D. V. Borysiuk, Cand. Sc. (Eng.)

MATHEMATICAL MODEL OF THE TURBOCHARGER ЯМЗ-650.1118011 DIAGNOSTICS

Concept of modern automobile transport development provides the increase of the engine power with the reduction of fuel consumption and emissions of the combustion products. To achieve the set goals the internal combustion engines are equipped with turbochargers, boost intercoolers, electric power storage systems of the fuel supply and electronic control elements.

Nowadays in greater part of cases faults of the boosting systems of the internal combustion engines are detected by the external features. It is also possible to improve the quality of the engines boosting systems diagnostics by means of developing new mathematical models of their functioning.

Modern methods and means of turbochargers diagnostics as the element of the boosting system of the engines of the motor vehicle transport have been analyzed. It was determined that the available methods and means of the turbochargers diagnostics do not allow in full scale to determine their current technical state that requires the development of the mathematical models of their units and elements as the object of the diagnostics.

Turbocharger ЯМЗ-650.1118011, which is the part of the boosting system of diesel engines ЯМЗ-650.10, ЯМЗ-6501.10 and ЯМЗ-6502.10 are selected as the object of the diagnostics.

Analysis of the characteristic features of ЯМЗ-650.1118011 construction as the object of diagnostics, was performed.

Replacement of real engineering devices with their idealized models enables to use various mathematical methods. Mathematical model is suggested in general form, this model represents the system of functional dependences between each diagnostic signal and structural parameters.

For turbocharger ЯМЗ-650.1118011 diagnostic matrix is composed, it comprises the list of failures and features of failures.

By means of the developed mathematical model it is possible to perform efficient diagnostics of the turbocharger ЯМЗ-650.1118011. In the process of mathematical model development it was taken into consideration that the inverse transform of the amount of the failure symptoms into the amount of the structural parameters (failures) of the object was single-valued.

Study of the suggested mathematical model of turbocharger ЯМЗ-650.1118011 diagnostics will enable to detect the failures of its units and parts depending on their features, this will increase the term of no-failure operation both of the turbocharger itself and the engine of the motor vehicle.

Key words: *mathematical model, diagnostics, internal combustion engine, turbocharger, diagnostics matrix, block-diagram, failure, failure symptom, Boolean function.*

Introduction

Considerable growth of the number of transport vehicles, increase of the brands and models, frequently of foreign production, complication of their construction and adaption of the requirements of the normative documentation, regarding the technical state of the transport vehicles to world standards needs the development of modern methods and tools for the diagnostics of their blocks and parts [1].

Trends of modern automobile building branch are directed on constant improvement of the automobile transport operation efficiency, in particular – improvement of the characteristics of the engine power and reduction of the fuel consumption and harmful substances emissions with the exhaust gases [2, 3]. One of the design solutions, enabling to improve considerably these parameters is the usage of the turbochargers.

Problem set up

Turbocharging system of motor-transport diesel engines in its classic realization consists of the engine, turbine and compressor. There is a mechanical coupling between the turbine and compressor, there exists gas coupling between the turbine and engine. Although the construction arrangement is rather simple and operation principle of turbocharger is not complex, determination of its technical state in the process of operation is not an easy task. Failures of any of its element which are progressively developing in the process of operation and are not visible, are revealed at certain operation modes and may cause failure of the turbocharger or engine on the whole.

Complexity of the turbocharger diagnostics is determined by numerous reasons. First, indices of the operation efficiency of turbocharger depend both on technical and mode characteristics of the engine and turbocharger itself. Secondly, nowadays, there are no reliable tools for the control of the technical state of the turbocharger in the process of operation. Determination of the most informational functional parameters of the turbocharger, determination of the limiting values, elaboration of the methods and means for their control is the primary target of the technical service of the internal combustion engines.

In spite of the fact that numerous scientific studies are devoted to the problems of turbochargers reliability and their operation conditions [4 – 10], complexity of the construction, low quality of manufacture and application of operational materials, incorrect operation causes premature failures, worsening technical-operational qualities of the engine – greatly decreases the power and increase fuel consumption and hazardous substances emission with the exhausted gases.

