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FUNCTIONAL-COST ANALYSIS OF THE AIR PRESSURE REGULATION SYSTEM IN THE TYRES OF THE MILITARY AUTOMOTIVE EQUIPMENT

Functional-cost analysis is the method of the system study of the object functions to find the balance between its cost price and utility.

Functional-cost analysis is carried out in the process of the development and putting into manufacture of new products, improvement of technical-economic level of the production. In the process of design the search of the optimal technical solutions, determination of the boundary target cost for manufacturing of the developed objects and determination of the most efficient conditions of their usage is carried out. At the stage of production for the improvement of the objects the unnecessary costs are revealed, disproportions between the significance of the functions for the consumers and expenses for their provision are determined, search for the reserves for decreasing the cost price and improvement of the products quality is carried out.

The given paper considers functional-cost analysis of the air pressure regulation system in the tires of wheels of the military automotive vehicle «KrAZ». Functional model of air pressure regulation system in the tires of the wheels of military automotive vehicle «KrAZ» and functions classification of its functional model has been developed.

The utility coefficient of the air pressure regulation system in the tires of the wheels of military automotive vehicle «KrAZ» has been determined by means of construction of the priorities matrix according to the known calculation technique.

Generalized expenses criterion in the process of technical and production systems design takes into account the expenses at all stages of the life cycle of the system, for their assessment the expenses matrix of the air pressure regulation system in the tires of the wheels of the military automotive vehicle «KrAZ» has been constructed, expenses coefficient is determined from this matrix.

Utility diagram of the functions of air pressure regulation system in the tire of the wheels of the military automotive vehicle «KrAZ», diagram of the functions ranking of the system relatively utility coefficient, functional-cost diagram of the system, diagram of the functions expenses of the system, diagram of the functions system ranking relatively the expenses coefficient, diagram of the values of the index of the functional cost of the system functions, diagram of the system functions ranking relatively the functional cost index have been constructed.

Functions of air pressure regulation system in the tire of the wheels of the military automotive vehicle «KrAZ», which have positive functional-cost index and the highest rating among the considered functions have been determined according to the constructed diagrams. Operations or functions, having the highest functional- cost index and rank are the operations, improvement of which leads to further development of the system or achieving the objective of the analysis.

Key words: *functional-cost analysis, system of air pressure regulation in the tires of the wheels, functional model, functions classification, utility coefficient, priorities matrix, expenses coefficient, functions utility diagram, functions ranking diagram, functional-cost diagram, function expenses diagram.*

Introduction

For making rational and substantiated decision it is expedient to apply functional-cost analysis, that

combines various methods of the aggregated analysis of the systems, creative search, optimization and decisions selection (1).

The basis of functional-cost analysis is the analysis of the functional perfection, ways of improving the system by means of comparison of the utility of its separate functions and expenses for its realization.

Objective of performing functional-cost analysis is to provide necessary utility of the system at minimum possible total expenses.

Thus, decision-making in case of functional-cost analysis is carried out on the base of two criteria – utility and cost [2, 3].

In Ukraine, for the implementation of the International system of quality ISO 9000 the manufacturer should use the methods of the design solutions analysis. Such analysis should be carried out both for the input data of the project and the output data. That is why, the enterprises, which develop or create quality products obligatory use either typical technologies of the analysis or functional-cost analysis, or use their own technologies.

Thus, functional-cost analysis is directed on the provision of the needed consumer properties of the object with minimal possible losses of the resources at all the stages of the production process [4].

Problem set-up

Main role in the optimization of the engineering projects, aimed at improvement of the production efficiency is devoted to performing the comprehensive study of the decisions made. Analysis, as the method of study, enables to reveal the available discrepancies and nonconformities in the developments, objects, systems and methods, establish cause-and-effect relations, providing the obtaining of information.

Among the known methods of analysis (engineering, technical-economic, economic, ecological) special position is occupied by functional-cost analysis, it is recommended to apply such analysis for the design of new products and technologies, upgrading of the equipment and start-up of the new materials, reconstruction of the industrial objects, reduction of the productive costs, etc.

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

Experience of using functional-cost analysis in automobile building shows [4]:

– main elements (functions) of the system, which represent 20 % of their total number, falls 85 % of the total cost of the system, that is why, consideration of the above-mentioned elements must be of top priority;

– errors of the definitive calculation in the process of performing functional- cost analysis must be by an order of magnitude less of the volume of the cost decrease.

Analysis of the recent research and publications

Two persons almost simultaneously originated functional-cost analysis – employee of the company «General Electric» – engineer L. D. Miles [5] and Yuriy Mykhailovych Sobolev – engineer-constructor of Perm telephone plant [6]. They are considered to be the founders of functional-cost analysis. Special attention to the importance of this type of analysis in the system of the methods, aimed at products quality improvement and production efficiency was paid in the studies of soviet economists.

