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Analysis of technological process on the basis of nonmaterials values

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ABSTRACT

Purpose: What determines the correcttness of industrial company's functiioning on the market is technological process. In order to improve it continuously the priority should be technology, technology management and controlling.
Design/methodology/approach: by means of this model one can analyzy the choosen technological processes for the sake of efficiency criteria. They describe following relationships: operation-material, operation-machine, operation- man, operation-technological parameters.
Findings: This analisis shows hypothetical technological processes on production of typical pieces for machines. One has also taken into account nonmaterials parameters of technological process. They are resulting from applied sampels and projecting of the technological process.
Practical implications: Thanks to the created aplication we can analyze efficiency of technological process in aspect of nonmaterial values. By the use of neural networks we can verify particle indicators of process operation quality, evaluate the process efficiency, which can constitute the optimization basis of particular operation.
Originality/value: Data effecting from this analisis allowed to optimize the technological process. They estimate influence of the analyzed parameters on the whole process and optimizethe conducting of any process.
Keywords: Production planning and control; Technological efficiency; Technological process; Optimisation, Neural networks

1. Introduction

From the qualitative and correctness of choose of technology point of view comprehensive technological processes assessment makes up the basis of technological efficiency analysis [1, 4-10, 12, 13].

During a technological effectiveness analysis one can use particle determinants of effectiveness that characterize an operation taking into account following criteria: operation – material, operation – machine, operation – a man, operation – technological parameters (Fig. 1).

In such a way conducted analysis shows the influence of particular criterion on the process effectiveness and determines the optimization direction.

Within the scope of operations control one has to determine the indicators for the sake of supposed criterion:

For the „operation – material" criteria one can use indicator of material efficiency (W_{EM}) (1), that characterizes correctness of material use.

$$W_{EM} = \frac{L_P - L_{PWM}}{L_{PW}} \cdot W_{zm} \tag{1}$$

where:
L_{PWM} – number of dismissed products, L_p – number of produced products, L_{PW} – put number of products, W_{zm} – indicator of material consumption.

Next, for the „operation – machine" criteria, the indicator of machine work effectiveness (W_{EPM}) (2), that determines the relation between time, choosing of machine type according to realized technology.

$$W_{EPM} = \frac{T_{ZP}}{T_{RZ}} \cdot W_m \quad (2)$$

where:
T_{ZP} – planned working time of the machine, T_{RZ} – real working time of the machine, W_m – indicator of technology correctness.

However for the „operation – man" criteria, the indicator of men's work effectiveness (W_{EPC}) (3), that proves law efficiency following mistakes of human work (conscious and unconscious).

$$W_{EPC} = \frac{L_P - L_{PWC}}{L_{PW}} \quad (3)$$

where:
L_p – number of products, L_{PW} – number of produced products, L_{PWC} – faulty products because of human's mistake.

Criteria „operation – technological parameters" one can characterize by the efficiency indicators, that determines the influence of main, normalized technological parameters on the correctness of operation realization (4).

$$W_{EX} = \frac{\sum_{1}^{n} W_P}{n} \quad (4)$$

where:
W_P – indicator evaluating correctness of parameters typical for a given type of operation (determined in standards), n – number of parameters.

Within the analysis of process effectiveness we should determine the indicator of product selection (W_{POL}), that analyzes the legitimacy of semi – finished article selection and indicator of material selection (W_{PD}) (Fig. 2).

Indicators selection allows to evaluate the efficiency indicator of particular operations (K_{iX}) (5).

$$K_{iX} = \frac{W_{EM} + W_{EPM} + W_{EPC} + W_{EX} + W_{PD}}{5} \quad (5)$$

The determined indicators of operation efficiency will be used to determine the value of efficiency for the sake of the art of applied processing (E_{OC}, E_{OU}, E_{OPZ}, E_{OPG}), and as a result to fix the technological efficiency of the whole process (E_{PT}) (6).

$$E_{PT} = \frac{\sum_{i=1}^{n} E_{OBi} + W_{POL}}{n+1} \quad (6)$$

2. Creation of computer application that allows the determination of particular indicators and a final efficiency evaluation and optimization of particular operations (AEPT)

Within the analisis of process effectiveness (Fig. 1) one has created a system of computer assist. To analyze the technological efficiency an application was created that partly makes it easier to calculate the technological efficiency of the process [5, 16, 17].

