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# Assessment of products risks of mechanical engineering by results of diagnosing

**Zorin V. A.[1], Baurova N.I.[2], Pegachkov A. A.[2]**
Moscow Automobile and Road Construction State Technical University, Russia

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**ABSTRACT**

Work is devoted to questions of assessment of risk indicators arising in use vehicles by means of diagnostic information.
As source of information on technical condition of a vehicle data complex (stationary and remote) diagnostic systems can be used.
Main objective of assessment of risks and creations of remote diagnostic systems is forecasting of reliability and safety of operation of the vehicle. The solution of this task requires timely detection and the prevention of approach of malfunction that demands allocation of special class of the intermediate states called by preemergency. Obtaining information and accumulation of statistical data on each vehicle model is possible on condition of creation of remote diagnostic systems.

***Corresponding Author:***

Zorin V. A.,
Departement of Automobiles and Road Construction machines,
Moscow Automobile and Road Construction State Technical University
64 Leningradsky st.125319, Moscow, Russia.
Email: madi-dm@list.ru

## 1. Introduction

Assessment and forecasting of risks of emergence of refusals is the most important requirement of the international standards for safety of vehicles [3, 4]. The existing methods of determination of risks are based on statistical information on the refusals and malfunctions arising in use vehicles [1]. Collecting, accumulation and processing of statistical data on failures of machines by traditional methods does not provide necessary efficiency and reliability of the obtained information. In this regard assessment and risk management by production and operation of vehicles with necessary reliability are not simple tasks.

Modern diagnostic systems have unlimited potential of timely registration and information transfer about technical condition of vehicles which can be used with success for the solution of objectives. Depending on the device and an arrangement of system of transfer, storage and information processing distinguish remote and stationary diagnostic systems [10, 11/12/13]. At modern development of means of communication and data transmission remote systems represent improved versions of stationary diagnostic systems [5].

## 2. Objective

Increase in indicators of non-failure operation, especially for parks of vehicless requires creation of control systems behind technical condition of the park with a possibility of collection of information on each model (for creation of the database included in decision-making process) [14, 15].

**3. Methodology**

We will give results of the researches executed by the vehicles equipped with system of onboard diagnostics OBD-2 with use of protocols as an example: SAE J1850 PWM; SAE J1850 VPW; ISO14230-4 KWP; ISO15765-4 CAN; SAE J1939 CAN; USER1 CAN; USER2 CAN, J1939.

For the purpose of automation of analysis process of the diagnostic information and recognition of parameters of technical condition of the vehicle the original computer program [6] is developed.

At the core of the program developed with use of base of frames applied unit which structure includes a diagnostic code, its interpretation, the description of malfunction, and also assessment of degree of importance of this malfunction System lies receives a code and generates the response message on an opportunity or impossibility of further operation of the vehicle. At the same time, for a possibility of collection of information, replenishment of the database and self-training the system is equipped with feedback. (fig. 1).

| Diagnostic code( DTC) | Malfunction description | Level of importance |
|---|---|---|

```
Type
Tf=record
Diag: string[ 5];{ Diagnostic code}
Simp: array [1..3] of string[70];{ Malfunction description }
 Lec: array [1..3] of string[1];{Level of importance }
Const N=3;
Type Tf=record
N: string[1];{ Level of importance }
Lec: array [1..N] of string[30];{ Level of importance description }
end;
```

Figure 1. Database frame structure.

For writing of the program of management of system of remote data collection and processing about technical condition of the vehicle the Delphi 7 language was used.

Types of the information signals received after processing and decision-making by system can be reduced up to three levels of importance.

"Level 1" characterizes emergency operation or detection of threat to security of functioning of the corresponding system of the machine in use. The immediate termination of use of the vehicle is a consequence. The obtained information on technical condition can be used for definition of indicators of non-failure operation and durability, and also for assessment of risk of emergence of refusal.

"Level 2" characterizes the normal modes of functioning of systems of the vehicle with high probability of emergence of malfunctions which can cause emergencies. Immediate return of the vehicle to a repair zone of the enterprise under the own steam is a consequence. The obtained information allows to predict a residual resource, probability of emergence of refusals after performing profound diagnostics, and also to carry out risk analysis.

"Level 3" is connected with the work of systems or mistakes which are not influencing safety or failure of the vital units of the vehicle. Need of the immediate address to technical specialists on return of the vehicle from flight for identification of the possible hidden insignificant damages is a consequence.

Assessment of the importance of the obtained diagnostic information can be carried out taking into account an algorithm (fig. 2) having in the basis expanded approach with use of the statistical saved-up data on technical condition of the vehicle taking into account weight of consequences of possible refusal [7,8].