Statistics of failures of separate blocks and units of the automotive internal combustion engines shows that 45% of all failures are the failures of the fuel and air supply system [10]. Thus, the studies, aimed at improvement of the methods and means of air supply systems of automotive engines with turbine inflate diagnostics in the process of technical maintenance is urgent scientific-engineering problem.

Analysis of the recent studies and publications

Survey of theoretical and experimental studies in the sphere of operation and determination of the technical state of the auto-tractor engines [11 – 19] showed that nowadays certain scientific-methodical and technical fundamentals of the technical service of the air-supply systems for motor-transport engines are created. At the same time, available technologies and methods of diagnostics, control and assessment of the technical state of separate elements of modern turbocharge systems do not completely take into consideration the characteristic features of their operation.

In the study [20] mathematical model of the efficiency of diagnostic tools for turbochargers of motor-tractor engines in the process of technical service and repair is presented.

In the studies [21 – 26] the survey of the available methods and means of diagnostic of the turbochargers for motor-tractor engines is performed, the analysis of these methods revealed main drawbacks in the calculations and design of the diagnostic equipment.

Problem of the improvement of motor tractor motors diagnostic methods and means is considered in [27 – 31], the analysis carried out, showed that greater part of the methods of turbochargers diagnostic do not completely take into account the characteristic features, they are rather expensive, the equipment, used for diagnostics is complex.

In the process of the analysis of the latest studies and publications on the suggested subject, it was determined that any specific mathematical dependences for the determination of the technical state of charging system of the engine were not revealed.

Aim of the research

Reliability of the transport vehicle depends on the reliability of its units and parts, one of these units is turbocharger of the internal combustion engine.

Enhancement of the reliability and decrease of labor consumption of the diagnostics in the process of turbocharger engines service can be achieved by means of improvement of the diagnostic tools, which can digitize the data, obtained by means of direct measurement and their further processing, using mathematical tooling.

Aim of the research is the improvement of the reliability of the turbocharge of the internal combustion engine, as a result of studying its operation parameters on the base of the developed diagnostic mathematical model of its minor components, which takes into account both failures and signs of failures.

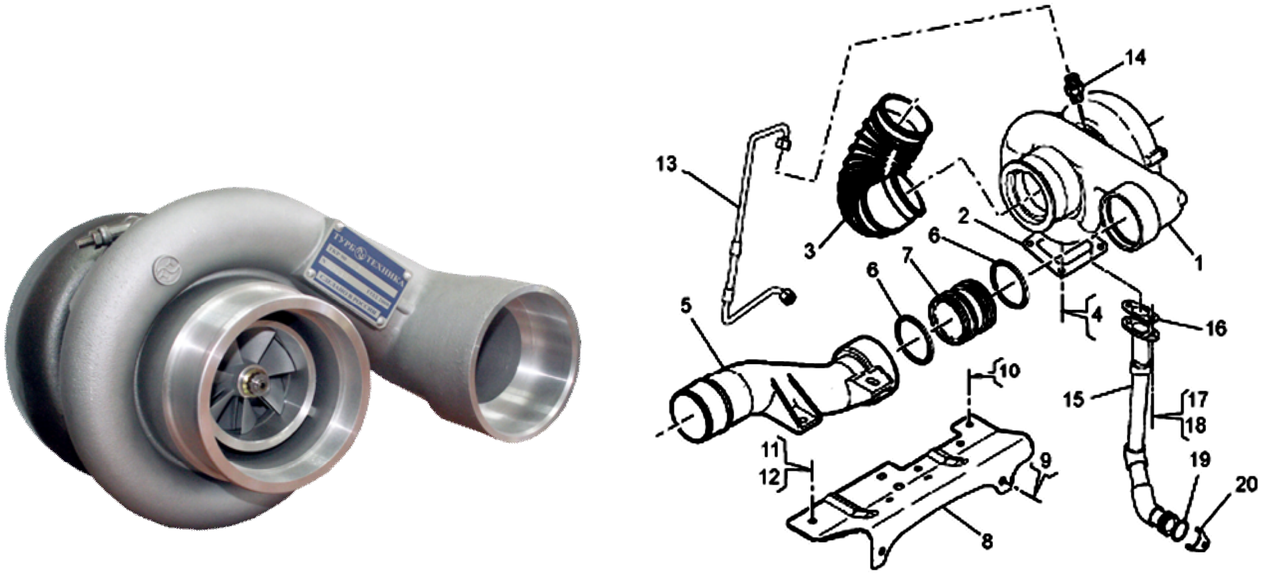
Analysis of the construction of turbocharger ЯМЗ-650.1118011

Turbocharger is the air pump, put into operation by the turbine, which rotates at the expense of the exhaust gases flow [14]. Rotation frequency of the turbocharge of the diesel engine is from 1000 to 130000 rpm.

