Archives of Materials Science and Engineering

Volume 36
Issue 2
April 2009
Pages 96-102

International Scientific Journal
published monthly by the
World Academy of Materials
and Manufacturing Engineering

Computer-assisted the optimisation of technological process

B. Krupińska*, D. Szewieczek, L.A. Dobrzański
Division of Materials Processing Technology, Management and Computer Techniques in Materials Science, Institute of Engineering Materials and Biomaterials, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: beata.krupinska@polsl.pl

Received 20.01.2009; published in revised form 01.04.2009

ABSTRACT

Purpose: One has worked out an application that allows to analyze the efficiency of technological process in aspect of nonmaterial values and has used neural networks to verify particle indicators of quality of a process operation. Indicators appointment makes it possible to evaluate the process efficiency, which can constitute an optimization basis of particular operation.

Design/methodology/approach: The created model made it possible to analyze the chosen technological processes for the sake of efficiency criteria, which describe the relationships: operation - material, operation - machine, operation - man, operation - technological parameters.

Findings: In order to automate the process, to determine the efficiency of technological operation (KiX) and possibly to optimize it, one has applied one of artificial intelligence tools - neural networks.

Practical implications: Application of neural networks allows to determine the value of technological efficiency of an operation. (KiX) without the necessity of detailed analysis as well of the whole process as of the particular operation. It makes it also possible to optimize operation efficiency by means of checking value of operation efficiency in the case of change in value of particular partial efficiency indicators.

Originality/value: Method of computer application makes it possible to point out the studied indicators and asses finally the process efficiency in order to plan optimization of particular operation.

Keywords: Technological efficiency; Technological process; Optimization; Neural network

Reference to this paper should be given in the following way:

B. Krupińska, D. Szewieczek, L.A. Dobrzański, Computer-assisted the optimisation of technological process, Archives of Materials Science and Engineering 36/2 (2009) 96-102.

METHODOLOGY OF RESEARCH, ANALYSIS AND MODELLING

1. Introduction

Very important aspect of factory development is continuous and systematic analysis of production process, namely technological process. Nowadays each enterprise, that wants to exist on the market must be competitive, and the product it is producing must be perceived as competitive in comparison with other of this type, so that it will draw the attention of a potential customer, and after buying it he should be satisfied enough and through this won't look for replacement by the competition[1,2].

Technical progression within the scope of material engineering increases the demands and expectation towards the products quality [3]. There is a lot of rules that allow its creation, like e.g. modeling of the production technology, multi – criteria optimization by the use of computer. From the qualitative and correctness of choose of technology point of view comprehensive technological processes assessment makes up the basis of technological efficiency analysis [4].

The essence of optimization of technological processes is the level of optimal value, however we can not forget that the most important is how this value ill be reached t.i. determination of efficiency of searching process [5]. Optimization can be divided into 2 stages: efficiency increasing and reaching the optimal value, what means that the main aim is improvement. Optimization of efficiency of technological processes normally lies in an economical analysis based on costs connected with the application of suitable types of technology or materials Successive such an analysis optimization is based on a number of activities connected with costs reduction, but only in sporadic cases with the analysis of technological parameters. It means, that the aim of optimization is the achievement of optimal value, that is timing at increasing the efficiency, and the efficiency of searching process, that is how it is reached, is being ignored.

It is necessary to take note of the fact, that optimization means increasing efficiency till the optimum will have been reached, that means that it constitutes of two stages: first of all „increasing efficiency", secondly „reaching the optimal value", what indicates the main aim of optimization, that is the improvement. Within the process of increasing the efficiency of technological processes one has to draw his attention not to the cost analysis ("increase of the efficiency") but to technological analysis ("process improvement") taking its costs into consideration [6].

