MODEL OF MACHINE STATE GENESIS

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Summary
In this work presented is the machine technical state genesis model whose elements are diagnostic parameters values genesis in the past and the estimation of the cause of the machine's disability state determined during state evaluation.

Keywords: machine state genesis, diagnostic parameters, technical state, approximation, interpolation.

MODEL GENEZOWANIA STANU MASZYN

Streszczenie
W pracy przedstawiono model genezy stanu technicznego maszyny, którego elementami jest genezowanie wartości parametrów diagnostycznych w przeszłości oraz szacowanie przyczyny stanu niezdatności maszyny określonego podczas oceny stanu.

Słowa kluczowe: genezowanie stanu maszyn, parametry diagnostyczne, stan techniczny, aproksymacja, interpolacja.

1. INTRODUCTION

Machine technical state genesis consists in [5]:

a) the determination (with incomplete or uncertain data of diagnostic parameters values) of the trend of diagnostic parameters values changes which characterizes the process of machine state aggravation in the past;
b) the comparison of diagnostic parameters momentary values with boundary values;
c) the estimation of the machine's technical state at a past time of machine's exploitation interesting for the user, e.g. in order to determine the cause of the machine's failure located at the moment of examination.

Global state of the machine, considering its change in time, is described by the dependence [6]:

$$G\ (X(\Theta), U(\Theta), Z(\Theta)) = Y(\Theta) \qquad (1)$$

where:

$X(\Theta)$ – machine state features vector,
$U(\Theta)$ – forcing vector,
$Z(\Theta)$ – interference vector,
$Y(\Theta)$ – output vector containing signals used in diagnostics (damage-oriented diagnostic symptoms-signals), diagnostic parameters,
G – global response function,
Θ - machine exploitation time.

The main way for the machine's utilitarian abilities loss recognition is a model which describes in a formalized way the time connections between the results of machine's diagnostic observations, and their relevance to criterial values describing the machine's genesis states. In the process of machine diagnosis, the base are usually sets of information generated by the system monitoring the machine's state, i.e. spotted histories of value changes of the supervised diagnostic parameters (vector $Y(\Theta)$). These sets, given in the form of the time row y_Θ,, are the realization of a certain aleatory process $\zeta(\Theta)$ whose parameters depend on the aleatory forcing vector $X(\Theta)$ forming the level of the researched process of machine wear (vector $U(\Theta)$) and the aleatory interference noise (vector $Z(\Theta)$) [6].

The effectiveness of the diagnostic parameters values determination both in the future (prognosis) and In the past (genesis), with the assumption of incomplete and unreliable (inaccurately or estimated with a certain mistake) their values at the time (Θ_1,Θ_b), is the higher the longer the possessed time row y_Θ is, and the simpler the mechanisms of its creation are. In diagnostic researches there is unfortunately a situation when time rows of the diagnostic observation are relatively short in relation to the needs connected with a correct identification of the systematic (determined) component creating the trend of the recognized phenomenon $\mu(\Theta)$, and contain a measurement mistake. Therefore, the basic problem in the analysis of time rows $\{y_\Theta\}$ is examining the row of collected measurement results. This problem is most often aimed at distinguishing in the time row deterministic (regular) components described with the trend $\mu(\Theta)$ and aleatory effects $\eta(\Theta)$, (e.g. loads, terrain conditions, climate conditions, operation quality, etc.). The trend in this matter is represented by a certain non-aleatory trend function $\mu_p(\Theta)$ setting the general direction of the development and describing the general regularity of changes of the controlled phenomenon of machine wear process, and the aleatory component

$\eta(\Theta)$ determines the oscillations around the systematic component caused by different aleatorily repeated forcings affecting the machine [6].

