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Spectral analysis of the oscillatory process of support assemblies on drilling machines

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ABSTRACT: The article presents relationship of a technical condition of elements bearing supports on drilling machines and spectral features based on the analysis of high-frequency component of the vibration signal, allowing to determine the type of defects and to predict their development.

KEYWORDS: Vibration, holder, separator, spectral density, frequency, amplitude, fluctuation, stiffness.

I.INTRODUCTION

Vibration is the result of interaction between mating parts. Changing properties of parts are shown in changing the character of their interaction, therefore vibration signal carries the most complete information about the technical condition of machine elements and mechanisms which form the kinematic pairs: a pair of wheels gearing; holder, rolling elements, rolling bearing separator; bushing-piston pumps in the elements, etc. In addition in this drilling machines have got place for dynamical interaction with executive body of the slaughter, conditional on excitation of forced oscillations of elements of drilling machines.

All variety of oscillatory processes in the drilling machine can be seen in the form of forced and natural oscillations. As the media about the technical condition of knots drilling machines can be used, these two kinds of oscillatory processes. And forced (usually low-frequency vibration) are an indicator of the quality of manufacturing units of the machine, while the natural oscillations in the medium - or high-frequency range carry information about the deterioration of the technical state of the calling process, which usually begin with contact interactions and initiates often wear and tear.

II. SIGNIFICANCE OF THE SYSTEM

Vibration, depending on the nature of the exciting forces it may be either deterministic (most periodical) or random.

The basis of the analysis of both periodic and quasi-periodic signal is the Fourier transform

$$S(\omega)=\frac{1}{2\pi}\int_{-\infty}^{\infty} y(t)\cdot e^{-j\omega t}dt, \qquad (1)$$

Where: $S(\omega)$ - spectral density of the signal; $y(t)$ - timing signal.

Random signals in contrast to deterministic have continuous spectra. In connection with this change of parameter of vibration signal by changing of a technical condition of bearing supports convenient to simulate not only the variation ratio of the spectral amplitudes A_k discrete components $S(k\omega_0)$, $k=1,2,\ldots,n$, and introduction of additional noise excitation $\omega_{Ш}(t)$ cuniform spectrum $S_{Ш}(t)$ in this frequency range:

$$x(t)=\sum_{k=1}^{n} A_k(t)\sin[k\omega_0 t+\varphi_k(t)]+\xi(t), \qquad (2)$$

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Where: $k\omega_0$ - average frequency of narrow- banded process; $A_k(t)$- random, slowly compared to $T_k = \frac{2\pi}{k\omega_0}$ modify, envelope of the narrowband process; $\varphi_k(t)$ - random, slowly varying phase; $\xi(t)$- noising (random) component, vibration signal.

Such a presentation vibration signal fairly well reflects an increase of noise component while increasing the degree of wear of the contacting surfaces of the friction bearing, is sensitive to the deterioration of lubrication conditions or loss of its lubricating ability due to aging, etc., in all cases where it is necessary to consider the appearance of or change in the random component that is a consequence of interaction of forces of friction, or shock perturbation.

Practice diagnosing drilling machine shows that vibrations are composed of a high-frequency process, modulated in amplitude at low frequency.

Forced oscillations of the support unit can be represented as a dynamic system with n degrees of freedom

$$[\vec{M}][\ddot{\vec{X}}]+[\vec{K}][\dot{\vec{X}}]+[\vec{C}][\vec{X}]=[\vec{G}], \quad (3)$$

where $[\vec{M}]$, $[\vec{K}]$ и $[\vec{C}]$ - symmetric matrices, respectively, describing properties of inertia, stiffness and damping; $[\vec{G}]$ - n - dimensional vectors characterizing of disturbing influences; $[\vec{X}]$ - n - dimensional output vector characterizing of vibration.

During operation, support assembly - increases radial clearance in bearings, causing a change in parameters:

$$[\vec{C}(s,t)];[\vec{K}(s,t)] \text{and} [\vec{G}(s,t)].$$

Determining directly in operation of disturbing influences, and the dynamic characteristics of support is difficult. However, about size of a deviation - type and depth of defect can be judged on the output information from sensors set the ground node:

$$\vec{X}(s,t) = L\cdot\vec{G}(s,t),$$

WhereL – systemoperator.

