A PROBLEM OF DYNAMIC DAMPING OF OSCILLATIONS OF A CONCENTRATED MASS SYSTEM

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Abstract. *In this work, the issue of nonlinear vibrations of a mechanical system with an elastic dissipative characteristic of the hysteresis type, combined with a dynamic damper with a liquid joint, in kinematic excitations is considered. A mathematical model of the anti-vibration system was obtained. An analytical expression of the transfer function has been determined in order to evaluate the dynamic damping efficiency.*
Key words: *mechanical system, dynamic damper, vibration, elastic, dissipative, hysteresis, fluid joint, transfer function.*

Ensuring long-term reliable operation as a result of protection of machines and mechanisms, accessories and their elements from harmful vibrations is one of the urgent problems in all areas of modern techniques and technologies. In this case, the considered objects are taken in the form of mechanical systems with aggregated or distributed parameters, and different types of dynamic dampers are used for them [1-3].

[4-7] - in order to reduce the vibrations of various mechanical systems with concentrated and distributed mass, dynamic dampers consisting of various devices with liquid joints were used in the works, their mathematical models were obtained, dynamics and priority were studied, conclusions given

Liquid-joint dynamic dampers are important in damping harmful vibrations of low-frequency systems [8].

In this work, a dynamic damper with a liquid joint is used to damp the vibrations of a mechanical system with an elastic dissipative characteristic of the hysteresis type.

The dissipative properties of the elastic damping element of the anti-vibration system consist of a non-linear, non-one-valued functional [9], and are taken into account in the equations in a linear view using the harmonic linearization method. In a dynamic damper, the properties of the liquid can be expressed through distributed parameters. In [8], the issue of considering fluid properties through accumulated mass parameters is justified. Liquid mass, kinematic and dynamic viscosity are expressed by specific coefficients, and the cavitation phenomenon is not taken into account. Viscosity coefficients of the fluid were calculated in a linear form for low-frequency small vibrations.

We write the differential equations of vibrational motions of the considered mechanical system together with a dynamic damper with a liquid joint as follows:

$$M_1\ddot{x}_1 + M_b\ddot{x}_2 + c_1\{1 + (-\eta_1 + j\eta_2)[D_0 + f(\xi_0)]\}x_1 = -M_1W_0\,;$$
$$M_b\ddot{x}_1 + M_n\ddot{x}_2 + k_2\dot{x}_2 + c_2x_2 = -M_bW_0\,, \qquad (1)$$

here

x_1 , x_2 - displacement coordinates of the mechanical system and the dynamic damper, respectively;

$M_1 = m_1 + m_2 + m_3;\ M_b = m_2 - m_b;\ M_n = m_2 + m_n;$

m_1 , m_2 , m_3 - the masses of the mechanical system, the dynamic damper, and the fluid, respectively; m_b - liquid mass displaced by a solid body of a dynamic damper; m_n - liquid mass added to the solid body of the dynamic damper; c_1 - coefficient of elasticity of the damping element of the mechanical system; c_2 , k_2 - elasticity and liquid damping coefficients of the dynamic damper spring, respectively; η_1 , η_2 - constant coefficients determined from experience, depending on the dissipative properties of the material of the damping element of the mechanical system; $f(\xi_0)$ - is the decrement of mechanical system vibrations and is expressed as follows:

$$f(\xi_0) = D_1\xi_0 + D_2\xi_0^2 + D_3\xi_0^3 + \ldots + D_r\xi_0^r ,$$

D_0 , D_1 , $D_2, \ldots , D_r$ - coefficients of the hysteresis contour determined from experience, depending on the damping properties of the material of the mechanical system damping element [10]; ξ_0 - relative deformation.