The solution of the presented postulate can be presented as the following algorithm [4]:

1. Let the phenomenon of the machine's state aggravation be represented by the time row y_Θ = <y_1, y_2, ..., y_b>, i.e. the set of discrete observations $\{y_\Theta = \zeta(\Theta);\ \Theta = \Theta_1, \Theta_2, ..., \Theta_b\}$ of a certain aleatory process $\zeta(\Theta)$.
2. With the assumption that the mechanism of value changes of an aleatory process at the time $\Theta \in (\Theta_1, \Theta_b)$ forms a trend $\mu(\Theta)$ interfered by different aleatory effects $\eta(\Theta)$:

$$y_\Theta = \mu(\Theta) + \eta(\Theta) \tag{2}$$

where:

$\mu(\Theta)$ – characterizes a determined component of the time row y_Θ describes the development tendency of the observed diagnostic parameter $y(\Theta)$,

$\eta(\Theta)$ – characterizes declinations from the trend and expresses the effect of accidental factors (load, terrain conditions, climate conditions, service quality, others),

such estimation $\{\mu_G(\Theta)\}$ is created for an unknown form of the trend $\mu(\Theta)$ which would provide a proper accuracy of the genesis $y_G(\Theta)$ for the machine's working time Θ_G, where $\Theta_G = \Theta_b - \tau_2$.

3. The estimation of $\mu_G(\Theta)$ determines the values of observed diagnostic parameters at the moment Θ_G, and at the same time the possibility of machine's technical state genesis $S(\Theta_G)$ on the basis of examining the admissible state of machine's exploitation S_{dop} at the moment Θ_G.
4. The admissible technical state of the machine S_{dop} In the time range (Θ_1, Θ_b) is assigned by the value of time for which separate geneses $\{y_{j,G}\}$ assigned in the subset $\Omega^y \in \Omega$ of available realizations of observed parameters $\{y_j(\Theta)\}$ and respective to them radiuses of the genesis mistake range $\{r_{jG}\}$ according to the accepted genesis method do not exceed the boundary values $\{y_{j,g}\}$.

$$r_G = q_{\gamma,K} \cdot \sigma_G \tag{3}$$

where:

$q_{\gamma,K}$ – constant parameter assigned from the Student's disintegration table for the required trust level γ and K-2 of the freedom level number,

σ_G – standard declination of the aleatory component of genesis mistake e_G;

5. In case of the machine operation system, the required form of machine state genesis is the information whether at the time (Θ_1, Θ_b) the technical state was an admissible state S_{dop}, which allows to estimate the machine's state in the past and plausible determination of the cause of the disability state recognized at the moment of machine examination Θ_b.

At present there are no utilitarian genesis methods of machine states which could be used in practice [1], hence considered was the possibility to use approximation methods (mean-square dot polynomial, trigonometric) and interpolation methods (polynomial, level-1 and level-3 combined functions) in the area of diagnostic parameters values genesis;

2. GENESIS OF DIAGNOSTIC PARAMETERS VALUES

The realization of the above presented algorithm is possible with the use of appropriate methods of assigning diagnostic parameters value for genesis (with the assumption of incomplete and uncertain history of their values at the time (Θ_1, Θ_b). This problem can be solved with the respective use, as stated on the basis of performed literature and introductory researches [2], of approximation method (mean-square dot polynomial) or interpolation (combined function method) [5].

Approximation of diagnostic parameter values

Approximation is the approximation of the function $Y(\Theta)$ called the approximated function with another function $Ya(\Theta)$ called the approximating function. Out of many approximation methods, on the basis of introductory researches [3], the following were chosen: mean-square dot polynomial approximation and trigonometric approximation.

Mean-square dot polynomial approximation

Given are time points $\Theta_1, \ldots, \Theta_i, \ldots, \Theta_j, \ldots, \Theta_b$ different in pairs, thus for $i \neq j \Leftrightarrow \Theta_j \neq \Theta_j$ and given are the values of diagnostic parameters in these points $y_1, \ldots, y_i, \ldots, y_b$, where $y = f(\Theta_i)$, $i = 1, \ldots, b$. The aim of approximation is, therefore, to find the values of coefficients $a_0, a_1, \ldots, a_m$ of the polynomial $Y_m(\Theta)$ of m-level so that the mean-square mistake is the smallest .

