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The reduction of diagnostic information in evolution condition machine

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Abstract

In this paper author introduces problem of the reduction of diagnostic information in evolution condition machine for estimating state prognosis algorithms which are the basis for determining conclusion rules for estimating the next machine operation term and for state genesis which is the basis for rules creating of machine state estimation in the past. Automation of the investigation system of the evolution of the technical systems machines condition in which diagnosing distinguishes itself of prognose of the state and the genesis of the state requires the qualifications of the gathering of diagnostic parameters describing the change of the condition of the machine during exploitation. The results of investigations connected with the implementation of the procedures of monitoring the technical machine engines condition and their investigation for the chosen arrangements of mechanical vehicles were introduced.

Introduction

Using in the exploitation process methods of machine state prognosis as a basis for automatization of state recognition process, it requires the diagnostic parameters sets optimization and prognosis methods. The solution of these problems depends on many factors connected with the level of machine complexity, application of multi-symptom observations, and exploitation process quality. The prognosis of vehicles' states is a process which ought to enable the anticipation of machine's state in the future, basis on an incomplete history of diagnostic tests research results. It allows to estimate the time of a faultless machine usage or the value of work done by it in the future. In the process of state prognosis, very important problem is to choice [1, 2, 3, 4, 5, 6, 7]:

a) a set of diagnostic parameters depending on the machine's work time, quality of time step and the size of an optimal diagnostic parameters set;
b) prognosis method depending on the prognosis horizon, the minimal number of elements of time row indispensable for running the prediction and the machine's operation time;
c) genesis method in relation to the genesis horizon, minimum number of elements of the time row indispensable for running the genesis, and the machine's working time.

The question of testing the above problems in the process of machine state prognosis, as well as the legal acts concerning the users' safety and environmental protection, are an impulse for searching new diagnostic methods and determining new measures and tools describing their contemporary states in their exploitation process, which are further presented as appropriate procedures, algorithms and conclusion rules.

The problem of examining the above problems in the process of machine state genesis, examining dynamics of their constructions, high requirements set by users, as well as effective legal acts concerning users' safety and environmental protection, are an impulse for searching new diagnosis methods and determining new measures and tools describing their current diagnostic states in the process of their exploitation, which are presented below as proper procedures and algorithms of state genesis, and stemming from them conclusion rules.

Suitable methods and procedures and algorithms taking into account these postulates were introduced below.

The choice of diagnostic parameters in the process of prognose and genesis

The parameters of the technical condition of the machine are changing sizes in the time, for they depend on the course of processes extorting aging. It distinguishes itself the parameters, which are characterize the minimum mistake of the diagnosis and the procedure of the choice of diagnostic parameters according to the minimum mistake of the diagnosis.

The qualification of the mistake of the diagnosis D is the essence of this method, i.e. the area of „cover" the thickness of the conditional probabilities of the parameter defined by Serdakow to the function [2, 8] dependence:

$$D = P\left(\frac{S_1}{y_j}\right)Q_1 + P\left(\frac{S_2}{y_j}\right)Q_2 \tag{1}$$

meanwhile probability of mistake and kind Q_1 consisting in credit of machine being in condition of fitness S_1 to condition of unfitness S_2:

$$Q_1 = \int_{y_{\mathrm{gr}}}^{+\infty} f\left(\frac{y_j}{S_1}\right)\mathrm{d}\,y_j \tag{2}$$

and the probability of the mistake II kind Q_2 consisting in credit of machine being in condition of unfitness S_2 to condition of fitness S_1:

$$Q_2 = \int_{-\infty}^{y_{\mathrm{gr}}} f\left(\frac{y_j}{S_2}\right)\mathrm{d}\,y_j \tag{3}$$

Then the choice of the "best" parameter through the minimization of the mistake of the diagnosis:

$$y^* = \min_j\left(D_j\right) \tag{4}$$

Choice of diagnostic parameters according to the introduced method moves then to:

1. Analysis of parameters depends on:
   a) the investigation significance of the value changes of diagnostic parameters near the change of the technical condition of the machine;
   b) marking and estimating the value border y_{gr} according to the criterion of the smallest risk Bayesa near the foundation of the value of the mistakes costs and II kind.
2. The quantitative analysis which consists in the choice of parameters under the angle of the criterion of the minimum mistake of the diagnosis.

