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MATHEMATICAL MODEL OF THE PROCESS OF MOTOR VEHICLE "KRAZ" STEERING SYSTEM DIAGNOSTICS

Modern motor vehicles can be considered as a dynamic system with a great number of parts, units, assembles. One of the assembles, responsible for the motor vehicle safe motion is steering system. Available methods and means for steering system diagnostics are characterized by low efficiency. For various reasons both declarative and available (supported by the equipment) methods, as a rule, are of low accuracy and are not able to localize the fault. Nowadays, in greater part of cases steering system faults are detected by the external features. It is possible to improve the quality of the steering system diagnostics, also by means of developing new mathematical models of this system operation.

Available methods and means of the steering system diagnostics, as the component of the motor vehicle transport have been analysed. It has been established that the available methods and means of steering system diagnostics do not allow to determine completely its current technical state, thus it is expedient to develop mathematical models of the system units and parts as the object of diagnostics.

Steering system of the motor vehicle "KrAZ" has been taken as the object of diagnostics. Analysis of the peculiarities of the steering system construction of the motor vehicle "KrAZ" as the object of diagnostics has been presented. Replacement of the real technical parts by their idealized models enables to apply various mathematical methods. Mathematical model, which represents the system of functional dependencies between each diagnostic signal and structural parameters has been suggested in general form. Diagnostic matrix is composed for the steering system of the motor vehicle "KrAZ", it comprises the list of faults and faults features. By means of the developed mathematical model efficient diagnostic procedure of the steering system of the motor vehicle "KrAZ" can be performed. In the process of the mathematical model development it is taken into account that the inverse transformation of the number of faults features into the number of the structural parameters (faults) of the object will be single-valued.

Study of the suggested mathematical model of steering system diagnostics of "KrAZ" motor vehicles will enable to detect the faults of its units and parts depending on their features, that will considerably increase the term of the fault-free operation of both steering system and transport vehicle.

Key words: *mathematical model, diagnostics, motor vehicle, steering system, diagnostics matrix, flow-chart, fault, fault feature, Boolean function.*

Introduction

Steering system of the motor vehicle provides a change of the motion direction according to the impact of the driver, and maintains the set direction of the motion in spite of the available external disturbances (road bank, lateral wind, irregularity of the tangential reactions in the road-wheel contact, etc.). For the assessment of these functions realization two operation characteristics are used – handling and stability. The requirement regarding the steering system of the motor vehicle include maneuverability, ease of steering [1]. Realization of all these demands in operation conditions is carried out as a result of the construction accomplishment and needed quality of the technical state, this is provided by the maintenance service of the enterprise. Important role in provision of the steering system reliability, among other technological operations, plays diagnostics.

Problem set up

Complexity of the steering system diagnostics is determined by numerous reasons. First, indices of steering system operation efficiency depend on technical and mode characteristics. Second, for today the reliable tools for the control of steering system technical state in the process of operation actually are missing. Steering play often shows the faults presence.

Statistics of units and parts failures of the motor vehicle «KrAZ» shows that 30 % of all the failures are steering system failures [2]. Thus, studies, aimed at the improvement of the methods and means of steering system diagnostics of the motor vehicle «KrAZ» is the relevant scientific-technical problem.

Analysis of the recent studies and publications

The survey of the theoretical and experimental studied in the field of operation and determination of the technical state of the motor vehicles steering system [3 – 9] showed that at present certain scientific-methodical and technical fundamentals of the technical service of the motor vehicles steering system are formed. At the same time, available technologies and methods of diagnostics, control and assessment of the technical state of separate elements of steering system do not take in consideration in full measure the characteristic features of their functioning.

Problem of the improvement of means and methods, aimed at the determination of the technical state of the motor vehicles steering system is considered in the papers [10 – 13]. In the process of their analysis it has been established that greater part of the methods of steering system diagnostics does not in full measure take into account the characteristic features of their functioning, are expensive and usage of the needed equipment is rather complicated.

