

ANALYSIS OF THE OPTIMIZATION MODEL OF TECHNICAL DIAGNOSTIC PROCEDURE OF HYDRO POWER PLANT

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Abstract: The aim of mathematical model is to choose diagnostic parameters which condition knowledge of allowed level of reliability and determined analytic expression which corresponds to precisely described condition of hydroelectric power plant components complex. Model of technical diagnostic procedures optimization is a specific approach to the problematics of preventive maintaining according to condition, and it is related to the conception of condition parameters change which represent a base for optimal solution for procedures of technical diagnostic of power plant components it also makes direct relations between the law of condition parameter change and reliability of the observed power plant components complex.

Key words: model, optimization, technical diagnostic, mechanic oscillation, temperature, worn out of bearings, components, parameters, correlations.

1. INTRODUCTION

The forming of universal model of optimization of procedures of technical diagnostic of composing components of power plants included the most significant parameters of theoretic and experimental analysis. The starting during the analyzing of parameters optimization was the total of noted failures of composing components. By analyzing the model we show up to which border values of universal equation in cases with or without applying parameters of power plant technical diagnostic procedures optimization. Also, to construct the curve whose values are presented in the correlation dependence diagram: mechanic oscillation and temperature, mechanic oscillation and bearings worn out and temperature and bearings worn out.

2. MODELS AND PROBLEMS POWER PLANT TECHNICAL DIAGNOSTIC PROCEDURES OPTIMIZATION

The optimization of technical diagnostic procedures is defined by the strategy of the process of finding out the power plant components condition and its division among complex components. It demands balance among long term aims non-precision of available data on power plant composing components performances.

The methodology of optimization, of technical diagnostic procedures is presented by the algorithm and condition of work analysis at determining the safety of power plant composing components functioning. For determining the optimal safety reliability of composing components performing on the basis of noted failures was taken: the number of failures (h) of power plant composing components on the basis of the beginning condition level and analysis of exploiting conditions of power plant composing components performing.

The model describes technical procedures optimization problems which is analytic or numeric interpretation of specific values during describing and functioning of power plant components performing. It also presents idealised picture of reality and parameters which influence solving specific actions and problems of power plant composing components performing.

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The model determines the connection of the periodicability of parameters condition control, and with it successfully is applied the analysis of technical diagnostic procedures optimization in providing of desired level of reliability and fulfillment of specific performing conditions. With it is also determined portative function of incoming parameters of failure according to outgoing function which includes the analysis of the model on the basis of resulting spacial curves.

The procedures and places of measurements of composing components of HE "Vrta - 3" and Derdap II are presented aiming to determine general condition of power plant composing components, to determine its behaviour and develop a plan of preventive measures with surprising components failures [2]. The measures of mechanical oscillation on turbine shaft, the measures of bearings temperature and observed worn out of bearings were taken during their life time aiming their reliability.

Examining the unincited generator when idle we check unbalance of a rotary. The shaft rotation speed usually changes in this way: 60, 80, 100, 115 and 130% from nominal. In case of bad rotary balance the amplitude of oscillation changes with the frequency square $A = f(f^2(t))$ of rotation. The examination with speeds less than 50% than normal is not recommended because of worse conditions for lubrication of bearings and danger of bearings surfaces damaging. Based on certain reliability values $N_7(t)_p, N_8(t)_p, N_9(t)_p, N_4(t)_p, N_6(t)_p$ change values can be determined $\eta_{1p} = N_7(t)_p \cdot N_8(t)_p \cdot N_9(t)_p \cdot \eta_{2p}$ [2].

Based on all determined parameters we get extreme values of universal equation of optimization with using mechanical oscillation parameters on chosen measuring places of power plant complexes. Also, based on shown and calculated values, we graphically get dependence $S_\eta(t) = f(P_{ti}(t) = \varphi(z) = N_i(t)\omega_i(t)A_i(t))_{\max, \min, opt, sr}$ which at the same time connect parameters of reliability optimization ($P_{ti}(t) = \varphi(z) = N_i(t, \eta_i)$) and mechanical oscillation ($\omega_i(t), A_i(t)$) [2].

Based on exploiting data of determined bearings working temperatures values, an interval of statistic assembly ($68^\circ\text{C} \leq T_i \leq 71^\circ\text{C}$) and certain showings of exploiting deviation. There are determined regions of safe optimal work and bearings risk, too. Based on these regions extreme values of bearings working temperatures are determined ($T_{mip}, T_{\max p}, T_{srp}, T_{optp}$), [2].