Oscillation with frequency $k\omega_1$, Evaluation which can detect the state of the node, i.e. the presence of clearances and defects perceived vibration pick mounted on the body support assembly. Information from the sensor corresponds to the accepted model of the diagnostic status of the bearing assembly.

Accounting for changes in time damping parameters [$\vec{C}$](t) stiffness [$\vec{K}$](t) fundamentally necessary for the bearing supports drilling machines, where simulation of vibrations without changing rigidity of bearing supports in time is wrong. Accounting for changes in stiffness over time [$\vec{K}$](t) leads to amplitude modulation of vibration signal, while the time dependence of the damping coefficient [$\vec{C}$](t) associated with frequency modulation signal. The development trend of the defect causes the modulation depth, i.e. increasing the amplitude of combination frequencies at the time of use, and has no effect on the amplitude of poly harmonic number of fundamental frequencies of excitation node [1,2]. In general, amplitude modulated signal is of form

$$x(t) = A[1+\mu B(t)]\sin(\omega_0 t+\varphi_0), \quad (4)$$

Where: ω_0 - frequency carrier; A - amplitude; μ - modulation depth (varies from 0 to 1); $B(t)$ It can be represented as

$$B(t) = \sum_{k=1}^{n} c_k \sin[k\Omega t+\varphi_k], \quad (5)$$

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Where: Ω - frequency modulation ($\Omega \prec \omega_0$).

The resultant amplitude-modulated process has form

$$x(t) = A\left[1 + \sum_{k=1}^{n} \mu_k \sin(k\Omega t + \varphi_k)\right] \sin(\omega_0 t + \varphi_0), \quad (6)$$

Where: μ_k - partial modulation factor; Ω - modulation of angular frequency; φ_k и φ_0 - phase shifts.

This complex process can be decomposed into a sum of simple harmonic oscillations:

$$x(t) = A\left\{\sin(\omega_0 t + \varphi_0) + \sum_{k=1}^{n} \frac{\mu_k}{2} \sin[(\omega_0 + k\Omega)t + \varphi_0 + \varphi_k] + \sum_{k=1}^{n} \frac{\mu_k}{2} \sin[(\omega_0 - k\Omega)t + \varphi_0 - \varphi_k]\right\}, \quad (7)$$

Where the first term - is fluctuations of carrier frequency; -n the second term fluctuations of upper sideband $\omega_0 + k\Omega$; -n the third term fluctuations lower sideband $\omega_0 - k\Omega$.

The width of the spectrum of amplitude modulated process is equal to twice the width of the spectrum envelope. Isolation of the envelope by means of an amplitude detector whose output signal is obtained form

$$x(t) = A\sum_{k=1}^{n} \frac{\mu_k}{2} \sin[(\omega_0 + k\Omega)t + \varphi_0 + \varphi_k]. \quad (8)$$

III. LITERATURE SURVEY

The parameters characterizing the depth of amplitude modulation of the basic frequency of forced vibrations, are used as diagnostic indicators of operational defects bearing supports drilling machines. Sensitive diagnostic signs of local defects of the contacting surfaces of the cavities such as fretting, pitting, chipped are n-dimensional vectors are formed from the components of spectrum envelope in the area of one of the forced frequency of defective unit.

IV. METHODOLOGY

In studies of vibrations on bearing supports of a drilling machine have been found to have high levels of the frequency components in the spectrum envelope (Fig. 1c). At the same time there was a tendency of growth of the amplitude of oscillations at all frequencies that are multiples of the frequency of rotation, indicating an increase in the value of the radial clearance. For ten days the average value of the oscillation amplitude increased by 63%. By the time the measurement of vibrations that the bearing assembly has worked 1400 hours. Because of the high level of the frequency components in the spectrum envelope assembly was stopped. Survey after dismantling the bearing unit have confirmed the emergence of local fatigue damage on the treadmill of its outer ring.

As can be seen from Fig. 1, and the spectrum envelope of the high frequency vibration without defect bearing no peaks of frequency components. The spectrum envelope of vibration of bearing with wear (see. Fig. 1, b) one is visible strong harmonic component, indicating smooth and periodic variation of signal strength of vibration. At the same bearing shock-power pulses of high frequency vibration changes abruptly, and in the spectrum of its envelope has been present for a number of multiple frequency components (see. Fig. 1c).