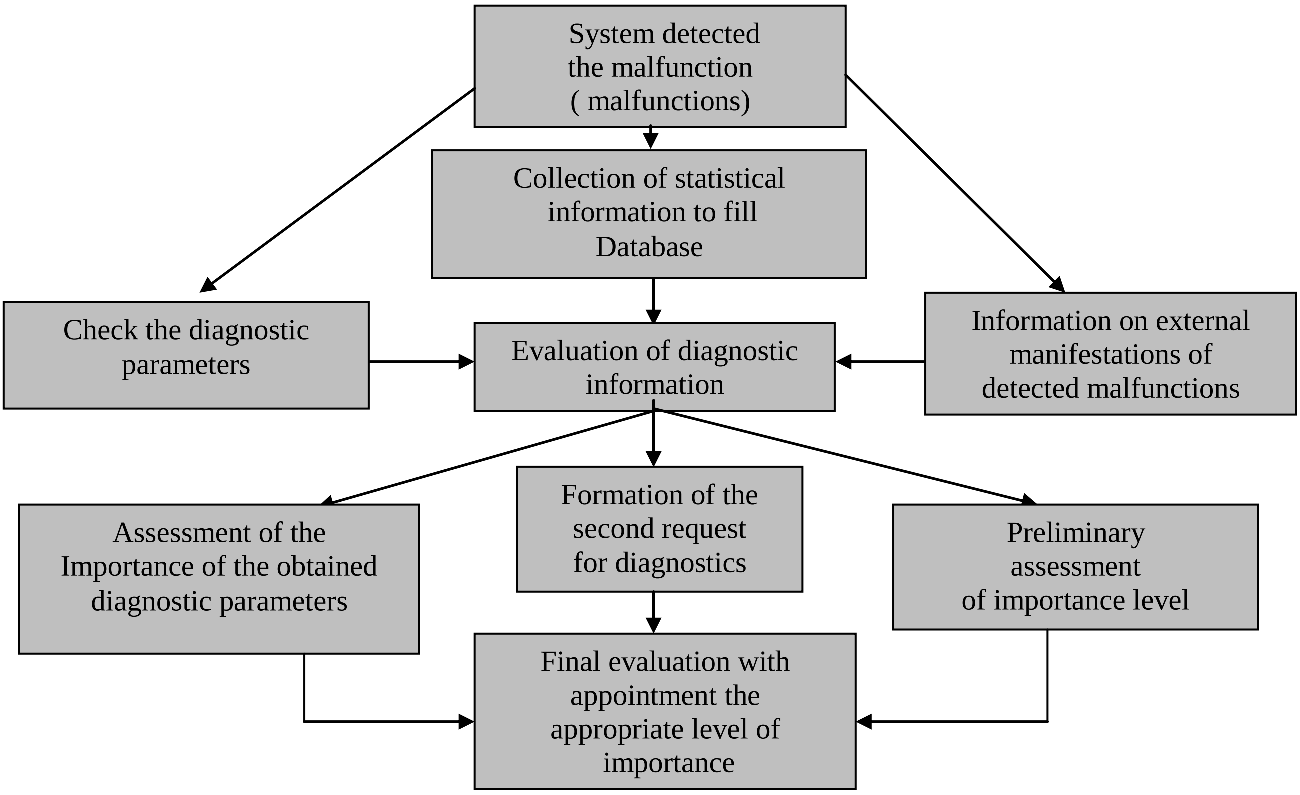


Figure 2. Algorithm for assessing the importance of diagnostic information.

At the description of remote system of collecting and the analysis of information on technical condition of the vehicle [9] the following designations are accepted: there is a set of the diagnostic K= (K1,K2 parameters,…, Kv), each of which with a certain probability characterizes one of n of casual conditions of an object Di. The task consists in recognition of a condition of an object on set of parameters K.

In case an object is in a condition of Di which is characterized by a simple sign of Kj, then the probability of joint emergence of these events (presence at an object of a condition of Di and the Kj parameter) according to Bayes (1) formula is equal:

$$P(D_i/K_i) = P(D_i) \cdot P(K_j/D_i) / P(K_j)\ , (1)$$

where *P(Di)* - probability of a condition of Di according to preliminary statistical data. So, if N objects are previously surveyed and Ni of objects had a condition of *Di*, then *P(Kj/Di)* - probability of emergence of the *Kj* parameter in objects with a condition of *Di*. If among *Ni* of the objects having a condition of *Di* at *Nij Kj* is shown, then

$$P(D_i) = N_{ij}/N_i\ ,$$

*P(Kj)* - probability of emergence of the *Kj* parameter in all objects irrespective of a state. If from total number N objects the Kj parameter is found in Nj of objects, then

$$P(K_i) = N_j / N\ ,$$

For reliable assessment of technical condition the size *P(Kj)* can be determined through *P(Di)* and P values *(K/Dj)* known for all possible states. More general is the case when examination is conducted on the complex of signs of K including signs of *K1,K2,…, Kv*, each of which has mj of categories (*Kj1, Kj2,, Kjv.)*. As a result of observation there is known realization of a complex of signs of K. For increase in reliability of assessment of a condition of the vehicle on a combination of diagnostic parameters, we suggest to use dependence (1):

$$P\left(D_i / K^*\right) = \frac{P(D_i)\cdot P(K^* / D_i)}{\sum_{s=1}^{n} P(D_s)\cdot P(K^* / D_s)}. \qquad (2)$$

where *P (Di/K *)* - a posteriori probability of a condition of Di after finding of signs of K.