In the process of the analysis of the recent studies and publications it has been established that specific mathematic dependences of the technical state of the motor vehicles steering system have not been revealed.

Objective of the study

Reliability of «KrAZ» motor vehicles depends on the reliability of their units and parts, one of these units is steering system.

Improvement of the validity and decrease of the labor intensity of the diagnostics in the process of technical service of the steering system can be achieved by improving the diagnostic facilities, which are able to digitize the data, obtained by direct measuring and their further processing, using mathematical tools.

Objective of the research is prolongation of the steering system operation term of the motor vehicle «KrAZ», studying its operation parameters on the base of the developed mathematical model of its units and parts diagnostics, the model takes into consideration both faults and faults signs.

Analysis of the construction of the motor vehicle «KrAZ» steering system

Steering system is intended for changing the direction of the motor vehicle motion by means of turning the front steer wheels, system consists of the steering mechanism and steer drive. In the steering systems of the motor vehicles the power steer is used to facilities the driving of the vehicle, it reduces pushes on the steering wheel, and enhances the safety of traffic.

Steering system of «KrAZ» motor vehicle (Fig. 1) consists of the steering mechanism with the built-in distributor, steering shaft with column and steering wheel coupling shaft, steering drag rods – longitudinal and steering linkage, hydraulic cylinder, oil pump, reservoir, pipes and hoses [11]. Oil pump is located on the engine, and steering linkage rod is located on the front axle.