It indicates need of verification of technological parameters of individual operations and an analysis makes all this possible. Basis for his analysis constitutes widely comprehended non-material technology. This analysis is based on research aspects and from its point of view it estimates the technological process, in contrast to the problematic of material technology, which estimates the process by material evaluation of the product and all his components, what means that it more corresponds with the cost's analysis of the process leading only to increasing its efficiency. Therefore processes of the material technology allow to look for innovations in the area of organization and management passing over the necessity of process modeling in the area of non-material technology. The above thesis points out the essential need of analyzing the technological processes, that allow to identify places of their necessary optimization. Within the scope of analyzed non-material technology it brings the possibility of process modeling by the strategy of technology choice. One can use the partial efficiency indicators and the issues of no-nmaterial technology to create the model of technological efficiency analysis. On their basis one can work out the indicators of technological efficiency of particular operations expressing correctness of the used technology, materials selection, technological parameters selection. Taking into account the non-material parameters of the technological process, which are based on many kinds of samples used and design of technological process, we can conduct the evaluation of technological process efficiency by creating indicators of technological operation efficiency. They lead to indicating places, that require their optimization in producing gear wheels, of which technological process covers: selection of semi- finished products, heat treatment operations and operations concerning loss treatment.

Analysis of the technological process can be automized by applying methods of artificial intelligence. One of them are neural networks, which are quit new and in many respects attractive informatics tools [7].

In principle in their establishment they are completely different from the computer tools, normally people use daily, but simultaneously remarkably convenient and productive. That is the reason why many researchers and practicing people are interested in them.The main trumps of neural networks is the fact, they present convenient and cheap proposal multiprocessors system with many elements converting parallel providing information and do not require programming, only use learning process [8,9,10].

2. Investigation procedure

Taking into account different parameters of technological process that base on types of applied samples and design of technological process, one has lead evaluation of technological efficiency of a process by determining indicators of technological efficiency of operation. It leads to isolating the weak points of gear wheels, which technological process covered: selection of semi- finished product, operation of heat treatment (hardening and tempering) and operations of loss treatment (turning, pull broaching, chipping, grinding).

Basis for development of model of technological process analysis were the partial efficiency indicators, technical and normalized parameters of the technological process depending on the applied sample. Such an approach make it possible to characterize the technological process taking into account characteristic parameters of particular operations, and by determination of an importance matrix of an operation also their systematization by the final classification.

One has determined efficiency scale making use of the dependence, that the value of efficiency aims at 1 and analyzing the process. Procedure running when determining the model of analysis the technological efficiency of technological processes has been presented below[11,12].

2.1. Determination of the model of efficiency analysis

Determination of the model of efficiency analysis (Fig. 1) for the chosen technological process and determination of partial efficiency indicators to fix technological efficiency of an operation K_{iX}. Indicator of materials' efficiency (W_{EM}) allows to correct the process from the point of material consumption and correctness of allowance selection. Normally to estimate the W_{EM} value one has to determine the number of products, which have been dismissed during the technological process and semi-finished products, which haven't been classified to attend in the production. Indicator of machine's job efficiency (W_{EPM}) estimates the technology correctness form the point of tools selection correctness in accordance. Value of the indicator is determined by comparing the planned working time of the machine, fixed by normalized standards, or determined in the service manual of the given machine with the real working time. Next step is determining the value of indicator of applied technology correctness from the point of using tools. Indicator of human's work efficiency (W_{EPC}) is fixed by determining the quantity of defective elements. Taking into accounts are these elements which have been rejected because of human's mistake during: material's selection, treatment planning (selection of