(1) differential equations $s = \frac{d}{dt}$ we reduce to algebraic equations through the differential operator, i.e

$$[M_1 s^2 + c_1\{1 + (-\eta_1 + j\eta_2)[D_0 + f(\xi_0)]\}]x_1 + M_b\, s^2 x_2 = -M_1 W_0 ;$$
$$M_b\, s^2 x_1 + [M_n s^2 + k_2 s + c_2]x_2 = -M_b W_0 . \quad (2)$$

This equals x_1 and x_2 we determine the variables using Kramer's rule

$$x_1 = \frac{A_1 W_0}{A_3 + jA_4} ; \quad (3)$$

$$x_2 = \frac{W_0[B_1 + jB_2]}{A_3 + jA_4} , \quad (4)$$

here

$$A_1 = (M_b^2 - M_1 M_n)s^2 - M_1 k_2 s - M_1 c_2 ;$$
$$B_1 = -c_2 M_b(1 - \eta_1)[D_0 + f(\xi_0)] ;$$
$$B_2 = -c_1\eta_2 M_b[D_0 + f(\xi_0)] ;$$
$$A_3 = (M_1 M_n - M_b^2)s^4 + M_1 k_2 s^3 + \{c_2 M_1 + c_1 M_n - c_1\eta_1 M_n[D_0 + f(\xi_0)]\}s^2 -$$
$$-\{c_1 k_2 - c_1\eta_2 k_2[D_0 + f(\xi_0)]\}s + \{c_1 c_2 - c_1 c_2\eta_1[D_0 + f(\xi_0)]\} ;$$
$$A_4 = c_1\eta_2 M_n[D_0 + f(\xi_0)]s^2 + c_1\eta_2 k_2[D_0 + f(\xi_0)]s + c_1 c_2\eta_2[D_0 + f(\xi_0)] ;$$

To check the dynamics of the mechanical system protected against vibrations, we determine its transfer function. For this, we find the absolute acceleration of this mechanical system, i.e

$$\ddot{x_a} = W_0 + \ddot{x_1} . \quad (5)$$

(5) we get an analytical expression of its transfer function based on the ratio of the absolute acceleration of the mechanical system to the base acceleration

$$\Phi(s) = \frac{\ddot{x_a}}{W_0} = 1 + \frac{s^2 A_1}{A_3 + jA_4} , \quad (6)$$

$s = j\omega$ Using the relation, we write the expression of the transfer function in terms of the vibration frequency as follows:

$$\Phi(j\omega) = \frac{H_1(\omega) + jH_2(\omega)}{H_3(\omega) + jH_4(\omega)} \quad (7)$$

here

$$H_1(\omega) = c_1\eta_2 k_2[D_0 + f(\xi_0)]\omega^3 + \{(c_1\eta_1 M_n + c_1c_2\eta_1)[D_0 + f(\xi_0)] - -c_1(M_n + c_2)\}\omega^2 ;$$

$$H_2(\omega) = M_1 k_2\omega^3 - c_1\eta_2 M_n[D_0 + f(\xi_0)]\omega^2 + c_1c_2\eta_2[D_0 + f(\xi_0)];$$

$$H_3(\omega) = (M_1 M_n - M_b^2)\omega^4 - \{c_2M_1 + c_1M_n - c_1\eta_1 M_n[D_0 + f(\xi_0)]\}\omega^2 - -c_1\eta_2 k_2[D_0 + f(\xi_0)]\omega + c_1c_2 - c_1c_2\eta_1[D_0 + f(\xi_0)] ;$$

$$H_4(\omega) = -M_1k_2\omega^3 + \{c_1k_2 - c_1(k_2\eta_1 + \eta_2 M_n)[D_0 + f(\xi_0)]\}\,\omega + +c_1c_2\eta_2[D_0 + f(\xi_0) ;$$

We write the module of the obtained transfer function in the form [7] as follows:

$$|\Phi(j\omega)| = \sqrt{\frac{H_1^2(\omega)+H_2^2(\omega)}{H_3^2(\omega)+H_4^2(\omega)}} \qquad (8)$$

Usage the analytical expression of the transfer function of the mechanical system protected against these vibrations, it is possible to evaluate the efficiency of vibration damping by choosing the structural optimal parameters of the considered mechanical system and the liquid joint dynamic damper.

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