The turbine is connected with the compressor by means of the rigid axle. Compressor draws in the air across the air filter, then the compresses the air and under pressure supplies it into the intake manifold of the engine. Great amount of air, supplied into the cylinder helps to turn greater amount of fuel, increasing the power of the engine.

In theory there exists the power balance between the turbine and compressor of the turbocharger. The greater is the energy of the exhaust gases, the more rapidly the turbine rotates.This means that the compressor also will rotate more rapidly.

To provide needed power indices, engines ЯМЗ-650.10, ЯМЗ-6501.10 and ЯМЗ-6502.10 are equipped with turbocharger ЯМЗ-650.1118011 (Fig. 1), it uses the energy of the exhaust gases for the engine pressure charging [32 – 34].



a B

Fig. 1. Turbocharger ЯМЗ-650.1118011 [34]:
a – general view; b – components;
1 – turbocompressor; 2 – gasket of the turbocompressor; 3 – inlet fitting ; 4, 9, 10, 11 – pin;
5 – air feeder for charge air cooler; 6, 19 – ring; 7 – connecting bushing; 8 – forward heat shield; 12 – screw; 13 – oil supply pipe for turbocompressor; 14 – connection; 15 –oil drain pipe from turbocompressor; 16 – gasket of oil drain pipe; 17 – external screw; 18 – washer;
20 – locking plate

Turbocharger ЯМЗ-650.1118011 contains radial axial turbine and centrifugal compressor, equipped with discharge valve.

Main material

Each turbocharge engine is characterized by a certain noise level. That is why, many failures can be detected when the normal noise changes. If the noise becomes sharper, the cause of the failure may be air leakage (between the turbocompressor and inlet manifold) or exhaust gases, also it may be the fault of the rotating axle. Intermittent noise can be explained by the pollution of the turbocompressor or operation at very low mode relatively the loading. Emergence of the vibrations may indicate the damage of the rotation axle. Sharp decrease of the noise level, accompanied by the emergence the black or dove smoke at the exhaust shows the total breakdown of the compressor. In all similar cases the engine must be stopped to avoid more serious damage of the engine or turbocompressor.

Due to the automation of the logic process of the diagnosis statement the above mentioned faults of turbocompressor can be avoided.

Solution of the problem of automation of the logic process of the diagnosis establishment requires the development of the models of turbocompressor elements as the objects of the diagnosis, describing on one mathematical level the connections between the infinite sets of possible faults and values of diagnostic parameters.

Replacement of the object of diagnosis by the model is connected with the allocation of basic, important for diagnosis establishment elements and properties, connected with the task of determining of the real technical state of the objects. Certain number of elements and connections of the object, very important from the point of view of its functioning as a device, designed for execution of certain work, become second rate and in the process of development the model of technical device, as the object of diagnostics, may be excluded.

Replacement of the real technical devices by their idealized models enables to use various mathematical models. Under mathematical model of the object of diagnostics, numerous analytical, logic, statistical graphic and any qualitative relation, connecting output parameters of the object with its input and internal parameters are meant.

Most universal model of the object of diagnostics is its representation in the form of the «black box», input and output parameters of which have finite set of values. It is supposed that all possible states of the object form finite set of states. In this case the object is a «black box» not because its internal structure and parameters are not completely known, but because the ban is imposed on the access to the structure and parameters, and the state of the object can be determined only studying its output parameters (without dismantling) [35 – 38].