AEPT program is created in accordance with the algorithm characterized by Fig. 3. Fig. 4. AEPT program window showing the efficiency of technological operations *Kix* of the analyzed process, systematized according to the value of an indicator of operation importance W_{WK}. [5].

Description of the stages of computer application of technological processes efficiency analysis according to the algorithm showed on the Fig. 3. After setting program from menu „application" in motion we choose the „new calculation" function in order to supplement the technological card consistent with the analyzed process. Next following the to the program enclosed instruction one should fulfill *„matrix of operation importance"* in order to determine the indicator (W_{WK}) for the operation in the analyzed process. Stage of determination of particular indicators of operation efficiency.

Determination of a material efficiency indicator (W_{EM}), indicator of machines work efficiency (W_{EPM}), indicator of humans work efficiency (W_{EPC}), efficiency indicator characterizing the operation kind during the proceeding (W_{EX}), indicator of material selection (W_{PD}). After getting the value of particular indicators of an operation we receive the technological operation efficiency (K_{iX}) systematized in accordance with the results of matrix of operation importance (Fig. 4).

Determination of technological efficiency for the sake of the applied proceedings (E_{OU}, E_{OC}, E_{OPZ}, E_{OPG}) and the technological efficiency of the whole process (E_{PT}) (2). Creation of graphs that show values of indicator of operation importance (W_{WK}), operation efficiency (K_{iX}) (Fig. 5) and technological efficiency for the sake of the applied proceeding (E_{OU}, E_{OC}, E_{OPZ}, E_{OPG}). Program results are written in form of report showing the conducted analysis of technological efficiency and one can save it in a txt version and print.

Showing by the use of program operations that require being improved. After estimating the minimal acceptable value K_{iXmin}, the program points At operation, that $K_{iX} < K_{iXmin}$ and marks particular indicators that decrease its value red marking. Optimization with the use of artificial neuron nets (point 3). Modification of particular indicators allows to estimate how the value of operation efficiency indicator (K_{iX}) will be changing, and to determine the value (K_{iX}) for single operations in the technological process.

