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FUNCTIONAL-VALUE ANALYSIS OF «COMMON RAIL» SYSTEM OF «ЯМЗ-5340» SERIES OF ENGINES

In Ukraine for the implementation of the international system of quality ISO 9000 the manufacturer must use the methods of the project solutions analysis. Such analysis must be subjected both input data of the project and output data. Enterprises, creating or developing quality products apply obligatory either typical technologies of functional-value analysis or use their own technologies. Functional-value analysis is directed at the provision of the necessary consumer characteristics of the object with minimum possible expenditures of the resource at all stages of the production process.

The given paper presents functional-value analysis of «Common Rail» system of «ЯМЗ-5340» series of engines. Functional model of «Common Rail» system of «ЯМЗ-5340» series of engines and the classification of the functions of its functional model has been developed.

Classification of the functions of the functional model of «Common Rail» system of «ЯМЗ-5340»series of engines has been presented. Utility coefficient of «Common Rail» system of «ЯМЗ-5340»series of engines has been determined by means of the priorities matrix construction according to the known calculation technique.

Generalizing criterion of the expenditures for the design of the engineering or production systems takes into account the expenditures at all the stages of the system life cycle, for their assessment input matrix of the system «Common Rail» of «ЯМЗ-5340» series of engines has been constructed, cost coefficient is determined from this matrix.

Value graph of the system «Common Rail» functions of the «ЯМЗ-5340»series of engines, ranking diagram of the system functions relatively the utility coefficient, functional-value diagram of the system, diagram of system functions expenses, diagram of the system functions ranking relatively expense ratio, diagram of the values of functional value index of the system, diagram of system functions ranking relatively the index of functional value have been constructed.

According to the constructed diagrams functions of the system «Common Rail» of «ЯМЗ-5340» series of engines which have positive functional-value index and the greatest rating from the considered functions have been determined. Operations or functions, having the greatest functional-value index and rank are the operations the improvement of which leads to further development of the system or achieving the aim of the analysis.

Key words: *functional-value analysis, system «Common Rail», functional model, classification of functions, utility coefficient, priorities matrix, cost coefficient, value graph, functions ranking diagram, functional-value diagram, expenditure functions diagram.*

Introduction

For making rational substantiated decision it is expedient to use functional-value analysis that combines various methods of the collective analysis of the systems, creative searching, optimization and decision-making [1].

The basic of functional-values analysis is the analysis of the functional perfection, ways of system improvement by means of comparison of separate functions utility and expenditures for its realization.

The objective of carrying out functional-value analysis is to provide the necessary usefulness of the system at minimal possible total expenditures.

Thus, the decision-making in case of functional-value analysis is realized proceeding from two criteria – utility and cost [2, 3].

In Ukraine for the implementation of the International Systems of Quality ISO 9000, the producer must use the methods of project decisions analysis. Both input project data and output data must be subjected to such analysis.That is why, the enterprises that create or develop quality products obligatory use either typical technologies of the analysis or functional-value analysis or use own technologies.

Functional-value analysis is directed to provide the necessary consumer properties of the object with minimal possible expenditures of the resources at all stages of the production process [4].

Problem set-up

Comprehensive analysis of the decision-making plays principle role in the process of the optimization of the engineering projects, aimed at improvement of the production efficiency. Analysis, as the method of investigation, enables to reveal available contractions and nonconformities in the developments, objects, systems and means, establish cause-consequence relations, providing the obtaining of the information.

Among the known methods of analysis (engineering, technical-economic, economic, ecological), functional-value analysis occupies important place, it is recommended to use this type of analysis during the design of new products and technologies, upgrading of the equipment and development of new products, reconstruction of the production objects, reduction of manufacturing expenses, etc.

The essence of the method of functional-value analysis is practical decomposition of the object (construction, technology, production processes management) into the components for determination of their role in general system, assessment of their functions and reduction of all unnecessary costs.

Experience of using functional-value analysis in automobile building industry testifies [4]:

– for the basic elements (functions) of the system, which comprise 20 % of their total amount, falls 85 % of the total cost of the system, that is why, these elements must be considered first of all;

– errors of the final calculation while performing functional-value analysis must be an order less than the value of the prime cost decrease.

Analysis of the recent studies and publications

Method of functional-value analysis was almost simultaneously initiated by two persons: engineer of the company «General Electric» – Lourence D. Miles [5] and engineer-designer of Perm telephone plant Yuriy Mikhailovych Sobolev [6]. They are considered to be the founders of the functional-value analysis. Soviet economists paid special attention to this type of analysis in the system of methods, aimed at the improvement of products quality and production efficiency.

In Ukraine functional-value analysis was considered as the component of crementation – branch of science, that studies the methods of creative thinking activations. The most known domestic scientists, who made great contribution in the development of functional-value analysis: M. Ivanov [2], N. Veselovskaya [3], Z. Lytvin [4], I. Tsyglyk [7], I. Prokopenko [8] and others.

Objective of the research

Objective of functional-value analysis is minimization of the object expenses at the stages of the design , production and operation without sacrificing or even increasing the usage of the object functions and enhancing its usefulness for the consumers.

Thus, the objective of the given research is the elaboration of functional-value analysis of «Common Rail» system of «ЯМЗ-5340» engines series for the determination of the system components functions, which are to be improved.

Main part

Engines, manufactured by PJSC «Avtodiesel» (ЯМЗ) – are engines of multipurpose designation. Technical characteristics, versatility, high level of unification and maintainability promote their wide application on the tractors and motor vehicles as well as other energy-driven facilities of various designation [9].

Series of diesels ЯМЗ-5340 gained wide application among the engines of PJSC «Autodiesel».

Engine ЯМЗ-5340 (Fig. 1, a) of ecological class «Euro-4» is basic four-cylinder model of the in line four-stroke turbo engine.