For the presentation of the object of diagnostics in the form of the «black box» it is necessary to set (Fig. 2):

– number of all input actions Y from stimulating devices and external environment;

– quantity of all output features of failures S;

– quantity of all failures o of diagnostics X;

– operator A, which converts quantities X and Y into quantity S:

$$S = A\{Y, X\}. \tag{1}$$

Taking into account the fact, that in the process of diagnostics, elements of the quantity Y are stabilized (or change according to the set law), the expression (1) is converted into the form:

$$S = A\{X\}. \tag{2}$$

In other words, any output parameter of the object of diagnostics is the function of its technical state at this state of inputs.

If the failure of the object of diagnostic $\{X_i\}$ is referred to the output parameters of the automated system, then the diagnostic problem is formed in the following way: by the known features of the fault $\{S_j\}$ determine the unknown failures of the object of diagnostics $\{X_i\}$.

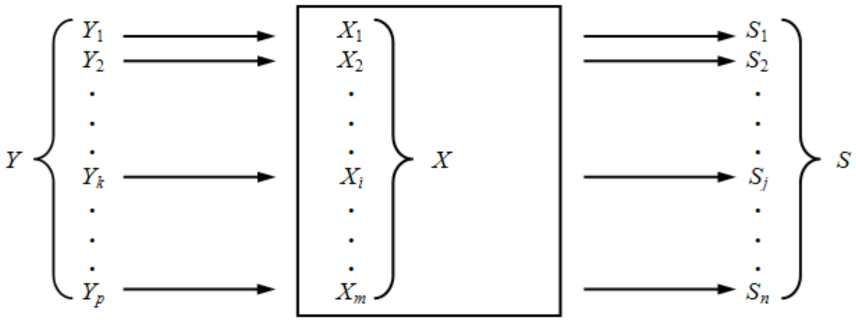


Fig. 2. Presentation of the object in the form of the «black box»

For the solution of this problem it is necessary to know the type of operator A, in other words, it is necessary to have the complete description of the connections between all output parameters and all possible states (failures) of the object.

A number of models of the diagnostic objects, which differ one from another by different forms of the description of those connections is described belowв.

If analytical model of the object of diagnostic is available, the problem the diagnosis establishment in general form is formulated in the following way. By the given features of the fault S_1, S_2, ..., S_n, obtained as a result of the corresponding measurement, determine the technical state (fault) of the object of diagnostics X_1, X_2, ..., X_m, if functional dependences between each diagnostic signal and structural parameter are known:

$$\begin{cases} S_1 = \varphi_1(x_1, x_2, ..., x_m); \\ S_2 = \varphi_2(x_1, x_2, ..., x_m); \\ .... \\ S_j = \varphi_j(x_1, x_2, ..., x_m); \\ .... \\ S_n = \varphi_n(x_1, x_2, ..., x_m). \end{cases} \tag{3}$$

System of equations is mathematical model of the object of diagnostics, that has m structural parameters and n diagnostic signals (3).

Obvious advantage of the diagnosis establishment, applying analytical model is the possibility of obtaining specific fault of the object of diagnostics, that enables to determine the technical state of the object not only at the moment of diagnostics but, accumulating information, obtained during several diagnostic examinations of the object, analyze the change of the structural parameters in order to forecast its technical state.

However, practical application of such analytical model is limited due to the following reasons:

– type of φ_j functions for greater part of nodes and mechanisms has not been determined yet;

– if function φ_j does not meet the requirements of the continuousness and differentiation by each of its arguments, that usually occurs in real models, then the solution of the system of equations (3) is connected with great mathematical difficulties;

– greater part of diagnostic parameters cannot be expressed in the form of the analytical functions of structural parameters.

In a number of papers, devoted to the problems of technical diagnostics of the machines and mechanisms, possible technical states (faults) of the units and systems, features of these faults are described in the form of the so-called diagnostic matrices [39 – 45].

From the experience of many years service of the engines ЯМЗ-650.10, ЯМЗ-6501.10 and ЯМЗ-6502.10 matrix of turbocompressor ЯМЗ-650.1118011diagnostics, these engines are equipped with, is presented in Table 1 [32, 33].

