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DYNAMICS OF SHEARER DRIVE AT RANDOM PERTURBATIONS

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Abstract

The paper considers the problem of the dynamics of a shearer actuator drive as a multibody system at random perturbations. It is shown that the drive system acts as a filter, which increases the load close to its natural frequency, and suppresses the load with a frequency different from its eigenfrequencies.

Keywords: drive, actuator, coal combine, filter

The drive of the actuator of a shearer is a dynamic (elastic) system under the influence of random perturbation, which is represented as a process with the properties of white noise [1].

Then, for a discharge (chain) drive circuit, Fig. 1c, (these are combines with a single-engine or two-engine drives), Fig. 1b, its mathematical model has the form

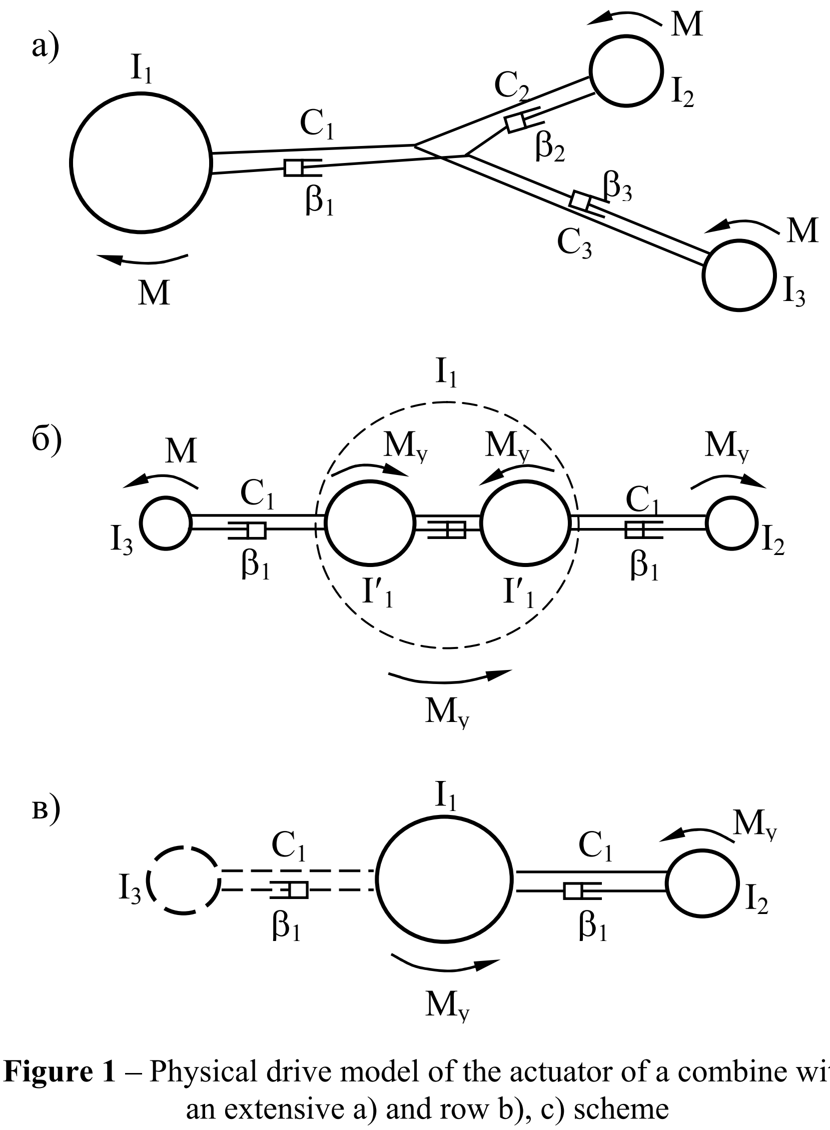

Figure 1 – Physical drive model of the actuator of a combine with an extensive a) and row b), c) scheme

