THE IMPLEMENTATION OF THE METHODOLOGY OF THE MACHINE'S STATE GENESIS

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Summary

Presented in his work is the author's conception of implementing the methodology of machine state genesis In the form of a computer program 'State Genesis'. Separate modules of the program are described along with the results of their work.

Keywords: machnine's state genesis, diagnostic parameters, technical state.

IMPLEMENTACJA METODYKI GENEZOWANIA STANU MASZYN

Streszczenie

W pracy przedstawiono koncepcję implementacji opracowanej przez autorkę metodyki genezowania stanu maszyn w postaci programu komputerowego „Genezowanie stanu". Opisano poszczególne moduły programu komputerowego oraz wyniki ich działania.

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

1. INTRODUCTION

Implementation is part of a decision-making process, consisting in realizing a made decision by of properly chosen means [5], in this case it is creating a computer program based on genesis methodology [5]. The range of the implementation of machine state genesis methodology procedures was created on the basis of the machine state Genesis methodology algorithm, that is:

a) examining the diagnostic parameters set in the aspect of determining the optimal set of diagnostic parameters for the genesis of diagnostic parameters values;
b) examining the quality of genesis in the aspect of:
  - determining the genesis method according to the genesis mistake function,
  - examining the influence of the number of diagnostic parameters set on the genesis mistake.

The algorithm of machine state genesis process has four stages [5]:

1.1. Data acquisition

During data acquisition the following are obtained:

a) set of diagnostic parameters values in the function of machine exploitation time $\{y_j(\Theta_k)\}$, obtained in the time of realization of the passive-active experiment where $\Theta_k \in (\Theta_1, \Theta_b)$;
b) set of diagnostic parameters values: $\{y_j(\Theta_1)\}$ – nominal values, $\{y_{jg}\}$ – boundary values, j=1, …, m;
c) set of machine states $\{\Theta_k$: $\{s_i\}$, k=1, …, K; i=1,…, I$\}$ obtained in the time of realization of the passive-active experiment where $\Theta_k \in (\Theta_1, \Theta_b)$;
d) diagnostic parameters cost $c(y_j)$ = const.

1.2. Diagnostic parameters values set optimization

Diagnostic parameters set is derived with:

a) correlation method of diagnostic parameters values with the machine state (with exploitation time, $r_j = r(W, y_j)$, $(r_j = r((\Theta, y_j))$;
b) method of information quantity of diagnostic parameters on the machine state h_j;
c) diagnostic parameters set reduction.

1.3. State genesis – determining the cause of state $s_i(T_{LU})$ occurrence located during the realization of the test T_{LU}:

1. Genesis of the diagnostic parameters set value $\{y_j^*\}$:

a) with approximation method of diagnostic parameter y_j^* in the time range (Θ_1,Θ_b) along with the approximation mistake radius of the 'mistake channel' $r_{j,a}$ with methods (mean-square method, trigonometric method);
b) with interpolation of diagnostic parameter value y_j^* In the time range (Θ_1,Θ_b) along with the interpolation mistake radius of the 'mistake channel' $r_{j,int}$ with methods (combined functions method);
c) the choice of method according to the minimum value of interpolation or approximation mistake radius (adjustment mistake);

2. Analysis of the cause of the state $s_i(T_{LU})$ occurrence:

a) presentation of the set $\{s_i(\Theta_k), i=1,\ldots, 1; k=1, \ldots, K\}$;
b) estimation of the common point of 'mistake channel' determined by the mistake radius $r^*=\max(r_{j,a}, r_{j,int})$ and the boundary value of the diagnostic parameter y_j^* at the moment $\Theta_S \in (\Theta_1,\Theta_b)$, which means that the cause of the occurred located state s_i was a 'momentary occurrence' of this state at the time (Θ_1,Θ_b);
c) estimation of more common points of the 'mistake channel' determined by the mistake radius $r^*=\max(r_{j,a},r_{j,int})$ and the boundary value of the diagnostic parameter y_j^* at the moments $\Theta_s \in (\Theta_1,\Theta_b)$, which means that the cause of the located occurred state s_i was 'growing development' of the state s_i at the time (Θ_1,Θ_b);
d) in case of absence of common points, estimation of the minimum distance between the 'mistake channel' and the boundary value at the moment $\Theta_S \in (\Theta_1,\Theta_b)$, which means that a probable cause of the located occurred state s_i was a 'momentary occurrence' of this state at the time (Θ_1,Θ_b);
e) analysis of the elements of the states set $\{s_i(\Theta_k), k=1, \ldots, K\}$ and located by T_{LU} state $s_i(\Theta_b)$ in order to determine the cause of its occurrence in the context of obtained 'common points' or the minimum distance of 'approximations';
f) estimation of the disability state $s_i(\Theta_b)$ through examining the dependence of circumstances of minimum distance occurrence d_{min} for the analyzed states $s_i = \{\{s_i(\Theta_k))$ in the context of a momentary occurrence of the state s_i in the past, and the conditions of the state s_i occurrence (load, terrain conditions, climate conditions).