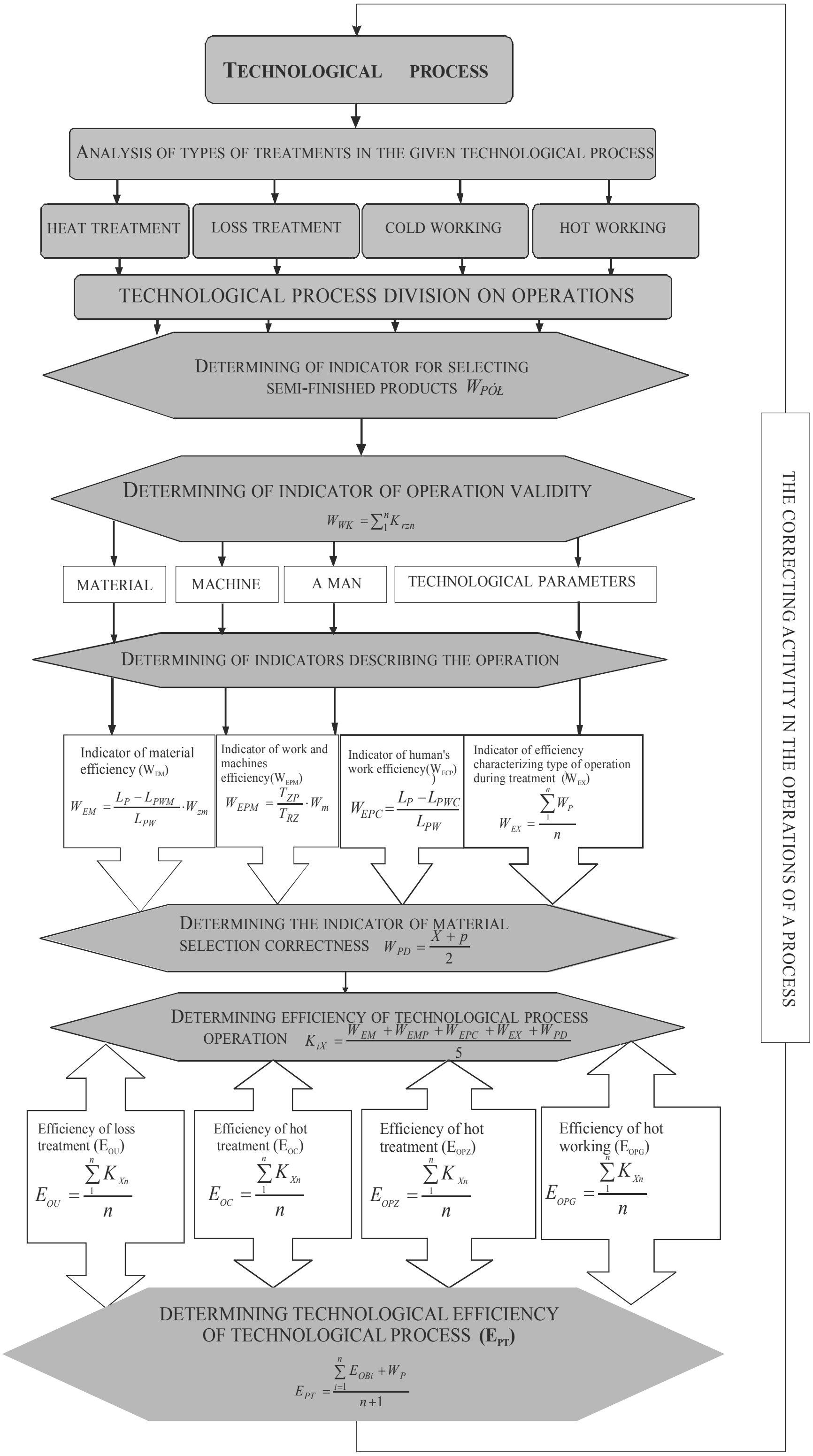

Fig. 1. The model of efficiency analysis [12]

treatment materials), wrong machine or tools operation (wrong programming of machine tools, wrong time calculation, wrong selection of allowances for the particular type of treatment and so on.) Indicator of efficiency characterizing the operation time during treatment (W_{EX}) determines the basis of parameters for a given operation (in accordance with standards determining requirements for a given element, or fixed by a technologist) Indicator of correctness of material selection. (this indicator has fix value for all operations) (W_{PD}) is determined on the basis of analytical method of constructive materials selection and lead to determining correctness of the material selection from the point of technological ownerships [11,12].

Determination of W_{PD} has to start from prepering a list of the most essential criteria showing the quality requirements concerning the considered engineering materials, which constitute criterial quality standard.

The next stage is determination or selection from suitable documents allowed and required values of conditions of absolute ownership (or characteristics) of the examined materials, with their introduction into suitable columns of the form blanc of the criterial quality standard.