$$\begin{cases} J_1\ddot{\gamma}_1 + \beta_1\dot{\gamma}_1 + \beta_{12}(\dot{\gamma}_1 - \dot{\gamma}_2) + \beta_{13}(\dot{\gamma}_1 - \dot{\gamma}_3) + \\ \qquad + c_{12}(\gamma_1 - \gamma_2) + c_{13}(\gamma_1 - \gamma_3) = M_{y1} \\ J_2\ddot{\gamma}_2 + \beta_2\dot{\gamma}_2 + \beta_{12}(\dot{\gamma}_2 - \dot{\gamma}_1) + c_{12}(\gamma_2 - \gamma_1) = M_{y2} \\ J_3\ddot{\gamma}_3 + \beta_3\dot{\gamma}_3 + \beta_{13}(\dot{\gamma}_3 - \dot{\gamma}_1) + c_{13}(\gamma_3 - \gamma_1) = M_{y3} \end{cases} . \quad (1)$$

Bearing in mind that $J_1 = J_{\partial в} >> J_2 = J_{p.o}$ where $J_{\partial в}, J_{p.o}$ are the moments of inertia, respectively, of the motor shaft and the actuator with rotating masses attached to them, for this drives circuit the reduced system of equations can be written as

$$J_2\ddot{\gamma}_2 + \beta_2\dot{\gamma}_2 + c_{12}\gamma = M_{y2}. \quad (2)$$

Omitting the indices and combining this equation to standard form, we obtain

$$\ddot{\gamma} + 2n\dot{\gamma} + \omega^2\gamma = \xi(t), \quad (3)$$

where $2n = \beta_2 / J_2, \quad \omega^2 = c_{12} / J_2, \quad \xi(t) = M_{y2} / J_2.$

Spectral density of the solution of this differential equation has the form [2]

$$S_\gamma(\lambda) = \frac{S_\xi(\lambda) = C}{(\omega^2 - \lambda^2)^2 + 4\lambda^2\omega^2}, \quad (4)$$

where λ is the frequency of external disturbance.

From dependence (4) it follows that if $\lambda = \omega$, i.e. when the frequency of external disturbance coincides with the natural frequency of the drive, the solution dispersion reaches the maximum

