THE ESTIMATION OF THE CAUSE OF THE MACHINES DAMAGES

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Summary
In this paper we introduce problem of determining algorithms for state genesis which is the basis for rules creating of machine state estimation in the past.

Keywords: machine state genesis, procedure algorithmization, conclusion rules.

SZACOWANIE PRZYCZYNY USZKODZENIA MASZYN

Streszczenie
W artykule przedstawiono problemy związane z określeniem algorytmów genezowania stanu, które są podstawą do wyznaczania reguł wnioskowania dla oszacowania stanu maszyny w przeszłości.

Słowa kluczowe: genezowanie stanu maszyn, algorytmizacja procedur, reguły wnioskowania.

1. PROBLEM CHARACTERISTICS

Usage in exploitation process of machine condition genesis methods, being the basis of state recognition process automatization, requires among others the optimization of diagnostic parameters set and genesis methods. The solution of these problems depends on many factors connected with the level of machine complexity, using multi-symptom observations, the quality of exploitation process, and wear process.

Machine state genesis is a process which enable to foreseeing the machine's state in the past, basis on an incomplete history of diagnostic researches results. It enables to estimate the machine's state in the past or to determine the cause of machine's disability determined at the moment of examination. In the state genesis process, very important problem is to choice:

a) diagnostic parameters set in relation to the machine's working time, value of time step, and the size of an optimal set of diagnostic parameters;
b) 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 problem of examining the above problems in the process of machines condition 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 condition genesis, and stemming from them conclusion rules.

2. OPTIMIZATION PROCEDURE FOR DIAGNOSTIC PARAMETERS SET

Set of diagnostic parameters is distinguished from the set of output parameters. Basis on researches results,, aiming at confirming some suggestions included in works concerning diagnostic information reduction in prognosis process, it is considered that the determination of diagnostic parameters set in prognosis process should include:

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

The postulates above can be presented as methods. These are: the correlation method of diagnostic parameters values with the machines state, and the method of informational capacity of a diagnostic parameter. An advantage of these methods is that they allow to choose single-element and multi-element sets of diagnostic parameters from the set of output parameters. A single-element set refers case, when the machine is decomposed into units and it is necessary to choose one diagnostic parameter. A multi-element set is obtained when in presented procedures less strict limitation is used consisting in qualifying into the diagnostic parameters set those parameters whose indicator values are higher (lower) than accepted, respectively for the method, small (large) positive numbers.

The estimation methodology algorithm of the optimal machines diagnostic parameters set consists stages:

1. Data acquisition:
   a) the set of diagnostic parameters in the function of machine exploitation time $\{y_j(\Theta_k)\}$, obtained in the time of passive-active experiment performance, 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, …, m;
   c) the set of machine states $\{\Theta_k: \{s_i\}, k=1, …, K; i=1,…, I\}$ obtained during the realization of the passive-active experiment, where $\Theta_k \in (\Theta_1, \Theta_b)$;
2. Optimization of diagnostic parameters set values (only in case of a large size of the set Y, e.g. m>10). The set of diagnostic parameters is estimated with the help 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.

As the result of output parameters set optimization, in order to choose a diagnostic parameters set, the weight values are obtained:

   a) calculation weights w_{1j};
   b) as the criterion for choosing a diagnostic parameter (diagnostic parameters), the maximization of weight values w_{1j} was accepted, and choosing diagnostic parameters according to the above criterion.
   c) in order to consider the user's preferences, it is possible for him/her to insert weights w_2 (standardized values) from the range (0,1), and choosing diagnostic parameters according to the above criterion.

3. THE PROCEDURE OF MACHINE STATE GENESIS

Problems appearing during the machine's technical state genesis process come down to:

1. The analysis of being the subject machine genesis, i.e. the process of its technical state deterioration, the determination of dynamics tendencies of state parameters changes, the selection of states in which the machine could be, the machine's decomposition into units and systems, the criteria of state selection and the probability of their occurrence, the selection of "the best" diagnostic parameters describing the machine's state change.
2. The selection of "the best" method of state genesis determination.
3. The use of information I_G, acquired from the state genesis for the analysis of the present state cause of the machine at the moment of machine examination.