Let's say that parameters are independent, even in the presence of correlation communications between them, then dependence will take a form:

$$P\left(K^*/D_i\right) = P\left(K_1^*/D_i\right)\cdot P\left(K_2^*/D_i\right)\cdot \ldots\cdot P\left(K_v^*/D_i\right),$$

For determination of probabilities of conditions of an object on a formula (2) it is necessary to create on a basis collected system of information a diagnostic matrix (tab. 1). The offered system of diagnosing with remote access allows to consider "the diagnostic value" of HDI of collected information by means of an indicator of value of each studied *Kj* parameter for all diagnosed set of conditions of $D_i$:

$$X_D = \sum_{i=1}^{n} P(D_i)\cdot Z_{D_i}(K_j),$$

where $P(D_i)$ - aprioristic probability of a condition of $D_i$, and $Z_{D_i}(K_j)$ - diagnostic weight.

$Z_{D_i}(K_j)$ - is considered also an indicator of value of information and information measure of diagnostic parameter.

Characteristic of diagnostic systems is that certain codes of malfunctions and their combination can be indicators of various conditions of the vehicle and lead to various consequences - from loss by the controllability vehicle to lack of signs of decrease in working capacity (the false diagnosis).

Table 1. Diagnostic matrix.

| Conditions $D_i$ | Parameters | | | | $P(D_i)$ |
|---|---|---|---|---|---|
| | $K_1$ | | $K_2$ | | |
| | $P(K_{11}/D_i)$ | $P(K_{12}/D_i)$ | $P(K_{12}/D_i)$ | $P(K_{22}/D_i)$ | |
| $D_1$…. …$D_n$ | | | | | |

## 4. Results and discussion

Allocation in system, only two states: "working capacity" and "refusal" excludes a possibility of forecasting of correct work of vehicles elements on a certain time span or an operating time.

For modern diagnostic systems especially important is not only a detection, but also the prevention of approach of malfunction (reliability forecasting, risk management) that demands allocation of a special class of the intermediate states called by preemergency.

Creation of remote diagnostic systems with a possibility of collecting statistical data on each model opens prospects of the solution of this task.

For the purpose of confirmation of a possibility of reliable assessment and forecasting of change of technical vehicle condition on the basis of information received by means of remote diagnostic system pilot studies in actual practice of operation were conducted.

During the experiments five models of the trucks having system of onboard diagnostics OBD-2 were used. At the same time imitation of seven various malfunctions connected with violation of processes of combustion of fuel in cylinders of each vehicle until fixing corresponding to the malfunction diagnostic code (tab. 2) was carried out.

Table 2. The studied codes of malfunctions.

| Malfunction code | System of ignition (description of malfunction) |
|---|---|
| P0300 | Multiple Cylinder Misfires Detected |
| P030N | Admissions of ignition in N- cylinder are found |
| P0134 | Malfunction operation of the oxygen sensor No. 1 |
| P0116 | Malfunction of engine coolant temperature sensor |
| P0335-P0344 | Camshaft Position Sensor malfunction |
| P035* | Primary/secondary chains of the coil ignition* is faulty |
| P0371 | Malfunction of variable valve timing /GRM system |

In the course of the researches the analysis of influence of malfunctions on diagnostic estimates of technical condition of the vehicle was made. At a research and identification of level of importance of diagnostic information, as an example of malfunction failure of catalytic converter (fig. 3) in which at a temperature over $960^0$C the irreversible processes bringing to its time develop was accepted to decision and failure.

Figure 3. Destruction of the catalytic converter.

In the course of pilot studies imitation of seven malfunctions for each of diagnostic codes was carried out:

1. For imitation of the diagnostic P035 code * (Primary or secondary chains of the coil of ignition are faulty) giving of tension on primary winding of the corresponding coil of ignition was interrupted.

2. For imitation of the diagnostic P038 code * (The spark plug is faulty) faulty spark plugs where the working gap increased to 3 mm were used.

3. Imitation of the diagnostic P0371 code (Failure in work of system of adjustable phases of the GRM system) was carried out by interruption of the operating signal on adjustable systems of phases of gas distribution.