One gets the gathering of the diagnostic parameters whose elements are characterize good distributive properties and the compartments of their changes are qualified near the change of the condition of technical object and value border $y_{\mathrm{gr}j}\,(y_{\mathrm{gr}d}, y_{\mathrm{grg}})$ together with the mistakes of the diagnosis in the result of the realization of the procedure.

Diagnostic parameters set is derived from the set of output parameters. Basis on researches results, aiming at confirming some of the proposals included in works concerning the reduction of diagnostic information in prognosis and genesis process [9, 10, 11, 12, 13] it is considered that the determination of diagnostic parameters set in the process of machine state prognosis ought to include:

a) the ability to reflect the machine state changes in exploitation time;
b) the quantity of information on the machine's state;
c) relevant changeability of diagnostic parameters values in the machine's exploitation time.

Suitable algorithms taking into account these postulates were moved as methods below.

The method of the maximum relative change of diagnostic parameter

In this method there is planning to go this diagnostic parameter which possesses the largest value of the coefficient k_j. It takes into account the average speed of the change of parameters in the compartment of the time (Θ_1, Θ_b). It defines itself according to dependence:

$$k_j = \frac{b_j}{\sum_{j=1}^{m} b_j}, \; b_j = \frac{1}{K}\sum_{i=1}^{K}\frac{\left|y_j(\Theta_{i+1}) - y_j(\Theta_i)\right|}{(\Theta_{i+1} - \Theta_i)\left|y_j(\Theta_1) - y_{j,g}\right|} \tag{5}$$

where: K – the number of the elements of the temporary row in the compartment (Θ_1, Θ_b).

Correlation method of diagnostic parameters values with the machine's state

It consists in examining the correlations of diagnostic parameters values with the state of the machine $r_j = r(W, y_j)$ (or the time of machine's exploitation ($r_j = r((\Theta, y_j))$):

$$r_j = \frac{\sum_{k=1}^{K}\left(\Theta_k - \overline{\Theta}\right)\left(y_{j,k} - \overline{y}_j\right)}{\sqrt{\sum_{k=1}^{K}\left(\Theta_k - \overline{\overline{\Theta}}\right)^2 \sum_{k=1}^{K}\left(y_{j,k} - \overline{y}_j\right)^2}} \tag{6}$$

$$\overline{\Theta} = \frac{1}{K}\sum_{k=1}^{K}\Theta_k \ , \ \overline{y}_j = \frac{1}{K}\sum_{k=1}^{K} y_{j,k} \qquad (7)$$

where $r_j = r(W, y_j)$, $j = 1, ..., m$ – coefficient of correlations between variables W (state of the machine) and y_j; $r_{jn} = r(y_j, y_n)$; $j, n = 1, ..., m$; $j \neq n$ – coefficient of correlations between the variables y_j and y_n.

In case of lack of data from the set W, they are replaced, assuming that the determination of state recognition procedures is realized within the range of normal wear with the time of machine's exploitation. Then, $r_j = r(\Theta_k, y_j)$; $j = 1, ..., m$; $k = 1, ..., K$ (r_j – coefficient of correlation between the variables $\Theta_k \in (\Theta_1, \Theta_b)$ (Θ_k – machine's exploitation time) and y_j).