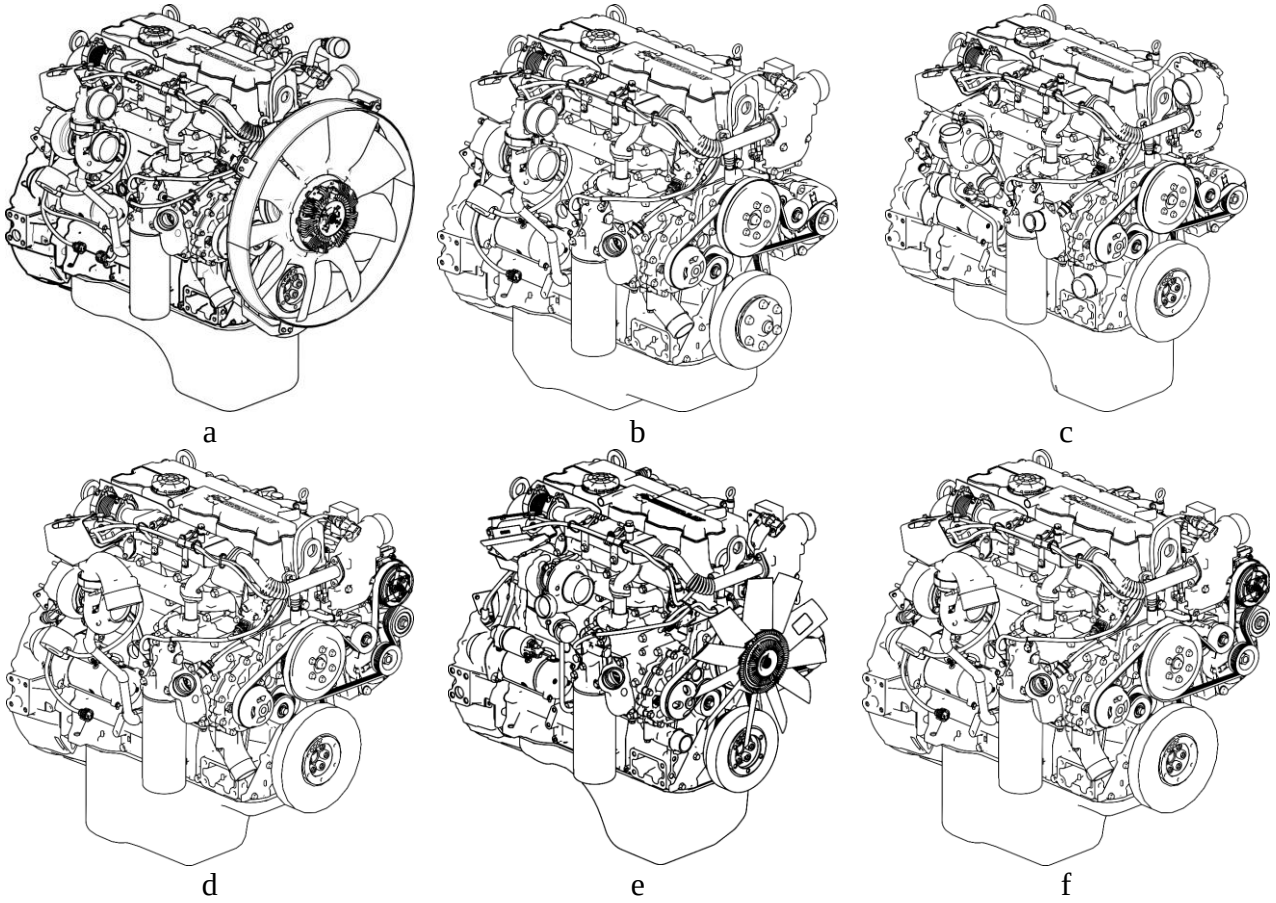

Fig. 1. Series of diesels ЯМЗ-5340 [9]:
a – ЯМЗ-5340 (basic model); b – ЯМЗ-5341-10; c – ЯМЗ-5344;
d – ЯМЗ-53402; e – ЯМЗ-53441-20; f – ЯМЗ-53423

Engines ЯМЗ-5341, ЯМЗ-5341-10 (Fig. 1, b), ЯМЗ-5342, ЯМЗ-5344 (Fig. 1, c), ЯМЗ-5344-10 and their packages of the ecological class «Euro-4» are the modifications of the engine ЯМЗ-5340, constructively manufactured similarly to the basic model, differ by the regulation of the setting parameters of the electronic control unit.

Engines ЯМЗ-53402 (Fig. 1, d), ЯМЗ-53422, ЯМЗ-53442 and their packages of the ecological class «Euro-4» structurally manufactured similarly to the basic model differ by the regulation of the fuel equipment due to the change of the setting parameters of the electronic control unit and are not equipped with the system of the exhausted gases recirculation (EGR).

Engines ЯМЗ-53411, ЯМЗ-53421, ЯМЗ-53431, ЯМЗ-53441-20 (Fig. 1, e), ЯМЗ-5346 and their packages of ecological class Euro-4 structurally manufactured similarly to the basic model, differ by the regulation of fuel equipment due to change of the setting parameters of electronic control unit, availability of the system of the emission control EOBD of the second stage11 (on-board diagnostics), for this system air temperature sensor is installed additionally on the engines

and the consumer connects the sensor of differential pressure to the system of the exhausted gases output.

Engines ЯМЗ-53403, ЯМЗ-53423 (Fig. 1, f), ЯМЗ-53443 and their packages of the ecological class «Euro-5» structurally manufactured similarly to basic model, differ by the fuel equipment, electronic control unit, change of a number of units and parts of the engine, availability of the system of on-board diagnostics (EOBD), for this system the engine is equipped with the air temperature sensor and the consumer connects the sensor of differential pressure to the system of the exhausted gases output.

Engines of «ЯМЗ-5340» series are equipped with the fuel system of storge-battery type «Common Rail System» (Fig. 2) with electronic control of the fuel supply, manufactured by the company «Robert Bosch» (Germany).

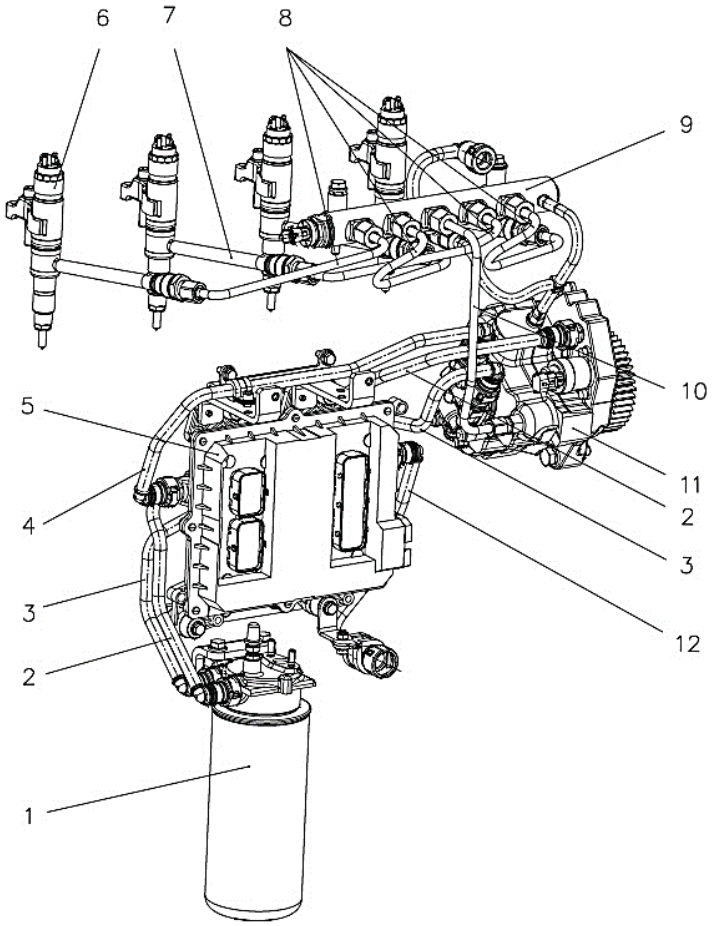

Fig. 2. Fuel system «Common Rail» of the diesels of «ЯМЗ-5340» series [9]:
1 – fine fuel filter; 2 – fuel inlet pipe to high pressure fuel pump;
3 – fuel inlet pipe to the filter; 4 – fuel inlet pipe to low pressure pump;
5 – electronic control unit; 6 – nozzle; 7 – side door choke; 8 – high pressure pipes; 9 – rail;
10 – high pressure fuel inlet pipe to the rail; 11 – high pressure fuel pump with low pressure pump; 12 – fuel inlet pipe to the engine