In Ukraine functional-cost analysis was considered as the component of crementation – science, studying the methods of activation of the creative thinking. Most prominent domestic scientists, who made considerable contribution in the development of functional-cost analysis are: M. Ivanov [2], N. Veselovska [3], Z. Lytvyn [4], I. Tsyzylyk [7], I. Prokopenko [8], D. Borysiuk [9], V. Zelinskyi [10] et al.

Among foreign publications in this sphere the works of O. Dinukova [11], Yu. Anikina [12], G. Todorov [13], T. Joshikava [14] et al. should be mentioned.

Objective of the research

Objective of functional-cost analysis is to minimize the object losses at the stages of the design, production, operation at saving or improvement the usage of the object functions, increasing of it utility for the consumers.

Thus, the **objective of the given study** is the development of functional-cost analysis of the system of air pressure regulation in the tires of military automotive vehicle «KrAZ» for the determination of system elements functions, which are expedient to improve.

Main part

Military automotive equipment includes all types of military vehicles, tracked towing vehicles and wheeled motor traction vehicles, transporters prime movers, tractors, trailers, semitrailers, mobile facilities for the repair and evacuation which provide everyday activity of the Armed Forces. Military moto -vehicles are constructed in accordance with tactical-technical-economic requirements of the Armed Forces and are intended for the transportation of the military personal, military loadings, mounting and transport of the armament and military equipment, transporting of the trailers and semitrailers of various designation. Military vehicles are divided into transport vehicles (cargo trucks, in particular, tactical truck tractors and motor vehicles) and special (intended for mounting special equipment).

Military trucks «KrAZ» correspond to all specifications of the military automotive supply. Motor vehicles «KrAZ» attract the attention of the military due to their high technical and operation characteristics of the Ukrainian off road vehicles.

Motor vehicles of special designation were always in the family of vehicles of the Private joint-stock company «AutoKrAZ». Nowadays «AutoKrAZ» manufactures the motor vehicles of special designation: high-sided KrAZ-6322 «Soldier» (6×6) and KrAZ-5233BE «Spetsnaz» (4×4), chassis KrAZ-63221, KrAZ-6322 (6×6), KrAZ-5233HE (4×4), tactical truck tractors KrAZ-6446 (6×6) and KrAZ-6443 (6×6).

Motor vehicles «KrAZ» participated almost in all military conflicts and wars of the end of XX – the beginning of XXI century. They implemented the fulfillment of the missions as a part of peace—keeping forces of the Armed Forces of Ukraine in Sierra Leone, Lebanon, Kosovo, Iraq, Afghanistan and

peace-keepers of Indonesia in Sudan. Modern «KrAZ» motor vehicles are used in the armies of 36 countries of the world, including Armed Forces of Ukraine, Georgia, Iraq, Egypt, India, Yemen, Angola, Nigeria.

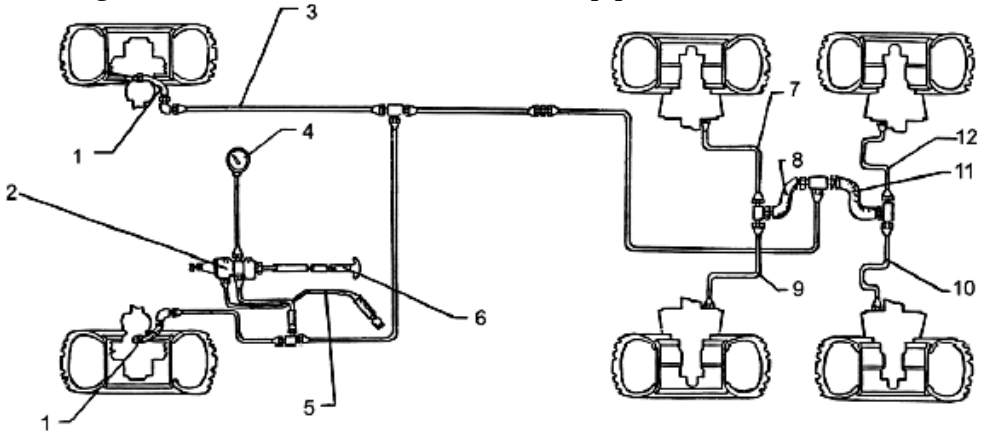
Experience of «KrAZ» trucks operation in military service and during military actions in different countries of the world showed that they successfully operate in the most complex extremal and natural-climatic conditions – deserts, jungles, mountains. Motor vehicles «KrAZ» are reliable machines, operating in temperature range of -50 to +65 °C, they can operate at the altitude up to 5 thousand meters above the sea level, they can overcome water obstacles of 1.5 m of depth and 0.6 m fall of snow. Army vehicles «KrAZ», due to available centralized system of pressure regulation in the tires have good cross-country ability on low-load bearing capacity soil.