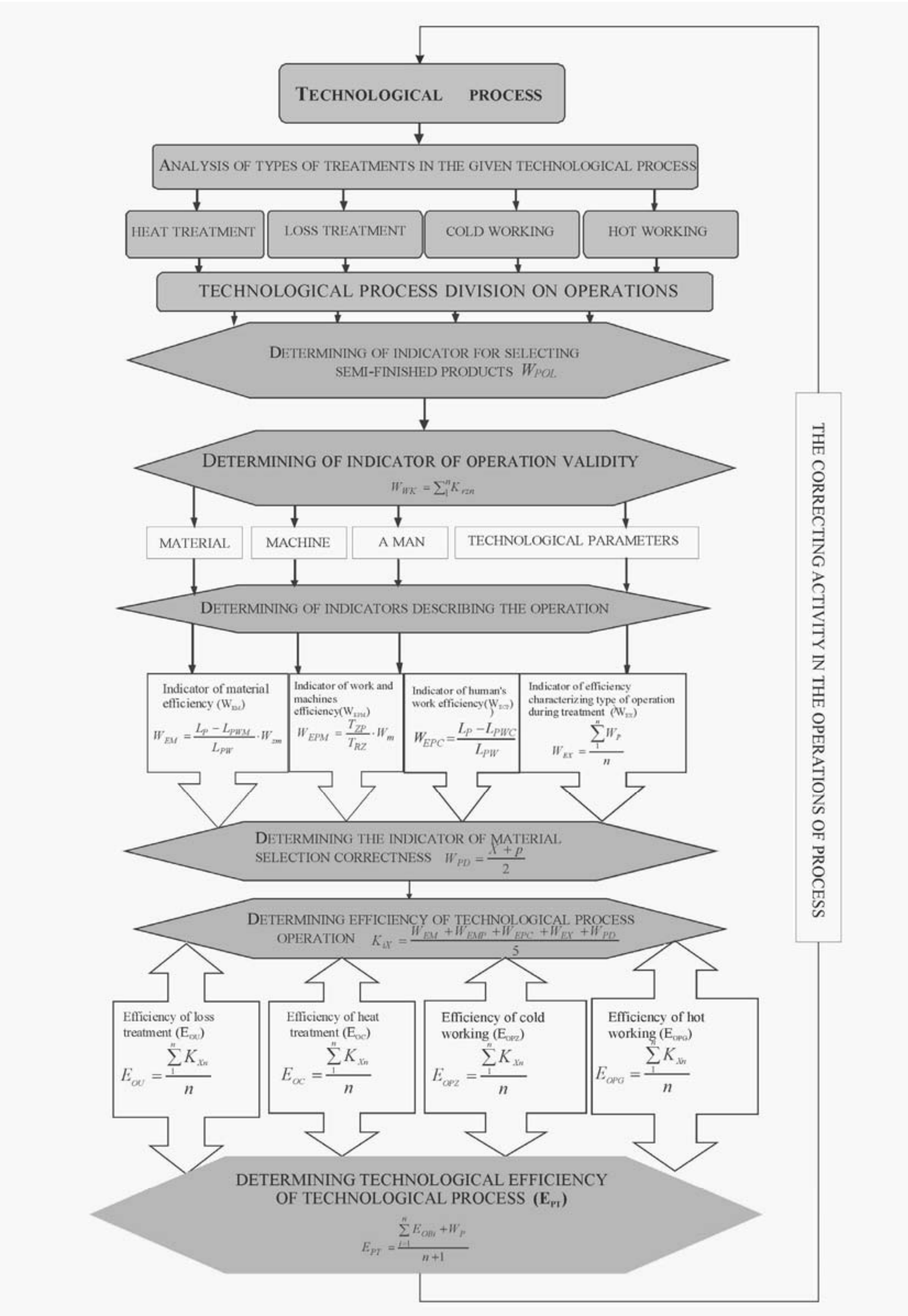

Fig. 1. The model of efficiency analysis [5]

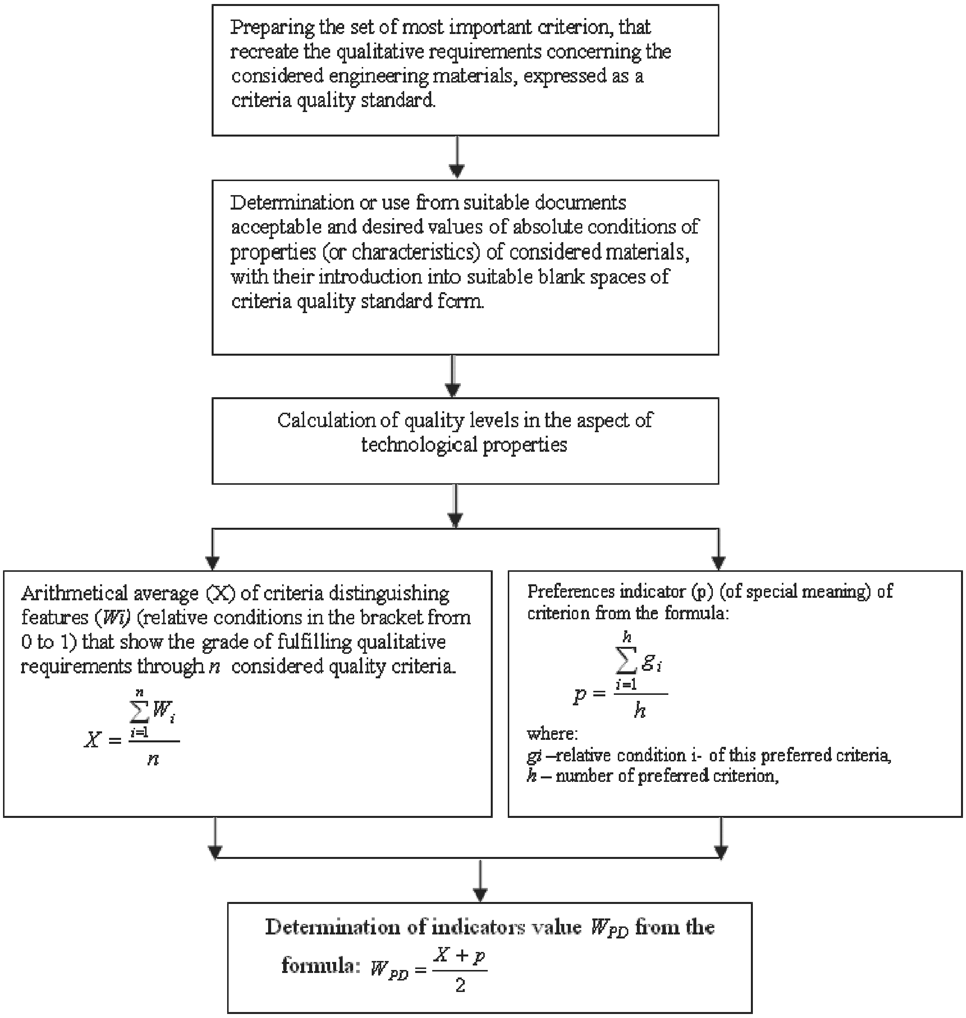

Fig. 2. Algorithm of material selection correctness indicator determination W_{PD} [1, 5]