Then calculation of quality levels in the aspect of technological ownerships of:

Arithmetic average (1) of criterial discriminants W_i (relative states within the interval from 0 till 1), showing the fulfillment of quality requirements by n considered quality criteria [13,14].

$$X = \frac{\sum_{i=1}^{n} W_i}{n} \tag{1}$$

Preference indicators (p) (of special meaning) of criteria from the formula (2) (Dobrzański, 2001):

$$p = \frac{\sum_{i=1}^{h} g_i}{h} \tag{2}$$

where:
gi – relative state i– his preferred criterion, h – number of preferred criteria

Determination of value indicator of W_{PD} (3) from the formula:

$$W_{PD} = \frac{X + p}{2} \tag{3}$$

When particular indicators are determined one can evaluate the technological efficiency of a given K_{iX} operation.

Determination of the importance of particular operations basing on the created matrix and determination of technological efficiency of K_{iX} operation.

Indicator (W_{WK}) determines the validity degree of a given operation in the whole technological process. Building of the matrix bases on fixing the weight of the analyzed operation (K_i), which is being determined in relation to other operations, and then particular values are cumulated (K_i). K_i value is determined by establishment of validity of the analyzed operation in relation to all operations appearing within the technological process (analyzed operation is more important from comparable operation – we give this operation K_i = 1 value and write it down to the matrix, if the weight of operations comparable for the technological process is the same – weight value of K_i = 0,25, but if the analyzed operation weight is higher, however the comparable operation has also some meaning, then we give the analyzed operation the value of K_i = 0.75)

After determining the sum of importance of particular operations in relation to all operations ($\sum_1^n K_{rzn}$) we can create operations according to their importance within the process W_{WK} (4)

$$W_{WK} = \frac{\sum_1^n K_{rzn}}{\sum_1^n K_{\max n}} \tag{4}$$

where: $\sum_1^n K_{rzn}$ - sum of importance of particular operations, $\sum_1^n K_{\max n} = (n \cdot 1) - 1$ - possible to reach maximal value of importance for operations within the analyzed process.

To put in order results we should create a chart, where the values of an indicator of operations efficiency and indicator of operation importance are putted, on which basis we can create diagrams showing: indicator of operation importance W_{WK} (from the most important) and indicator of efficiency of technological operation K_i.

2.2. Efficiency of technological process (E_{PT})

Efficiency of technological process depending on the applied type of treatment should be determined, that means by adding up efficiency of the operations, which are subordinate to her. In effect we can determine the whole technological efficiency of the process E_{PT} (5).

$$E_{PT} = \frac{\sum_{i=1}^{n} E_{OBi} + W_{PÓŁ}}{n+1} \tag{5}$$

The first step is determination of efficiency of loss treatment (E_{OU}), heat treatment (E_{OC}), cold working (E_{OPZ}), hot working (E_{OPG}) (Table 1).

Table 1.
The efficiency for the sake of the art of applied processing

Efficiency indicators	Indicator equation	
Efficiency of loss treatment	$E_{OU} = \frac{\sum_1^n K_{Xn}}{n}$	K_{Xn} – efficiency of particular operations of the loss treatment, n – number of operations
Efficiency of heat treatment	$E_{OC} = \frac{\sum_1^n K_{Xn}}{n}$	K_{Xn} – efficiency of particular operations of the loss treatment, n – number of operations
Efficiency of cold working	$E_{OPZ} = \frac{\sum_1^n K_{Xn}}{n}$	K_{Xn} – efficiency of particular operations of cold working, n – number of operations
Efficiency of hot working	$E_{OPG} = \frac{\sum_1^n K_{Xn}}{n}$	K_{Xn} – efficiency of particular operations of hot working, n – number of operations

The latest stage is determination of indicator of semi-finished product selection ($W_{PÓŁ}$).There are many factors that influence its selection, e.g. material advised by the constructor, serial production, next stage of process designing and selection of suitable types of treatment (determination of allowances necessary during loss treatment, suitable selection of form in relation to the final product).When determining this indicator one has to bear in mind the scale of semi-finished product selection, that allows him to choose criteria its evaluation, and is based on requirements made towards an element, as also on knowledge of the scientist.

