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Dynamic Damping Process Control

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Abstract

The article discusses the vibration isolation system with a dynamic damper, which is connected in series with a movable base with a controlled damper intermittent. As a result of solving the optimization problem of dynamic oscillation damping for synthesizing control feature, which eliminates the resonance phenomena and provides attenuation of transients within the same kinematic effect period.

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1. Introduction

Additional mass is elastically attached to a protected object, are used to implement the method of dynamic damping, based on the increase in reactance of the system in a certain range of frequencies [1]. Such elastically attached mass is called dynamic absorbers. The positive effect of vibration is achieved only in the case of synchronization of oscillations of the additional mass and securable to the partial frequencies [2]. In this case, the kinetic energy of the oscillations of the system are redistributed between the protected object and the additional mass, which leads to a decrease of the amplitudes of the oscillations of the protected object.

The transition to control systems, which are elastically attached mass (dynamic absorbers), is undertaken with the aim to eliminate known drawbacks of the method of dynamic damping [3-5]. The main disadvantages of this method are associated with the need to fulfill the condition of synchronization of oscillations in the partial frequencies to take into account the large (resonant) oscillation amplitude of the attached mass and the duration of transient processes.

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There are various ways to control the process of dynamic damping [6,7]. The most promising is a method of indirect control of parameters of elastic-damping elements of the system that utilizes "full" information about the movement of the protected object and the attached mass, and the movable base [8-11]. Among the relevant systems that implement indirect control it is necessary to allocate system with damper intermittent and the additional elastic element of variable hardness [12,13].

To understand how are compensatory effects, which is achieved positive effect of the implementation of a control process of dynamic quenching oscillations, it is necessary to correctly formulate and solve the corresponding dynamic optimization problem. To solve these problems using mathematical apparatus of optimal control theory [14-19]. However, to obtain an analytical solution possible only in individual cases. Therefore, as a rule, use numerical methods and modern computer technology [20].

2. Mathematical model, formulation and solution of the optimization problem control

A design scheme of vibration isolation system with controllable dynamic damper shown in Fig. 1.

Process control dynamic damping of vibrations is done by changing the viscous resistance of the damper, which is installed in series between the dynamic damper and a movable base [21]. This arrangement controlled damper allows the use of "full" current information for the efficient formation of a compensation effect.

In theoretical terms, control is identified with the viscous resistance $U(t) = b(t)$.

Accept that the values of viscous resistance is limited to $0 \le U(t) \le U_0$.

By a deterministic kinematic perturbation $y(t) = y_0 \sin \omega t$ equation describing the motion of this system have the following form:

$$\begin{aligned} &m_1\ddot{z}_1 + b_1(\dot{z}_1 - \dot{y}) + c_1(z_1 - y) + b_2(\dot{z}_1 - \dot{z}_2) + c_1(z_1 - z_2) = 0, \\ &m_2\ddot{z}_2 + b_2(\dot{z}_2 - \dot{z}_1) + c_2(z_2 - z_1) + U(\dot{z}_2 - \dot{y}) = 0. \end{aligned} \quad (1)$$

Let the following dimensionless variables:

$\tau = \omega t$ – time;

$\xi_1 = z_1/y_0$, $\dot{\xi}_1 = \dot{z}_1/y_0\omega$, $\ddot{\xi}_1 = z_1/y_0\omega^2$, $\xi_2 = z_2/y_0$, $\dot{\xi}_2 = \dot{z}_2/y_0\omega$, $\ddot{\xi}_2 = \ddot{z}_2/y_0\omega^2$ – displacement, velocity and acceleration of the protected object and the dynamic damper;

$u = U/m_1k_1$ – control.

Let denote the eigenfrequencies $k_1 = \sqrt{c_1/m_1}$, $k_2 = \sqrt{c_2/m_2}$ and introduce the following dimensionless parameters:

$\eta = \omega/k_1$ – relative frequency;

$\lambda = c_2/c_1$ – the ratio of the coefficients of stiffness of the elastic elements;

$\mu = m_2/m_1$ – is the mass ratio of dynamic absorber to the mass of the protected object;

$\varepsilon_1 = b_1/m_1k_1$, $\varepsilon_2 = b_2/m_1k_1$ – is the relative damping;

$u_0 = U_0/m_1 k_1$ $(0 \le u \le u_0)$.

Using dimensionless variables and parameters, let transforming the system of equations (1) to the form

$$\begin{aligned} &\ddot{\xi}_1 + \frac{\varepsilon_1}{\eta}\left(\dot{\xi}_1 - \cos(\tau)\right) + \frac{1}{\eta^2}\left(\xi_1 - \sin(\tau)\right) + \frac{\varepsilon_2}{\eta}\left(\dot{\xi}_1 - \dot{\xi}_2\right) + \frac{\lambda}{\eta^2}\left(\xi_1 - \xi_2\right) = 0, \\ &\ddot{\xi}_2 + \frac{\varepsilon_2}{\mu\eta}\left(\dot{\xi}_2 - \xi_1\right) + \frac{1}{\mu\eta^2}\left(\xi_2 - \xi_1\right) + \frac{u}{\mu\eta}\left(\dot{\xi}_2 - \cos(\tau)\right) = 0. \end{aligned} \quad (2)$$