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

During creating the computer model were used artificial neurons nets were partial, technical efficiency indicators and also normalized parameters of technological process (Fig. 1). From many indicators to learn the neuron nets W_{zm}, T_{RZ}, W_m, W_{EX}, W_{PD}. have been applied. To practice the neuron 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 (7) [2, 3, 5-7, 11, 14, 15].

$$E_{Ki} = \frac{1}{n} \cdot \sum_{i=1}^{n} \left(\left| x_{zi} - x_{oi} \right| \right) \tag{7}$$

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.

For determination of the indicator of process efficiency K_i many neuron 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 neuron nets (Table 1) [5].

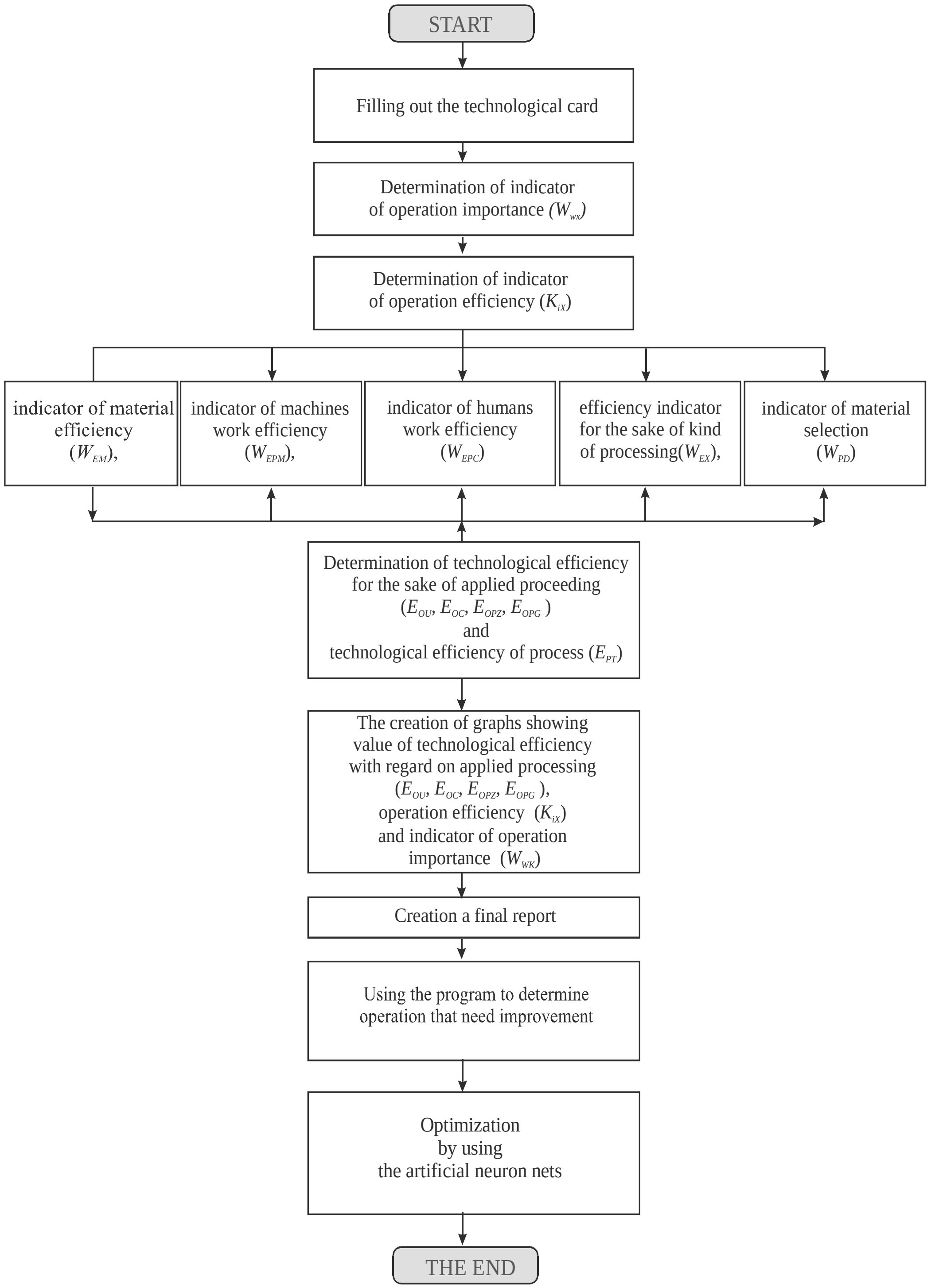

Fig. 3. Algorithm of proceedings by conducting the analysis of technological process efficiency by the use of computer application (AEPT) [5]

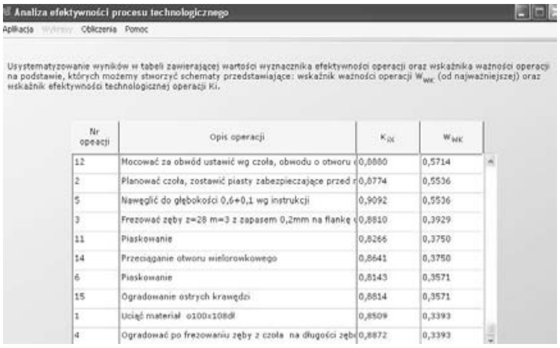

Fig. 4. AEPT program window showing the efficiency of technological operations *Kix* of the analyzed process, systematized according to the value of an indicator of operation importance W_{WK} [5]

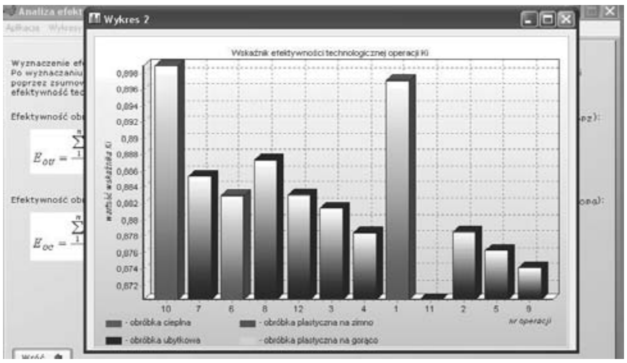

Fig. 5. AEPT program window presenting the graph of technological efficiency operation [5]

Table 1.
Quality indicator of the applied network [5]