The machine's technical state genesis should consist in the determination (with complete and incomplete data) of diagnostic parameters trend of values changes, characterizing the process of the machine's technical state deterioration in the past, comparing instantaneous values of diagnostic parameters to boundary values and on this basis estimating the time of reliable work of the machine's systems and units in interesting for the user past time of the machine's exploitation, or the analysis of the cause of the located at the moment of examining damage.

The solution of the presented postulate can be presented by the following algorithm:

1. Let the phenomenon of technical state deterioration be presented by the time row $y_t = <y_1, y_2, ..., y_b>$, then it is the set of discrete observations $\{y_\Theta = \zeta(\Theta);\ \Theta = \Theta_1, \Theta_2,..., \Theta_b\}$ of a certain non-stationary stochastic process $\zeta(t)$.
2. With the assumption that the mechanism of stochastic process values changes in time $\Theta \in (\Theta_1, \Theta_b)$ is determined by the trend $\mu(\Theta)$ interfered by random reactions $\eta(\Theta)$

$$y_\Theta = \mu(\Theta) + \eta(\Theta)\,, \tag{1}$$

where:

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

$\eta(\Theta)$ – characterizes the aberrations from the trend and expresses the effect of random factors (terrain conditions, climate conditions, operation quality).

Such estimation $\{\mu_p(\Theta)\}$ is constructed for an unknown form of the trend $\mu(\Theta)$ which would assure proper accuracy of the genesis $y_G(\Theta)$ with the interpolation (or approximation) $\mu_G(\Theta)$ on a period of the machine's work (Θ_b, Θ_G), $\Theta_G = \Theta_b - \tau_2$.

3. Estimating $\mu_G(\Theta)$ also determines values of the observed diagnostic parameters at the moment Θ_G, and thus enables the genesis of the machine's technical state $W(\Theta_G)$.
4. As the acceptable machine's exploitation state W_{dop} in the time range (Θ_b, Θ_G) the value of time is accepted, for which the boundaries of the mistake range for separate geneses $\sigma(y_t, y_G, G(y_\Theta, \tau))$ determined on the subset $\Omega^y \in \Omega$ of available realizations of the observed parameters $\{y_j(\Theta)\}$ and their geneses $\{y_{j,G}\}$ according to the accepted genesis method $G(y_\Theta, \tau)$ did not exceed with the radius of the mistake range r_G the boundary values $\{y_{j,g}\}$.

$$r_G = q\sigma_G, \tag{2}$$

where:

$q_{\gamma,K}$ - the constant parameter estimated from the Student decomposition table for the required trust level γ and K-2 of the number of degrees of freedom,

σ_G - standard aberration of the random component of genesis mistake e_G

5. In case when system operation dependent on the technical state, the required form of the machine's state genesis is the information about the time (Θ_1, Θ_b) the technical state was in accepted state W_{dop} (on this basis the machine's state in the past can be estimated). It is also proposed that the additional values of GST (machine's state genesis) are the radius of genesis mistake range r_G (Fig. 1):

$$GST = < W_{dop}, r_G > \quad (3)$$

The time range (Θ_1, Θ_b) is then the estimation period of the genesis mistake expected value e_G and the radius of the genesis mistake range $r_{\sigma G}$, and the time period Θ_b - τ_2 will be the period of the active genesis, i.e. the estimation of:

a) the genesis value of the diagnostic parameter for the genesis horizon time τ_2, $y_{jG}(\Theta_b-\tau_2)$;
b) the estimation of the range radius of the genesis mistake $r_G(\Theta_b - \tau_2)$;
c) the estimation of potential times $\{\Theta_{Gi}\}$ of the machine's entering the disability state.