System of air pressure regulation in the tires is intended for the improvement of the cross-country ability of the motor vehicle on hard sections of the route due to air pressure decrease in the tires and in case of the puncture the given system gives the possibility to continue motion to the car park (station of technical maintenance) without replacing the wheel on condition that the efficiency of the compressor allows to fill up the leakage in the damaged tire.

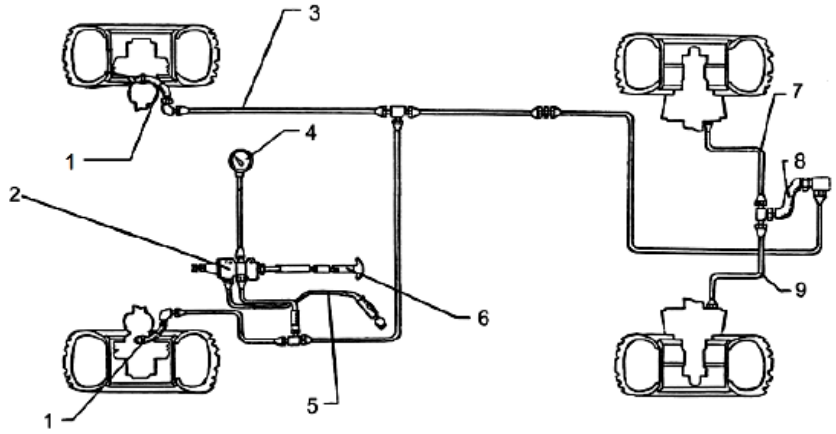
Control of the system is carried out from the cab, this enables to perform the continuous control of the pressure in tires according to the readings of the manometer on the dash panel and regulate pressure, depending on the road conditions and traffic speed.

Scheme of the centralized system of air pressure regulation in the tires of «KrAZ» motor vehicles is presented in Fig. 1.

The system of air pressure regulation in the tires consists of: pressure control valve, limiting valve, wheel valves, sealing unit in the wheel hubs, air ducts, hose pipes and manometer [11].



a



b

Fig. 1. Scheme of the centralized system of air pressure regulation in the tires of wheels:
a) six-axle motor-vehicle «KrAZ»:
1 – Hose pipes for air admission to the front wheels; 2 – control valve of the centralized tire inflation system; 3 – air inflation manifold; 4 – manometer; 5 – manifold of air admission to the control valve; 6 – control valve bar; 7 – air conduit of the right middle wheel; 8 – hose pipe for air admission to the intermediate axle; 9 – air conduit of the left middle wheel; 10 – air conduit of the left rear wheel; 11 – hose pipe for air admission to the rear axle; 12 – air conduit of the right rear wheel.
b) four axle truck «KrAZ»:
1 – hose pipes for air admission to the front wheels; 2 – control valve of the centralized tire inflation; 3 – inflation manifold; 4 – manometer; 5 – manifold of air admission to the control valve; 6 – control valve bar; 7 – air conduit of the right rear wheel; 8 – hose pipe for the admission of air to the rear axle; 9 – air conduit of the left rear wheel

Pressure control valve consists of the body with an inlet opening for air admission to the tires and output opening for the exit of air from the tires into the atmosphere.

Limiting valve (of the diaphragm type) installed on the control valve, is intended for the disconnection of tires pumping system from the pneumatic drive of the brake in case of pressure diminution in the receivers below 600 kPa.

Limiting valve enables to perform the air intake for tires pumping only if the pressure in the receivers is above 600 kPa, at lower pressure centralized pumping of the tires is not possible.

Wheel valves are fixed to the bar covers, welded to the wheels rims. These valves are intended for the disconnection of the tires from the system of pumping during long stops of the motor vehicle and in case of the damage of the collars of the sealing unit in the wheel hubs.

Sealing unit consists of four elastic rubber collars with the compressing springs, which provide sealing of the moving connection.

Study of the system of air pressure regulation in the tires of military vehicle «KrAZ» at functional-

cost analysis is based on functional approach, in this case the system is considered as the set of functions, performed by it. Further, the searching of better principle of these functions realization is carried out. Functional-cost analysis is carried out on the base of functional model [3, 4, 10, 15].

Functional model is graphic or mathematic representation of the arranged set of the system functions and their connections. Graphic representation of the functional model can be realized in the form of graph (tree of functions) or technological chain. Functional model of the system of air pressure regulation in the tyres of wheels of military automotive supply «KrAZ» is show in Fig. 2.

