following expression:

$$F = f_1 C(\overline{X}_{\partial\phi}; \overline{X}_{c\phi}) + f_2 Q(\overline{X}_{\partial\phi}; \overline{X}_{c\phi}) + f_3 HT(\overline{X}_{\partial\phi}; \overline{X}_{c\phi}) + f_4 MT(\overline{X}_{\partial\phi}; \overline{X}_{c\phi}), \quad (7)$$

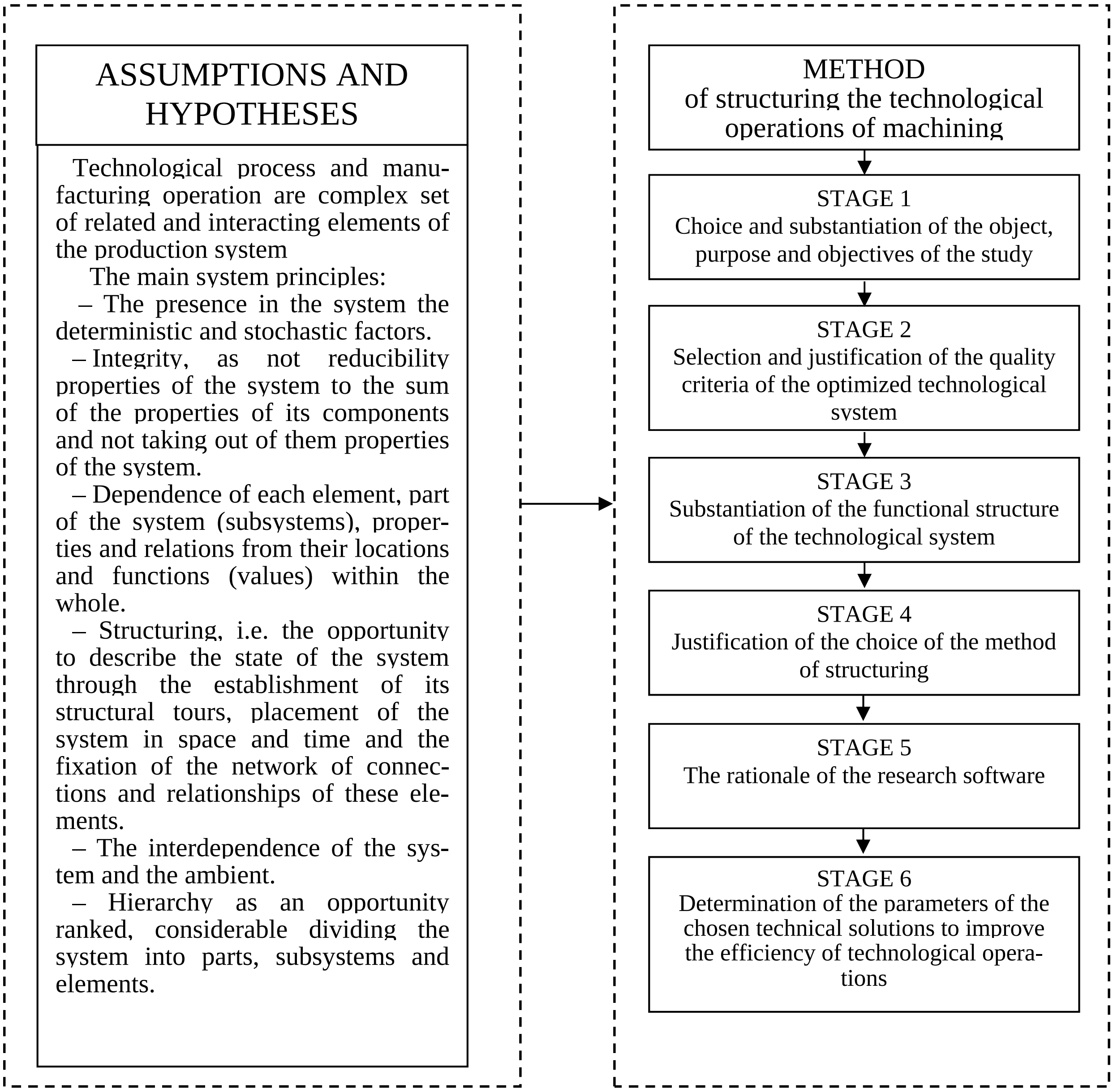

Fig.1. The method of structuring the processes of machining operations

Based on the characterization of deterministic factors of manufacturing operation were made the conclusions about the appropriateness of applying for lathe operation the cutters equipped with interchangeable unresharpen plates from hard alloy grade of steel T14K8 and determined the modes of working, which under given conditions were: the cutting speed V = 53 m/min, the supply S = 0,45 mm/rev.