The resulting model included the most important parameters of connectivity of dependence expression $S_\eta(t) = f(P_{ti}(t) = \varphi(z) = N_i(t), \omega_i(t), A_i(t))$ working temperature T_{mi} and clearance values $\bar{z}$. These values will determine correlations which are defined in the methodology of optimization of power plant technical diagnostic procedures, [2].

The model included the sub model analysis 1,2 and 3 including co related dependence changes η_1 i η_2 in take on oscillation and frequency amplitude values, extreme values of universal equation are determined $S_\eta(t)_{\max}, S_\eta(t)_{\min}, S_\eta(t)_{sr}, S_\eta(t)_{opt}$, without applying technical diagnostic optimization procedures parameters and with applying these parameters as well $S_\eta(t)_{\max p}, S_\eta(t)_{\min p}, S_\eta(t)_{srp}, S_\eta(t)_{optp}$ [2].

The optimal model analysis includes methodology with help of block diagram in determining the safety of integral components functioning of analysed power plants complexes. The methodology included monitoring system construction optimization and algorithm for constructing the model for diagnostic parameters determining (table 1.) [2]. The components are arranged by complexes, from turbine working circuit to waken, taking their functionality and intention, so reduction of complex structures of block diagrams was done.

The model analysis conducted step by step in submodel determination according to chosen measuring places for determining mechanical oscillation level, and then the structure of block scheme was done for submodel connecting on the way power plant complex of composing component move.

The model of reliability block diagram at analysed power plant complexes, at solving of this model will be done by reduction at getting the optimal reliability function $G_p(t)$. In table 2 [2] you can see a model of a reliability of composing components block diagram, and it is about the open system of automatic direction of reliability.