System «Common Rail» with electronic control unit provides:

– accurate dosing of the cyclic fuel supply for each operation mode and multiphase injection;

– regulation of the lead angles of fuel injection, depending on the rotation rate, load, temperature;

– flexible regulation of fuel injection pressure in wide range;

– easy engine start with minimal emission of harmful substances in the atmosphere at any temperature conditions;

– correction of the fuel supply process, depending on the environmental conditions to decrease the emission of the harmful substances;

– compatibility with the electronic systems of the motor vehicle and on-board control system and diagnostics via CAN channel, provides diagnostic process, performs the functions of speed limitation, emergency protection of the engine, cruise-control and doubling of the control from the additional organ from the operator panel.

Study of the system «Common Rail» of the engines «ЯМЗ-5340» series at functional-value analysis is based on the functional approach when the system is considered as the set of functions, performed by it. Further the searching of the better principle of realization of these functions is carried out. Functional-value analysis is performed on the base of the functional model [3, 4, 10].

Functional model is graphic on mathematical representation of the arranged set of the system functions and their interconnections. Graphic image of the functional model can be presented in the form of the graph (tree of functions) or technological chain. Functional model of the system «Common Rail» of the engines of «ЯМЗ-5340» is shown in Fig. 3.

Construction of the functional model is only the initial stage of functional-value analysis, the final aim of this analysis is the establishment of the analytical connections between separate factors, influencing the course of the process and final indices of the system operation [10].

After the construction of the functional model classification of the functions is realized.

Function is the external manifestation of the properties of the object, caused by certain actions, aimed at transformation of the input impacts into output results. Function may be of dynamic character, i. e., be directed to the realization of certain work and static.

Structuralization and analysis of functional model provide the allocation of the main function, which defines the objective and designation of the system and basic functions, without which the main function can not be executed. And the allocation of the auxiliary and redundant (harmful) functions.

Classification of the system functions is performed by two criteria – character and properties of the function. Classification of the functions of the functional model of «Common Rail» system of «ЯМЗ-5340» series is presented in the Table. 1.

External function is realized by the system or its elements at the interaction with the environment (supersystem).

Internal function is the result of the interactions in the system.

Main function – it is the external function, which reflects the objective and designation of the system.

Basic function – it is the internal function, that provides the realization of the consumer values of the object, its functional serviceability.

Auxiliary function promotes the realization of the basic ones and also is internal.

Useful functions are the functions, meeting the requirements of people, regarding their usefulness.

Redundant functions are not obligatory functions but their execution improves the quality of the system operation.

Neural functions – are the functions, which do not execute functional loading, but provide the location of the object in certain place, at certain time.

Harmful functions – are the functions which can be simultaneously useful but have the obligatory element of the harmful action.

1. Fuel supply by means of gearing fuel boost pump, executed within a single housing of high pressure fuel pump, under the pressure of 700...800 kPa into fine fuel filter from the fuel tank across preliminary filter and electronic control unit

2. Fuel cleaning by fine fuel filter

3. Fuel supply to the high pressure fuel pump

4. Fuel supply by high pressure fuel pump in common fuel supply line (Rail)

5. Fuel supply by high pressure fuel supply lines to each nozzle

6. Preliminary injection of fuel with small supply value, that decreases the noise of combustion

7. Basic fuel injection under the pressure of 180…200 MPa via the nozzles into the combustion chamber

8. Additional fuel injection, that enables reduce the level of the exhausted gases emission

9. Duration of the injection is determined by the duration of the electric pulse from electronic control unit of the engine

10. Level of the fuel pressure in the rail, optimal to this level of the engine operation, is set by the electronic control unit and is determined by the balance of fuel consumption via the nozzles and performance of the fuel pump

11. Transfer of the information about engine systems operation to the electronic control unit by the sensors, located on the engine

12. Usage of the information by the control unit about the operation of the engine systems for the control of the fuel injection process

13. Usage of the information by the control unit about the operation of the engine systems for the control of the process of signal supply to the instrument panel

14. Usage of the information by the control unit about the operation of the engine systems for the control of the execution mechanisms, that provides the operation of the engine

15. Easy start of the engine with a minimal emission of the harmful substances into the atmosphere at any temperature conditions

16. Correction of the fuel supply process depending on the conditions of the environment in order to decrease the emission of the harmful substances

17. Provision of the process of the engine diagnostics

Fig. 3. Functional model of the system «Common Rail» of the engines of «ЯМЗ-5340» series

The next step of functional-value analysis is the determination of the usefulness coefficients of each function. Usefulness coefficient is determined by means of construction of the priorities matrix (Table 2) by the known calculation technique [1, 3, 10].

Table 1

Classification of the functions of the functional model of the system «Common Rail» of the engines of «ЯМЗ-5340» series

№ of function	Name of the function	Character of the function	Properties of the function
1	Fuel supply by means of gearing fuel boost pump, executed within a single housing of high pressure fuel pump, under the pressure of 700...800 kPa into fine fuel filter from the fuel tank across preliminary filter and electronic control unit	Internal auxiliary	Neutral
2	Fuel cleaning by fine fuel filter	Internal auxiliary	Neutral
3	Fuel supply to the high pressure fuel pump	Internal auxiliary	Neutral
4	Fuel supply by high pressure fuel pump in common fuel supply line	Internal auxiliary	Neutral
5	Fuel supply by high pressure fuel supply lines to each nozzle	Internal auxiliary	Neutral
6	Preliminary injection of fuel with small supply value, that decreases the noise of combustion	External auxiliary	Redundant
7	Basic fuel injection under the pressure of 180…200 MPa via the nozzles into the combustion chamber	External main	Useful
8	Additional fuel injection, that enables reduce the level of the exhausted gases emission	External auxiliary	Redundant
9	Duration of the injection is determined by the duration of the electric pulse from electronic control unit of the engine	External main	Useful
10	Level of the pressure in the rail, optimal to this level of the engine operation, is set by the electronic control unit and is determined by the balance of fuel consumption via the nozzles and performance of the fuel pump	External main	Useful
11	Transfer of the information about engine systems operation on the electronic control unit by the sensors, located on the engine	External auxiliary	Redundant
12	Usage of the information by the control unit about the operation of the engine systems for the control of the process of fuel injection	External auxiliary	Useful
13	Usage of the information by the control unit about the operation of the engine systems for the control of the process of signal supply to the instrument panel	External auxiliary	Harmful
14	Usage of the information by the control unit about the operation of the engine systems for the control of the execution mechanisms, that provides the engine operation	External auxiliary	Useful
15	Easy start of the engine with a minimal emission of the harmful substances into the atmosphere at any temperature conditions	External auxiliary	Useful
16	Correction of fuel supply process depending on the conditions of the environment in order to decrease the emission of the harmful substances	External auxiliary	Useful
17	Provision of the process of the engine diagnostics	External auxiliary	Useful