Accounting of stochastic factors (level of intensity of the machine operator NT and the level of motivation of the machine operator MT) has shown that the defined above regimens are corrective depending on the values of these levels to 15–18 %.

Is found that at *f1 = 0,4; f2 = 0,4; f3 = 0,1; f4 = 0,1* the value V and the value S conform with criteria of productivity production. If *f1 = 0; f2 = 1; f3 = 0; f4 = 0* the value of V and S conform with the criteria of the unit cost of the operation. The change of the NT from the value 5 to 6 requires the correction of V and S. The changes of value MT from 4 to 5.5, and higher also change the values of V and S.

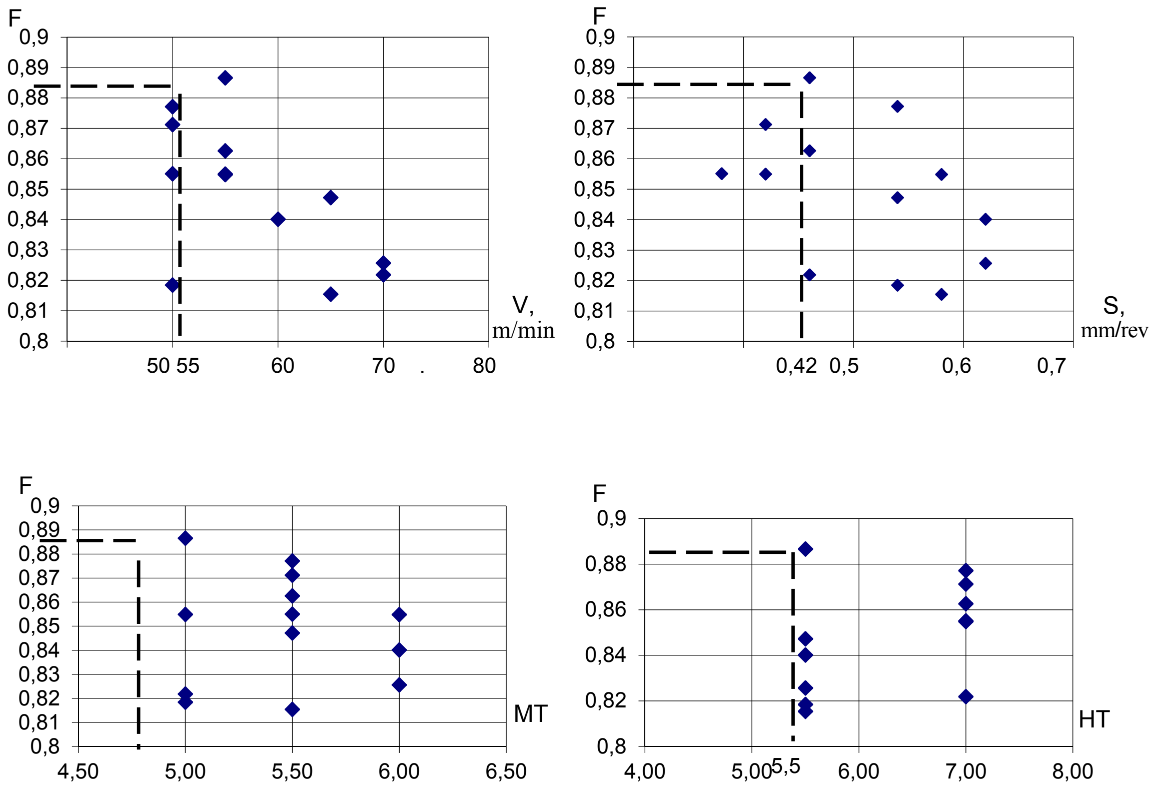

Fig. 2. Results of the complex structuring of deterministic and stochastic factors of lathe machining operation by the roll cold rolling

The selection of given technological regimes by the value of productivity production influences positively on reducing the cost of processing, but will increases to the rise of value of surface roughness an average of 10–12 %.