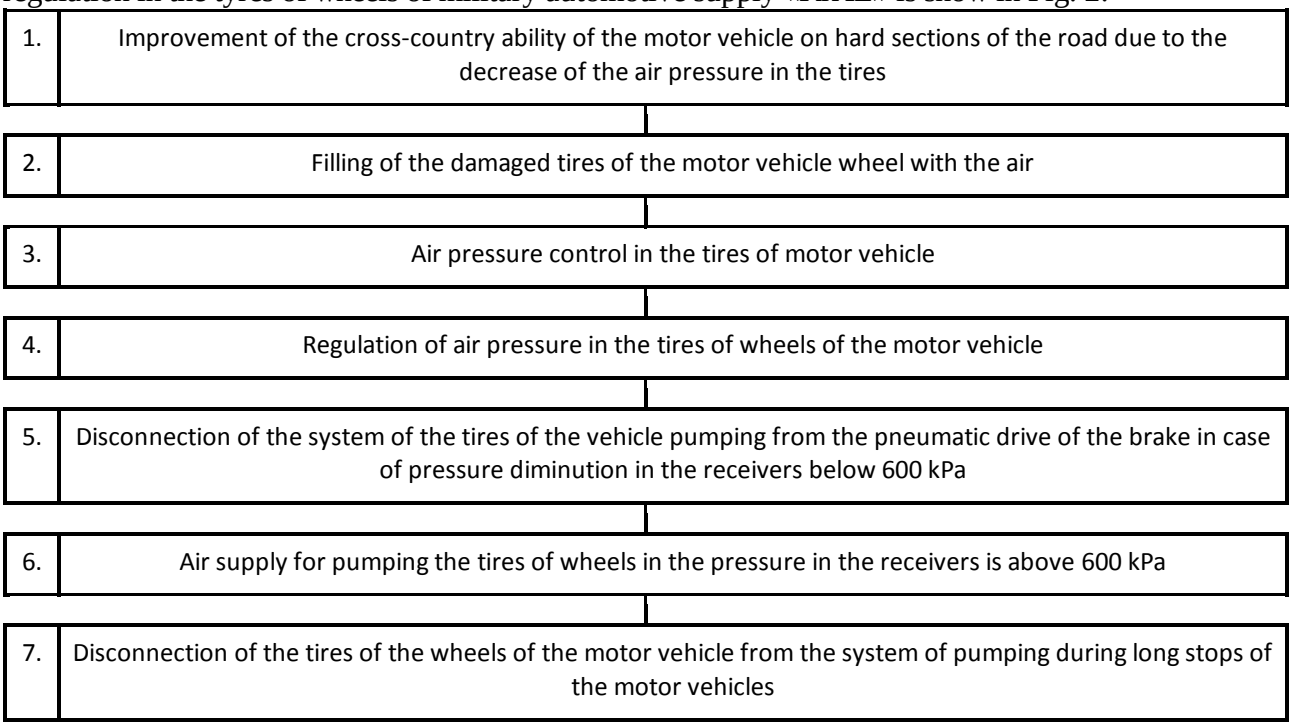


Fig. 2. Functional model of the system of air pressure regulation in the tires of the military motor vehicle «KrAZ»

Construction of the functional model is only the initial stages of functional- cost analysis, final objective of the analysis is the establishment of the analytical connections among the separate factors, influencing the course of the process and final indices of the system operation [9, 10].

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

The function is the external manifestation of the object properties, stipulated by certain actions, regarding the transformation of the input impacts into the output results. Function may have both dynamic character, i. e., be directed to the realization of a certain work and static character.

Structurization and analysis of the functional model provide the allocation of the main function, which determines the objective and designation of the system and basic functions, without which the main function cannot be performed and 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 the system of air pressure regulation in tires of the wheel of the motor vehicles «KrAZ» is shown in Table 1.

External function is realized by the system or its element in the process of the interaction with the medium (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, which provides the realization of the consumer properties of the object, its functional suitability.

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

Useful functions are the functions, which meet the requirements of the person, regarding their utility.

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

Neutral functions are the functions, which do not perform functional loading.

However, they provide the location on the object in certain place, at certain time.

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

The next step of performing functional-value analysis is the determination of the utility coefficients of each function. Utility coefficient was determined by means of construction of the priorities matrix (Table 2), according to the known calculation technique [1, 3, 9, 16].