Table 2

Priorities matrix of «Common Rail» system of the engines of «ЯМЗ-5340» series

№ of function	Number of the function / Advantage coefficients																	Sum of advantages coefficient	Absolute priority	Utility coefficient	Rank of the function
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17				
1	1	1	1	1	1	1.5	0.5	1.5	0.5	0.5	1.5	0.5	1.5	0.5	0.5	0.5	0.5	15	231	0.05038	11
2	1	1	0.5	1.5	0.5	1	0.5	1.5	0.5	0.5	0.5	0.5	1.5	0.5	0.5	0.5	0.5	13	203	0.04426	13
3	1	1.5	1	0.5	0.5	1.5	0.5	0.5	0.5	0.5	0.5	0.5	1.5	0.5	0.5	0.5	0.5	12.5	191	0.04180	15
4	1	0.5	1.5	1	1.5	1	0.5	0.5	0.5	0.5	0.5	0.5	1.5	0.5	0.5	0.5	0.5	13	199	0.04349	14
5	1	1.5	1.5	0.5	1	1.5	0.5	0.5	0.5	0.5	0.5	0.5	1.5	0.5	0.5	0.5	0.5	13.5	204	0.04464	12
6	0.5	1	0.5	1	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	1.5	0.5	0.5	0.5	0.5	11	172	0.03759	16
7	1.5	1.5	1.5	1.5	1.5	1.5	1	1.5	1.5	1	1	1.5	1.5	1.5	1.5	1.5	1.5	24	402	0.08791	1
8	0.5	0.5	1.5	1.5	1.5	1.5	0.5	1	1.5	1.5	1	0.5	1.5	0.5	0.5	0.5	0.5	16.5	265	0.05797	9
9	1.5	1.5	1.5	1.5	1.5	1.5	0.5	0.5	1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	23	382	0.08338	2
10	1.5	1.5	1.5	1.5	1.5	1.5	1	0.5	0.5	1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	22.5	371	0.08103	3
11	0.5	1.5	1.5	1.5	1.5	1.5	1	1	0.5	0.5	1	0.5	1.5	0.5	0.5	0.5	0.5	16	245	0.05349	10
12	1.5	1.5	1.5	1.5	1.5	1.5	0.5	1.5	0.5	0.5	1.5	1	1.5	1.5	1.5	1.5	1.5	22	353	0.07715	4
13	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	9	149	0.03256	17
14	1.5	1.5	1.5	1.5	1.5	1.5	0.5	1.5	0.5	0.5	1.5	0.5	1.5	1	1	1.5	1	20	312	0.06824	6
15	1.5	1.5	1.5	1.5	1.5	1.5	0.5	1.5	0.5	0.5	1.5	0.5	1.5	1	1	1	0.5	19	293	0.06398	7
16	1.5	1.5	1.5	1.5	1.5	1.5	0.5	1.5	0.5	0.5	1.5	0.5	1.5	0.5	1	1	0.5	18.5	283	0.06180	8
17	1.5	1.5	1.5	1.5	1.5	1.5	0.5	1.5	0.5	0.5	1.5	0.5	1.5	1	1.5	1.5	1	20.5	322	0.07032	5
Sum																			4576	1	-

For the construction of the priorities matrix the coefficient of the advantage k_{ij} of the element of the i^{th} row (a_i) in comparison with the element of the j^{th} column (a_j) are written on the cross-section of the row and column.

Advantage coefficients may have the values:

– 1,5 – if the function in the i^{th} row has greater advantage that the function in the j^{th} column ($k_{ij} = 1{,}5 \rightarrow a_i \succ a_j$);

– 1 – at the same significance of the functions ($k_{ij} = 1 \rightarrow a_i \approx a_j$);

– 0,5 – if the function in the i^{th} row has less advantage than the function in the j^{th} column ($k_{ij} = 0{,}5 \rightarrow a_j \succ a_i$).

Further the parameter P_i (absolute priority) is found. Parameter P_i is determined as the sum of the products of each element of the i^{th} raw on the elements of vector-column Σk_{ij}, i. e. [2, 3]:

$$
\begin{aligned}
P_1 &= k_{11}\sum k_1 + k_{21}\sum k_2 + \ldots + k_{1j}\sum k_i + \ldots + k_{1n}\sum k_n;\\
P_2 &= k_{21}\sum k_1 + k_{22}\sum k_2 + \ldots + k_{2j}\sum k_i + \ldots + k_{2n}\sum k_n;\\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\\
P_i &= k_{i1}\sum k_1 + k_{i2}\sum k_2 + \ldots + k_{ij}\sum k_i + \ldots + k_{in}\sum k_n;\\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\\
P_n &= k_{n1}\sum k_1 + k_{n2}\sum k_2 + \ldots + k_{nj}\sum k_i + \ldots + k_{nn}\sum k_n.
\end{aligned}
\qquad (1)
$$

Then the utility coefficient λ of each function is found [1, 3]:

$$\lambda_i = P_i / \Sigma P_i \ \text{при} \ \Sigma\lambda_i = 1. \qquad (2)$$

The rank of the function is determined depending on the value of the utility coefficient λ. The

greater is the utility coefficient, the higher rank has the function.

Having performed the above-mentioned calculations the value graph (Fig. 4) and ranking (Fig. 5) of the functions of «Common Rail» system of the engines of «ЯМЗ-5340» series relatively utility coefficient will be constructed .