Based on the above ascertations and using the computer analysis results in machine diagnostics [1, 2, 3], tasks for implementation were formulated, that is:

1. Measurement data acquisition:
   a) data input;
   b) data import from other databese systems or text files;
   c) data edition;
   d) saving the introduced data in the database;
2. Diagnostic parameters set optimization;
3. Machine state genesis:
   a) determining the set of genesis methods;
   b) calculating the genesis value of diagnostic parameters,
   c) determining the genesis mistake,
   d) determining the minimum values of the distance between the mistake range and the boundary value of the diagnostic parameter;
   e) saving the genesis results in the database in order to perform comparative analyses;
4. Reporting and data visualization:
   a) visualization of chosen rows In the form of linear and dot diagrams;
   b) possibility to enlarge a chosen piece of the diagram;
   c) possibility to move the contents of the diagram;
   d) displaying the results of performed simulations in tabular form.

2. MODULES OF THE "STATE GENESIS" COMPUTER PROGRAM

As the result of the analysis of the above assignations, the following modules of the 'State Genesis' software were determined [5]:
a) **Data Acquisition** (insertion, edition, saving, interpolation and approximation of initial data),
b) **Diagnostic Parameters Optimization** (observation matrix, parameter-state relations, diagnostic parameters set reduction according to the 'ideal point' method);
c) **State Genesis** (genesis value, genesis mistake, determining and examining the minimal values of the distance between the mistake range and parameter boundary value, examining the cause of located machine states);
d) **Reporting** (grouping separate simulations in order to compare the results).

The created program works with Windows [4]. It was written by the author of this article in Java language with the use of Firebird 1.5 as database engine. Moreover, advanced components of the Swing packet for Java™ SE Runtime Environment 6 packet were used.

Data Acquisition

The acquisition module consists of five folds:
a) Machine Group,
b) State List,
c) Parameter List,
d) Object List,
e) Measurement List.

In the fold **Machine Group** we insert the name of a machine group and the unit operating for his group, NR_GRUPY (Group No) is assigned automatically after approving changes with the button Zapisz Zmiany (Save Changes).

In the fold **State List** we can insert possible states for the chosen group of machines, NR_LISTY_STANÓW (State List No) is assigned automatically and is unrepeatable in the fold Lista Stanów (State List).

In the fold **Object List** and the fold **Parameter List**, we can insert possible object and parameter names for the chosen machine group (Fig. 3) with simultaneous possibility of their removal.

In the fold **Measurement List**, there is a possibility to insert diagnostic parameters for chosen objects, diagnostic parameters values can be keyed in (Nowy Wiersz (New Line) button) or inserted with the use of CSV file – after choosing, from the menu for Measurement List, the option 'load diagnostic parameters for one object'.

Summing up, the acquisition module allows to assign machines, systems or arrangements to machine groups, and to acquire diagnostic parameters values and machine states for appropriate times (mileages). The possibility to redefine the number of diagnostic parameters of machine groups has been anticipated (boundary values changes, cost changes, name changes, etc., and deleting or adding another diagnostic parameter).

Diagnostic Parameters Optimization

In the module **Diagnostic Parameters Optimization** the calculation of criteria functions values and diagnostic parameters weights takes place on the basis of initial data for the chosen object, with the possibility to save it in a text file.

The set of diagnostic parameters is estimated with the use of:

a) correlation method of diagnostic parameters values with the machine state;
b) quantity method of diagnostic parameters information on the machine state h_j;
c) in order to choose the diagnostic parameters set, the weight values w_l are used.

As the criterion to choose the diagnostic parameter(s), the maximization of w_l weight values and chosen diagnostic parameters according to this criterion have been accepted. For each diagnostic parameter, the values of linear correlation coefficient and the indicator of information quantity are calculated.

State Genesis

In this module the following take place:

- estimation of diagnostic parameter genesis value and genesis mistake;
- estimation of the minimum distance between diagnostic parameter genesis value and its boundary value;
- examination of the influence of exploitation factors (parameter number, time row size) on state genesis;
- visualization and saving of approximation or interpolation functions for chosen parameters of the chosen object in the form of a drawing;
- calculation of ranges between diagnostic parameter genesis value and diagnostic parameter boundary value.