Type of network	Error test	Quality test
MLP 5-9-1	0.02942	0.9428132

Comparison of real values of the efficiency indicator with values calculated by means of neuron nets have benn presented on the diagram (Fig. 6).

The example of the technological efficiency of the process

The productive series of cylindrical gear wheel with straight teeth (Tables 2-6) of 1000 were carried out, and the forging was the semi – manufactured article. The gear wheel with straight teeth was put into the test of technological process, whose the geometrical parameters and processing are not compiled (Fig. 7). Steel is the material used in the production of wheel C45 (PN EN 10083-2) [5].

Table 2.
Operation sheet of technological gear wheel process [5]

	Description of operation	$\sum K_{rz}$	W_{WK}
65	Surface hardening	9	0.81
45	Turn the outer face	6.75	0.613
40	Turn the front surfaces and external	6.5	0.59
50	Chiseling teeth	6.25	0.568
80	Grinding gear teeth	6	0.545
20	Turn the forehead and outer face Ø103.4 roughly	5.75	0.53
30	Hole broaching	5.5	0.5
05	Hardening and temper to hardness 26÷32 HRC	5	0.4166
75	Grinding Ø 75.6	4.75	0.432
15	Turn the outer face Ø76.2 and forehead, roughly Ø76.2 and Ø106 reboring Ø40.0 chambering hole Ø41.6	3.75	0.34
35	Rectifying of burr, refraction sharply edges	3.5	0.318
55	Refraction sharply edges on the side of tooth	3.25	0.295