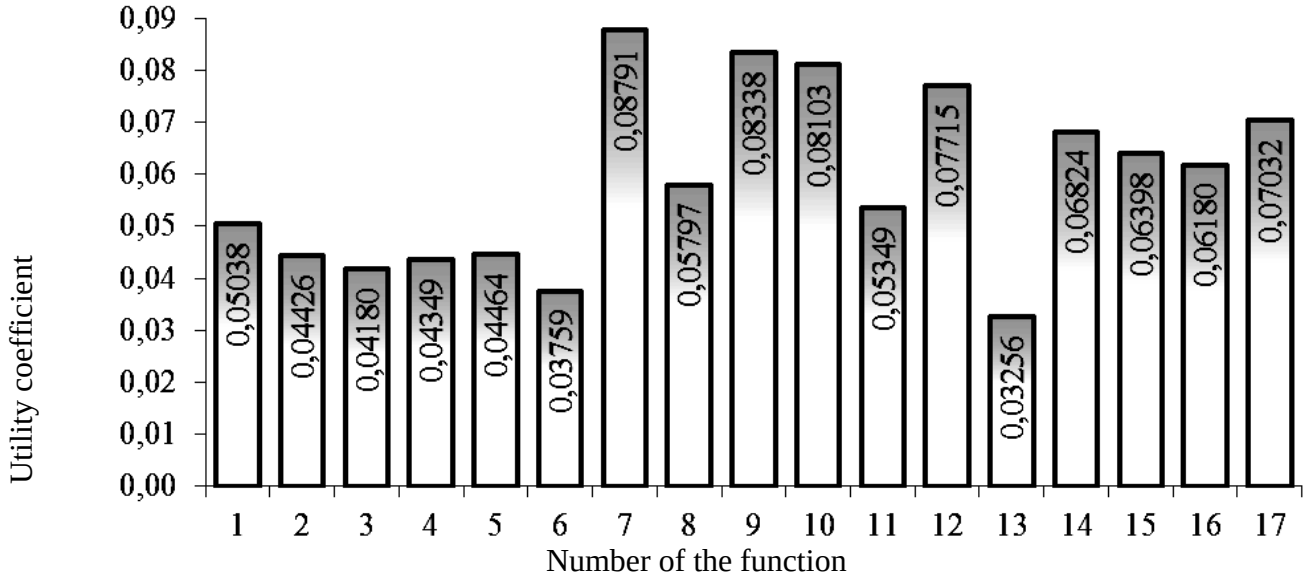

Fig. 4. Value graph of the functions of «Common Rail» system of the engines of «ЯМЗ-5340» series

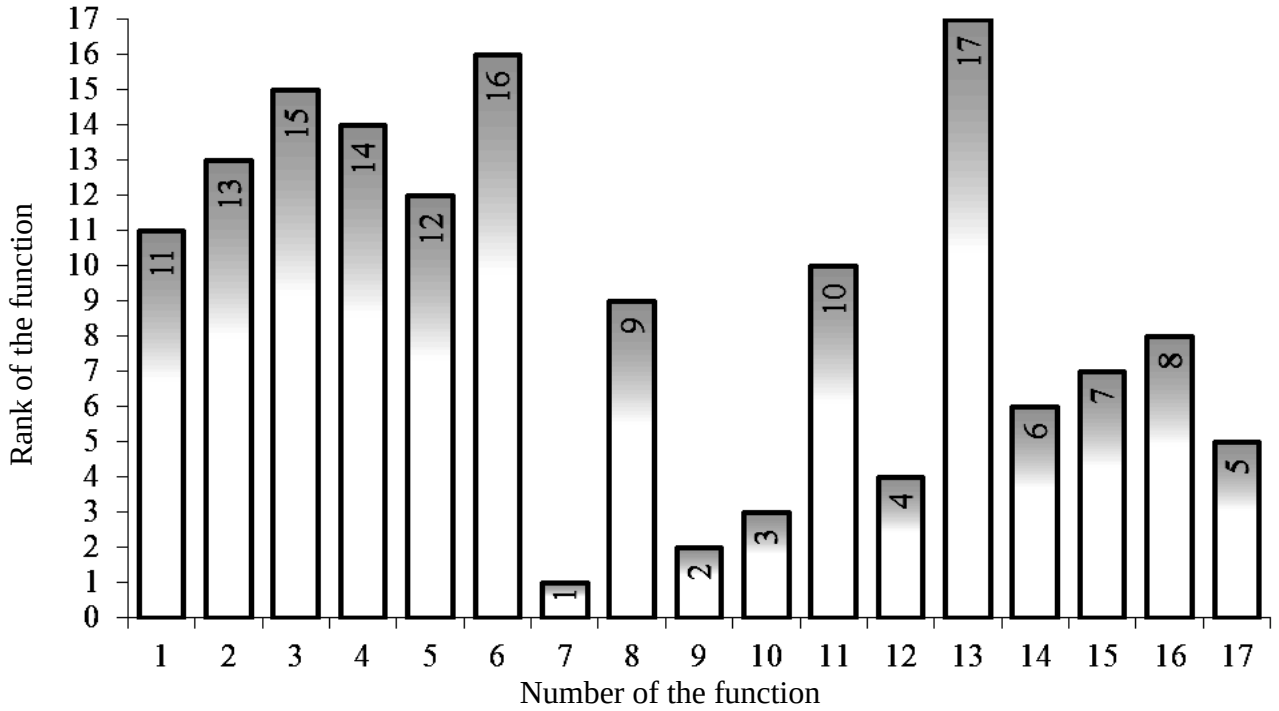

Fig. 5. Diagram of functions ranking of the «Common Rail» system of the engines of «ЯМЗ-5340» series relatively utility coefficient

Expenses in functional-value analysis are considered as the payment for utility. Generalized criterion of the expenses for the design of technical or production systems takes into account the expenses at all the stages of the system life cycle, for their assessment matrix of expenses is constructed (Table 3), the expense ratio is determined from this matrix.

Table 3

Matrix of expenses of the system «Common Rail» of the engines of «ЯМЗ-5340» series

№ of function	Name of the function	Share of the function in the expenses	Utility factor	Expense ratio	Rank of the function
1	Fuel supply by means of gearing fuel boost pump, manufactureed within a single housing of high pressure fuel pump, under the pressure of 700...800 kPa into fine fuel filter from the fuel tank across preliminary filter and electronic control unit	0.002	0.05038	0.040	14
2	Fuel cleaning by fine fuel filter	0.001	0.04426	0.023	16
3	Fuel supply to the high pressure fuel pump	0.001	0.04180	0.024	15
4	Fuel supply by high pressure fuel pump in common fuel supply line(Rail)	0.061	0.04349	1.403	7
5	Fuel supply by high pressure fuel supply lines to each nozzle	0.061	0.04464	1.366	8
6	Preliminary injection of fuel with small supply value, that decreases the noise of combustion	0.102	0.03759	2.713	1
7	Basic fuel injection under the pressure of 180…200 MPa via the nozzles into the combustion chamber	0.101	0.08791	1.149	10
8	Additional fuel injection, that enables to reduce the level of the exhaused gases emission	0.102	0.05797	1.759	4
9	Duration of the injection is determined by the duration of the electric pulse from electronic control unit of the engine	0.011	0.08338	0.132	13
10	Level of the fuel pressure in the rail, optimal to this level of the engine operation, is set by the electronic control unit and is determined by the balance of fuel consumption via the nozzles and performance of the fuel pump	0.015	0.08103	0.185	12
11	Transfer of the information about the engine systems operation to the electronic control unit by the sensors, located on the engine	0.101	0.05349	1.888	2
12	Usage of the information by the control unit about the operation of the engine systems for the control of fuel injection process	0.101	0.07715	1.309	9
13	Usage of the information by the control unit about the operation of the engine systems for the control of the signal supply process to the instrument panel	0.017	0.03256	0.522	11
14	Usage of the information by the control unit about the operation of the engine systems for the control of the execution mechanisms, providing the operation of the engine	0.001	0.06824	0.015	17
15	Easy start of the engine with a minimal emission of the harmful substances into the atmosphere at any temperature conditions	0.101	0.06398	1.579	5
16	Correction of fuel supply process depending on the conditions of the environment in order to decrease the emission of the harmful substances	0.111	0.06180	1.796	3
17	Provision of the process of the engine diagnostics	0.111	0.07032	1.578	6
Sum		1	1	-	-