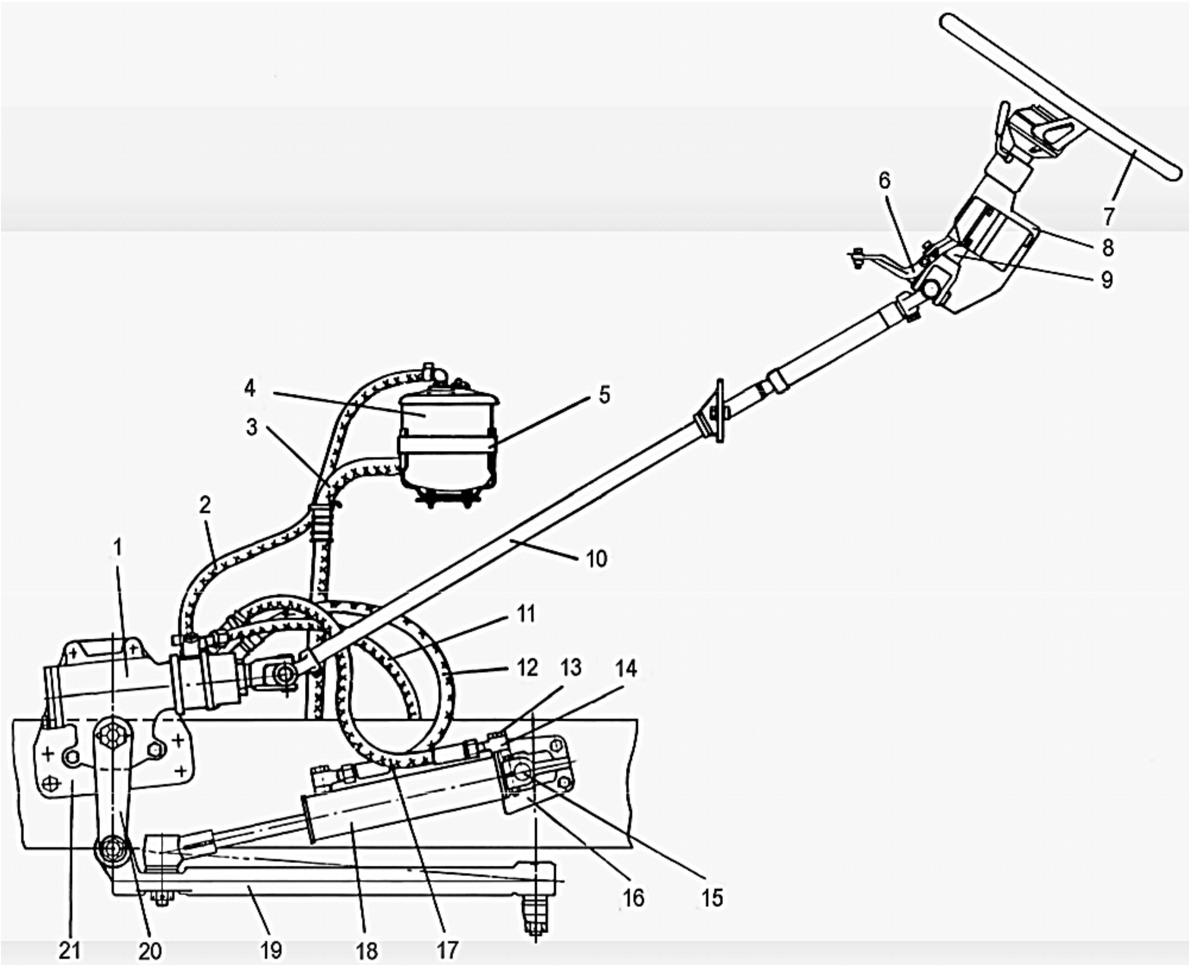

Fig. 1. Steering system of the motor vehicle «KrAZ»:
1 – steering mechanism with the distribution device; 2 – drain hose; 3 – pump oil supply hose; 4 – oil reservoir; 5 – oil reservoir bracket; 6 – steering column bracket; 7 – steering wheel; 8 – turn indicators switch unit; 9 – steering shaft with column; 10 – coupling shaft of the steering system; 11 – oil supply hose from the pump; 12, 17 – power cylinders hoses; 13 – drive bolt; 14 – rod end; 15 – pin; 16 – power cylinder bracket; 18 – power cylinder; 19 – longitudinal steering drag rod; 20 – arm; 21 – steering system bracket

Steering system of the motor vehicle «KrAZ» consists of the screw and ball nut-rack bar that is in coupling with the notched segment.

Pump of the hydraulic booster of the blade type (during one rotation of the pump shaft two complete cycles of the intake and injection occur). The pump of the hydraulic booster is fixed to the cover of the cam shafts on the left side of the engine and oil reservoir is fixed on the left wind. Pump and reservoir are connected by means of the hose.

Steering system drive of the motor vehicles «KrAZ» consists of the longitudinal and transversal steering drag rods with ball joints.

Longitudinal steering drag rod is tubular with two ball joints, it connects power cylinder with the upper lever of the steering knuckle of the front left wheel.

Transversal steering drag rod is a link rod, at its end the rod end are located, where the ball pins are fixed. Transversal drag rod of the steering linkage connects lower levers of the steering knuckles of the front wheels. By means of the rod ends the length of the steering drag rod can be changed and wheels toe can be regulated.

Main material

Steering system is complex and well-balanced assembly of the interconnected units and parts. If something in the steering system got out of order or operates incorrectly it is difficult to drive the motor vehicle and the risk of the road accident increases.

Steering system is an integral unit, it is prohibited to violate the completeness of its parts.

Noise, change of feeling in the process of steering wheel manipulation and knocks are main features of the faults in the steering system. The general rule for such cases is to inspect the motor vehicle by the specialist as the steering system and its components, due to their complexity, as a rule, are to be replaced but not changed.

All basic faults of the steering system must be eliminated in the shortest possible time. Otherwise, the driver exposes to danger both himself and his passengers.

In the construction of the steering system of the motor vehicles «KrAZ» the rail -and-pinion steering gear is used, this enables to reduce considerably the number of faults. However, there remains a number of faults, which are divided into:

– faults of directly steering system;

– faults of the steering system booster.