Value of $W_{PÓŁ}$ is between 0 and 1, below the value of 0,5 value of the indicator of semi-finished product selection is inadmissible, that means we have to analyze the problem and select once again. If $W_{PÓŁ}$ has value above 0,91 the semi-finished product has been selected effectively, in accordance with the requirements of the process and standards.

After determining the efficiency value of the process, choosing the type of operation (E_{OU}, E_{OC}, E_{OPZ}, E_{OPG}) and indicator of semi-finished product selection ($W_{PÓŁ}$) we determine efficiency of the technological process. As a result of such a conducted analysis we can point out not only the efficient operations, but also these which cause the decrease of the total technological efficiency of the process. It allows also to show detailed factors influencing decrease In efficiency of a given operation.

2.3. Creation of a computer application of analysis of technological process (AEPT), that enables determination of particular indicators and the final efficiency evaluation

Taking into account the prepared model of technological efficiency analysis (fig.1) a special assisting computer system has been created, that means that an application has been prepared to make it partly easier to calculate the technological efficiency of the process.

The program consists of many stages of introducing necessary data to get the final report showing the conducted analysis of technological efficiency for a chosen process.

Conduction of an efficiency analysis according to further recommendations in the AEPT program we get a final report showing the whole analysis and diagrams of operation efficiency and hot treatment efficiency (Fig. 2).

2.4. Application of artificial intelligence tools to the optimization technological process

Basis for creating the computer model based on artificial neural networks were partial, technical efficiency indicators and also normalized parameters of technological process (Fig. 1.) From many indicators to learn the neural networks W_{zm}, T_{RZ}, W_m, W_{EX}, W_{PD}. have been applied. To practice the neural network 200 vectors have been used, that have been divided suitable into files: learning (60%), validating (20%) and testing (20%). Calculations have been made in the STATISTICA Neural Networks program. To estimate the marked values of K_i an average mistake has been used for the testing files, determined by the dependence (6) [15]:

$$E_{Ki} = \frac{1}{n} \cdot \sum_{i=1}^{n} \left(\left| x_{zi} - x_{oi} \right| \right) \qquad (6)$$

where: E_{Ki} – mistake for the indicator K_i, n – number of data in the testing file, x_{zi} – i- measured value, x_{oi} – i- calculated value.

Prediction of K_i efficiency indicator.

For determination of the indicator of process efficiency Ki many neural networks have been used. However best results gave the experiment when using the multi-ply perceptron with structure 5-9-1, learned by algorithm of reverse propagation and concentration gradients. The chart shows the mistakes value and quality of the applied neural networks.

Comparison of real values of the efficiency indicator with values calculated by means of neural networks have been presented on the Fig. 3.

3. Conclusions

The current production technique is based on two main achievements; computer and microelectronic, that made it possible to increase the speed, elasticity and efficiency of modern design, production and production control. Evaluation of the technological efficiency according to the created scheme allows to determine the technological efficiency of the process in the non-material value aspect. It allows also to analyze this efficiency by means of following factors: selection of material (indicator of material consumption), selection of semi-finished product (indicator of efficiency of semi-finished product selection), design of technological process for the sake of the used treatment and creation of the process structure (indicator of operation importance, indicator of technological efficiency of the operation).

Optimization of a process operation can begin with parameters that mostly wander from the established one, because efficiency of a given operation is made of many stages concerning the particular indicators, that show the operation form the perspective of: material, operation parameters, machine and human.

The analysis allows to find the reason of efficiency decrease of the whole process, they play the diagnostically role in the process. It constitutes the first step of technological process optimization. In this way gained knowledge is connected with knowledge necessary to their improvement, constitutes an essential determinant of a given industrial company. To carry it correctly out very important role plays the technologist, who decides about: particular determinants concerning the process and indicators of efficiency.