Table 1

Matrix of turbocompressor ЯМЗ-650.1118011 diagnostics

Fault of turbocompressor ЯМЗ-650.1118011	Feature of turbocompressor ЯМЗ-650.1118011 fault							
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
x_1	+	+	-	+	+	+	+	-
x_2	+	-	-	-	-	-	-	-
x_3	+	+	+	+	+	+	+	-
x_4	-	+	-	+	-	-	-	-
x_5	+	-	-	+	-	-	-	-
x_6	+	+	-	-	-	-	-	-
x_7	+	+	-	+	-	-	-	-
x_8	+	+	+	+	+	-	+	+
x_9	+	+	+	+	+	-	+	-
x_{10}	+	+	+	+	-	-	-	-
x_{11}	-	-	+	-	+	-	+	+
x_{12}	-	-	+	-	-	-	-	-
x_{13}	-	-	+	-	+	+	-	-
x_{14}	-	-	-	+	+	+	+	-
x_{15}	-	+	-	-	-	-	-	-
x_{16}	-	-	-	+	+	-	-	-
x_{17}	-	-	-	-	+	-	+	+

In diagnostics matrix the following faults of turbocompressor ЯМЗ-650.1118011 will be indicated:

x_1 – clogging of the air filter;
x_2 – faulty charge air cooler (plugged pipes);
x_3 – plugged or pinched air intake manifolds (between the air filter and turbocompressor);
x_4 – plugged or pinched intake manifolds of air charge (between the turbocompressor and engine);
x_5 – intrusion of foreign objects between the air filter and turbocompressor;
x_6 – plugging in gas exhaust system;
x_7 – air leakage or exhaust fumes leakage between the turbocompressor and engine;
x_8 – damaged or plugged turbine nozzle box;
x_9 – damaged impeller blades of turbocompressor;
x_{10} – incorrect operation of the pressure regulation system of turbocompressor;
x_{11} – plugging of the engine breather;
x_{12} – oil consumption;
x_{13} – faulty pneumocompressor;
x_{14} – insufficient leakroofness of the connection between air filter and turbocompressor;
x_{15} –plugged or pinched exhaust system;
x_{16} – insufficient lubrication of turbocompressor;
x_{17} – plugged or pinched oil out line.

Features of the above-mentioned faults of turbocompressor ЯМЗ-650.1118011 are also input in the diagnostic matrix:

S_1 – decrease of the engine power;
S_2 – exhaust fumes are of black color;
S_3 – exhaust fumes are of grey color;
S_4 – noise in turbocompressor;
S_5 – excessive oil comsumption;
S_6 – oil presence in air intake pipes of turbocompressor;
S_7 – oil presence in air pipes after turbocompressor;

S_8 – oil presence of exhaust manifolds after turbocompressor.

As it is seen from the Table 1, each fault is characterized by a certain combination of its features values, which may take two conventional values: «-» or «+».

At the intersection of the i^{th} row and j^{th} column «+» is put, if in case of the i^{th} fault the domain error is observed, otherwise «-» is put.

For the synthesis of such matrix it is necessary to replace the infinite number of technical states of the object by the finite set of technical states, each of them is connected with certain fault (or their combination) or with the serviceable state (Fig. 3).