As a result of the automation of the logic process of diagnostics the above-mentioned faults of the steering system can be prevented.

Solution of the problem of the automation of the diagnostics logic process requires the development of the models of steering system elements as the objects of diagnostics, describing at the same mathematical level equal interconnections between numerous possible faults and numerous values of diagnostic parameters.

The replacement of the object of diagnostic by the model is connected with the task of determination of real technical state of the object. Certain number of elements and links of the object, important from the point of view of its operation as the device, intended for the realization of certain work, became of minor importance and can be excluded while the development of the model of technical device as the object of diagnostics.

Replacement of the real technical devices by their ideal models enables to use various mathematical models. Under the mathematical model of the object of diagnostics numerous analytical, logic statistical, graphic and in general any qualitative relations which link the output parameters of the object with its input and internal parameters are understood.

The most universal model of the object of diagnostics is its presentation in the form of the «black box», input and output parameters of which have finite set of values. It is provided, that all the possible states of the object form finite set of states. In this case, the object is the «black box» not because it internal structure and parameters are completely unknown, but because the prohibition is imposed for the access to them and the state of the object can be determined, studying its output parameters (without decomposition) [3].

To present 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 the stimulating devices and external environment;

– number of all output features of faults S;

– number of all fault of the object of diagnostics X;

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

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

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

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

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 diagnostics $\{X_i\}$ is referred to the output parameters of the automated system, then the diagnostic task is formulated in the following way: determine the unknown failures of the object of diagnostic $\{X_i\}$ by the known sings of the failure $\{S_j\}$.

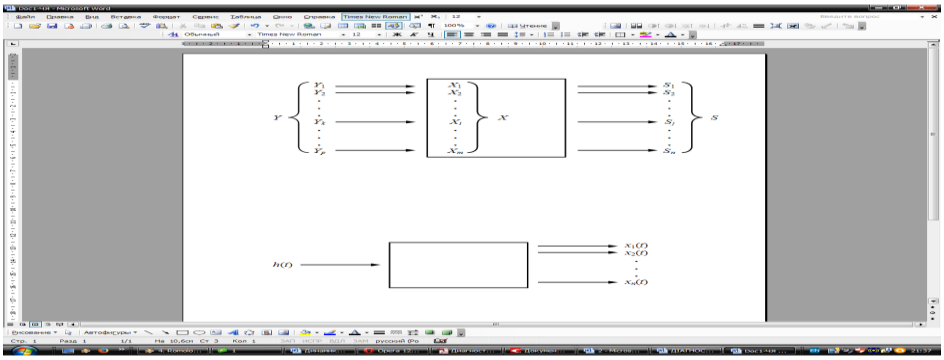

Fig. 2. Presentation of the object of diagnostic in the form of the «black box»

For the successful solution of this task it is necessary to known the type of operator A, in other words, the complete description of the links between all the output parameters and all possible states (failures) of the object is required.

A number of the models of the objects of diagnostic, differing one from another by different forms of the above-mentioned links description is shown below.

If analytical model of the object of diagnostic is available the task of diagnostics in general form is formulated in the following way. Determine the technical state (failures) of the object of diagnostic X_1, X_2, ..., X_m by the given signs of the failure S_1, S_2, ..., S_n, obtained as a result of the corresponding measurements, if functional dependences between each diagnostic signal and structural parameters are known :

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

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

Obvious advantage of diagnosing, using analytical model is the possibility of obtaining specific fault of the diagnostic object, this allows to determine the technical state of the object not only at the moment of diagnosing but accumulating the information, obtained in the course of several diagnostic inspections of the object, analyze the change of the structural parameters in order to predict its technical state.

However, practical usage of such analytical model is limited due to the following circumstances:

– type of functions φ_j for greater part of units and mechanisms has not been established yet;

– if function φ_j does not meet the requirements of continuity and differentiation conditions by each of its arguments, which is typical in real models, then the solution of the equations system (3) is connected with serious mathematical difficulties;

– greater part of diagnostic parameters in principle can not be expressed in the form of the analytical functions of the structural parameters.