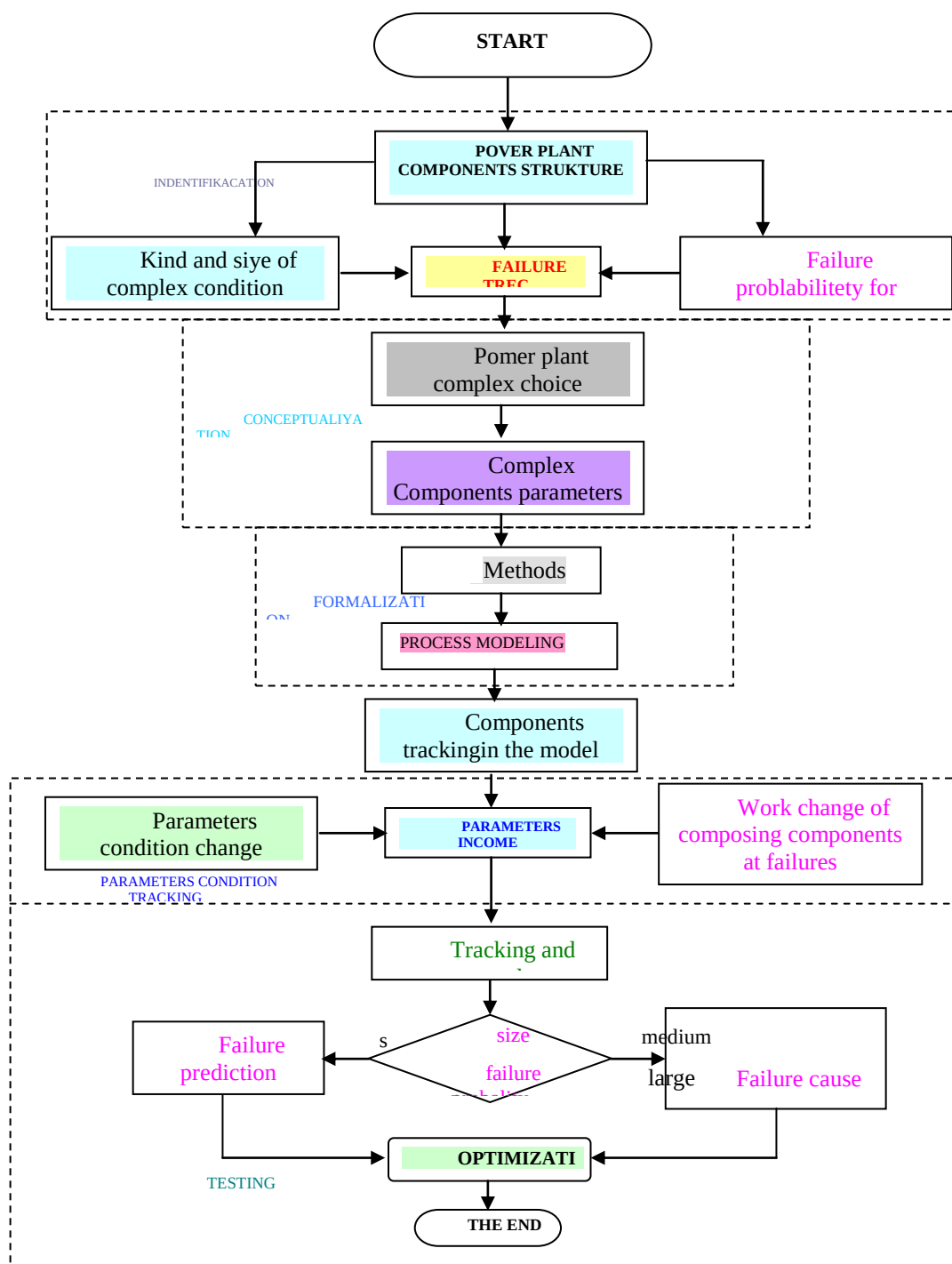


Table 1. Algorithm for tracking and determining of parameters for optimization of technical diagnostic procedures for HE "Vrta - 3" components [2]

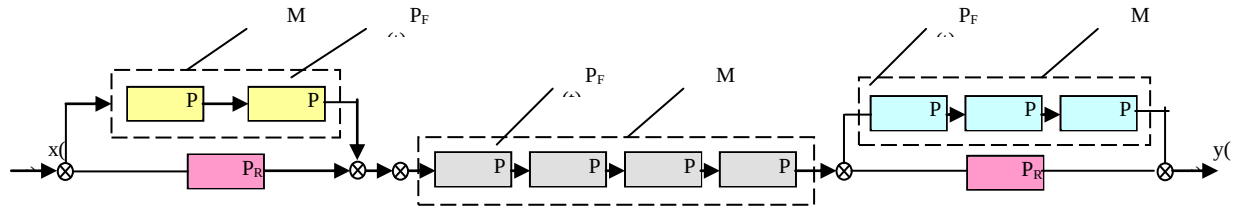


Table 2. The model of reliability block diagram at analysed power plant complex components

Where:

M_1 - measuring place for oscilation level on turbine shaft,

M_2 - measuring place for temperature on bearings,

M_3 - measuring place for bearings worn out measuring.

The model of reliability block diagram at analysed components of power plant complex according to chosen measuring places of oscilation level, table 3 [2], it is about open system of reliability automatic menagment.

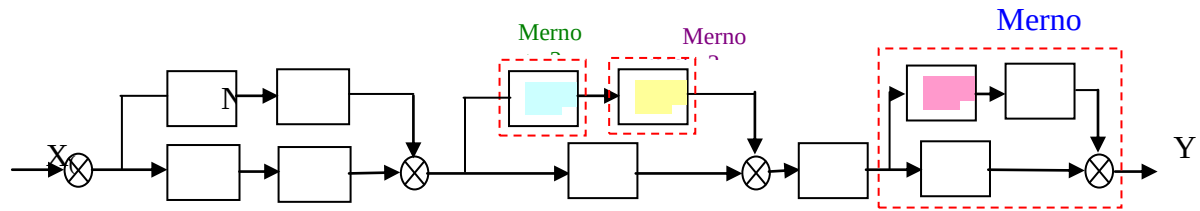


Table 3. The model of reliability block diagram at analysed components of power plant complexes according to measuring places of mechanical oscilation level, temperature and bearings worn out HE "Vrla - 3" [2]

Measuring place 1: includes components: turbine leading bearing (N_7), carbon washer (N_8) and working circuit (N_9), [2].

Competent circular speed is the biggest speed of working circuit rotation (ω_{N_9}):

$$M_{N_7} = \frac{N_7(t) \cdot A_7(t)_{N_7}}{\omega_{N_7}} \quad M_{N_8} = \frac{N_8(t) \cdot A_8(t)_{N_8}}{\omega_{N_8} = \omega_{N_7}} = \frac{N_8(t) \cdot A_7(t)_{N_7}}{\omega_{N_7}} \quad A_7(t)_{N_7} = A_8(t)_{N_8} = A_9(t)_{N_9}$$

$N_7(t)$ - reliability composing components of upper turbine bearing,

$N_8(t)$ - reliability composing components of carbon washer,

$$M_{N_9} = \frac{N_9(t) \cdot A_9(t)_{N_9}}{\omega_{N_9}} = \frac{N_9(t) \cdot A_7(t)_{N_7}}{\omega_{N_7}}$$

$N_9(t)$ - reliability of working circuit composing components.