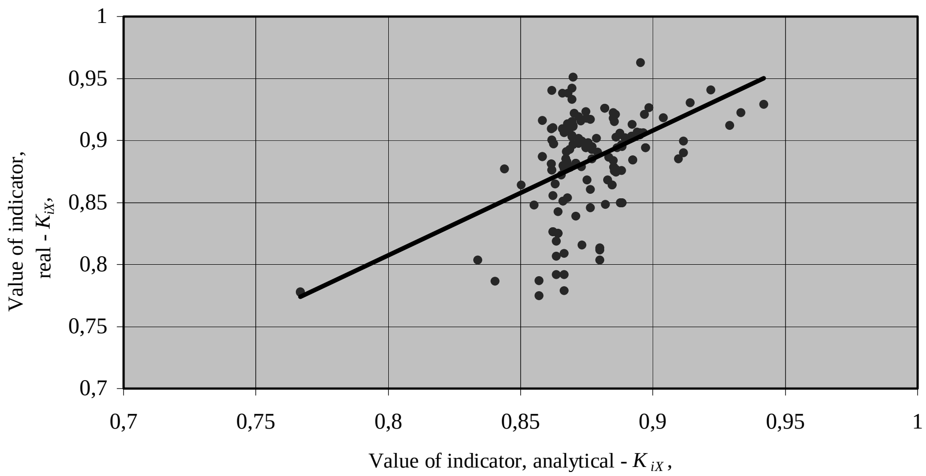

Fig. 6. Comparison of real values with calculated values of the indicator K_{iX} [5]

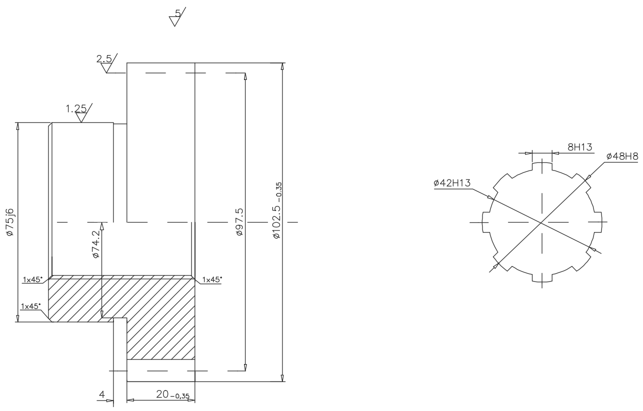

Fig. 7. Executive drawing of analysed cylindrical gear wheel with straight teeth [5]

Table 3.
Indicator of materials' efficiency W_{EM} [5]

W_{EM}	L_P	L_{PWM}	L_{PW}	W_{ZM}	W_{EM}
W_{EM1}	1000	1	1000	1	0.7867
W_{EM2}	1000	1	1000	0.97	0.7631
W_{EM3}	1000	1	1000	0.97	0.7631
W_{EM4}	1000	0	1000	0.97	0.7639
W_{EM5}	1000	0	1000	0.97	0.7639
W_{EM6}	1000	0	1000	0.98	0.7718
W_{EM7}	1000	0	1000	0.98	0.7718
W_{EM8}	1000	0	1000	0.98	0.7718
W_{EM9}	1000	3	1000	0.96	0.7537
W_{EM10}	1000	0	1000	1	0.7875
W_{EM11}	1000	0	1000	0.97	0.7639
W_{EM12}	1000	2	1000	0.99	0.7781

Indicator of correctness of material selection (Fig. 2):

$$W_{PD} = \frac{0{,}7875 + 0{,}8}{2} \cong 0{,}8 \qquad (8)$$

Table 4.
Indicator of machine's job efficiency W_{EPM}

W_{EPM}	T_{ZP}	T_{RZ}	W_M	W_{EPM}
W_{EPM1}	79	79	0.97	0.9700
W_{EPM2}	3368	3370	0.97	0.9694
W_{EPM3}	1980	1982	0.98	0.9790
W_{EPM4}	938	940	0.97	0.9679
W_{EPM5}	300	300	0.98	0.9800
W_{EPM6}	615	616	0.97	0.9684
W_{EPM7}	1427	1427	0.98	0.9800
W_{EPM8}	4263	4263	0.98	0.9800
W_{EPM9}	2500	2500	0.98	0.9800
W_{EPM10}	45	45	0.97	0.9700
W_{EPM11}	1980	1980	0.95	0.9500
W_{EPM12}	5940	5940	0.95	0.9500

Table 5.
Indicator of human's work efficiency W_{EPC} [5]