At this stage method of expert assessments, comparison with the «ideal model» is used, also the level of the significance of each function and expenses for it is compared. For this purpose the expense ratio per function is used, it is calculated by comparing the share of the parameter (function) in the expenses to its utility coefficient.

Expense ratio is determined by the following formula [2, 3]:

$$K_i = \varepsilon_i / \lambda_i \text{ if } \Sigma\lambda_i = 1, \Sigma\varepsilon_i = 1, \quad (3)$$

where ε – is the share of the function in the expenses.

Share of the function in the expenses is determined by the following formula [2, 3]:

$$\varepsilon_i = \frac{B_i}{\sum_{i=1}^{n} B_i}, \tag{4}$$

where B_i – is the value of each function; $\sum_{i=1}^{n} B_i$ – is the sum of values of all the functions of the system.

In theory and practice of functional-value analysis such assessment criteria of the expense ratio per function are accepted [1, 3]:

– expense ratio equals «1» or close to «1» – the ratio between expenses and function is justified;

– expense ratio is less than «1» the ratio is favourable;

– expense ratio is greater than «1» – measures, aimed at reducing the expenses for function obtaining should be reduced .

Specific procedure of functional-value analysis is the construction of functional-value diagrams, which are the graphic image of the ratio between the utility of the functions and expenses for their realization. Construction of the functional-value diagrams is performed to reveal the discrepancy of the expenses regarding the utility of the function. Functional-value diagram is constructed for the group of functions, having common vertex. In the first quadrant the utility or significance of the function is presented, in the second-expenses for functions (Fig. 6).

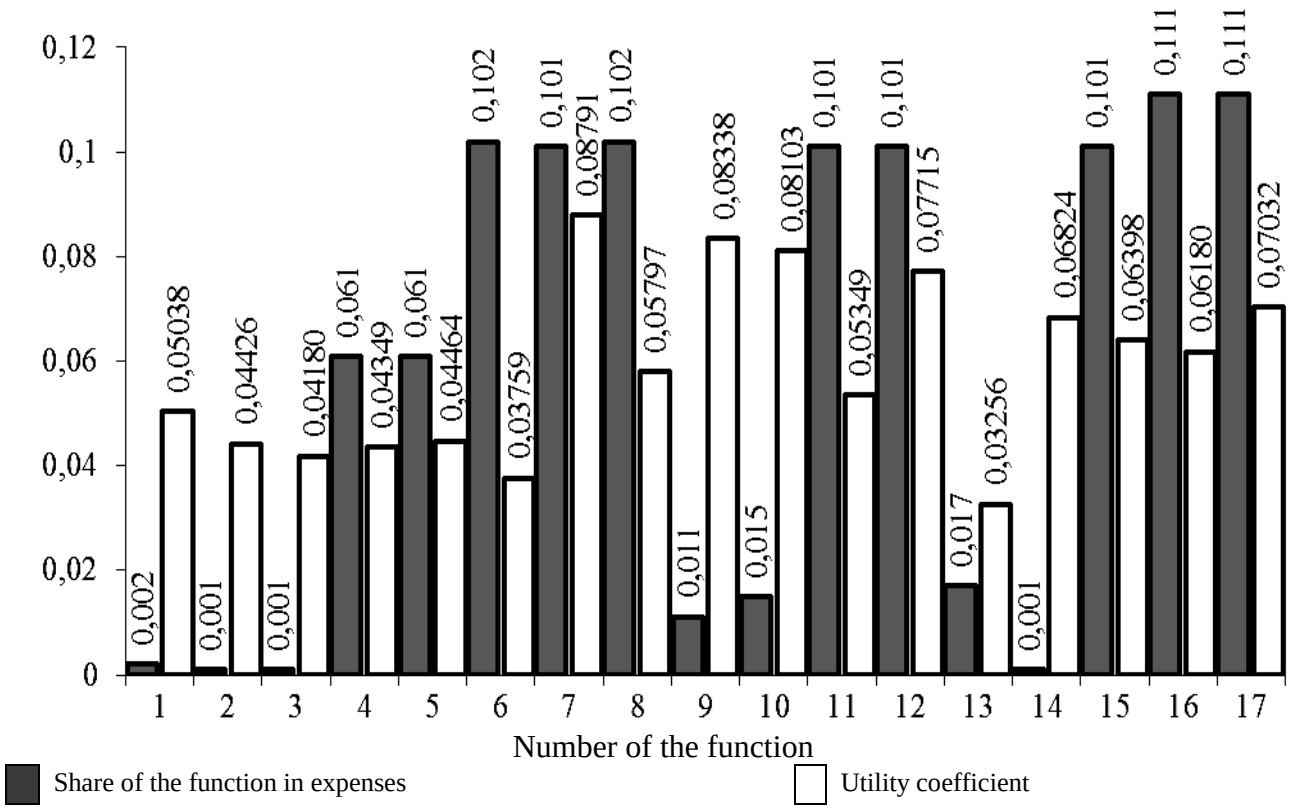

Fig. 6. Functional-value diagram of the system «Common Rail» of the engines of «ЯМЗ-5340» series

Having carried out the above-mentioned calculations, diagrams of expenses (Fig. 7) and ranking (Fig. 8) of the functions of the system «Common Rail» of the engines of «ЯМЗ-5340» series relatively the expense ratio will be constructed.