The aim of the mean-square dot approximation goes down to solving m+1 equations of m+1 unknowns.

Trigonometric approximation

Trigonometric approximation is utilized when the approximated function is a periodic function and the points of the time row $Y = \{yi(\Theta)\}$coming from the observation of diagnostic parameter value changes are equally distant.

The idea of approximation, therefore, comes down to calculating the values of the polynomial coefficients.

Interpolation of diagnostic parameter value

Let us assume that given are the values of the function $Y(\Theta)$(diagnostic parameters values) in the set of time points $\Theta_1, \ldots, \Theta_k, \ldots, \Theta_b$ called interpolation nods. The task of the interpolation is to determine approximate values of the function

Y(Θ)called the interpolated function in points not being interpolation nods. The interpolating function is a function of a certain class. Most often it will be an algebraic polynomial, trigonometric polynomial, rational function or combined function. Interpolation is most often used when we do not know the analytical form of the function Y(Θ) (it is only tabled) or when its analytical form is too complicated. In the work, on the basis of initial researches, Lagrange's interpolation and interpolation with combined functions were used.

Lagrange's Interpolation

Lagrange's interpolation idea is characterized by the requirement that the values of the interpolating function equal the values of the interpolated function in n+1 points. Let us assume that we know several values of the function Y(Θ) for several arguments $\Theta_1, \ldots, \Theta_k, \ldots, \Theta_b$, and we want to learn what the values for other arguments are. It is possible to perform thanks to interpolation functions. It is required that their graph runs through the interpolation nods (discrete points whose coordinates we know) $y(\Theta_1), \ldots, y(\Theta_k), \ldots, y(\Theta_b)$ and beyond them, that it as best as possible approximates the archetype.

In order to find the value of the function in every point of the domain, it is necessary, on the basis of the knowledge of several discrete values, to assign interpolation polynomial.

The estimation is to a great extent dependent on the displacement of arguments of discrete points Θ_k.

Interpolation with combined functions

In so-far dissertations the function was interpolated with one polynomial. Of course, if the number of nods increases, the level of the interpolation polynomial rises as well, and it can occur that it will not be convergent with the interpolated function.

The problem of interpolation with combined functions requires that their graph goes through interpolation nods (discrete points whose coordinates we know) $y_1, \ldots, y_i, \ldots, y_b$, , and beyond them, that it as best as possible approximates the archetype with the help of appropriate functions in separate ranges.

Having calculated the coefficients of the polynomial, we can calculated the needed polynomial value, whilst interpolation mistake with combined functions is assigned according to the dependence:

The analysis of the above presented methods of estimating the genesis value of diagnostic parameters, and respective to them genesis mistakes, allows to state that in order to estimate the genesis value of diagnostic parameters on the basis of their uncertain and incomplete values from the time range (Θ_1, Θ_b), it is necessary to use:

1. In the area of approximation methods:
a) mean-square dot polynomial approximation;
b) trigonometric approximation,
2. In the area of interpolation methods:
a) interpolation with combined functions of 1 and 3 level for the time range (Θ_1, Θ_b).

The estimation of the diagnostic parameters values with the use of the above presented genesis methods allows to determine their genesis values $\{y_{j,int}(\Theta)\}$, which allows to estimate the state of machines in the past.

CONCLUSIONS

All the presented algorithms allow to assign optimal, as far as the accepted criterion is concerned, genesis values of diagnostic parameters in the time range (Θ_1,Θ_b), whilst for the research the following were used:

a) approximation method of diagnostic parameter value y_j^* (mean-square method, trigonometric method;
b) interpolation method of diagnostic parameter value y_j^* (level-1 and -3 combined functions method);
c) the choice of the method according to the maximum value of the radius of approximation or interpolation mistake (adjustment mistake).

In the following work, the author suggests the verification of the performed procedures of the state genesis methodology for machine systems of diversified wear process (e.g. aircrafts, mechanical vehicles and working machines).

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