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

Advantages coefficients may have the following values:

– 1,5 – if the function in the i^{th} row has greater advantage than 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 that 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 a sum of the products of each element of the i^{th} row on the elements of the vector-column Σk_{ij}, i. e. [2, 3]:

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

Table 1

Classification of the functions of the functional model of the system of air pressure regulation in the tires of military motor vehicle «KrAZ»

№ of function	Name of the function	Character of the function	Properties of the function
1	Improvement of the cross-country ability of the motor vehicle on hard sections of the road due to the decrease of the air pressure in the tires	Internal basic	Useful
2	Filling of the damaged tires with the air	External main	Useful
3	Air pressure control in the tires of motor vehicle	Internal auxiliary	Useful
4	Regulation of air pressure in the tires of wheels of the motor vehicle	Internal basic	Useful
5	Disconnection of the system of the tires of the vehicle pumping from the pneumatic drive of the brake in case of pressure diminution in the receivers below 600 kPa	Internal auxiliary	Neutral
6	Air supply for pumping the tires if the pressure in the receivers is above 600 kPa	Internal auxiliary	Useful
7	Disconnection of the tires of the wheels of the motor vehicle from the system of pumping during long stops of the motor vehicles	Internal auxiliary	Redundant

Table 2

Priorities matrix of the system of air pressure regulation in the tires of the wheels of military motor vehicle «KrAZ»

№ of function	Name of the function	Number of the function / Coefficients of the priorities							Sum of the advanyage coefficients r	Absolute priorities	Coefficient of priority	Rank of the function
		1	2	3	4	5	6	7				
1	Improvement of the cross-country ability of the motor vehicle on hard sections of the road due to the decrease of the air pressure in the tires	1	0.5	1.5	1	1	1	1.5	7.5	49.3	0.15271	3
2	Filling of the damaged tires of the motor vehicle with the air	1.5	1	1.5	1.5	1.5	1.5	1.5	10	68.5	0.21240	1
3	Air pressure control in the tires of motor vehicle	0.5	0.5	1	1	1	1	1.5	6.5	42.3	0.13101	5
4	Regulation of air pressure in the tires of the motor vehicle	1	0.5	1	1	1.5	1.5	1.5	8	52.5	0.16279	2
5	Disconnection of the system of the tires of the vehicle pumping from the pneumatic drive of the brake in case of pressure reductionb in the receivers below 600 kPa	1	0.5	1	0.5	1	0.5	1.5	6	38.5	0.11938	6
6	Air supply for pumping the tires of the wheels if the pressure in the receivers is above 600 kPa	1	0.5	1	0.5	1.5	1	1.5	7	45	0.13953	4
7	Disconnection of the tires of the wheels of the motor vehicle from the system of pumping during long stops of the motor vehicles	0.5	0.5	0.5	0.5	0.5	0.5	1	4	26.5	0.08217	7
Sum										322.5	1	-

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

$$\lambda_i = P_i / \Sigma P_i \text{ if } \Sigma\lambda_i = 1. \quad (2)$$

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

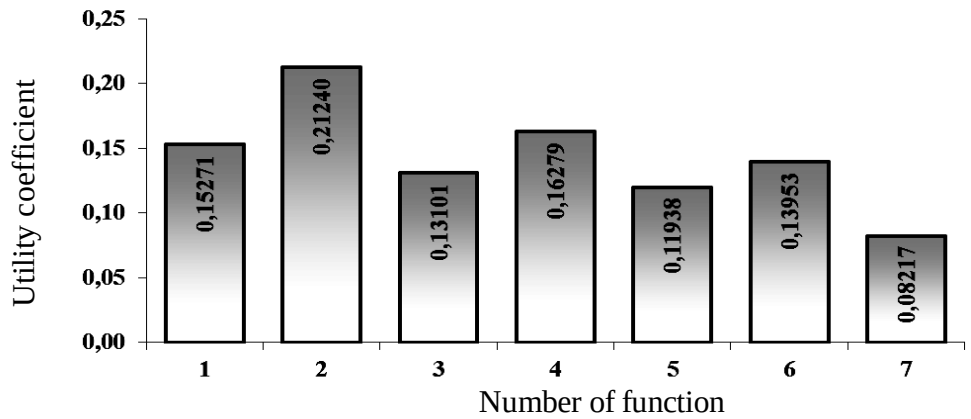


Fig. 3. Diagram of the utility function of the air pressure regulation system in the tyres of the military automotive supply «KrAZ»

Having performed the above-mentioned calculations the utility diagram (Fig. 3) and ranking diagram (Fig. 4) of the functions of the air pressure regulation system in the tires of the wheels of the motor vehicle «KrAZ» will be constructed relatively the utility coefficient.