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Timing signals are high-frequency vibration   Spectra envelope of high-frequency vibration

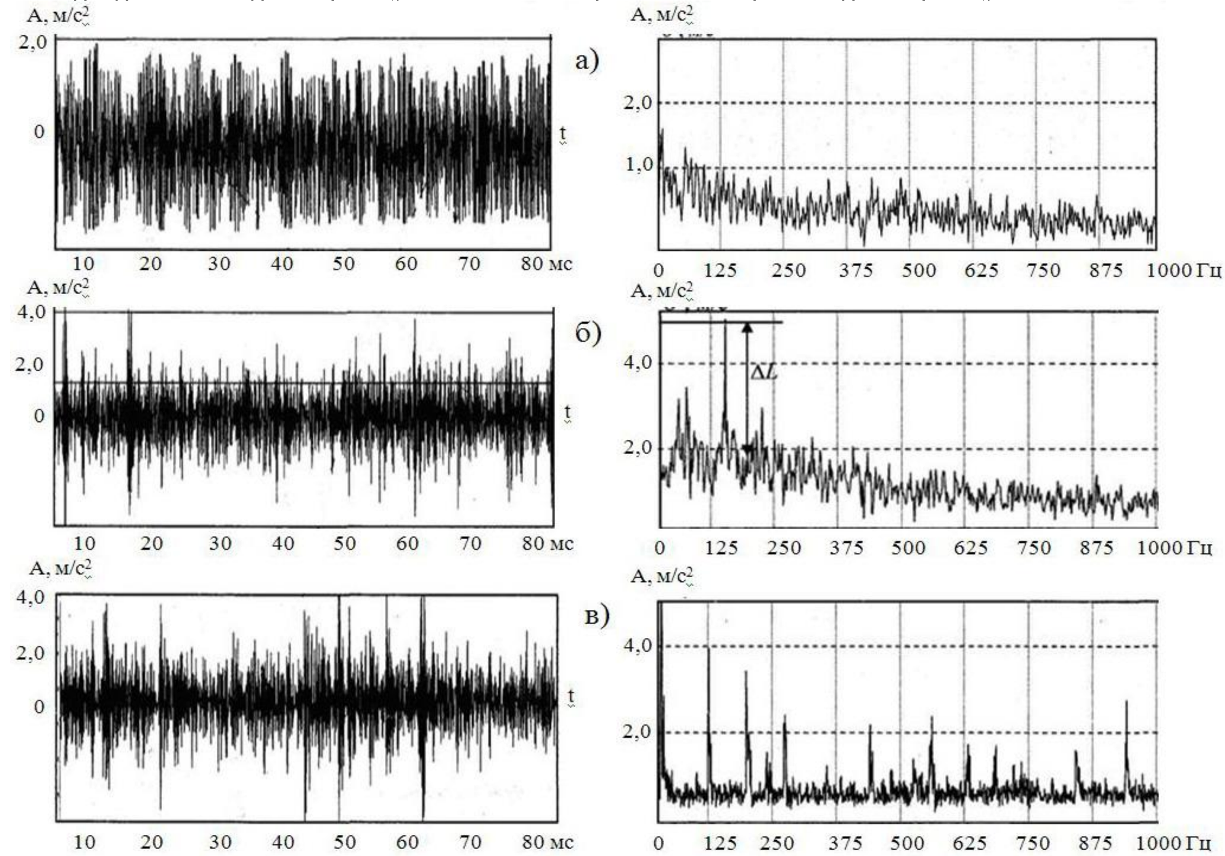

Fig. 1. Timing signal of high frequency vibration support unit drilling machines and range of its envelope: a) - defective bearings; b) - bearing wear and tear of friction surface; in - bearing with increased clearance