Resulting part of submodel's measuring place 1 is:

$$S_1(t) = \frac{N_7(t) \cdot N_8(t) \cdot N_9(t) \cdot A_7^3(t)_{N_7}}{\omega_{N_7}^3 - N_7(t) \cdot N_8(t) \cdot N_9(t) \cdot A_7^3(t)_{N_7}}$$

Measuring place 2: includes composing component of lower part of generator's leading bearing $(N_6(t))$, [2].

Resulting part of submodel's measuring place 2 is:

$$S_2(t) = \frac{N_6(t) \cdot A_6(t)_{N_6}}{\omega_{N_6}}$$

Measuring place 3: includes composing component of upper generator's bearing $(N_4(t))$.

Resulting part of submodel's measuring place 3 is:

$$S_3(t) = \frac{N_4(t) \cdot A_4(t)_{N_4}}{\omega_{N_4}}$$

General safety shape of power plant composing components functioning depending on amplitude oscilation level on chosen places is expressed trough the general universal equation of optimal model which is, [2]:

$$S_\eta(t) = \frac{1}{1 - S_2(t) \cdot S_3(t)} \cdot S_1(t)$$

A part in equation $\frac{1}{1 - S_2(t) \cdot S_3(t)}$ is shown trough the return compound without considering component $N_5(t)$ - rotary, because mechanical oscilation influences are not measured on it as well as component $R_2(t)$ - regulator.

$$S_\eta(t) = \frac{S_1(t)}{1 - S_2(t) \cdot S_3(t)}$$

By mathematical arranging we get:

$$S_\eta(t) = \frac{\frac{N_7(t) \cdot N_8(t) \cdot N_9(t) \cdot A_7^3(t)_{N_7}}{\omega_{N_7}^3 - N_7(t) \cdot N_8(t) \cdot N_9(t) \cdot A_7^3(t)_{N_7}}}{1 - \frac{N_6(t) \cdot A_6(t)_{N_6}}{\omega_{N_6}} \cdot \frac{N_4(t) \cdot A_4(t)_{N_4}}{\omega_{N_4}}}$$

General form of composing components functiong equations:

$$S_\eta(t) = \left(\frac{N_7(t) \cdot N_8(t) \cdot N_9(t) \cdot A_7^3(t)_{N_7} \cdot \omega_{N_6} \cdot \omega_{N_4}}{(\omega_{N_7}^3 - N_7(t) \cdot N_8(t) \cdot N_9(t) \cdot A_7^3(t)_{N_7}) \cdot (\omega_{N_4} \cdot \omega_{N_6} - N_6(t) \cdot A_6(t)_{N_6} \cdot N_4(t) \cdot A_4(t)_{N_4})} \right)$$

By further arranging equation we get:

$$S_{\eta}(t) = N_7(t) \cdot N_8(t) \cdot N_9(t) \cdot A_7^3(t)_{N_7} \cdot \omega_{N_6} \cdot \omega_{N_4} \leq 1,0$$

$$S_{\eta}(t) = \omega_{N_7}^3 \cdot \omega_{N_4} \cdot \omega_{N_6} - \omega_{N_7}^3 N_6(t) A_6(t)_{N_6} \cdot N_4(t) \cdot A_4(t)_{N_4} - \omega_{N_4} \omega_{N_6} \cdot N_7(t) \cdot N_8(t) \cdot N_9(t) \cdot A_7^3(t)_{N_7} - N_7(t) \cdot N_8(t) \cdot N_9(t) \cdot A_7^3(t)_{N_6} \cdot A_6(t)_{N_6} \cdot N_4(t) \cdot A_4(t)_{N_4}$$

change:

$$N_7(t) \cdot N_8(t) \cdot N_9(t) = \eta_1$$

$$N_6(t) \cdot N_4(t) = \eta_2$$

Introducing change we get the expression:

$$S_{\eta}(t) \approx \frac{\eta_1 A_7^3(t)_{N_7}}{\omega_{N_7}^3 + \eta_1 A_7^3(t)_{N_7}} = \frac{-\eta_2 A_{N_6}(t) \cdot A_4(t)_{N_4}}{\omega_{N_4} \cdot \omega_{N_6} (1 - \omega_{N_7}^3)}$$