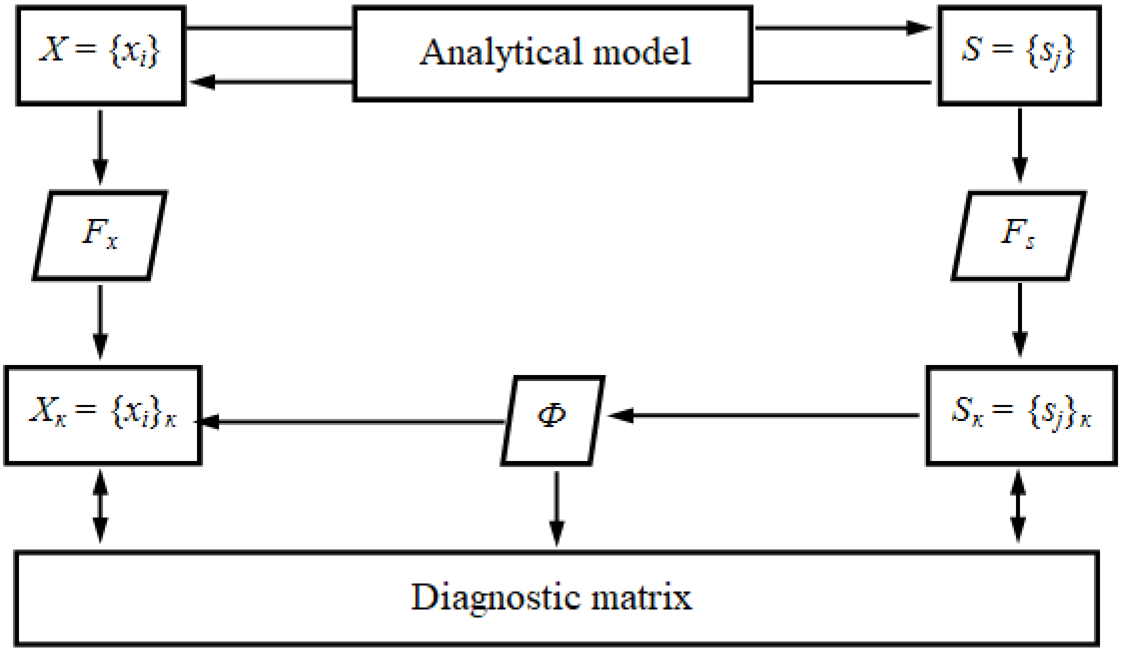


Fig. 3. Block diagram of the synthesis of the diagnostic matrix of turbocompressor ЯМЗ-650.1118011:
$X = \{x_i\}$ – is infinite number of technical states of the object;
$X_\text{к} = \{x_i\}_\text{к}$ – is finite number of technical states;
$S = \{s_j\}$ – is infinite set of the features of the technical states of the object;
$S_\text{к} = \{s_j\}_\text{к}$ – is finite set of the features of the technical states of the object;
F_x – is operator, converting quantity $\{x_i\}$ into quantity $\{x_i\}_\text{к}$;
F_s – is operator, converting quantity $\{s_j\}$ into quantity $\{s_j\}_\text{к}$;
Φ – is operator, converting the quantity of the technical states of the object into the quantity of the diagnostic parameters

Such transformation can be written in the form:

$$\{x_i\}_\text{к} = F_x\{x_i\}, \tag{4}$$

where $\{x_i\}$ – is the set of the features of technical states of the object of diagnostic, each of them may take in general case infinite amount of values; $\{x_i\}_\text{к}$ – is finite set of features of technical states of the object of diagnostics each of them may take only two conventional values «-» and «+», which correspond to the absence and presence of the i^{th} fault; $i = 1, 2, ..., m$; F_x – is operator which converts the quantity $\{x_i\}$ into quantity $\{x_i\}_\text{к}$ in the following way: for any i^{th} parameter x_i the value «-» is assigned if the value is in the domain of the admissible values, otherwise the value «+» is assigned.

Transformation of the infinite amount of parameters values of the output processes into the finite amount of diagnostic parameters values can be written in the form:

$$\{s_j\}_\kappa = F_s\{s_j\}, \tag{5}$$

where $\{s_j\}$ – is the amount of features of the output processes, each of them may take in general infinite quantity of values in certain interval; $\{s_j\}_\kappa$ – is finite amount of diagnostic features, each of them may take only two conventional values: «-» or «+»; $j = 1, 2 \ldots, n$; F_s – is operator converting quantity $\{s_j\}$ into quantity $\{s_j\}_\kappa$ in the following way: any j^{th} feature s_j is assigned conventional value «-», if the value is in the values domain, which correspond to operation conditions of the object under test, otherwise value «+» is assigned.

As a result of the transformations, carried out, two finite values $\{x_i\}_\kappa$ and $\{s_j\}_\kappa$, are obtained, their elements are connected in a definite way with one another.

In general form this connection can be expressed as:

$$\{s_j\}_\kappa = \Phi\{x_i\}_\kappa, \tag{6}$$

where Φ – is operator, converting the amount of the technical states of the object into the amount of diagnostic parameters.

Transformation (6) reflects the functioning of any engineering object as the transformer of the quantity of the structural parameters into the quantity of the diagnostic parameters and is the modification of the model (1).

Transformation (6) can be expanded by means of the system (3).