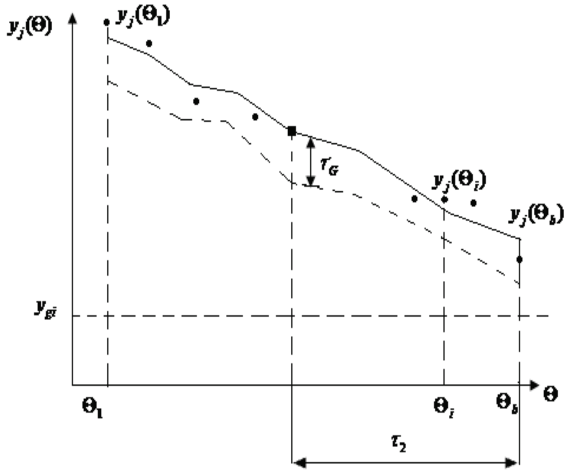

Fig. 1. Scheme of estimating the genesis diagnostic parameter value

Taking up considerations of machine state genesis [1,2,3,4,5,6,7,8,11,12], it is impossible to indicate the advantage of some genesis methods enabling the genesis of diagnostic parameters values and the estimation of machine technical state $S(\Theta_1,\Theta_b)$. It is, however, possible to apply some criteria concerning the requirement connected with:

a) genesis form (genesis value of a diagnostic parameter, estimated machine's state in the past, the value of the work done by it in the past, or another form of machine state genesis);
b) the changes influence on machine's exploitation and maintenance actions conditions over the machine's exploitation characteristics, which should be considered while choosing the genesis method;
c) possible to use genesis methods (e.g. quality methods, modified exploitation methods of trend, and modified adaptation methods).

Among the small number of methods enabling machine state genesis, two groups can be distinguished: quality methods (*situational genesis*, basis on the registered symptoms; *expert genesis* basis on the information collected from the environment) and analytical methods (approximation and interpolation methods) [2,3,4,6,7,8].

Situational genesis

In case of situational genesis, the cause of the disability is estimated basis on the visual inspection of the machine performed directly after the state's occurrence. Collected information's (situational data) are used to compare with situational data being the result of modeling of some damages. Then, data correspondent to the input situational data are searched. During modeling of a certain event, the cause is known for which the machine's disability occurred, and at the moment of damage, created in his way situational data is collected in order to create a base correspondent to some, often typical, damages. This procedure can be used at the estimation of the occurred machine's disability state through the comparison of the collected data with the situational data respective to specific events (also with the use of the user's knowledge), which enables the determination of a probable cause of the damage occurrence.

Genesis basis on the information acquired from the environment

The method consists in determining the causes of the occurred machine state basis on the information collected from witnesses relations of a certain event. For example, in car accident, it is possible to determine the cause of the accident basis on the of witnesses' relations. Another case can be the information given by the machine's operator who can provide very important data on the machine's behavior before the event. In industry, industrial cameras are often used, which can help in determining the cause of the occurred disability.

Genesis basis on the registered values of diagnostic parameters

Assuming the possibility of registering diagnostic parameters values and the machine's states in the time of its exploitation (e.g. in the time of passive–active experiment), a data base is obtained in the form of information matrix: diagnostic parameters values – machine state – exploitation time. At the moment of the machine's ability loss, there will probably be the possibility to determine, on the basis of the collected information and visual inspection of the machine, what could be the cause of the disability state occurrence.

The above presented machine state genesis methods, their synergy and the user's experience, ought to allow the creation of appropriate procedures whose realization ought to enable the machine's state genesis.The presented methods analysis of diagnostic parameters estimation genesis value, and correspondent to them genesis mistakes, allows to state that in order to estimate the diagnostic parameters genesis value on the basis of their uncertain and incomplete values from the time range (Θ_1, Θ_b), it is necessary to use:

1. Within the range of approximation methods:
   a) multinomial point mean-square approximation with the radius of genesis mistake range r_{ja}:
   $$r_{ja} = e_{Gj} = \max_{k=1,K} B = \left| y_{j,a}(\Theta_k) - y_j(\Theta_k) \right| \quad (4)$$
   b) trigonometric approximation with the radius of genesis mistake range r_{ja} :
   $$r_{ja} = e_{Gj} = \max_{k=1,K} B = \left| y_{j,a}(\Theta_k) - y_j(\Theta_k) \right| \quad (5)$$
2. Within the range of interpolation methods:
   a) interpolation with the use of combined functions type 1, 2 and 3 for the time range (Θ_1, Θ_b) of the size r_1 with the radius of genesis mistake range $r_{j,int}$ [7,9]:
   $$r_{j,int} = e_{Gj} = \max_{k=1,r2} B = \left| y_{j,int}(\Theta_k) - y_j(\Theta_k) \right| \quad (6)$$

The estimation of diagnostic parameters value, with use of above presented genesis methods, allows to determine their genesis values $\{y_{j,int}(\Theta)\}$, which then allows to formulate the below presented algorithm of machine's state genesis.

The algorithm of machine state genesis according to the scheme of estimating diagnostic parameters values includes:

1. The genesis of the diagnostic parameters value set $\{y_j^*\}$:
   a) with use of approximation method of diagnostic parameter value y_j^* in time range (Θ_1,Θ_b) with the radius of approximation mistake of the "mistake channel" r_a with methods (mean-square method, trigonometric method);
   b) with use of diagnostic parameter value interpolation y_j^* in the time range (Θ_1,Θ_b) with the radius of interpolation mistake of the "mistake channel" $r_{j,int}$ with methods (combined functions type 1, 2 and 3 method);
   c) method selection according to the minimal and maximal value of the radius of the approximation or interpolation mistake (matching mistake e_G).
2. The analysis of state occurrence cause $s_i(T_{LU})$:
   a) the presentation of the set $\{s_i(\Theta_k),\ i=1,\ldots, 1;\ k=1, \ldots, K\}$.
   b) the estimation of the common point of the "mistake channel" appointed by the mistake radius $r^*_j = \max(r_{ja}, r_{ji})$ 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 located state s_i was a "momentary occurrence" of the state at the time (Θ_1,Θ_b);
   c) the estimation of a bigger number of common points of the "mistake channel" appointed by the mistake radius $r_j = \max(r_{j,a}, r_{j,int})$ and the boundary value of the diagnostic parameter y_j^* at the moments $\Theta_s \in (\Theta_1,\Theta_b)$ means that the cause of the located state s_i was the "increasing development" of the state s_i at the time (Θ_1,Θ_b)
   d) in case of common points lack, the estimation of the minimal distance of the "mistake channel" from the boundary value at the moment $\Theta_S \in (\Theta_1,\Theta_b)$, which means that the probable cause of the located state s_i was a "momentary incomplete appearance" of this state at the time (Θ_1,Θ_b);
   e) the analysis of the identity of state sets $\{s_i(\Theta_k),\ k=1, \ldots, K\}$and located by T_{LU} state s_i in order to determine the cause of its occurrence in the context of the obtained potential "common points" or the minimal distance of "approximations".

The presentation of different possibilities to determine the machines' state genesis allows to formulate the following conclusions:

1. All the algorithms allow to estimate the optimal, as far as the accepted criterion is concerned, diagnostic parameters genesis values in the time range (Θ_1,Θ_b), whilst for further research it is proposed to:
   a) use approximation methods of the diagnostic parameter value y_j^* (mean-square method, trigonometric method), with the radius of approximation mistake of the "mistake channel" $r_{j,a}$;
   b) use interpolation methods of the diagnostic parameter value y_j^* (combined functions of different types method) with the radius of interpolation mistake of the "mistake channel" $r_{j,int}$;
   c) select the method according to the minimal and maximal value of the radius of the approximation or interpolation mistake (matching mistake).
2. Analysis methods of the state occurrence cause $s_i(T_{LU})$:
   a) the estimation of the common point of the "mistake channel" appointed by the mistake radius $r^*_j = \max(r_{ja}, r_{ji})$ 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 located state s_i was a "momentary occurrence" of the state at the time (Θ_1,Θ_b);
   b) the estimation of a bigger number of common points of the "mistake channel" appointed by the mistake radius $r^*_j = \max(r_{ja}, r_{ji})$ and the boundary value of the diagnostic parameter y_j^* at the moments $\Theta_s \in (\Theta_1,\Theta_b)$ means that the cause of the located state s_i