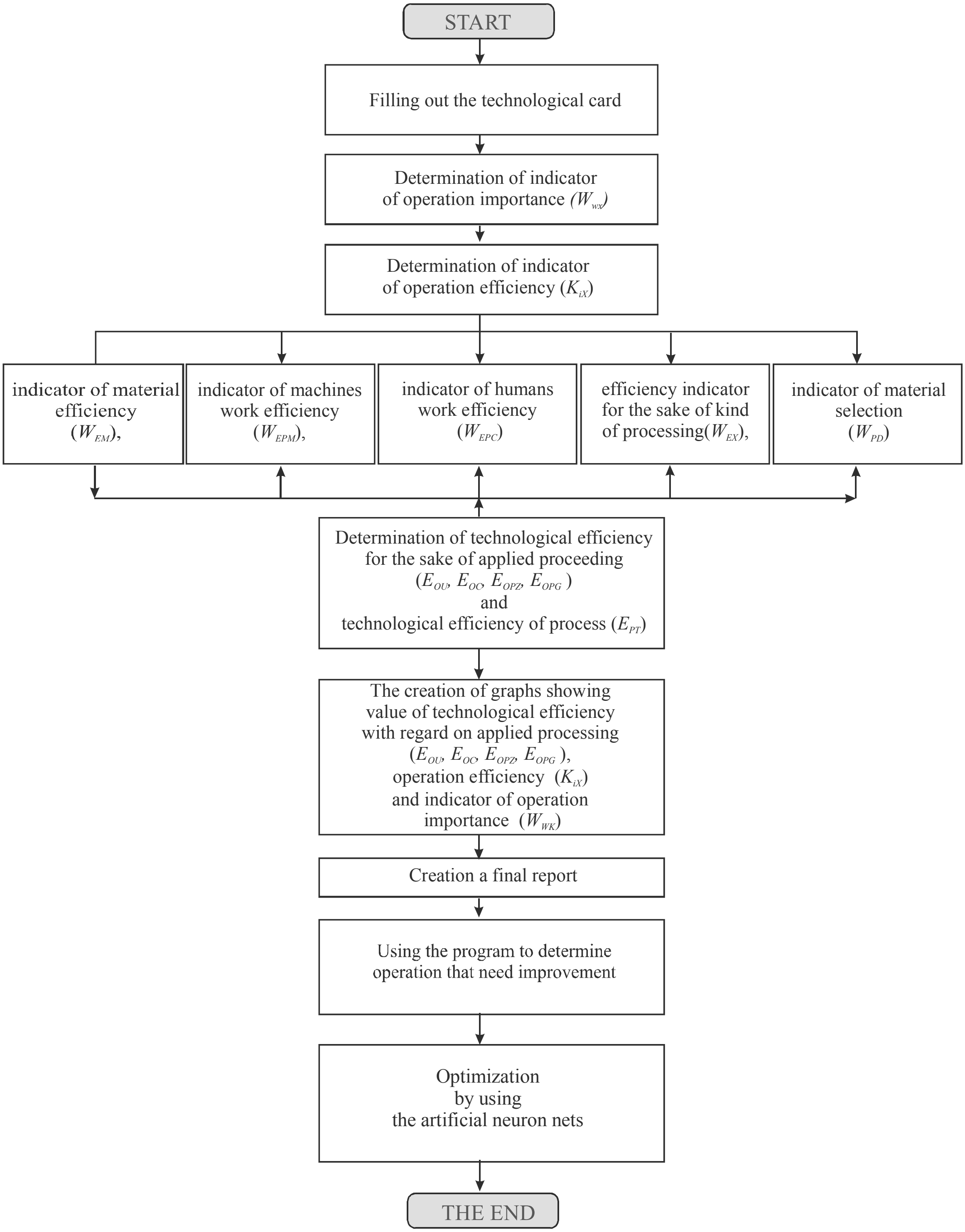

Fig. 2. Algorithm of proceedings by conducting the analysis of technological process efficiency by the use of computer application (AEPT)