W_{EPC}	L_P	L_{PWC}	L_{PW}	W_{EPC}
W_{EPC1}	1000	3	1000	0.9970
W_{EPC2}	1000	2	1000	0.9980
W_{EPC3}	1000	2	1000	0.9980
W_{EPC4}	1000	0	1000	1.0000
W_{EPC5}	1000	0	1000	1.0000
W_{EPC6}	1000	0	1000	1.0000
W_{EPC7}	1000	0	1000	1.0000
W_{EPC8}	1000	0	1000	1.0000
W_{EPC9}	1000	0	1000	1.0000
W_{EPC10}	1000	0	1000	1.0000
W_{EPC11}	1000	0	1000	1.0000
W_{EPC12}	1000	0	1000	1.0000

Table 6.
Systematizing in dependence results from value K_{iX} as well as W_{WK} [5]

	Description of operation	K_{iX}	W_{WK}
65	Surface hardening	0.8990	0.8182
45	Turn the outer face	0.8854	0.6136
40	Turn the front surfaces and external	0.8830	0.5909
50	Chiseling teeth	0.8874	0.5682
80	Grinding gear teeth	0.8831	0.5455
20	Turn the forehead and outer face Ø103.4 roughly	0.8815	0.5227
30	Hole broaching	0.8785	0.4955
05	Hardening and temper to hardness 26÷32 HRC	0.8971	0.4545
75	Grinding Ø 75.6	0.8703	0.4318
15	Turn the outer face Ø76.2 and forehead, roughly Ø76.2 and Ø106 reboring Ø40 chambering hole Ø41.6	0.8786	0.3409
35	Rectifying of burr, refraction sharply edges	0.8763	0.3182
55	Refraction sharply edges on the side of tooth	0.8742	0.2955

Indicator of efficiency characterizing the operation time during treatment (W_{EX}) [5]: W_{EX1} = 0.9445, W_{EX2} = 0.8750, W_{EX3} = 0.8800, W_{EX4} = 0.8733, W_{EX5} = 0.8500, W_{EX6} = 0.8875, W_{EX7} = 0.8875, W_{EX8} = 0.8975, W_{EX9} = 0.8500, W_{EX10} = 0.9500, W_{EX11} = 0.8500, W_{EX12}=0.9000.

The technological efficiency of the process:

$$E_{PT} = \frac{E_{OC} + E_{OU} + W_{POL}}{n+1} = \frac{E_{OC} + E_{OU} + W_{POL}}{3} \qquad (9)$$

The efficiency of heat treatment:

$$E_{OC} = \frac{K_{05} + K_{15}}{2} = \frac{0{,}942 + 0{,}944}{2} = 0{,}943 \qquad (10)$$

The efficiency of loss treatment:

$$E_{OU} = \frac{K_{15} + K_{20} + K_{30} + K_{35} + K_{40} + K_{45} + K_{50} + K_{55} + K_{75} + K_{80}}{10}$$

$$E_{OU} = 0{,}92199 \qquad (11)$$

The whole technological efficiency of the process E_{PT}:

$$E_{PT} = \frac{E_{OC} + E_{OU} + W_{PD}}{n+1} = \frac{E_{OC} + E_{OU} + W_{PD}}{3} =$$
$$= \frac{0{,}943 + 0{,}92199 + 0{,}98}{3} = 0{,}94833 \qquad (12)$$

Bringing the E_{PT} value to the efficiency scale one can affirm that it's on very good level and it's confirmation of very well design. Taking into account continuous changes and progress in the production technology, any process, if it's possible, should be continuous improved beginning from the most important and the least effectively operations.

4. Conclusion

Technical progression within the scope of material engineering increases the demands and expectation towards the products quality.

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.

In order to automate the process, to determine the efficiency of technological operation (K_{iX}) and possibly to optimize it, one has applied one of artificial intelligence tools – neuron nets. The model with the use of neuron nets that has been worked out allows to calculate the efficiency indicator (K_{iX}) with average mistake equal to 0.02, what goes to show that determination of value indicator (K_{iX}) by means of nets is very accurate. Estimating the accuracy of efficiency calculations one should take into account the fact, that the average mistake that occurs during the control of nets didn't exceed 3.89% of the value scope of the operation efficiency indicator form the bracket 0 to 1. Similar values of nets quality assessment indicators are calculated for the text and verification set, confirm the correctness of the prepared model and point at the ability of the proposed neuron net for application during the determination of indicator of operation efficiency.

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