was the "increasing development" of the state s_i at the time (Θ_1,Θ_b);

c) in case of common points lack, the estimation of the minimal distance of the "mistake channel" from the boundary value at the moment $\Theta_S \in (\Theta_1,\Theta_b)$, which means that the probable cause of the located state s_i was a "momentary incomplete appearance" of this state at the time (Θ_1,Θ_b);

d) the analysis of the identity of state sets {s_i (Θ_k), k=1, …, K} and located by T_{LU} state s_i in order to determine the cause of its occurrence in the context of the obtained potential "common points" or the minimal distance of "approximations".

4. THE PROCEDURE OF MACHINE STATE GENESIS EXAMINATION

Examining the procedures includes:

a) examining the diagnostic parameters set in the aspect of estimating an optimal set of diagnostic parameters for diagnostic parameters values genesis according to the algorithm (point 2);

b) estimating genesis methods of diagnostic parameters values according to the algorithm (point 3);

c) examining the genesis value of diagnostic parameters with the genesis mistake, and the manner of estimating the cause of the machine's disability state depending on the following parameters:
   - genesis method of diagnostic parameters values,
   - the size of diagnostic parameters set,
   - genesis horizon.

In order to obtain measurement data for procedure researches, the set of diagnostic parameters Y_1 was used from exploitation researches of the combustion engine of the car Star 11422 [7] in the form of time rows whose elements are the values of diagnostic parameters of fumes analysis: CO – carbon oxide [ppm], CO_2 – carbon dioxide [ppm], NO – nitro oxide [ppm], NO_2 – nitro dioxide [ppm], NOx – nitro oxides [ppm], CxHx - hydrocarbons [ppm], K - smoking [1/m]. xamining the procedure of estimating an optimal set of diagnostic parameters for the prognosis of diagnostic parameters values consisted in estimating an optimal set of diagnostic parameters according to the algorithm (point 2).

Tab. 1. Set of Diagnostic Parameters for the Object S11422_1

Diagnostic Parameters Matrix for S11422_1				
PAR	**NAME**	**RJ**	**DJI**	**W1J**
NO_2	Nitro dioxide	0,75	0,01	0,922
K	Fume smoking	0,64	0,30	0,030
CxHx	Nitrocarbons	0,48	0,67	0,013
NOx	Nitro oxides	0,32	0,99	0,009
CO	Carbon oxide	0,28	1,05	0,008
CO_2	Carbon dioxide	0,22	1,14	0,008
NO	Nitro oxide	0,11	1,29	0,007

For the set of output parameters Y_1, the set of diagnostic parameters with appropriate weight values was obtained (Table 1).
Result analysis for the object S11422_1 showed that the highest weight values w_{j1} are possessed by the diagnostic parameters (NO_2, K, CxHx), and the lowest weight values w_{j1} by the diagnostic parameters (CO_2, NOx). In order to optimize the diagnostic parameters set for the object S11422 (parameters number, the value of the weight w_{1j}), it is advised to accept diagnostic parameters of weight values $w_{1j} \geq 0{,}01$ (a 3-element set is obtained).

In case for a rest objects of the Star11422 group, the highest and lowest values of the weight w_{j1} are possessed by different diagnostic parameters: the highest: CxHx, K, CO, NOx, (it is advised to accept diagnostic parameters of weight values $w_{1j} \geq 0{,}02$ – 2-, 3- and 4-element sets are obtained), the lowest: CO_2, NO with weight values $w_{1j} \leq 0{,}01$;
Summing up the performed researches of diagnostic parameters optimization procedures for engines of cars Star11422, it is stated that:

a) in genesis procedures researches of machine state, it is suggested to accept diagnostic parameters of weight values $w_{1j} \geq 0{,}07$ and corresponding to it size of the set;

b) it is also suggested to consider a single-element set of diagnostic parameters for which the weight w_{1j} takes maximum value;

c) the accepted optimization criteria unambiguously identify the sets of parameter values having the largest quantity of information on the technical state and the variables in exploitation time of the cars Star 11422 combustion engines.