$$S_\gamma(\lambda)_{\max} = \frac{C}{4\lambda^2\omega^2}. \quad (5)$$

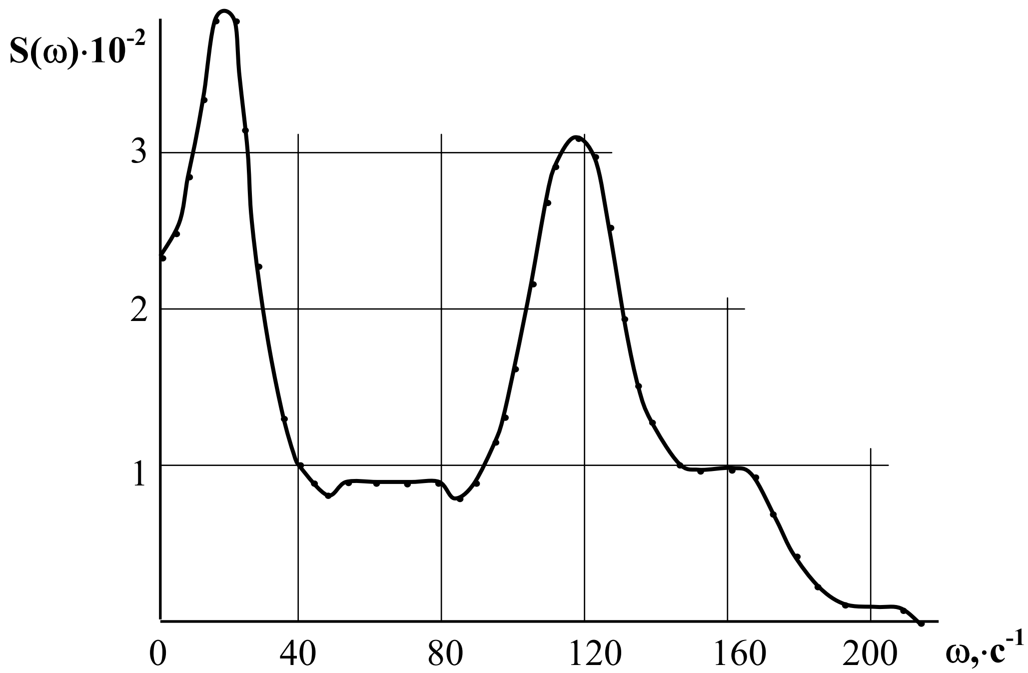

Figure 2 – Graph of the normalized spectral density of elastic moment in the drive of the actuator of the combine Type 1K-101 (mine research)

Solution (5) coincides with the results of spectral analysis of the resistance moment in the drive of the shearer actuator obtained by mining research work of the combine, Fig.2. On Fig. 2, except the peak at frequency close to the natural frequency of drive vibration , there is a maximum at a lower frequency. The studies have shown that it is the load frequency caused by "uneven" scheme of cutting tool set, which is 1.67 Hz (10.48 s-1) for a combine of the type 1 K-101, and represents its deterministic component.

Thus, in general, we can write

$$S_{\gamma}^{(j)}(\lambda) = \frac{C}{(\omega_j^2 - \lambda^2)^2 + 4\lambda^2\omega_j^2}, \ j = \overline{1,2}, \tag{6}$$

where $\omega_{j=1} = \omega_{cx}$ - the frequency of "irregularity" of the scheme of the cutting tool set of the actuator of the combine; $\omega_{j=2} = \omega_{np}$ - the natural frequency of the drive.

Since the spectrum of the load represents a process, which has the properties of "white" noise over a wide frequency range, then there is always a load with a frequency equal to $\omega_{j=1} = \omega_{cx}$ and $\omega_{j=2} = \omega_{np}$. For a load with specified frequency the spectral density of the solutions will take the maximum values. This is confirmed by experimental studies of the combine in mines. The scheme of its drive represents an in-line circuit with one engine - Combine Type 1K-101U.

With an extensive scheme of the actuator drive, Fig. 1 a), its mathematical model has the form

$$\begin{cases} J_1\ddot{\gamma}_1 + \beta_1\dot{\gamma}_1 + \beta_{10}(\dot{\gamma}_0 - \dot{\gamma}_1) + c_{10}(\gamma_1 - \gamma_0) = M_{y1} \\ J_2\ddot{\gamma}_2 + \beta_2\dot{\gamma}_2 - \beta_{20}(\dot{\gamma}_2 - \dot{\gamma}_0) - c_{20}(\gamma_0 - \gamma_2) = -M_{y2} \\ J_3\ddot{\gamma}_3 + \beta_3\dot{\gamma}_3 - \beta_{30}(\dot{\gamma}_3 - \dot{\gamma}_0) - c_{30}(\gamma_0 - \gamma_3) = -M_{y3} \end{cases} . \tag{7}$$

It is a system of three linear differential equations of the second order. Taking into account that $J_1 = J_{\partial в} >> J_2 + J_3$, i.e., the moment of inertia of the drive motor with rotating masses attached to it is much greater than the sum of the moments of actuators with rotating masses attached to them a mathematical model of the drive can be simplified and represented as

$$\begin{cases} J_2\ddot{\gamma}_2 + \beta_2\dot{\gamma}_2 - \beta_{20}(\dot{\gamma}_2 - \dot{\gamma}_0) - c_{20}(\gamma_0 - \gamma_2) = -M_{y2} \\ J_3\ddot{\gamma}_3 + \beta_3\dot{\gamma}_3 - \beta_{30}(\dot{\gamma}_3 - \dot{\gamma}_0) - c_{30}(\gamma_0 - \gamma_3) = -M_{y3} \end{cases} . \tag{8}$$

In this scheme of the actuator drive we can single out three branches:

- branch 1 - The drive from the working body 1 (J_2) to the "point " of branching
- branch 2 - The drive from the working body 2 (J_3) to the "point " of branching
- branch 3 - The drive from the "point " of the ramifications to the engine.

