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TABLE OF CONTENTS

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METHOD OF WEIGHT COEFFICIENTS CALCULATION OF ARTIFICIAL NEURAL-LIKE NETWORK IN DIAGNOSTIC SYSTEMS OF HYDRAULIC UNITS

The mathematical model of ANLN is shown in detail in [1-2], that is why we will turn our attention to the results of its operation – by determining the probability of the fact that certain vibration factor may cause excessive vibration displacement.

The informative probability indicator of $PV_{k\tau}$ factor that corresponds to k th neuron, as of the time point τ, is determined as follows^

$$\forall k = 1,6 \forall i = 1,4 \forall j \in \Psi_k \left(PV_{k\tau} = \sum_{i,j} w_{kij} d_{kij\tau}^{norm} \right), \quad (1)$$

where w_{kij} – weight coefficients that define the significance of accounting for wavelet coefficients of AFTS's j th frequency band of the i th vibration signal at the probability level of the k th neuron;

$d_{kij\tau}^{norm}$ – standardized values of wavelet coefficients of AFTS's j th frequency band of the i th vibration signal at the probability level of the k th neuron as of the time point τ; Ψ_k – the multitude of frequency bands' numbers, where the influence of vibration factor exists, which corresponds to the k th neuron.

The mathematical model for determination of cross-correlation coefficients is shown in detail in [3-6]. Let us recall its main provisions.

The hydraulic unit is shown as a relatively stationary distributed quasilinearized inseparable elastic system with space-variant stiffness coefficients [7]. Another specificity of a controlled unit (CU) lies in its exposure to k spatially distributed uncompensated forces of different physical nature, amplitude and vector direction that vary randomly with time function. Generalized structure of such CU may be shown as follows (fig. 1).

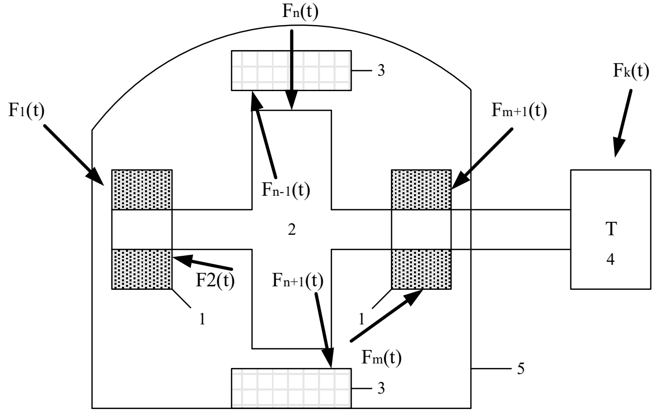

Fig. 1 Generalized structural diagram of hydraulic unit (1 – bearings; 2 – rotor; 3 – stator; 4 – turbine; 5 – housing)

In view of such system's inseparability, any of k external uncompensated disturbing forces will evoke in the system's randomly chosen point (assembly) the occurrence of kth component of vibration signal (response), the amplitude of which will different than zero. This being the case, in view of the system's quasilinearity, the vector-similar force, the resultant of which is applied to one and the same point of electrical machine with time delay Δt will cause the occurrence of the system's identical response with the same time delay in any randomly selected unit assembly. Hence, for a randomly selected controlled assembly in relation to each of k possible disturbing forces, one can obtain a link function. For a randomly selected assembly A being a part of CU, the following equation system will be true:

$$\begin{cases} \psi_{A1}(t) = F_1(t) \cdot H_{A1}(t), \\ \psi_{A2}(t) = F_2(t) \cdot H_{A2}(t), \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ \psi_{Ak}(t) = F_k(t) \cdot H_{Ak}(t), \end{cases} \qquad (2)$$

where F1(t) – Fk(t) – uncompensated force affecting an electrical machine; HA1(t) – HAk(t) – link functions in relation to disturbing forces F1(t) – Fk(t), respectively; ψA1(t) –ψAk(t) – system’s response at point A to the disturbing action in the form of F1(t) – Fk(t) force, respectively.

Such being the case, the resulting vibration signal to be observed at point A may be obtained on the basis of superposition principle

$$\psi_A(t) = \sum_{i=1}^{k} \psi_{Ai}(t) = \sum_{i=1}^{k} F_i(t) \cdot H_{Ai}(t).$$

On similar grounds for point B, the dependence between vibration signal response and disturbing forces will be written in the following form

$$\psi_B(t) = \sum_{i=1}^{k} \psi_{Bi}(t) = \sum_{i=1}^{k} F_i(t) \cdot H_{Bi}(t)$$

, and the dependence between each system response at point B and system response at point A will appear as:

$$\psi_{Bi}(t) = \frac{H_{Bi}(t)}{H_{Ai}(t)} \psi_{Ai}(t).$$

Hence, general system response at point B is defined as

$$\psi_B(t) = \sum_{i=1}^{k} \frac{H_{Bi}(t)}{H_{Ai}(t)} \psi_{Ai}(t). \qquad (3)$$

In a similar way, other points belonging to the CU may be interconnected.