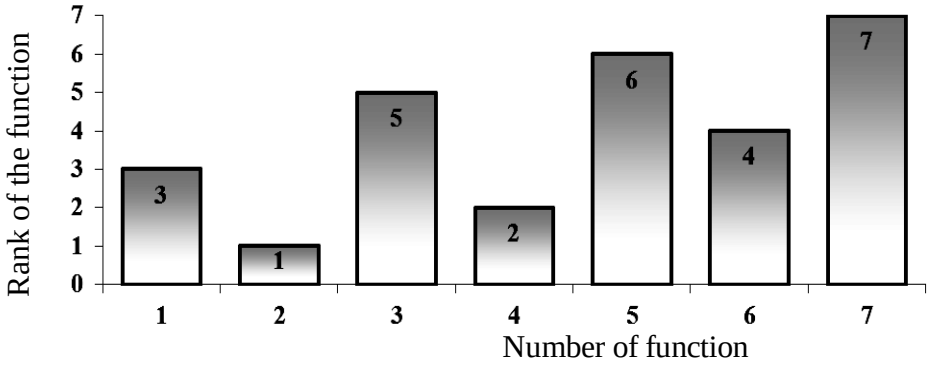


Fig. 4. Diagram of the functions ranking of the air pressure regulation system in the tyres of the wheels of military automotive supply «KrAZ» relatively utility coefficient

Costs in the process of functional-value analysis are the payment for utility. Generalized costs criterion in the process of the design takes into account costs at all the stages of the system life cycle, for their assessment costs matrix is constructed (Table 3), losses coefficient is determined from this table.

Table 3

Costs matrix of the air pressure regulation system functions in the tires of the military motor vehicle «KrAZ»

№ of function	Name of the function	Share of the function in the losses	Utility coefficient	Costs coefficient	Function rank
1	Improvement of the cross-country ability of the motor vehicle on hard sections of the road due to the decrease of the air pressure in the tires	0.19	0.15271	1.244	4
2	Filling of the damaged tires of the motor vehicle wheel with the air	0.23	0.21240	1.083	5
3	Air pressure control in the tires of motor vehicle	0.01	0.13101	0.076	7
4	Regulation of air pressure in the tires of the motor vehicle	0.02	0.16279	0.123	6
5	Disconnection of the system of the tires of the vehicle pumping from the pneumatic drive of the brake in case of pressure reduction in the receivers below 600 kPa	0.17	0.11938	1.424	2
6	Air supply for pumping the tires if the pressure in the receivers is above 600 kPa	0.19	0.13953	1.362	3
7	Disconnection of the tires of the motor vehicle from the system of pumping during long stops of the motor vehicles	0.19	0.08217	2.312	1
Sum		1	1	-	-

At this stage the method of the expert assessments is used, also significance level of each function and its costs are compared. For this purpose cost coefficient per function is used, it is calculated by comparing the share of the parameter (function) in the costs with its utility coefficient.

Losses coefficient 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 losses.

Share of the function in the costs 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 cost of each function; $\sum_{i=1}^{n} B_i$ – is the sum of the cost of all the functions of the system.

In theory and practice of the functional- value analysis the following criteria of the costs coefficient per function assessment are accepted [1, 3]:

– cost coefficient equals «1» or is close to one – the ratio between cost and function is justified;

– cost coefficient is less than «1» – the ratio is favorable;

– cost coefficient is more than «1» – measures should be taken, aimed at reduction of cost for function obtaining.

Specific procedure of functional -value analysis is the construction of functional- value diagrams, which are graphic representation of the ration between the utility of the functions and costs for their realization. Construction of the functional -value diagrams is performed to reveal discrepancy of the cost relatively function utility. Functional -value diagram is constructed for a group of functions, having common peak. In the first quadrant the utility or significance of the function is shown, in the second – costs for the function (Fig. 5).

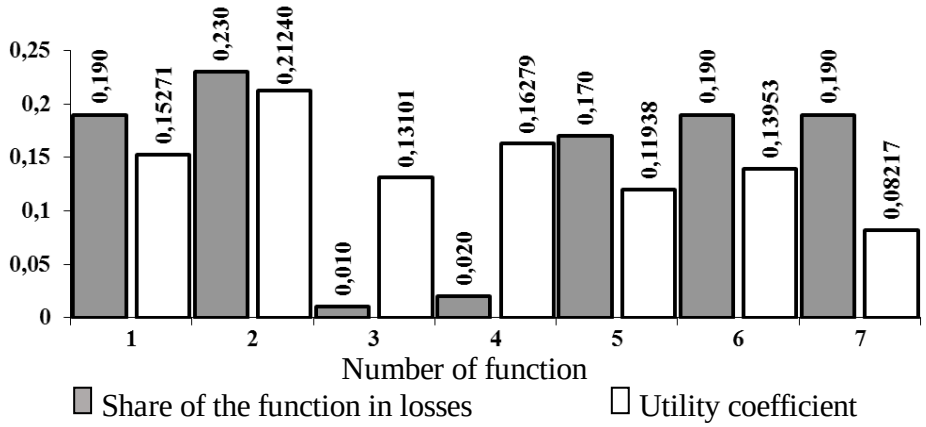


Fig. 5. Functional- value diagram of the air pressure regulation system in the tires of military motor vehicle «KrAZ»

Having carried out the above-mentioned computations we will construct the cost diagram (Fig. 6) and diagram of functions ranking (Fig. 7) of the system of air pressure regulation in the tires of the motor vehicles «KrAZ» relatively cost coefficient.