Examining the genesis procedure of the state for the engines of cars Star11422 in the aspect of determining the genesis method of diagnostic parameter value according to the genesis mistake function, examining the influence of the size of the diagnostic parameters set on the genesis mistake, as well as examining the manner of determining the cause of the disability state on the basis of the genesis value of the diagnostic parameter realized on the basis of:
1. Estimating the genesis methods of diagnostic parameters values, and the manner of determining the cause of the appearance of the disability state at the moment of machine's examination according to

the algorithm (point 3). For the set of diagnostic parameters, obtained was a visualization of values changes of chosen diagnostic parameters of the highest weight values in the function of the accepted working time for the analyzed methods of approximation and interpolation. Example visualizations for the object S11422 and the parameter NO_2 are shown in the Fig. 2. Example data enabling the analysis of values of the analyzed parameters In order to estimate the machine state – diagnostic parameters function value correlation for the genesis method of diagnostic parameters values of the lowest genesis mistake value.

The analysis of results showed that:

a) for S11422_1 different best (according to the minimum value of the genesis mistake) genesis methods for diagnostic parameters are obtained:
   - for NO_2 – interpolation method of 1 degree (genesis mistake = 10,9%),
   - for K – interpolation method of 1 degree (genesis mistake = 8,7%),
   - for CxHx – approximation method of 2 degree (genesis mistake = 27,7%);

b) in the other objects of Star11422, different best (according to the minimum value of the genesis mistake) genesis methods for diagnostic parameters are obtained (CxHx, K, CO, NOx). Respectively obtained are: for CxHx – interpolation method of 1 degree (genesis mistake = 7,4%), for K – approximation method of 2 degree (genesis mistake = 6,6%), for CO – interpolation method of 1 degree (genesis mistake = 2,9%), for NOx – interpolation method of 1 degree (genesis mistake = 5,1%);

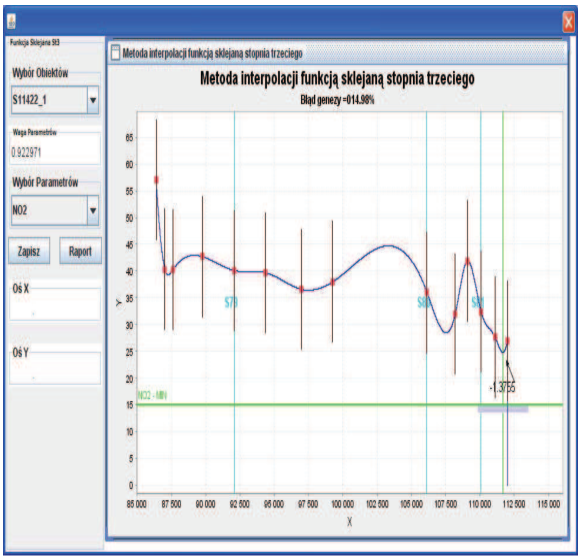

Fig. 2. Estimating the genesis value of the parameter NO_2 (weight w_1=0,9229) for the interpolation with the combined function, type 3

c) in order to determine the cause of the machine's disability basis on the distance of the genesis value of diagnostic parameters with genesis mistake from the diagnostic parameter boundary value for the group objects: Star266, Star11422, the algorithm (point 3) was used: diagnostic parameters analysis according to the maximum weight value, the analysis of genesis methods of diagnostic parameter value according to the minimum genesis mistake, estimating the minimum distance from the boundary value; for S11422 interpolation method of 1 degree is obtained, K parameter (distance = 1,9);

d) an alternative solution can be analyzed of genesis methods only for parameters of the highest weight values, which causes changes in the area of genesis method, diagnostic parameter, and the distance from the value.