Since in view of a stochastic nature of disturbing uncompensated forces F1(t) – Fk(t) the analyzed CU may be considered a stochastic system, presented expressions serve the theoretical substantiation for presence of cross-correlation connections between vibration signal responses at various points of the electrical machine under research.

A considerable challenge in the use of proposed approach lies in obtaining of cross-correlation coefficients' instantaneous values. Since vibration processes in electrical machines' controlled assembles are of occasional nature, precise evaluation of linear relationship between two values ψA(t) and ψB(t) would require the use of the following expression [8]

$$K_{\psi}(t_1,t_2)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}(\psi_1-m_A(t_1))(\psi_2-m_B(t_2))\cdot f(\psi_1,\psi_2,t_1,t_2)\,d\psi_1 d\psi_2, \qquad (4)$$

where mA(t1), mB(t2) – mathematical expectations of functions ψA(t) and ψB(t) at time points t1 and t2., respectively; $f(\psi_1,\psi_2,t_1,t_2)$ – two-dimensional probability of occasional process ψ(t), which preconditions the occurrence of vibration signals in A and B assemblies.

In its turn, $f(\psi_1,\psi_2,t_1,t_2)=\dfrac{\partial^2 F(\psi_1,\psi_2,t_1,t_2)}{\partial\psi_1\partial\psi_2}$, where $F(\psi_1,\psi_2,t_1,t_2)$ is a two-dimensional function of occasional process probability distribution ψ(t), which assigns the value of probability of the fact that at time point t1 inequality ψA≤ ψ1 is implemented, with inequality ψB≤ ψ2 being implemented at time point t2, that is

$$F(\psi_1,\psi_2,t_1,t_2)=P(\psi_A(t_1)\le\psi_1,\psi_B(t_2)\le\psi_2). \qquad (5)$$

Considering the particularity of CU, the coefficient of auto-correlation between signals ψA(t) and ψB(t) would be advisable to be determined for one and the same time point $t_1=t_2$, that is $K_{\psi}(t_1,t_2)=K_{\psi}(t_1)$.

Given stationary external disturbances F1(t) – Fk(t) signals ψA(t) and ψB(t) may be considered ergodic, that is why, following the chain of transformations, the required quasiinstantaneous cross-correlation coefficient can be obtained as $K_{\psi}^{*}(t_1)=\dfrac{1}{T}\int_{0}^{T}(\psi_A^{*}(t_1))(\psi_B^{*}(t_1))dt_1$, and for discrete time implementations, with due regard to known Pearson's equation, one can write the following correlation:

$$K_{\psi}^{*}(t_1)=\frac{\sum\limits_{i=1}^{n}\psi_{Ai}^{*}\psi_{Bi}^{*}}{\sqrt{\sum\limits_{i=1}^{n}\psi_{Ai}^{*2}\cdot\sum\limits_{i=1}^{n}\psi_{Bi}^{*2}}}, \qquad (6)$$

where ψ*Ai and ψ*Bi – ith values of time implementations of ψA(t) and ψB(t) functions.

Based on the foregoing mathematical model, the calculation method was developed, the algorithm for which implementation is shown below:

Selection of synchronized time implementations of vibration signals of the support ψA and tested assemblies ψB with the length of n and starting at time moment t.

Calculation of amplitude-frequency-time spectra of supporting assembly’s vibration signal.

Calculation of amplitude-frequency-time spectra of tested assembly’s vibration signal.

Assignment of the initial value (j=1) to the control mark.

Calculation of neuron’s jth weight coefficient responsible for the tested assembly using formula (6).

Recording the calculated jth weight coefficient in ANLN.

Raising the control mark by one (j=j+1) and in the case when the value obtained does not exceed the number of tested harmonics, going on to item 5, otherwise – termination of the calculation.

This algorithm was implemented by the example of real archived values of vibration signals obtained from the sensors installed at journal-and-thrust bearing and turbine bearing of the other hydraulic unit of Nyzhnyodnistrovs’ka HPP (Ukraine) in the process of its commercial operation.

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CREATING A PISTON COOLING SYSTEM FOR INTERNAL COMBUSTION ENGINES

The current stage of creating internal combustion engines is characterized by the use of compression cycles with a high compression number. It is these engines that meet modern requirements for toxicity of exhaust gases, fuel efficiency and long