After reduction of the simplified mathematical model of the drive to a standard form we have

$$\begin{cases} \ddot{\gamma}_2 + 2n_2\dot{\gamma}_2 - 2n_{20}(\dot{\gamma}_2 - \dot{\gamma}_0) - \omega_{20}^2(\gamma_0 - \gamma_2) = -\xi_2(t) \\ \ddot{\gamma}_3 + 2n_3\dot{\gamma}_3 - 2n_{30}(\dot{\gamma}_3 - \dot{\gamma}_0) - \omega_{30}^2(\gamma_0 - \gamma_3) = -\xi_3(t) \end{cases} , \tag{9}$$

where

$$2n_i = \beta_i / J_i, \; 2n_{i0} = \beta_{i0} / J_i, \; \omega_{i0}^2 = c_{i0} / J_i, \; \xi_i = M_{yi} / J_i, \; i = \overline{2,3}$$

Dividing the drive into partial parts we can represent the spectral densities of the dispersion of their solutions in the first approximation as

$$S_\gamma^{(i)}(\lambda) = \frac{C}{(\omega_i^2 - \lambda^2)^2 + 4\lambda^2\omega_i^2}, \; i = \overline{2,3}. \tag{10}$$

In addition, each of the "partial" spectral densities will have, as a rule, two maxima - one at the frequency due to uneven circuit of cutting tools working body set, the second - at a frequency close or equal to the natural frequency of the branch.

Spectral density of the total variance of the branch (from the engine to the "point " of branching) can have from one to several peaks depending on the dynamic properties of this branch and partial branches of the drive, as well as the relative position of the working bodies of a combine.

In case of mutual arrangement of the working bodies, in which the amplitudes of the low-frequency component of the resistance moment (it is almost deterministic component) will be equal in magnitude and frequency and opposite to the "point" of branching there will be at least one less maximum of spectral density for this branch of the drive.

The maximum of spectral density of the solution for this branch of the drive is conditioned both by the frequency of its own vibration and the frequency of partial branches of the drive and the total low-frequency (almost deterministic) component of the load.

The correctness of this position is confirmed by experimental results of the combine 2K-52 in mining conditions [3], Fig. 3. The drive of its actuator is represented as a branched pattern.