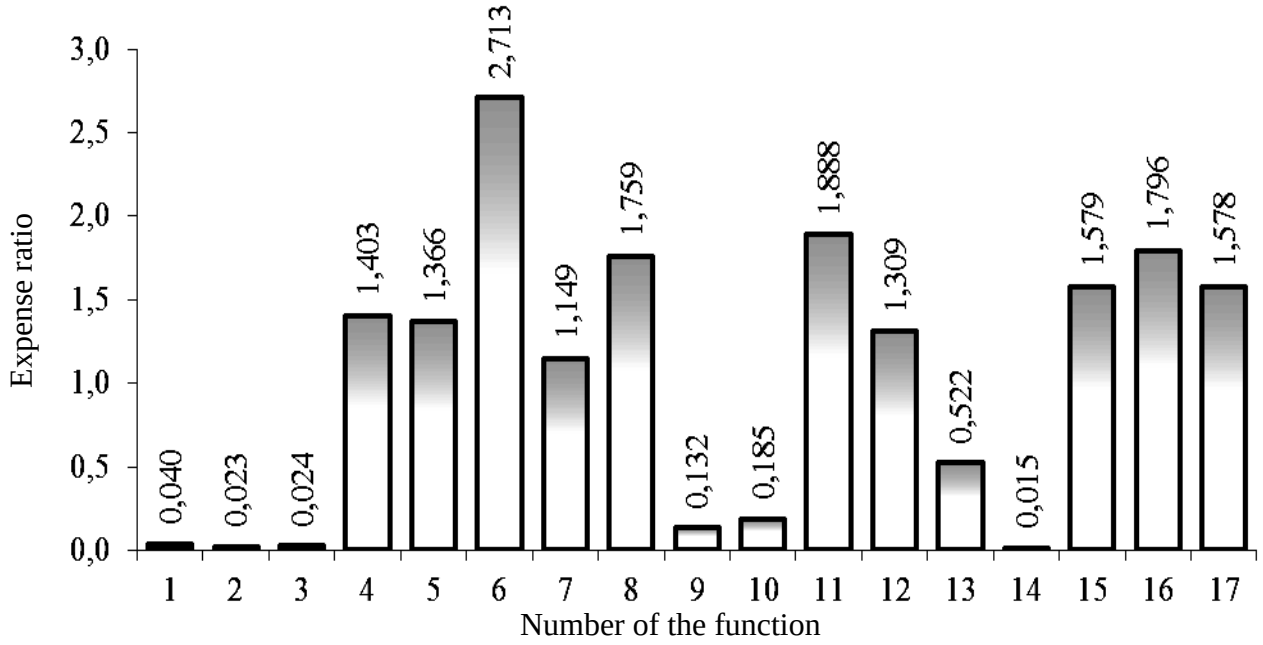

Fig. 7. Diagram of the expenses function of the system «Common Rail» of the engines of «ЯМЗ-5340» series

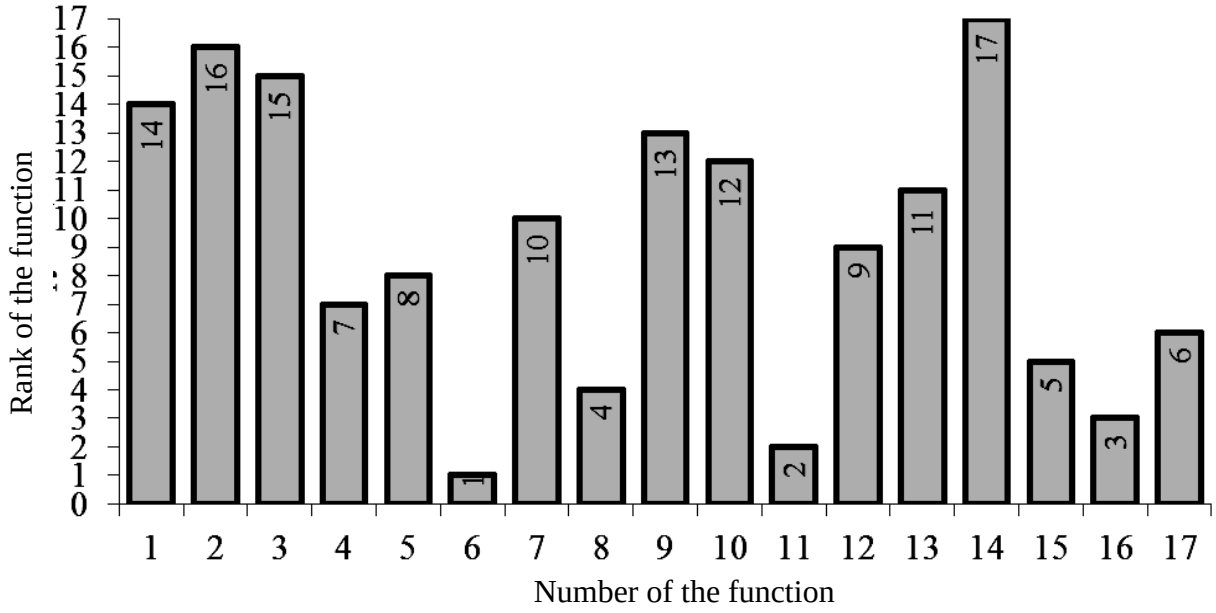

Fig. 8. Diagram of ranking the functions of the system «Common Rail» of the engines of «ЯМЗ-5340» series relatively expense ratio

The next stage of functional-value analysis is determination of the functional-value index [2, 3]:

$$П_{fvi} = \lambda_i - K_i. \quad (5)$$

Functional-value index shows how much the expense portion of the operation performance or function is greater than the useful function. Value of the indices of the functional value of the function of the system «Common Rail» of the engines of «ЯМЗ-5340» series relatively expense ratio are presented in Table 4.

Table 4

Values of functional value indices of the function of the system «Common Rail» of the engines of «ЯМЗ-5340» series

№ of function	Name of the function	Function-value index	Rank of the function
1	Fuel supply by means of gearing fuel boost pump, manufactured within a single housing of high pressure fuel pump, under the pressure of 700...800 kPa into fine fuel filter from the fuel tank across preliminary filter and electronic control unit	0.011	4
2	Fuel cleaning by fine fuel filter	0.022	2
3	Fuel supply to the high pressure fuel pump	0.018	3
4	Fuel supply by high pressure fuel pump in common fuel supply line(Rail)	-1.359	11
5	Fuel supply by high pressure fuel supply lines to each nozzle	-1.322	10
6	Preliminary injection of fuel at a small supply value, that decreases the noise of combustion	-2.676	17
7	Main fuel injection under the pressure of 180…200 MPa via the nozzles into the combustion chamber	-1.061	8
8	Additional fuel injection, that enables to reduce the level of the exhaused gases emission	-1.702	14
9	Duration of the injection is determined by the duration of the electric pulse from electronic control unit of the engine	-0.049	5
10	Level of the pressure in the rail, optimal to this level of the engine operation, is set by the electronic control unit and is determined by the balance of fuel consumption via the nozzles and performance of the fuel pump	-0.104	6
11	Transfer of the information about engine systems operation to the electronic control unit by the sensors, located on the engine	-1.835	16
12	Usage of the information by the control unit about the operation of the engine systems for the control of fuel injection process	-1.232	9
13	Usage of the information by the control unit about the operation of the engine systems for the control of the process of signal supply to the instrument panel	-0.489	7
14	Usage of the information by the control unit about the operation of the engine systems for the control of the execution mechanisms, providing the operation of the engine	0.054	1
15	Easy start of the engine with a minimal emission of the harmful substances into the atmosphere at any temperature conditions	-1.515	13
16	Correction of fuel supply process depending on the conditions of the environment in order to decrease the emission of the harmful substances	-1.734	15
17	Provision of the process of the engine diagnostics	-1.508	12

From the economic point of view it is expedient to develop the functions with positive functional-value index.