In some articles, devoted to the problem of machines and mechanisms diagnostics, possible technical states (faults) of the units and systems and the signs of these faults are described in the form of the so-called diagnostic matrices [9, 14 – 23].

From the long-term experience of the motor vehicles «KrAZ» operation Table 1 contains the matrix of diagnostics of the steering system, these motor vehicles are equipped with [11].

Table 1

Diagnostic matrix of the motor vehicles «KrAZ» steering system

Steering system fault	Sign of the steering system fault									
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}
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}	-	-	-	+	-	-	-	-	-	-
x_{18}	-	-	-	+	-	-	-	-	-	-
x_{19}	-	-	-	-	+	-	-	-	-	-
x_{20}	-	-	-	-	+	+	-	-	-	-
x_{21}	-	-	-	-	-	+	-	-	-	-
x_{22}	-	-	-	-	-	+	-	-	-	-
x_{23}	-	-	-	-	-	-	+	-	-	-
x_{24}	-	-	-	-	-	-	-	+	-	-
x_{25}	-	-	-	-	-	-	-	-	+	-
x_{26}	-	-	-	-	-	-	-	-	+	-
x_{27}	-	-	-	-	-	-	-	-	+	-
x_{28}	-	-	-	-	-	-	-	-	+	-
x_{29}	-	-	-	-	-	-	-	-	-	+
x_{30}	-	-	-	-	-	-	-	-	-	+

The following faults of the steering system of «KrAZ» motor vehicle will be denoted in the matrix:

x_1 – loose fixation of spring U-Bolts;

x_2 – loose fixation of the covers of the spring pads;

x_3 – destruction of the spring pads;

x_4 – irregularity of the driving wheels alignment adjustment;

x_5 – loosen fixation of the driven wheels;

x_6 – increased free wheeling;

x_7 – seizure of the gate valve or reactive pistons in the distributor body;

x_8 – lost of the output of the steering hydraulic booster of the steering system (insufficient tension of the pump drive belt);

x_9 – increased tension of the spheric bearings of the steering mechanism;

x_{10} – low level of oil in the reservoir of the pump booster;

x_{11} – presence of air in the hydraulic system of the steering;

x_{12} – presence of water in the hydraulic system of the steering;

x_{13} – periodic hanging (seizure) of the discharge valve as a result of contamination;

x_{14} – power loss of the relief valve spring or non-observance of the valve adjustment;

x_{15} – breaking of the drive belt of the pump hydraulic booster;

x_{16} – loosening of the relief valve seat tightening;
x_{17} – relief valve spring breakage;
x_{18} – discharge valve leakage as a result of foreign particles entering under the ball of the relief valve;
x_{19} – loosening of the belt tension of the pump drive of the hydraulic booster;
x_{20} – clogging or damage of the pump filter;
x_{21} – high level of oil in the reservoir;
x_{22} – loosening of the retaining nuts tension of the pump cover;
x_{23} – worn-out or damaged collar of the pump shaft;
x_{24} – emergence of the gap in the gear clutch of the steering mechanism;
x_{25} – presence of the contamination under the working edge of the collar;
x_{26} – damage of the working edge of the collar;
x_{27} – insufficient tension of the collar on the external diameter;
x_{28} – traces of the corrosion at the input shaft of the sector in the place of the contact with the collar;
x_{29} – worn of the rod on the external diameter;
x_{30} – worn-out or damaged collar of the hydraulic cylinder.