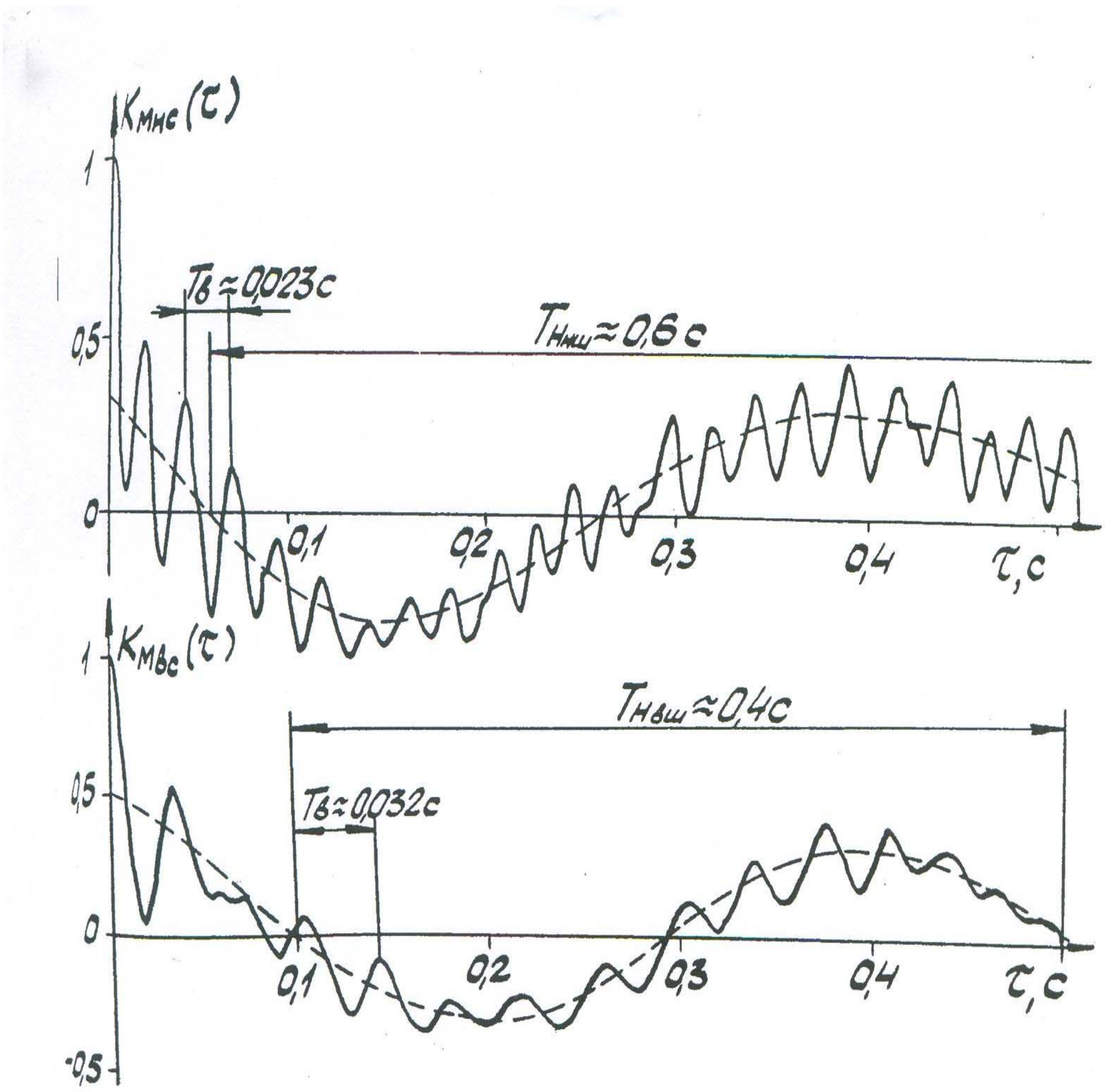

Figure 3 – Graphs of the normalized correlation functions of the resistance moment in the drive of the combine 2K-52 (mine research)

When the engines work to the summing shaft and in two-engine actuator drive, the drive circuit almost repeats row (chain) scheme, and the spectral density of the solution is almost identical to the spectral density for a discharge circuit and single engine drive.

Thus, the results obtained under the condition that the external perturbing effect on the drive of the actuators of shearers (which is an electromechanical dynamic system) is a random process over a wide frequency range having the property of white noise, do not contradict the results of experimental studies of these combines in real (mine) conditions of their operation. On the basis of the obtained results in order to study electromechanical dynamic systems analogous to actuator drives it is possible to take a random process with white noise properties as an external perturbation.

References:

1. Исполнительные органы очистных комбайнов для тонких пологих пластов / Н.Г.Бойко, А.В. Болтян, В.Г. Шевцов, Н.А. Марков; под ред. Н.Г. Бойко. – Донецк: «Донеччина», 1996. – 223 с.
2. Свешников А.А. Прикладные методы теории случайных функций / А.А. Свешников. – М.: Наука, 1968. – 464 с.
3. Гуляев В.Г. Научные основы оптимизации динамических свойств очистных комбайнов демпфирующими устройствами: автореф. дисс. … докт. техн. наук. / В.Г. Гуляев. – Днепропетровск: ИГТМ, 1986. – 37 с.

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