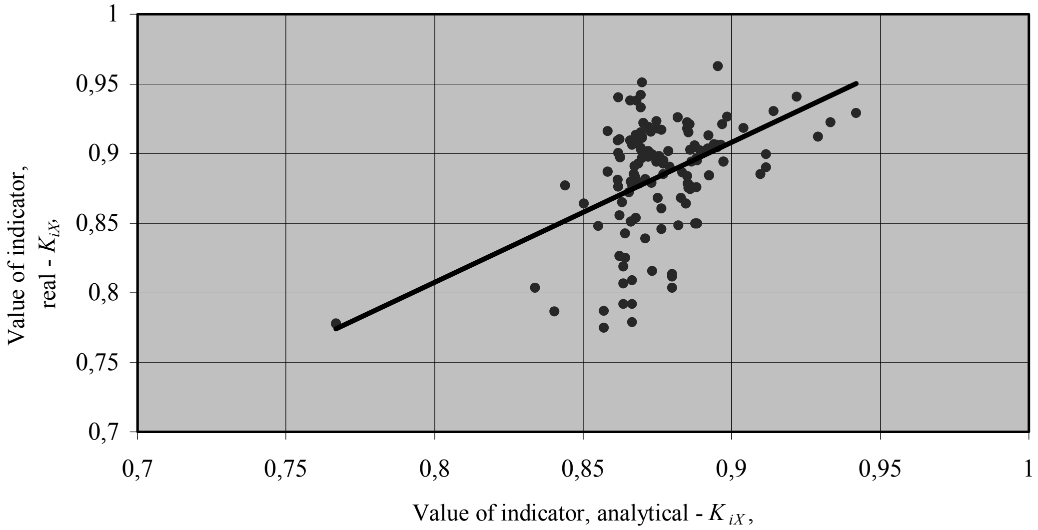

Fig. 3. Comparison of real values with calculated values of the indicator K_{iX}

References

[1] M. Sokovic, J. Kopac, and A. Smolej, Model of quality managment in development of new free-cutting Al-alloys, Journal of Achievements in Materials and Manufacturing Engineering 19/2 (2006) 92-98.

[2] M. Sokovic, D. Pavletic, E. Krulcic, Six Sigma process improvements in automotive parts production, Journal of Achievements in Materials and Manufacturing Engineering 19/1 (2006) 96-102.

[3] K. Metaxiotis, D. Askounis, J. Psarras, An Object-Oriented Analysis and Design of a Model for Production Planning and Control in Industry, The International Journal of Advanced Manufacturing Technology 18 (2001) 657-664.

[4] J. Madejski, Survey of the agent-based approach to intelligent manufacturing, Journal of Achievements in Materials and Manufacturing Engineering 21/1 (2007) 67-70.

[5] B.G. Kingsman, Modelling input-output workload control for dynamic capacity planning in production planning systems, International Journal of Production Economics 68 (2000) 73-93.

[6] G. Rummler, A. Branche, Increasing the efficiency of organization, PWE, Warsaw, 2000 (in Polish).

[7] V. Cariapa, K. S.Abkay, R. Rudraraju, Application of neural networks for compliant tool polishing operations, Journal of Materials Processing Technology 28 (1991) 241-250.

[8] M. Krupinski, L.A. Dobrzański, J.H. Sokolowski, W. Kasprzak, G. Byczynski, Methodology for automatic control of automotive Al-Si cast components, Materials Science Forum 539-543(2007) 339-344.

[9] D.G. Luenberger, Theory of optimization, PWN, Warsaw, 1984 (in Polish).

[10] E. Westkämper, T. Schmidt, Computer-assisted manufacturing process optimization with neural networks, Journal of Intelligent Manufacturing 9/4 (1998) 289-294.

[11] B. Krupińska, D. Szewieczek, Computer assistance in the procss efficiency analisis, Journal of Achievements in Materials and Manufacturing Engineering 20 (2007) 543-546.

[12] B. Krupińska, D. Szewieczek, Analisis of technological process on the basis of efficiency criterion, Journal of Achievements in Materials and Manufacturing Engineering 17 (2006) 421-424.

[13] L.A. Dobrzański, Basis of science about materials and metallographic, Engineering materials with basis of material projecting, WNT, Warsaw, 2002 (in Polish).

[14] L.A. Dobrzański, The principles of selection of engineering materials from cards of profiles, WNT, Warsaw, 2001.

[15] R. Tadeusiewicz, Neural Networks, PLJ, Warsaw, 1999 (in Polish).