Method of informational size of diagnostic parameter

The object of this method consists in the choice of the parameter which provides the largest quantity of information on the machine's state. A diagnostic parameter is the more important for the state change estimation, the more it is correlated with it and the less it is correlated with other diagnostic parameters. This relation is presented in the form of the size indicator of the diagnostic parameter h_j, which is a modification of the indicator relating to the set of variables explaining the econometric model [14]:

$$h_j = \frac{r_j^2}{1 + \sum\limits_{j,n=1, j\neq n}^{m} \left| r_{j,n} \right|} \qquad (8)$$

$$r_{j,n} = \frac{\sum\limits_{k=1}^{K}\left(y_{j,k} - \overline{y}_j\right)\left(y_{n,k} - \overline{y}_n\right)}{\sqrt{\sum\limits_{k=1}^{K}\left(y_{j,k} - \overline{y}_j\right)^2 \sum\limits_{k=1}^{K}\left(y_{n,k} - \overline{y}_n\right)^2}} \qquad (9)$$

$$\overline{y}_j = \frac{1}{K}\sum_{k=1}^{K} y_{j,k} \ , \quad \overline{y}_n = \frac{1}{K}\sum_{k=1}^{K} y_{n,k} \qquad (10)$$

In case of lack of data from the set W, they are replaced, assuming that the determination of state recognition procedures is realized within the range of normal wear, with the time of machine's exploitation.

Algorithm of the reduction of the diagnostic machines parameters gathering

The estimation methodology algorithm of the optimal machines diagnostic parameters set consists stages [13, 15, 16, 17, 18]:

1. Data acquisition:
   a) the set of diagnostic parameters values in the function of machine's exploitation time $\{y_j(\Theta_k)\}$, acquired in the time of passive-active experiment realization, where $\Theta_k \in (\Theta_1, \Theta_b)$;
   b) the set of diagnostic parameters values: $\{y_j(\Theta_1)\}$ – nominal values, $\{y_{jg}\}$– boundary values, $j = 1, \ldots, m$;
   c) the set of machine's states $\{\Theta_k: \{s_i\}, k = 1, \ldots, K; \ i = 1, \ldots, I\}$ determined in the time of passive-active experiment realization, where $\Theta_k \in (\Theta_1, \Theta_b)$;
2. The optimization of diagnostic parameters set values (only in case of large size of Y, e.g. $m > 10$). Diagnostic parameters set is estimated with use of:
   a) correlation method of machine's state diagnostic parameters (exploitation time), $r_j = r(W, y_j)$, $(r_j = r((\Theta, y_j))$;
   b) method of machine's state diagnostic parameters information quantity h_j.

In order to choose a diagnostic parameters set, weight values are used:

a) standardized calculation weights w_{1j}:

$$w_{1j} = \frac{1}{d_j}, \ d_j = \sqrt{\left(1 - r_j^*\right)^2 + \left(1 - h_j^*\right)^2} \qquad (11)$$

$$r_j^* = \frac{r_j}{\max r_j}, \ h_j^* = \frac{h_j}{\max h_j} \qquad (12)$$

b) as the criterion of diagnostic parameter (diagnostic parameters) selection, the maximization of the values of weights w_{1j} and the diagnostic parameters selection according to the above criterion were accepted;

c) in order to consider the user's preferences, it ought to be possible for him/her to insert the weights w_{2j} (standardized values) from the range (0, 1) and choose parameters according to the above criterion.

Conclusions

Recapitulating considered above questions relating to the theoretical bases of the methodology of the diagnostic information reduction it can state that:

1. The process of recognizing the condition of machines hugs the following kinds of diagnostic investigations: the opinion of the state, genesis and prognosis.

2. Delimitation of the gathering of diagnostic parameters is basic question in the process of recognizing the condition of machines:
   a) in the process of the opinion of the condition of machines – regard of criterion difference of the conditions of the machine;
   b) in the process of prognosis and genesis with utilization of the methods: the correlation of the value of the diagnostic parameter with the state and sometimes the exploitation of machine and the informative capacity of the diagnostic parameter.

One of the main tasks is the formulation of the problems solving resulting from the diagnostic investigation of the evolution of the machines condition:

a) the change of the condition of the machine during exploitation;
b) the description of the condition of machine for the help of the features of the state and dependence among the features of the state and diagnostic parameters.

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