Having performed the above-mentioned calculations the diagrams of the index of the functional-value (Fig. 9) and ranking (Fig. 10) of the functions from the system «Common Rail» of the engines of «ЯМЗ-5340» series relatively functional value index will be constructed.

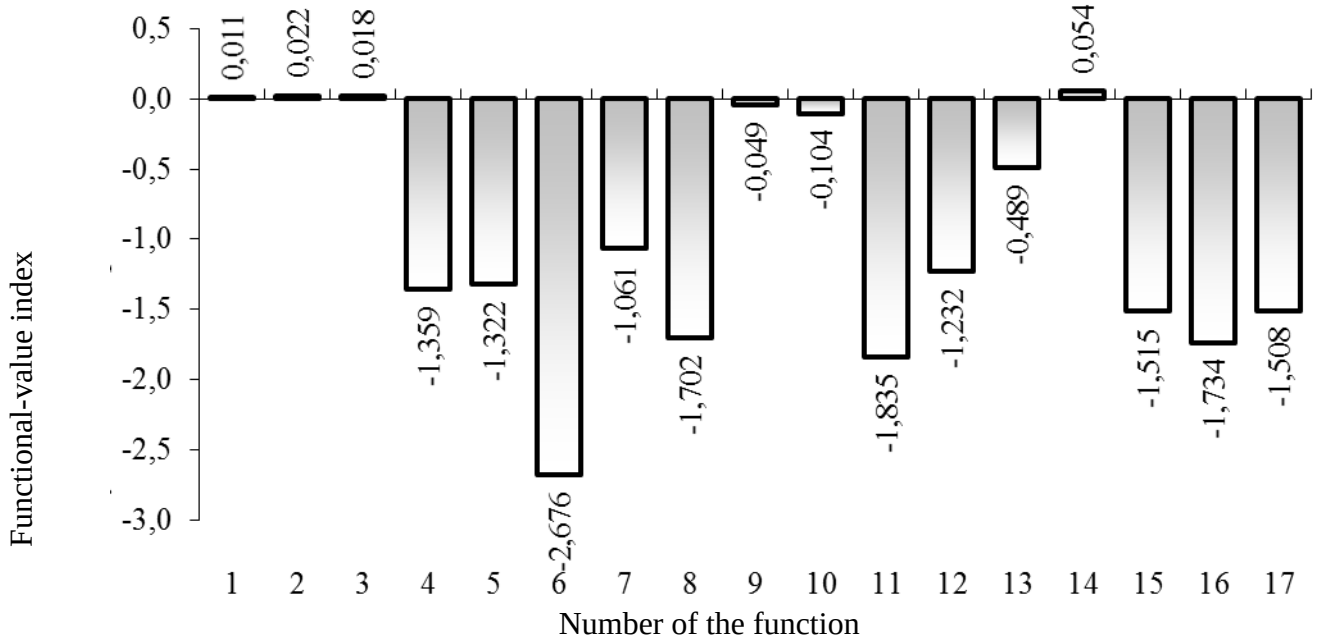

Fig. 9. Diagram of the values of functional value index of the functions of the system «Common Rail» of the engines of «ЯМЗ-5340» series

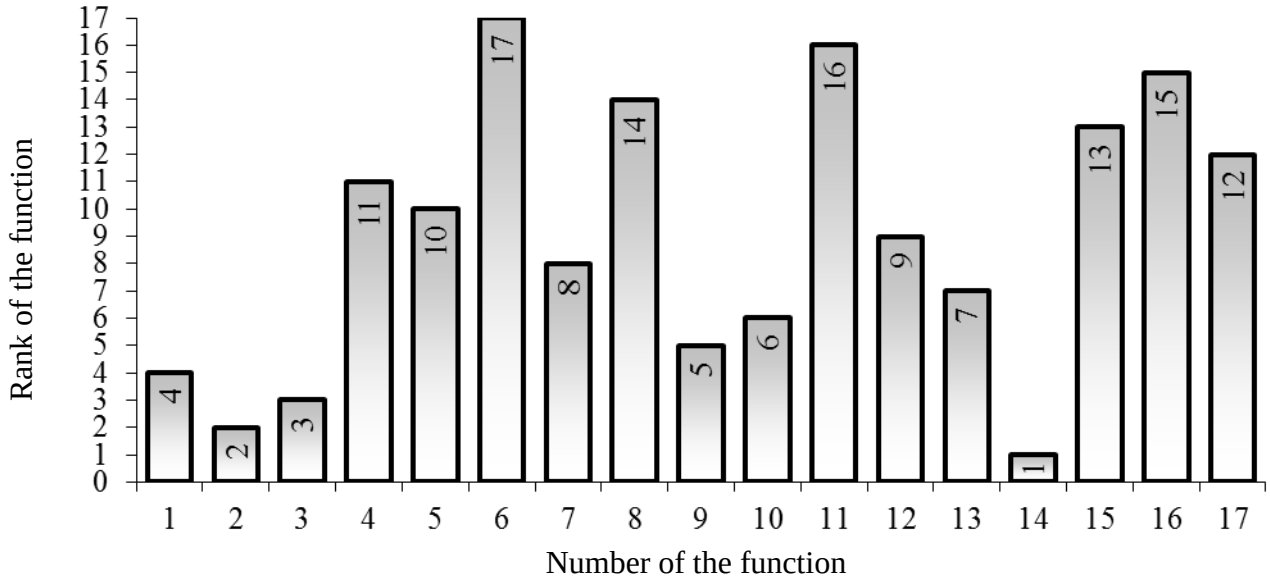

Fig. 10. Diagram of function of the system «Common Rail» of the engines of «ЯМЗ-5340» series ranking relatively the index of functional value

Functions, having positive functional-value index and the highest rating of the considered functions are determined by the diagrams 9, 10. Operations or functions, having the greatest functional-value index and rank are those operations, the improvement of which leads to further development of the system or achieving the aim of the analysis.

Conclusions

1. Functional-value analysis of the system «Common Rail» of the engines of «ЯМЗ-5340» series carried out, showed that the highest rank and greatest functional-value index has function №7 «Main injection of fuel under the pressure of 180…200 MPa by the nozzles into the combustion chamber» the basis of which is the principle task of the developed technical system.

2. According to the results of the calculation of functional-value indices of the system «Common Rail» of the engines of «ЯМЗ-5340» series, the conclusion can be made that the

functions №14 «Usage of the information by the control unit regarding the operation of the engine systems for the control of the operating mechanisms, providing the operation of the engine» and function №2 «Fuel clearing by the fine fuel filter» are those functions, the improvement of which leads to further development of the system.

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