The equation gets this form:

$$S_{\eta}(t) \approx \frac{1}{1 + \frac{\omega_{N_7}^3}{\eta_1 A_7^3(t)_{N_9}}} = \frac{-\eta_2 A_{N_6}(t) \cdot A_4(t)_{N_4}}{\omega_{N_4} \cdot \omega_{N_6} (1 - \omega_{N_7}^3)}$$

The equation is:

$$\eta_2 A_{N_6}(t) \cdot A_4(t)_{N_4} \cdot \left(1 + \frac{\omega_{N_7}^3}{\eta_1 A_7^3(t)_{N_9}}\right) + \omega_{N_4} \cdot \omega_{N_6} (1 - \omega_{N_7}^3) = S_{\eta}(t)$$

General equation of optimization depending on the reliability and mechanical oscillation amplitude level on measuring placesis:

$$\eta_1, \eta_2 = P[f(\omega_i, A_i)]$$

$$\eta_2 \left(1 + \frac{\omega_{N_7}^3}{\eta_1 \cdot A_7^3(t)_{N_9}}\right) + \frac{\omega_{N_4} \cdot \omega_{N_6} (1 - \omega_{N_7}^2)}{A_{N_6}(t) \cdot A_4(t)_{N_4}} = S_{\eta}(t)$$

knowing that reliability is:

$$\eta_1 = N_7(t) \cdot N_8(t) \cdot N_9(t), \quad \eta_2 = N_4(t) \cdot N_6(t)$$

$$\eta_2 + \frac{\eta_2 \cdot \omega_{N_7}^3}{\eta_1 \cdot A_7^3(t)_{N_7}} + \frac{\omega_{N_4} \cdot \omega_{N_6} (1 - \omega_{N_7}^2)}{A_{N_6}(t) \cdot A_4(t)_{N_4}} = S_{\eta}(t)$$

considering that: $\xi = \frac{\eta_2}{\eta_1} \Rightarrow \eta_2 = \xi \cdot \eta_1$

$$\xi \cdot \eta_1 + \xi \frac{\omega_{N_7}^2}{A_7^2(t)_{N_7}} + \frac{\omega_{N_4} \cdot \omega_{N_6} (1 - \omega_{N_7}^2)}{A_{N_6}(t) \cdot A_4(t)_{N_4}} = S_{\eta_1}(t)$$

arranging the expression we get:

$$S_{\eta_1}(t) = \frac{\omega_{N_4} \cdot \omega_{N_6} (1 - \omega_{N_7}^2)}{\eta_2 \left(\frac{\omega_{N_7}^2}{\eta_1 \cdot A_7^2(t)_{N_7}} - 1 \right) \cdot (A_{N_4}(t)_{N_4}) \cdot (A_{N_6}(t)_{N_6})}$$

The equation of model of mechanical oscilation optimization level on the chosen measuring places of pomer plant complexes is [2]:

$$S_{\eta}(t) = \frac{\omega_i^2(t)(1 - \omega_i(t))}{\eta_2 \cdot A_i^2(t)} \cdot \frac{1}{\left(\frac{\omega_i^2(t)}{\eta_1 \cdot A_i(t)} - 1 \right)}$$

where is:

η_1, η_2 - dependance corelation,

$\omega_{N_4}, \omega_{N_6}, \omega_{N_7}$ - ciricuit oscilation frequencies on joing components (bearings)

of power plant. Their values are gotten from measuring, $\omega_{N_4} = \frac{2\pi}{T}$ - circuit frequency,

$A_{N_7}(t)_{N_7} = A_{N_6}(t)_{N_6} = A_{N_4}(t)_{N_4} = A_i(t)$ - amplitude value, [3], [7].

The finall equation of model of optimisation of tracking temperature changes at tearings measuring while working [1]:

$$T_{mi} = T_i + \frac{T - T_i}{F(t)(T_{j+1})} \cdot \left(\frac{1}{2} - \sum_{i=1}^j F(t)(T_i) \right)$$

where is:

T_i - arithmetic middle of temperature measuring samples,

$F(t)$ - points of temperature devision function, [4], [6].

The finall equation of model of tracking wornont changes optimision et bearingesmeasuring during the working process [1]:

$$Z_{sN_i} = \sqrt{\frac{\sum_{i=1}^n (Z_i - \bar{Z}_{\max})^2}{n - 1}}$$

where is:

n - number of deariance independent measurings,

z_i - clearances of all measured inner bearings diameter.