System of the equation (3) connects each feature of the fault S_j with all structural parameters of the object under the test that reflects the connections between structural parameters and diagnostics signals.

Diagnostic matrix as the model of the objects under the test, shows that it is a tabular form of the equations system recording (1).

Parameter S_1 in the diagnostic matrix can be considered as double-valued Boolean function which depends on the argument x_1. Boolean function depends on the argument x_1, if the relation takes place:

$$\varphi(x_1,\ x_2,\ \ldots,\ x_{i-1},\ 0,\ x_{i+1},\ \ldots,\ x_m) \neq \varphi(x_1,\ x_2,\ \ldots,\ x_{i-1},\ 1,\ x_{i+1},\ \ldots,\ x_m).$$

As it follows from this definition and Table 1, S_1 essentially depends only on $x_1, x_2, x_3, x_5, x_6, x_7, x_8, x_9$ and x_{10}.

Dependence $S_1 = \varphi_1\ (x_1, x_2, x_3, x_5, x_6, x_7, x_8, x_9, x_{10})$ is expressed in this case in the form of the logical addition function (disjunction):

$$S_1 = x_1 + x_2 + x_3 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10}.$$

Corresponding analysis of other features of faults enables to write down the system of equations (3) for this matrix of turbocompressor ЯМЗ-650.1118011 diagnostics in the following form:

$$\begin{cases} S_1 = x_1 + x_2 + x_3 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10}; \\ S_2 = x_1 + x_3 + x_4 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{15}; \\ S_3 = x_3 + x_8 + x_9 + x_{10} + x_{11} + x_{12} + x_{13}; \\ S_4 = x_1 + x_3 + x_4 + x_5 + x_7 + x_8 + x_9 + x_{10} + x_{14} + x_{16}; \\ S_5 = x_1 + x_3 + x_8 + x_9 + x_{11} + x_{13} + x_{14} + x_{16} + x_{17}; \\ S_6 = x_1 + x_3 + x_{13} + x_{14}; \\ S_7 = x_1 + x_3 + x_8 + x_9 + x_{11} + x_{14} + x_{17}; \\ S_8 = x_8 + x_{11} + x_{17}. \end{cases} \tag{7}$$

All the sequential transformations, leading to the synthesis of the model of the object under the test in the form of the diagnostic matrix, are presented in block-diagram (Fig. 3). In the case when the model of the object under the test is presented in the form of the diagnostic matrix, diagnostic problem is formulated in the following way.

By the features of faults $S_1, S_2, \ldots, S_n$ obtained as a result of diagnostic examination, it is necessary to determine the faults $x_1, x_2, \ldots, x_m$ at the moment of examination, if functional dependence between the diagnostic parameters and all the structural parameters, set in the form of the diagnostic matrix or system of equations of the type (7), are known. Each structural parameter and each diagnostic parameter takes only two values: «-» or «+».

It is obvious that for the solution of the diagnostic problem the reverse transformation of the quantity of diagnostic parameters into the quantity of structural parameters is needed, because while making the diagnosis the values of diagnostic parameters are known.

In general form the reverse transformation can be presented by the expression

$$\{x_i\}_к = \Phi^{-1}\{s_j\}_к,$$

or in the expanded form

$$\begin{cases} x_1 = f_1(S_1,\ S_2,\ \ldots,\ S_n); \\ x_2 = f_2(S_1,\ S_2,\ \ldots,\ S_n); \\ x_m = f_m(S_1,\ S_2,\ \ldots,\ S_n). \end{cases} \tag{8}$$

Type of f_m functions can be easily established in each case on the base of the following considerations.