The signs of the above-mentioned faults of the steering system of the motor vehicle «KrAZ» are introduced in the diagnostic matrices:
S_1 – motor vehicle «does not hold the road»;
S_2 – increased effort and jerks on the steering wheel (especially at the wheels turn in-place);
S_3 – complete absence of the effort on the steering wheel at different rotation frequency of the engine shaft;
S_4 – sharp increase of the effort on the steering wheel at drive wheels in-place and in motion;
S_5 – increased noise in the process of pump operation;
S_6 – pump deregulation;
S_7 – constant drop of the oil level in the pump reservoir ;
S_8 – knock in the steering mechanism;
S_9 – oil leakage from behind the collars of the input shaft and shaft of the sector of steering mechanism;
S_{10} – oil leakage from behind the rod seal of the hydraulic cylinder of the steering mechanism.

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

On the cross of the i^{th} row and j^{th} column «+» is put, if in case of the i^{th} fault the withdrawal of the j^{th} sign from the domain of its admissible values is observed, otherwise «-» is put.

For the synthesis of the 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 a certain fault (or their combination) or with operational state (Fig. 3).

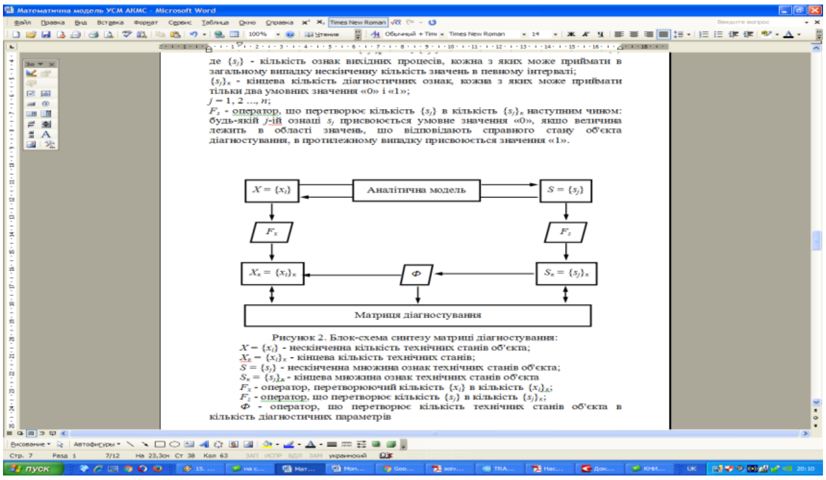

Fig. 3. Bloc-diagram of the synthesis of the diagnostic matrix of the motor vehicle «KrAZ»:
$X = \{x_i\}$ – non finite number of the technical states of the object;
$X_\kappa = \{x_i\}_\kappa$ – finite number of technical states;
$S = \{s_j\}$ – non finite set of signs of technical states of the object;
$S_\kappa = \{s_j\}_\kappa$ – finite set of the technical states of the object signs;
F_x – operator, that converts quantity $\{x_i\}$ into quantity $\{x_i\}_\kappa$;
F_s – operator, that converts quantity $\{s_j\}$ into quantity $\{s_j\}_\kappa$;
Φ – operator that converts the quantity of technical states of the object into the quantity of diagnostic parameters

Such conversion can be written in the form:

$$\{x_i\}_\kappa = F_x\{x_i\}, \qquad (4)$$

where $\{x_i\}$ – is the set of signs of technical states of the object of diagnostic each of which can take in the general case infinite number of values; $\{x_i\}_\kappa$ – is the finite set of signs of the technical states of the diagnostic object, each of which can 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 the operator, which converts the quantity $\{x_i\}$ into the quantity $\{x_i\}_\kappa$ in the following way: for any i^{th} parameter x_i assigns the value «-», if this value is in the domain of the acceptable values, otherwise value «+» is assigned.

Conversion of the infinite number of the values of the output processes parameters in the finite number of values of the diagnostic parameters can be written in the form:

$$\{s_j\}_\kappa = F_s\{s_j\}, \qquad (5)$$

where $\{s_j\}$ – is the number of the output processes signs, each of which can take in general case the infinite number of values in a certain interval; $\{s_j\}_\kappa$ – is finite number of diagnostic signs, each of which can take only two conventional values: «-» or «+»; $j = 1, 2 ..., n$; F_s – is the operator, that converts the quantity $\{s_j\}$ into the quantity $\{s_j\}_\kappa$ in the following way: any j^{th} sign s_j is assigned conventional value «-», if the value is in the domain of values which correspond to the operational state of the object of diagnostics, otherwise the 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 interconnected.