In order to determine dependence of mutual binding correlations ($S_\eta(t)$, T_{mi} , $\bar{z}$) we begin with forming of squaredeterminor of 3×3 form with correlation coefficient [1].

$$K_1 = f\left(S_\eta(t), T_{mi}, 0\right) \quad K_2 = f\left(0, T_{mi}, \bar{z}\right) \quad K_3 = f\left(S_\eta(t), 0, \bar{z}\right)$$

$$K_{(t)} = \begin{bmatrix} K_3 \\ K_2 \\ K_1 \end{bmatrix} = \begin{bmatrix} 0 & T_{mi} & \bar{z} \\ S_\eta(t) & 0 & \bar{z} \\ S_\eta(t) & T_{mi} & 0 \end{bmatrix}$$

The final equation of model of technical diagnostic procedures optimization is this form [2]:

$$K_{(t)} = \frac{\omega_i^4(t)(1-\omega_i(t))^2 \cdot T_{mi}^2 \cdot \bar{z}^2}{\eta_2^2 \cdot A_i^4(t) \cdot \left(\frac{\omega_i^2(t)}{\eta_1 - A_i(t)} - 1\right)^2}$$

In table 4. curves of correlation dependence in space are shown and they include certain values of technical diagnostic of working temperatures procedures optimization parameters, mechanical oscillation and bearings worn out applying procedures optimization parameters. Based on these parameters extreme values of mechanical oscillation, temperature and bearing worn out also determined.

Introducing optimization parameters (improving surface quality and shaft size changes) the middle size amplitude percentage lowers for 11,8% which justifies introducing this parameter. Applying optimization parameters (lowering of recucling oil interval and constant filtration) we also keep working temperatures range from $59,5^\circ\text{C} \div 65^\circ\text{C}$. In percentage, the increase of functioning of technical diagnostic procedures optimization is $O_b = \Delta K(t) / \Delta K(t)_p \cong 42,5\%$ for 42,5% safety territory of power plant components functioning is increased, [2].

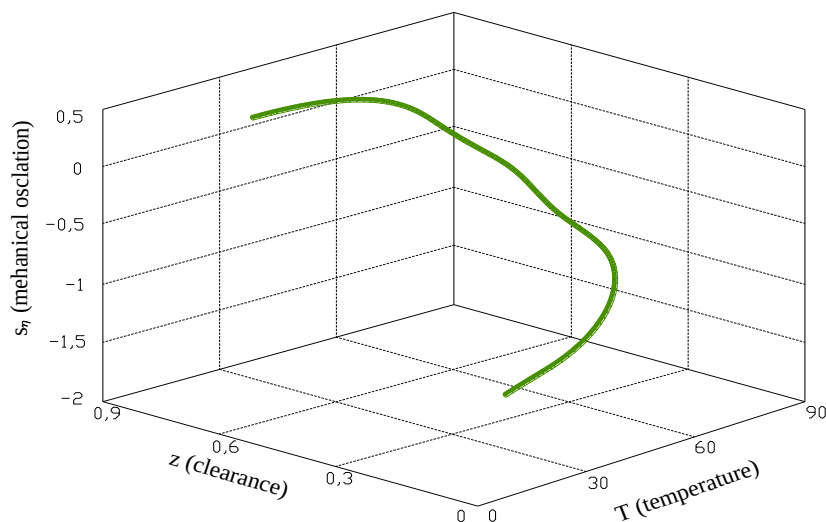


Table 4. Dependence correlation diagram of mechanical oscillation,

*temperature and bearings worn out applying parameters of
power plant technical diagnostic procedures optimization*

Power plant components reliability in exploiting can be increased by introducing new parameters and applying model on power plant complex components. Based on done researches it's concluded that it is necessary to apply appropriate condition parameters during components work in development phase in order to get reliable values. Within that, for technical diagnostic procedures optimization are considered all important and necessary influential technical diagnostic parameters which also satisfy all the important optimization criteria at power plant complex work.

3. CONCLUSION

By the given model an analysis's performed of complex functioning safety at any moment, that is in every moment of exploiting work of its composing components. Based on these analysis you can precisely determine time of complex safe work, on which basis you can plan and enforce planned preventive maintaining technology procedures, which makes components last longer in their work. Gotten results represent scientific justification and essence of the model of technical diagnosing condition, and parameters check gives continuous tracking of chosen parameters changing which in one way and surely describes observed power plant complex components condition. Based on this way identified reliability parameters, need procedures of preventive maintaining of power plant joining complex components are determined.

4. LITERATURE

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