Summing up the performed researches of the machine state genesis procedure, it is stated that:

a) as the result of machine state genesis procedures researches, it was concluded that it is necessary to accept diagnostic parameters (algorithm – point 2) and genesis methods according to the algorithm (point 3) as shown above;

a) the accepted optimization criteria and the presented algorithm unambiguously identify diagnostic parameter enabling the determination of the cause of the disability state, which confirms the propriety of the formulated procedure and ought to enable the formulation of appropriate diagnostic conclusion rules in the range

The analysis of machine state prognosis methodology research results allows to formulate dedicated conclusion rules of type "IF – THEN" or "IF – THEN – ELSE" in the area of:

a) diagnostic parameters optimization;
b) state genesis.

In case of the combustion engines of cars Star11422, the generated conclusion rules have form:

a) for the diagnostic parameters optimization set of Y^o:
   - if $w_{1j} \geq 0{,}07$ then $y_j \in Y^o$,
   - or if $w_{1j} = w_{1jmax}$ then $y_j \in Y^o$;

b) for state genesis:
   - if there is a combustion engine probable damages set Star11422 cars, the determination of the set of its disability states according to the level of probability of appearing damages according to the rule: if $p(s_i) \geq 0{,}5$ then $s_i \in S$,
   - if there is not a combustion engine probable damages set Star11422 cars, the determination of the set of its disability states according to the value of

exploitation measurement: if $\Theta_i \geq \Theta_l$ then $s_i(\Theta_l) \in S$,

- if the genesis mistake of the approximation method type 2 for the set Y^o ≤ genesis mistake of the interpolation method type 1 for the set Y^o, then the genesis method of the value of the set Y^o is the interpolation method type 1, otherwise the genesis method of the value of the set Y^o is the approximation method type 2,
- if the distance of the genesis value of the diagnostic parameter $y_j \in Y^o$ with the genesis mistake from the parameter boundary value y_{jg}: d(y_{jg} – value ($y_{jG} + r_G$) for $y_{jG} > y_{jG}$), d(value (y_{jg} – ($y_{jG} - r_G$) for $y_{jG} < y_{jG}$) then the minimum value d(•) is the minimum distance d_{min},
- if $d_{min} = 0$, then there is one common point with the boundary value (size [d_{min}] = 1), if $d_{min} < 0$, then there are more than one common points with the boundary value (size [d_{min}] > 1), if $d_{min} > 0$, then there are no common points with the boundary value,
- if $d_{min} = d_{min}(\Theta(s_i))$, then the minimum value $d^s_{min} = d_{min}$ appears at the state in the time $\Theta_S \in (\Theta_1, \Theta_b)$, chich means that the cause of the located state s_i In the time of realization of the test T_{LU} was a "momentary appearance" of his state in the time (Θ_1, Θ_b)), otherwise d_{min} # d_{min} (Θ (s_i)), which means it is impossible to determine the cause of the state s_i estimated during the realization of the test T_{LU},
- if the size [d^s_{min}] > 1, it means that the cause of the located state s_i was an "increasing development" in the time $\Theta_S \in (\Theta_1, \Theta_b)$ of the conditions of the state appearance s_i (estimated during the realization of the test T_{LU}),
- if $d_{min} > 0$ and there is no common point with the boundary value, then it means that the probable cause of the located state s_i (estimated during the realization of the test T_{LU}) was a "momentary incomplete appearance" of the state in the time (Θ_1, Θ_b);

The presented conclusion rules in the range of machine state genesis, after performing appropriate verification researches, could be basis for dedicated software of a machine state recognition system in an on–line mode (for an on-board system) and off–line (for a stationary system).

5. CONCLUSION

This paper shows machine state genesis procedures that allows to formulate the following conclusions:

1. The presented procedures allow to determine optimal, as far as the accepted criterion is concerned:
   a) diagnostic parameters set;
   b) diagnostic parameters values genesis and the estimation of the cause of the machine's disability state.
2. In order to determine the set of diagnostic parameters and state genesis, the above presented procedures can be the basis for estimating conclusion rules in the range of:
   a) determining an optimal set of diagnostic parameters;
   b) estimating the values of diagnostic parameters in the past, and estimating the cause of the disability state located during the machine examination.

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