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PERIODICALLY NONSTATIONARY RANDOM PROCESSES METHODOLOGY FOR INVESTIGATION OF THE VIBRATION CONDITION OF AIRCRAFT ENGINES

To investigate the condition of the complex mechanical systems, in that aircraft planer and engines, helicopter engines and main gear require detecting and identifying existing faults that have not yet led to failure or accidents. Extraction of defect signatures and evaluation of their development is grounded on a detailed analysis of vibration signal structure, considering the kinematics and dynamics of the diagnosed mechanisms. To describe this structure it is necessary to have an appropriate mathematical model of the signal, presenting the necessary set of features to assess the mechanisms of technical condition in details. These key characteristics of vibration signals include repeatability, stemming from the cyclic operation principle of mechanisms, as well as stochasticity, caused by fluctuations in lubricant thickness and viscosity, changes in friction forces, spontaneous load variations, turbulence, etc. Most importantly, they also encompass existing defects.

Nucleation and growth of defects introduces nonlinearity into mechanical oscillating systems, where repeatability and stochasticity develop in vibration signal properties. Nature of interaction between repeatability and stochasticity results in the oscillatory process properties that are quite important for evaluation of the technical condition of mechanism. Periodic and nearly periodic nonstationary random processes (PNRP) are appropriate mathematical models for describing and analyzing such interactions [1]. An approach based on these models was developed over years

at the Karpenko Physico-mechanical Institute of the National Academy of Sciences of Ukraine, tested [2], and implemented in industrial enterprises across Ukraine.

In the representation of a vibration signal as a PNRP its probabilistic characteristics – mathematical expectation, autocorrelation function, spectral density – are periodic functions in time:

$$m(t) = E\xi(t) = m(t+T), \quad \overset{\circ}{\xi}(t) = \xi(t) - m(t),$$

$$b(t,u) = E\overset{\circ}{\xi}(t)\overset{\circ}{\xi}(t+u) = b(t+T,u), \quad f(\omega,t) = f(\omega,t+T),$$

where E is an operator of the mathematical expectation.

Mathematical expectation describes the deterministic periodic fluctuations; dispersion represents the periodicity of the power of spontaneous fluctuations around a periodic function; the correlation function characterizes the periodic variability of the correlation relations between the values of the stochastic component of the signal separated by a time interval; spectral density depicts the power distribution of the random component of oscillations on the "frequency-time" plane.

Mathematical expectation $m(t)$ describes the deterministic (regular) periodic oscillations; variation $\text{var}(t) = b(t,0)$ is the periodicity of the power of spontaneous fluctuations around the periodic function $m(t)$; the correlation function $b(t,u)$ characterizes the periodic variability on t of the correlation relations between the values of the stochastic component of the signal shifted by a time interval u ; spectral density $f(\omega,t)$ is a power distribution of the random component of oscillations on the "frequency-time" plane.

Knowledge of correlation period of the PNRP is a necessary condition for evaluating of its probabilistic characteristics. When analyzing vibration signals, for example, the value of the period in many cases can be obtained grounding on the technical characteristics of the mechanism, as well as the parameters of its nodes. However, the accuracy of such a period assignment does not satisfy the requirements of the stochastic processing of signal realization by PNRP methods. In addition, the value of the period can be a separate diagnostic parameter. Previous research has shown that the required methods can be created based on the analysis of the temporal variability of estimates of the first and second order characteristics of vibration signal. The formulation of the problem of detecting of the hidden periodicities in terms of stochastic evaluation of the probabilistic characteristics of PNRP makes it possible to eliminate the existing contradictions of traditional approaches by separating

searching of the deterministic periodic oscillations and regularities of periodic variability of fluctuation processes.

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