SYNTHESIS OF PERIODIC REGIMES OF UNIDIMENSIONAL VIBROCONTACT METERS

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An analytical model is proposed for analyzing and synthesizing the periodic regimes of unidimensional vibrocontact systems. The model is based on relationships between the displacement of the center of vibration, amplitude, and the phase parameter.

Further progress in machine-building depends to a significant extent on the availability of equipment to automatically monitor the dimensions, displacements, and strains of stationary and moving products and instruments in the production processes realized with these machines.

Serially produced contact monitoring devices can be used for such purposes only for stationary or relatively slow-moving objects. Thus, the development and introduction of measuring instruments employing the vibrocontact principle of operation has become a high priority in recent years.

Vibrocontact instruments realize a certain law of oscillatory vibropercussive motion and constitute an efficient means of automatic monitoring and control.

Analytic and graphical relations between the amplitudes of steady-state vibrations and the frequencies of external forces have been established [1, 2] for vibrocontact systems with symmetric and asymmetric characteristics. In such systems, the vibrocontact regime takes one of two forms. A pre-impact vibrocontact system undergoes small vibrations on an elastic suspension and is described by the model of a harmonic oscillator. A movable post-impact system is characterized by a change in elastic properties due to impact of the measurement head against a stop (the object being measured).

Studies of these regimes and a determination of ways to improve the accuracy and efficiency of dynamic systems of the vibrocontact type are necessary not only to develop theoretical models and methods of analyzing and synthesizing elemental structures, but also to obtain data that can be used in instrument design.

Asymmetric (bilinear) vibrocontact systems [3] have come into wide use for automatic monitoring by virtue of their unilateral elastic coupling with the object being measured.

The design diagram of the simplest vibrocontact meter (Fig. 1) has a working element schematized in the form of a translating spring-opposed mass colliding with the surface of the body that is being measured.

As a first approximation, the dynamic characteristic of such a system is represented by an elastic component that can be described by an asymmetric piecewise-linear relation (Fig. 2) and a dissipative component that accounts for losses in the material of the spring mechanism — and possibly losses occurring during the impact of the measurement head against the surface being measured. We use the following notation: m is the mass of the meter; x is the absolute coordinate; ɛ1 is the stiffness of the elastic suspension; ɛ2 is the stiffness of the body being measured; Ʉ is the gap between the measured surface and the equilibrium position of the meter; b is the linear damping factor; H is the amplitude of the exciting force; ω is frequency; ɣ is the phase shift. Here, the dynamic equation of the given system has the form

$$m\ddot{x} + f(x) + bx = H\cos \omega t,$$

where

$$f(x) = \begin{cases} ɛ_1 x, & x < Ʉ; \\ (ɛ_1 + ɛ_2) x, & x \geq Ʉ. \end{cases}$$

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Integrating (1) by the method of harmonic balance, we obtain a system of transcendental equations linking the displacement of the center of vibration \( a_0 \), the amplitude of the forced vibrations \( a \), and the phase parameter \( \psi_1 \):

\[

\begin{align*}
\frac{1}{a_0} &= \frac{1}{1-c/\Delta (x-1)(\psi_1-\psi_1)}; \\
\psi_1 - \frac{1}{\pi} \sin 2\psi_1 &= \frac{z}{2k} \\
\end{align*}
\]

where

\[

\begin{align*}
a_0 &= a_0/\Delta; \\
a &= a/\Delta; \\
x &= (c_1 + c_2)/c_1 \\
\end{align*}
\]

is the stiffness of the asymmetric system; \( \eta = H/m\Delta k_1^2 \) is the level of harmonic loading; \( \xi = \omega/K_1 \) is a coefficient expressing the frequency difference; \( K_1 \) is the frequency of free vibration.

We can use system (2)-(3) to limit the number of constant parameters (with elimination of \( \Delta \) and \( K_1 \) from the notation) and simplify the analysis of the approximate solutions.

System (2)-(3) is solved with allowance for the condition for coupling of the phases determined by the function \( \xi(\psi_1) \). Here, in accordance with the method of harmonic balance, the conditions for coupling of the phases of the asymmetric elastic characteristic along the coordinate \( \xi = x/\Delta \) have the form

\[

\begin{align*}
\xi &= a_0 + \alpha (a > 1), & f(\xi) &= f(a_0 + \alpha) \\
\xi &= 1, & f(\xi) &= f(1) \\
\xi &= a_0 - \alpha (a < -1), & f(\xi) &= f(a_0 - \alpha) \\
\end{align*}
\]

Conditions (4) mean that piecewise-linear relations \( f(\xi) \), capable of being represented by several expressions on the corresponding sections, are integrated separately over the intervals of each component of the elastic characteristic (see Fig. 2).

Transcendental system (2)-(3) is solved for the unknowns \( a_0, \alpha, \) and \( \psi_1 \) within the range \( 0 \leq \psi_1 \leq \pi/2 \) and makes it possible to construct not only resonance relation \( \alpha(\xi) \) — used universally in the study of nonlinear systems — but also the rela-