The estimation of diagnostic parameter genesis value and the determination of the cause of the incapacity state s_i at the moment of machine examination are estimated with the use of the algorithm presented above, i.e.:

1. Value genesis of the diagnostic parameters set $\{y_j^*\}$:

- with the use of approximation methods of diagnostic parameter values y_j^*;
- with the use of interpolation methods of diagnostic parameter values y_j^*;
- the choice of a method according to the minimum value of the radius of approximation or interpolation mistake e_G;

2. The analysis of the cause of the state $s_i(T_{LU})$ located during the realization of the diagnostic test T_{LU}, through the presentation of the set $\{s_i(\Theta_k), i=1,\ldots,1; k=1,\ldots,K\}$ in the range $\Theta_K \in (\Theta_1, \Theta_b)$ and its analysis in order to:

- determine the common point of 'mistake channel' estimated by the mistake radius r^*_j and the boundary value of the diagnostic parameter y_j^* at the moment $\Theta_S \in (\Theta_1, \Theta_b)$, $d_{min}=0$ (Fig. 1, 2);
- determine a larger number of common points of 'mistake channel' (e.g. n – points) estimated by the mistake radius r^*_j and the boundary value of the diagnostic parameter y_j^* at moments $\Theta_S \in (\Theta_1, \Theta_b)$, $nd_{min}=0$ (Fig.2);
- determine the minimum distance of 'mistake channel' from the boundary value at the moment $\Theta_S \in (\Theta_1, \Theta_b)$, $d_{min}<0$ (Fig. 3);

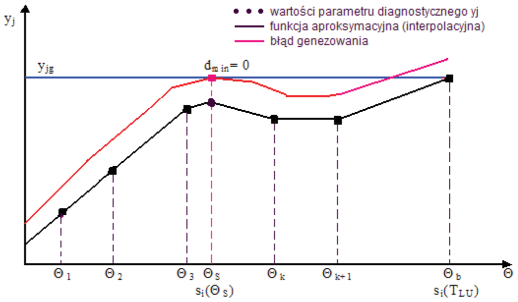

Fig. 1. Interpretation of machine state genesis for one common point (d_{min}=0)

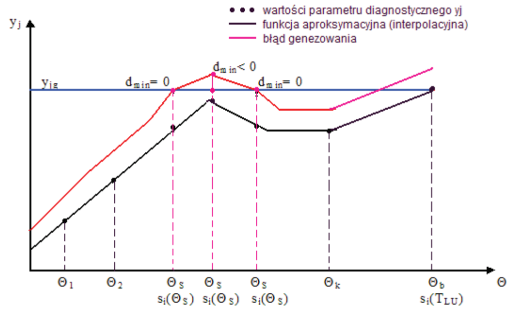

Fig. 2. Interpretation of machine state genesis for n common points ($n(d_{min}=0)$) and for $d_{min}<0$

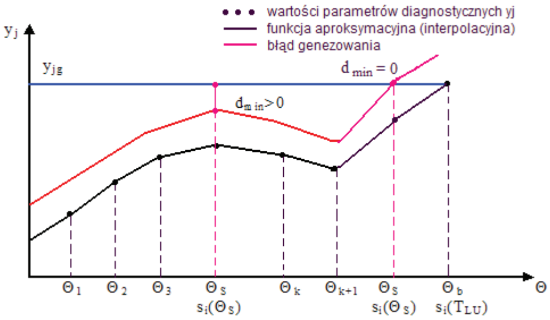

Fig. 3. Interpretation of machine state genesis for $d_{min}>0$ and one common point (d_{min}=0)

- analyze the elements of state set $\{s_i(\Theta_k), k=1,\ldots,K\}$ and state set $\{s_i(\Theta_S)\}$, and the located state

$s_i(T_{LU})$ in order to determine the cause of its occurrence.

For each diagnostic parameter chosen in the module 'Diagnostic Parameters', estimated is the number of "approximations" of the approximated (interpolated) value of the diagnostic parameter with the calculated genesis mistake $e_{Gj} = \max(r_{j,a}, r_{j,int})$ to the diagnostic parameter boundary value y_{jg} ($d_{min}= 0$, $nd_{min}= 0$, $d_{min}> 0$, $d_{min}< 0$). At the same time, the list of states $\{s_i(\Theta_k)\}$ appears, which were determined in the module 'Data Acquisition'.