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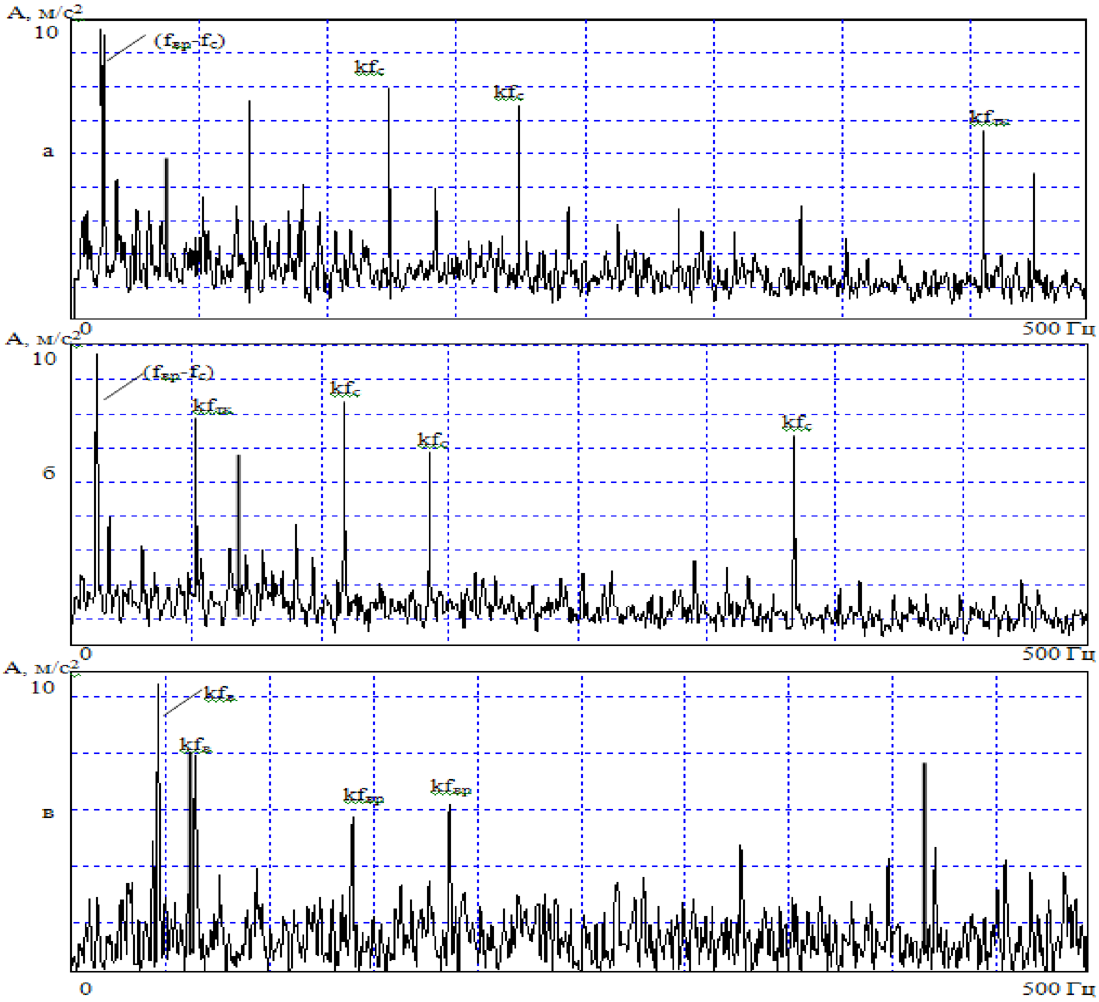

Fig. 2. The spectrum envelope of high-frequency vibration bearing rotator
and - the wear of the rolling elements; b - wear separator; in - uneven wear (shell on a treadmill inner ring).

V. EXPERIMENTAL RESULTS

Fig. 2 shows the spectra envelope of high frequency vibration bearing support on drilling machines for different types of defects. In the spectrograms clearly traced characteristic diagnostic features (harmonics of frequencies that are multiples of speed), indicating the increased wear of the separator, the rolling elements - the node failure

For formation of spectrum envelope is compulsory choice of frequency range, and in this range should not get comparable power components of different nature. Most of the defects in the bearings occurring during the manufacturing process and operation, have an impact on the frequency spectrum of the vibration. We have set the frequency ranges in which the most effective control of the defects that arise in the course of developing and exploitation of drilling machines.

In the spectrum of vibration drilling machines present the low frequencies are in the 2-12 Hz frequency of 20-60 Hz medium and high frequency vibrations caused by the processes occurring in the bearings themselves. Established frequency ranges (rotator F = 4-6 kHz reference node F = 6-8 kHz compressor F = 8-10 kHz pump F = 8-10 kHz), which is most effective to control the defects that occur in the process of developing and operation.

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VI. CONCLUSION AND FUTURE WORK

The analysis of theoretical and experimental data shows that the vibrational state of drilling machines depends essentially on regime parameters drilling (axial force, speed, depth of the well and the rock fortress). With the growth of axial loads oscillation intensity decreases, whereas with increase of the rotational speed and the depth of the well, it increases.

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