In general form this connection can be expressed in the form:

$$\{s_j\}_\kappa = \Phi\{x_i\}_\kappa, \qquad (6)$$

where Φ – is the operator that transforms the number of technical states of the object into the number of diagnostic parameters.

Transformation (6) represents the functioning of any technical object as the converter of the number of structural parameters into the number of diagnostic parameters and is the modification of the model (1).

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

System of the equations (3) connects each sign of the fault S_j with all structural parameters of the object of diagnostic that represents the links between structural parameters and diagnostic signals.

Diagnostic matrix, as the model of the object of diagnostic, shows that it is the tabular form of the system of equations record (1).

Parameter S_1 in the diagnostic matrix can be considered as binary Boolean function, that depends on the argument x_1. Boolean function depends on the argument x_1, if the relation $\varphi(x_1,\ x_2,\ ...,\ x_{i-1},\ 0,\ x_{i+1},\ ...,\ x_m) \neq \varphi(x_1,\ x_2,\ ...,\ x_{i-1},\ 1,\ x_{i+1},\ ...,\ x_m)$ takes place

As it follows from this definition and Table 1, S_1 greatly depends only on x_1, x_2, x_3, x_5, x_6 and x_7.

Dependence $S_1 = \varphi_1\ (x_1, x_2, x_3, x_5, x_6, x_7)$ is expressed in this case in the form of the function of logic addition (disjunction):

$$S_1 = x_1 + x_2 + x_3 + x_5 + x_6 + x_7.$$

Corresponding analysis of the other signs of the faults allows to write the system of equation (3) for this matrix of steering system diagnostics of «KrAZ» motor vehicles in the form:

$$\begin{cases} S_1 = x_1 + x_2 + x_3 + x_5 + x_6 + x_7; & S_6 = x_{20} + x_{21} + x_{22}; \\ S_2 = x_8 + x_9 + x_{10} + x_{11} + x_{12} + x_{13} + x_{14}; & S_7 = x_{23}; \\ S_3 = x_{15} + x_{16}; & S_8 = x_{24}; \\ S_4 = x_{10} + x_{13} + x_{17} + x_{18}; & S_9 = x_{25} + x_{26} + x_{27} + x_{28}; \\ S_5 = x_{10} + x_{11} + x_{19} + x_{20}; & S_{10} = x_{29} + x_{30}. \end{cases} \quad (7)$$

All serial transformations, which lead to the synthesis of the model of the diagnostic object in the form of the diagnostic matrix, are presented in the block-diagram (see Fig. 3). In the case, when the model of the diagnostic object is presented in the form the diagnostic matrix, the diagnostic problem is formulated in the following way. By the sings of faults S_1, S_2, …, S_n, obtained in the process of diagnostics, it is necessary to determine the faults x_1, x_2, …, x_m at the moment of verification, if the functional dependences between diagnostic parameters and all the structural parameters, set in the form of diagnostic matrix or system of equations of the type (7) are known. Each structural parameter and each diagnostic parameter accepts only two values: «-» or «+».

It is obvious, that for the solution of the diagnostic problem the inverse transformation of the number of diagnostic parameters in the number of the structural parameters is needed, as in the process of diagnostics the values of diagnostic parameters are known.

In general form the inverse transform can be presented by the expression:

$$\{x_i\}_\kappa = \Phi^{-1}\{s_j\}_\kappa,$$

Or in the expanded form

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

It is not difficult to determine in each case the type of functions f_m on the base of the following considerations.