The selection of technological regimes by the value of specific productivity working (productivity of manufacturing operation) corresponds to the particular case of structuring by the integrated criterion with coefficients $f1 = 0,2; f2 = 0,4; f3 = 0,2; f4 = 0,2.$

The values of given regimes coincide with the values, obtained during the complex determined structuring of determined factors by the technological operation with particular criteria of specific cost of the operation and productivity production (Fig. 2).

For successful practical application of the proposed methodological principles and approaches need to follow the next rules:

1. To form representative sample of data about the precedents of technological processes, set a list of deterministic and stochastic factors. In the number of well formalized factors encouraged to take the regime part in the presence of interchangeable equipment – the list of equipment, tools and billets. Among the stochastic factors mainly include the level of intensity of the machine operator and the level of motivation. The assessments of determined factors choose from technical documentation, well founded and worked in the production processes. Levels of strength and motivation of work determine on the basis of expert assessments with averaging of experts data with aim to eliminate the subjectivity of thoughts and limitations of techniques.
2. To choose the list of specific criteria of *C, Q, IT, Ra* and (or others), and taking into account that it is selected the ceiling amount of distinct criteria that must be taken into account.
3. Out of the total data $\overline{X}_{\partial\phi}$ and $\overline{X}_{c\phi}$ to form two sets: studies and testing on which to determine the parameters of the models *C, Q, IT, Ra*, to assess the reliability of the adequacy

of the model based on the evaluation results of the test sample. The main requirement – the error of test sample shall not exceed the sampling learning error.

4. To form an array of possible values of the factors, that it is structured.

5. To form an array of individual criteria and carry out the normalization of values between 0 and 1, where 0 – the minimum, and 1 – the maximum values of the criterion.

6. To determine the criteria for an integrated array of data specified in claim 5, changing the experts value *f in* limits $\sum f_i = 1$.

7. To make at maximum of value *F* the factor values that meet this maximum.

To make effective use of this approach in the enterprise should establish a regulatory characteristics of the work organization of machine-operator for different levels *NT* and various operating conditions, including not limited the work of small, average, heavy machine tools, and to form the normative characteristics that determine the level of *MT* (coefficient of quality bonuses for their work on time, cost for the in time work, economy for different types of resources, etc.).

Assessing the economic feasibility of universal set of models complex is proved their advantages in comparison with existing ones. The implementation of the proposed models complex will improve the efficiency of technological processes of parts processing, which take into account the demands of modern production and provide the payback for 0,4–0,6 of year.

CONCLUSIONS

1. The proposed methodology of cognitive structuring allows to design the process technological operations, based on the principle of the integrity of the system and taking into account the influence on the rational choice of the cutting set of deterministic (techno-logical characteristics) and stochastic (organizational characteristics) factors. The technique can be used on a variety of machine-building enterprises, as the universality of the proposed approach leaves the possibility of adapting the method for the structuring of the other parameters of the process of machining, as well as other stages of the process of production.

2. Has been showed the influence of restrictions on improving the efficiency of turning operations on heavy lathes. It is found, that within the limits of working quality on the basis of physical cutting processes the range of changing speed can be adjusted by 15–18 %.

3. Have been got the comparative effects depending of deterministic and stochastic factors on the efficiency of manufacturing operation, which is estimated by a number of private criteria, concluding to infer about, that in such significance levels of significance as productivity Q = 10–3 pc/min = 0,5, the unit cost *C* in UAH / min = 0,2, precision of working *IT* = 0,2 and processing quality of *Ra*, m = 0,3, it is advisable to use such modes: cutting speed $V = 55$ m / min , feed $S = 0{,}42$ mm / rev , the level of intensity of work of machine operator *HT* = 5,5, and the level of motivation of the operator*MT* = 5.

4. Has been confirmed the complex of experimental researches, that confirmed, that the implementation of research results in the production gives the chance increase of opportunities technological operations by 15–18 %, the reduce unit costs of the technological machining operation in roll cold rolling production by 10–12%. The experimental results confirmed the adequacy of the theoretical calculations of the actual value of the technological parameters. The calculation of error was 8–10 %.

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