4. For imitation of the P0335-P0344 code (Shows us to camshaft position sensor malfunction) it was necessary to create such malfunction which anyway would provide giving of a signal from the sensor to the engine management module, but the signal had to be distorted. For this purpose on a rotor of an asterisk of a bent shaft between two teeth the special metal element, of the size of one tooth was pasted.

5. For imitation of the P030N code (admissions of ignition in N-cylinder) especially faulty coils of ignition were used.

6. For imitation of the P0116 code (Malfunction of engine coolant temperature sensor ) the rupture of the alarm wire going to the control unit of the engine was carried out.

7. For imitation of the P0134 code (the oxygen sensor malfunction operation) the rupture of the alarm wire going to the control unit of the engine was carried out.

As key parameters of assessment of a condition of catalytic converter at emergence of a mistake 3 values were accepted: Catalyst $T_k$-temperature at the time of emergence of a code; $T_{кв}$ - catalyst temperature in 5 minutes after emergence of the DTC code; $t_k$ - time before emergence of the corresponding code of malfunction.

Temperature can be estimated, by tracking of the identification CATT11_DSD parameter, (catalyst temperature in degrees Celsius, $^0$C) the Conducted pilot studies (tab. 3) showed that wrong judgments of diagnostic importance of information on the basis of use only of a diagnostic code were received in 34% of cases. At inquiry by this code of value of this or that corresponding parameter the quantity of cases of wrong judgments of diagnostic importance of information decreased to 17%. Thus, increase in reliability of assessment of technical condition of an object requires obtaining additional information on values of diagnostic parameters (additional inquiry, for obtaining bigger number of data). Introduction of an additional algorithm of inquiries to a code of malfunction will lower the number of wrong judgments to 4-5%.

Table 3. Aprioristic probabilities of states and probability of parameters.

| $D_i$ | $P(K_1 / D_i)$ | $P(\overline{K_1} / D_i)$ | $P(K_2 / D_i)$ | $P(\overline{K_2} / D_i)$ | $P(D_i)$ |
|---|---|---|---|---|---|
| $D_1$ | 0,3 | 0,8 | 0,2 | 0,7 | 0,05 |
| $D_2$ | 0,4 | 0,6 | 0,5 | 0,5 | 0,15 |
| $D_3$ | 0,0 | 1,0 | 0,05 | 0,95 | 0,80 |

Use of the innovative equipment in remote systems of diagnosing (fig. 4) allows to obtain at the same time information on technical condition of basic elements of the car in online the mode with a possibility of accumulation and processing of the obtained data. On the basis of this information it is possible to receive timely assessment of an operating time of elements of the car on refusal and to calculate sizes of the arising risks. At the same time, assessment of risks represents a number of the logical steps allowing to apply system approach to consideration of factors of danger [1,2].

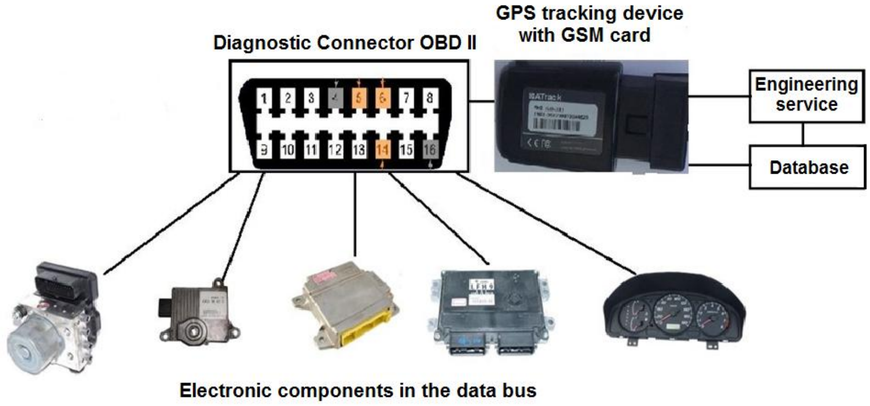


Figure 4. Remote diagnostic system.

Basis for assessment of risks of *R* within management of reliability and safety are the functionality of *F* connecting probability *P* emergence of an adverse event (malfunction, refusal), and population mean of damage of *U* from this adverse event:

$$R = F_R\{U, P\} = \sum_i [F_R(U_i, P_i)] =$$
$$= \int C(U)P(U)dU = \int C(P)U(P)dP$$

where $i$ - types of adverse events; $C$ - the weight functions considering mutual influence of risks.

**5. Conclusion**

Between values of the weight functions considering mutual influence of risks and indicators of diagnostic weight of $ZD_i$ $(K_j)$, obviously, there is a close correlation connection. Thus, use of values of the parameters of the importance of diagnostic information on technical condition of the vehicles received by means of system of remote diagnosing provides a possibility of timely definition of indicators of the risks connected with failures of machines in use.

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