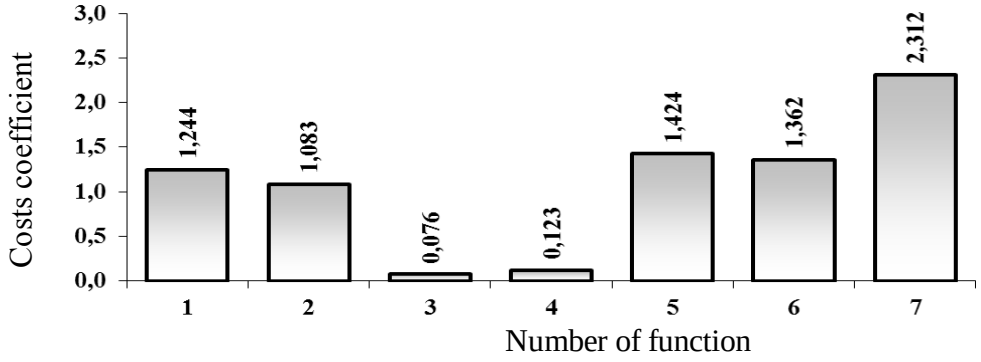


Fig. 6. Diagram of costs of the functions of air pressure regulation system in the tires of wheels of military motor vehicle «KrAZ»

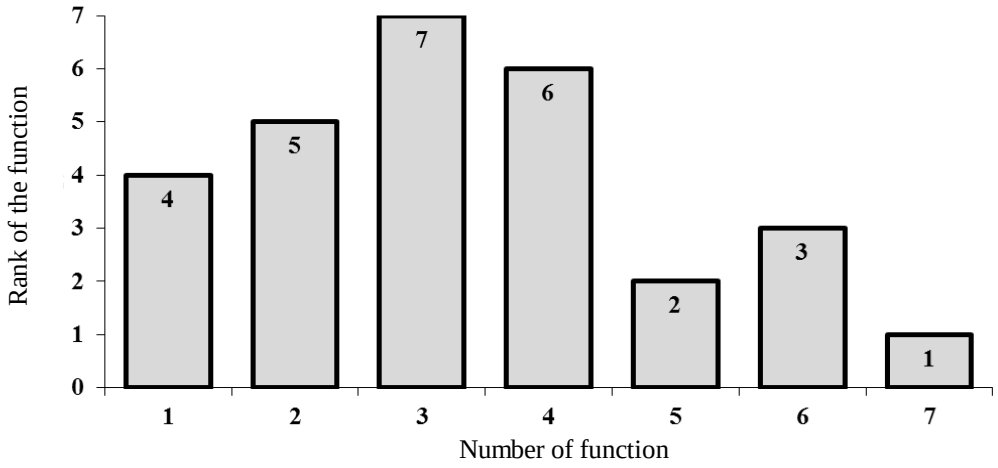


Fig. 7. Diagram of functions ranking of the air pressure regulation system in the tires of military motor vehicle «KrAZ»

The next stage of the functional - value analysis is the determination of functional cost index [2, 3, 15]:

$$П_{FCi} = \lambda_i - К_i. \quad (5)$$

Functional- cost index shows how the cost portion of the operation execution or function is greater than the useful function. Values of the indices of the functional-cost functions of the system of air pressure regulation in the tires of the motor vehicles «KrAZ» relatively cost coefficient is shown in Table 4.

Table 4

Value of the indices of functional cost of the functions of air pressure regulation system in the tires of the military motor vehicle «KrAZ»

№ of function	Name of the function	Functional cost index	Rank of the function
1	Improvement of the cross-country ability of the motor vehicle on hard sections of the road due to the decrease of the air pressure in the tires	-1.091	4
2	Filling of the damaged tires of the motor vehicle wheel with the air	-0.870	3
3	Air pressure control in the tires of motor vehicle	0.055	1
4	Regulation of air pressure in the tires of wheels of the motor vehicle	0.040	2
5	Disconnection of the system of the tires of the vehicle pumping from the pneumatic drive of the brake in case of pressure reduction in the receivers below 600 kPa	-1.305	6
6	Air supply for pumping the tires of wheels if the pressure in the receivers is above 600 kPa	-1.222	5
7	Disconnection of the tires of the motor vehicle from the system of pumping during long stops of the motor vehicles	-2.230	7

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

Having performed the above-mentioned calculations, we will construct the diagrams of functional cost index (Fig. 8) and raking (Fig. 9) values of the functions of the air pressure regulation system in the tires of the motor vehicles «KrAZ» relatively the index of functional cost.