In the diagnostic matrix one of the rows will be considered separately, for instance, the tenth row. It is seen from the matrix that the presence of the fault x_{10} simultaneously results in the output of the signs S_2, S_4 and S_5 in the domain of their admissible values. The values of other diagnostic parameters if only fault x_{10} is available, remain with the limits of the norm. Thus x_{10} is Boolean function, in this case conjunction (or function of the logic multiplication):

$$x_{10} = S_2 \cdot S_4 \cdot S_5.$$

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

$$\begin{cases} x_1 = S_1; & x_{11} = S_2 \cdot S_5; & x_{21} = S_6; \\ x_2 = S_1; & x_{12} = S_2; & x_{22} = S_6; \\ x_3 = S_1; & x_{13} = S_2 \cdot S_4; & x_{23} = S_7; \\ x_4 = S_1; & x_{14} = S_2; & x_{24} = S_8; \\ x_5 = S_1; & x_{15} = S_3; & x_{25} = S_9; \\ x_6 = S_1; & x_{16} = S_3; & x_{26} = S_9; \\ x_7 = S_1; & x_{17} = S_4; & x_{27} = S_9; \\ x_8 = S_2; & x_{18} = S_4; & x_{28} = S_9; \\ x_9 = S_2; & x_{19} = S_5; & x_{29} = S_{10}; \\ x_{10} = S_2 \cdot S_4 \cdot S_5; & x_{20} = S_5 \cdot S_6; & x_{30} = S_{10}. \end{cases} \quad (9)$$

As it is seen from this example, the process of diagnostics on the base of the model of the diagnostic object, expressed in the form of the diagnostic matrix, consists of the following stages:

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

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

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

Proceeding from the fact that the diagnostic object is operational only in case of the absence of all faults, then the function of its performance will have the form:

$$F_P = \overline{x_1 + x_2 + x_3 + ... + x_{30}}. \quad (10)$$

Turning back to the block-diagram of the diagnostic matrix synthesis (Fig. 3), the condition of the diagnostics realization can be formulated in general term as: for the realization of the diagnostics it is sufficient that the inverse transform of the quantity of faults signs into the quantity of structural parameters (faults) of the object be single-valued.

If in the process of synthesis of the diagnostic matrix this conditions is not satisfied and in the system (8) there are two or more equal functions, then the list of diagnostic parameters must be supplemented with a new parameter, which would be included as the additional argument only to one of the considered equal functions.

Conclusions

1. Analyzing the latest studies and publications on the considered subject, the specific mathematic dependences dealing with the determination of the technical state of the steering system were not revealed.

2. Analysis of the characteristic features of the steering system construction of the motor vehicle «KrAZ», as the object of diagnostics was performed.

3. Steering system of the motor vehicle «KrAZ», as the diagnostic object was presented in the form of a «black box», its input and output parameters have finite set of values

4. Diagnostic matrix composed for the steering system of the motor vehicle «KrAZ» comprises the list of faults and faults signs. Diagnostic matrix, as the model of the diagnostic object, shows that it is a tabular form of the mathematical models record of the diagnostic object.

5. In the process of diagnostic matrix synthesis it was revealed, that in the system (9) there are such equal functions as:

$x_1 = x_2 = x_3 = x_4 = x_5 = x_6 = x_7 = S_1$; $x_8 = x_9 = x_{12} = x_{14} = S_2$; $x_{15} = x_{16} = S_3$; $x_{17} = x_{18} = S_4$; $x_{21} = x_{22} = S_6$; $x_{25} = x_{26} = x_{27} = x_{28} = S_9$; $x_{29} = x_{30} = S_{10}$.

Thus, the list of the diagnostic parameters of the steering system of the motor vehicle «KrAZ» must be supplemented with new parameters, which would be included as the additional arguments only in one of the considered equal functions.

6. Developed mathematical model for the automation of the diagnostic process of the steering system of the motor vehicle «KrAZ» requires the introduction of new additional diagnostic parameters, that is the subject of further scientific studies of this direction.

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