The analysis of the number of "approximations" (minimum values d_{min}) and respective to them states $s_i\in\{s_i(\Theta_k)\}$ and the conditions of their occurrence (load, terrain conditions, climate conditions, others) allows to determine the cause of the state $s_i(T_{LU})$, noticed at the moment of machine examination Θ_b. It stems from the following assumptions:

a) if we know the states $s_i\in\{s_i(\Theta_k), \Theta_k\in(\Theta_1,\Theta_b)\}$ and the conditions of their occurrence, and a single common point of the 'mistake channel' ($d_{min}=0$) at the moment Θ_S are distinguished by the state $s_i(\Theta_S)=s_i(T_{LU})$, then the cause of the occurrence of the state $s_i(T_{LU})$ were the circumstances and conditions estimated for the state $s_i(\Theta_S)$ and "momentary occurrence" of the state at the time (Θ_1,Θ_b);

b) if we know the states $s_i\in\{s_i(\Theta_k), \Theta_k\in(\Theta_1,\Theta_b)\}$ and the conditions of their occurrence, and many common points of the 'mistake channel' ($nd_{min}=0$, $d_{min}<0$) at the moment Θ_S are distinguished by the state $s_i(\Theta_S)=s_i(T_{LU})$, then the cause of the occurrence of $s_i(T_{LU})$ were the circumstances and conditions estimated for the state $s_i(\Theta_S)$ and "growing development" of this state at the time (Θ_1,Θ_b);

c) if we know the states $s_i\in\{s_i(\Theta_k), \Theta_k\in(\Theta_1,\Theta_b)\}$ and the conditions of their occurrence, and the minimum distance $d_{min}>0$ (Fig. 4.10) At the moment Θ_S is distinguished by the state $s_i(\Theta_S)=s_i(T_{LU})$, then the cause of the occurrence of $s_i(T_{LU})$ were the circumstances and conditions estimated for the state $s_i(\Theta_S)$ and "momentary incomplete occurrence" of this state at the time (Θ_1,Θ_b);

d) if we do not know the states $s_i\in\{s_i(\Theta_k), \Theta_k\in(\Theta_1,\Theta_b)\}$ and we know the conditions of the machine exploitation in the time range (Θ_1,Θ_b) and the value of the minimum distance $d_{min}= (d_{min}=0 \lor d_{min}>0 \lor d_{min}<0)$ at the moment Θ_S is approximate (with a mistake about 10%) to the value $d_{min}(s_i(T_{LU}))$, then it is possible to determine the cause of the occurrence of the state $s_i(T_{LU})$, as these will probably be the circumstances and conditions estimated for the moment Θ_S;

e) if we do not know the states $s_i\in\{s_i(\Theta_k), \Theta_k\in(\Theta_1,\Theta_b)\}$ and we do not know the conditions of the machine exploitation in the time range (Θ_1,Θ_b) and the value of the minimum distance $d_{min}= (d_{min}=0 \lor d_{min}>0 \lor d_{min}<0)$ at the moment Θ_S is not approximate (with a mistake about 10%) to the value $d_{min}(s_i(T_{LU}))$, then it is not possible to determine the cause of the state occurrence $s_i(T_{LU})$.

The presented options of the state $s_i(T_{LU})$ occurrence estimation are limited with accepting many conditions connected with the process of machine exploitation. The result is that it is necessary to verify them on the basis of examinations of chosen machine systems.

Reporting

The following results of simulation researches of the genesis procedures of machine groups or machine object states are presented:

1. Optimal set of diagnostic parameters with the values of linear correlation coefficient $r_j = r(\Theta_i, y_j)$, the coefficient of the information capacity of the diagnostic parameter h_j and the weight w_{1j};
2. State Genesis. Data allowing to interpret and account for the cause of the located during the examination state $s_i(T_{LU})$: "Working time (mileage)", "Machine state", "Weight w_{1j}", "Genesis mistake for the genesis method of diagnostic parameters values", "Description of approximations to (distances from) the diagnostic parameter boundary value" and "Minimum distance d_{min} with the graph of state genesis interpretation".

Reporting is done by grouping separate simulations in order to compare results, and by visualizing data through drawing chosen rows in the form of linear graphs. There is also the possibility to enlarge a chosen area of the graph and to present the performed simulations it in tabular form.

3. CONCLUSIONS

The crucial original achievements of the 'State Genesis' computer program are the options:

a) diagnostic parameters set examinations in the aspect of estimating the optimal set of diagnostic parameters for their value genesis;

b) state genesis methodology researches:
   - estimating the genesis method according to the function of genesis mistake,
   - estimating the cause of the machine independence state $s_i(T_{LU})$ on the basis of examining the distance between the diagnostic parameter genesis value with the genesis mistake and the diagnostic parameter boundary value, and estimating the minimum value d_{min} at the moment Θ_S,
   - analyzing the set elements of the state $\{s_i(\Theta_S)\}$ and the state $s_i(T_{LU})$ In order to determine the cause of its occurrence.

The created program was used to verify machine state genesis methodology, which is aimed at confirming the soundness of their utilization for the estimation of the machine's disability cause located during the machine's examination.

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