In the diagnostic matrix one of the columns, for instance the first one, will be considered. It is seen from the matrix, that the available fault x_1 causes the simultaneous exit of the features S_1, S_2, S_4, S_5, S_6 and S_7 from their values domain. Values of other diagnostic parameters if only fault x_1 is available remain within the limits of the norm. Thus, x_1 is Boolean function, in this case the conjunction (or function of logical multiplication):

$$x_1 = S_1 \cdot S_2 \cdot S_4 \cdot S_5 \cdot S_6 \cdot S_7.$$

Corresponding analysis of all other columns of the considered matrix enables to write down the inverse transform (3) in the form of the system of Boolean functions (conjunctions):

$$\begin{cases} x_1 = S_1 \cdot S_2 \cdot S_4 \cdot S_5 \cdot S_6 \cdot S_7; \\ x_2 = S_1; \\ x_3 = S_1 \cdot S_2 \cdot S_3 \cdot S_4 \cdot S_5 \cdot S_6 \cdot S_7; \\ x_4 = S_2 \cdot S_4; \\ x_5 = S_1 \cdot S_4; \\ x_6 = S_1 \cdot S_2; \\ x_7 = S_1 \cdot S_2 \cdot S_3; \\ x_8 = S_1 \cdot S_2 \cdot S_3 \cdot S_4 \cdot S_5 \cdot S_7 \cdot S_8; \\ x_9 = S_1 \cdot S_2 \cdot S_3 \cdot S_4 \cdot S_5 \cdot S_7; \\ x_{10} = S_1 \cdot S_2 \cdot S_3 \cdot S_4 \cdot; \\ x_{11} = S_3 \cdot S_5 \cdot S_7 \cdot S_8; \\ x_{12} = S_3; \\ x_{13} = S_3 \cdot S_5 \cdot S_6; \\ x_{14} = S_4 \cdot S_5 \cdot S_6 \cdot S_7; \\ x_{15} = S_2; \\ x_{16} = S_4 \cdot S_5; \\ x_{17} = S_5 \cdot S_7 \cdot S_8. \end{cases} \tag{9}$$

As it is seen from this example, the process of making the diagnosis on the base of the model of the object under the test, expressed by the diagnostic matrix, consists of the following stages:

– by means of the corresponding measurements and transformations (5) features of all faults S_1, S_2, …, S_n are defined;

– values of diagnostic parameters are substituted in the system of Boolean functions (8);

– values of all Boolean functions of the faults x_i ($i = 1, 2, \ldots, m$) are calculated, if $x_i = 1$, then i^{th} fault is in the object.

Proceeding from the fact that the object under the test is serviceable only in case when all the faults are missing, the function of its serviceability takes the form:

$$F_P = \overline{x_1 + x_2 + x_3 + \ldots + x_{17}}. \qquad (10)$$

Turning to the block-diagram of the diagnostic matrix synthesis (Fig. 3) the condition of diagnosis establishing can be formulated in general form: for establishing the diagnosis it is sufficient that the inverse transformation of the quantity of faults features into the quantity of the structural parameters (faults) of the object was single-valued.

If in the process of synthesis of diagnostic matrix this condition is not realized and in the system (8) there are two or more equal functions, then the list of diagnostic parameters should be completed with new parameter, which would enter as the additional argument only in one of the considered equal functions.

Conclusions

1. Analyzing the recent studies and publications on the considered subject, it was established that there are no specific mathematical dependences for the determination of the state of the engine turbocharge system.
2. Analysis of the characteristic features of the construction of turbocompressor ЯМЗ-650.1118011, as the object under the test is presented.
3. Turbocompressor ЯМЗ-650.1118011, as the object under the test, is presented in the form of the «black box», its input and output parameters have finite set of values.
4. For turbocompressor ЯМЗ-650.1118011 diagnostic matrix is composed, the matrix includes the list of faults and features of faults. Diagnostic matrix, as the model of the object under the test, shows that it is a tabular form of the recording of the mathematical model of the object under the test.
5. By means of the developed mathematical model it is possible to carry out efficient diagnostics of turbocompressor ЯМЗ-650.1118011. In the process of the mathematical model development it is taken into consideration that the inverse transformation of the quantity of the faults features into the quantity of the structural parameters (faults) of the object was single-valued.
6. Studies of the suggested mathematical model of turbocompressor ЯМЗ-650.1118011 diagnostics will enable to reveal faults of its units and parts, depending on their features, this will considerably increase the term of the fault-free operation both of turbocomprerssor and engines ЯМЗ-650.10, ЯМЗ-6501.10 and ЯМЗ-6502.10.

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Borysiuk Dmytro – Cand. Sc. (Eng.), Assistant with the Department of Motor Vehicles and Transport Management.

Vinnytsia National Technical University.