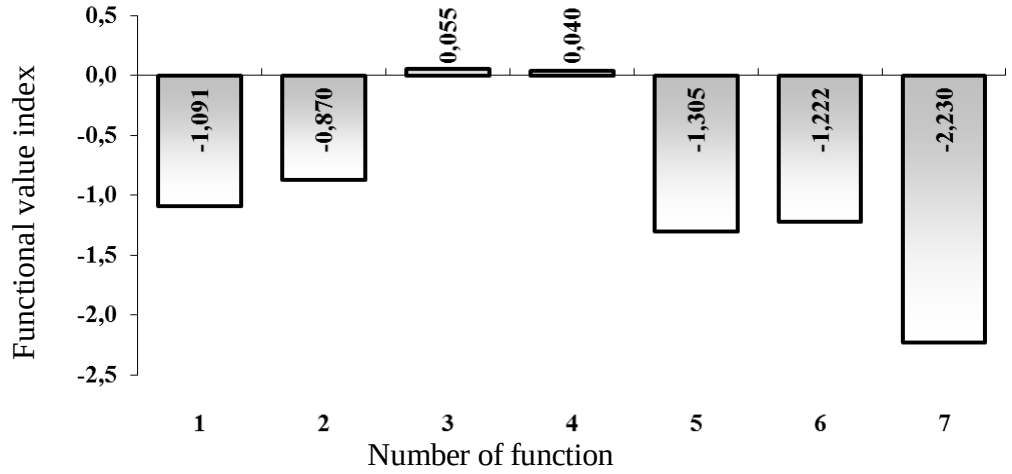


Fig. 8. Diagram of the functional cost index values of the air pressure system functions in the tires of military motor vehicle «KrAZ»

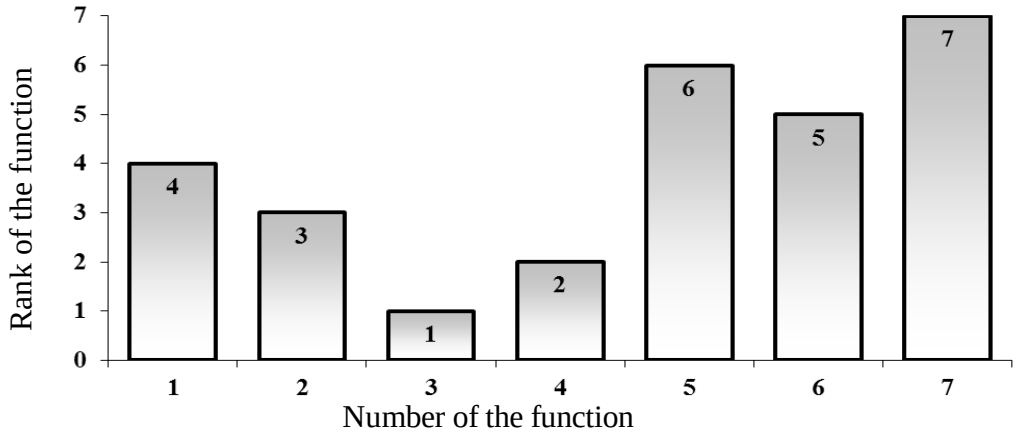


Fig. 9. Diagram of functions ranking of the air pressure regulation system in the tires of military motor vehicle «KrAZ» relatively the index of functional cost

Functions, having positive functional value index and the highest rating of the considered functions are determined by the diagrams (Fig. 8 and 9). Operations of functions, having the greatest functional-value index and rank are those operations, improvement of which will lead to further development of the system or achieving the objective of the analysis.

Conclusions

1. Functional value analysis, carried out, of the air pressure system in the tires of the military motor vehiclev «KrAZ» showed that the highest rank and greatest functional value index has function №2 «Filling in the leakage of the damaged tire of the motor vehicle » the basis of which is put the main task of the developed technical system.

2. By the results of the calculation of functional -value indices of the air pressure regulation system in the tires of military motor vehicle «KrAZ», the conclusion can be made, that the function №3 «Air pressure control in the tires of the motor vehicle» and №4 «Air pressure regulation in the tires of the motor vehicles » are those functions, improvement of which will lead to further development and improvement of the system.

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