TECHNICAL SCIENCE. MECHANICS

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PECULIARITIES OF DYNAMIC EFFECTS IN VIBRATION INTERACTIONS WITH OPERATING MEDIA AND THEIR EVALUATION

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Abstract

The article focuses on the problems of development of variants and a substantiation of structural and technical schemes of the measuring devices reacting to special modes of interaction of the granulated operating medium with a vibrating surface. Analytical approaches to the theory of vibrational displacements are used in the paper. Continuous tossing modes and the time of the medium element approach, multiple of the period of the support surface oscillation, are also proposed and studied. It is shown that the interaction processes with the continuous tossing have properties that can be reflected in the forms of self-organized motion of the measuring device elements.

Keywords: vibration interaction, vibration hardening, vibration measurement, vibration collision, vibration technology.

Introduction.

The control of technological processes associated with the use of the effects of vibrational interactions is a rather complex problem that is encountered in specific issues of vibrational transportation, displacement, shock interaction for the purpose of hardening surfaces, etc. [1-3].

I. General provisions. Statement of the research task.

The paper addresses problems of development of measuring means for controlling the parameters of the vibration hardening process of long products. In these products, the necessary properties of the surface layer are formed in the process of continuous collisions of the granular medium elements and a vibrating surface [4].

The model vibratory technological machine (Fig. 1) includes the surface 1 of the working member mounted on the elastic elements 2, the source of vibration excitation 3, the container 5 with the workpiece 6 and the "operating medium" layer 7 of the steel balls, the model sensor 9 with the elements of the "model medium" 9. Dynamic characteristics of the vibration table are varied by means of the device 4 of the transformation of motion *L*.

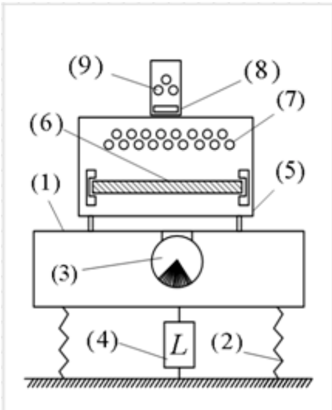

Fig. 1. Schematic diagram of a vibrating technological machine with a sensor. 1 is the surface of the working member, 2 is the elastic element, 3 is the source of vibration excitation, 4 is the motion transformation device, 5 is the body, 6 is the workpiece, 7 is the "operating medium", 8 is the sensor, 9 is the "model medium"

The research task is to develop the principles of construction and methods for designing sensors that register the effects of vibration processes that express the features of the interaction of the particle layer, the vibrating surface and the workpiece.

II. Principles of construction and design features of sensors.

Existing methods of research and sensors used record the parameters of the vibration process by measuring the displacement, speed, acceleration, sharpness of individual points of the vibrating table or individual points of the workpiece. As for the quality of the workpiece, it can be estimated on the basis of experimental data obtained from the comparison of the parameters of vibrational interactions and the results of evaluating the properties of the hardened surface of the workpiece.

The sensor of the boundary parameters. To register critical modes of vibration interactions with the formation of a rupture, an experimental boundary-value sensor was developed, the schematic diagram of which is shown in Fig. 2: 1 is a cylindrical body, 2 is an inertial body, 3 is a piezo-sensitive element, 4 is a fastening element, 5 is a vibrating base, 6 is conductors.

Dynamic state estimator. To take into account the interaction of several elements, a test sensor for estimating dynamic states is proposed (Fig. 3). The test sensor is mounted on the surface of the vibrating table (5) and contains a cylindrical housing (1); inertial elements of the operating medium (2); a piezoelectric element (3); a fastening element (4); current leads (6). The housing of the dynamic state estimator contains several "specimens" of the operating medium of the vibratory technological machine. The sensor device, in its turn, assumes a large "resolution" for recording the physical effects occurring within the working layer.

The sensor of integral evaluation of the dynamic state of the medium. To record the integral characteristics of the interaction of elements of the operating medium on the basis of indirect indicators, a sensor for the integral evaluation of the dynamic states of the medium has been developed.

Figure 4 shows the sensor diagram, containing a cylindrical housing (1), elements of the operating medium (metal balls) (2); microphone (3); fastening of the cylindrical sensor on the bearing surface of the vibration table (4); bearing surface of the vibration table (5); microphone current leads (6); the microphone holder (7).

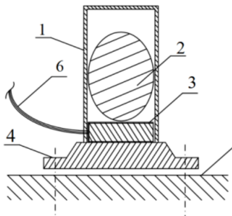

Fig. 2. The sensor of the boundary parameters

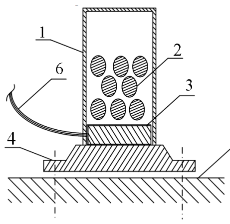

Fig. 3. The sensor for estimating the dynamic states of the operating medium

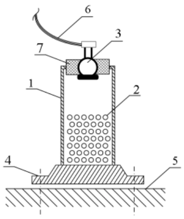

Fig. 4. The sensor of integral estimation of dynamic states of the operating medium

The sensor (Fig. 4) works as follows: with periodic disturbance from the vibrating base 5 of the vibratory technological machine, movement of the inertial elements 2 of the "model medium" occurs, accompanied by shocks, displacements, tossing. As a result, oscillations of the air column occur inside the sensor housing and are transferred to the membrane microphone 3. The signal from the microphone through the current leads is transferred to the analog-digital converter.

The proposed designs of sensors are based on the assumption of the similarity or interrelation between the dynamic characteristics of the "operating medium" of the vibratory technological machine and the "model medium" of the sensor placed inside the sensor housing.

III. Justification of the technical result.

To confirm the possibility of obtaining a technical result, a prototype sensor was developed and a comparative experiment was performed on a laboratory vibration unit with signal transmission to an analog-to-digital converter. Signals I from the prototype sensor and signals II from a specially modified sensor recorded on a laboratory vibration table, operating at a frequency of 20-30 Hz with an amplitude of no more than 1 mm are recorded. Signals I and signals II have spectral representations in the form of graphs of functions depending on frequency (Fig. 5). The presented coefficients in the Fourier expansion of signals I and signals II indicate the difference of signals, but the statistical significance of their differences requires confirmation.

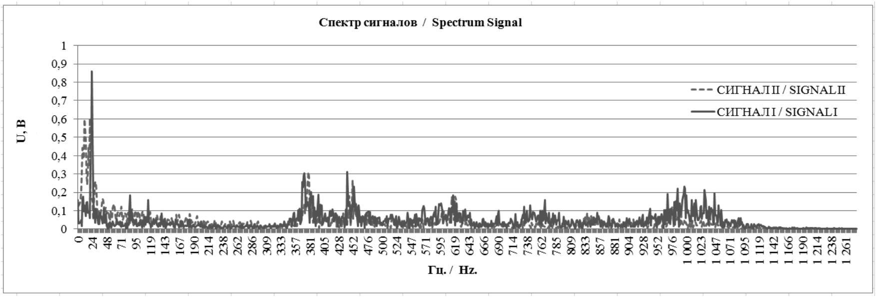

Fig. 5. Spectral representations of signals I and signals II

In Fig. 6, there is a graph of the signal I recorded by the recording equipment for the case where the metal balls are placed inside the sensor housing of the integral estimation of dynamic states (Fig. 4). Figure 7 shows a graph of the signal II recorded by the recording equipment for the case where metal balls are absent inside the sensor housing. Using the sensor prototype, an experiment was performed to confirm or deny the fact that the prototype sensor, taking into account the imposition of noise and external noise, registers a useful signal that records the interaction of inertial elements of the "model medium" of the sensor.

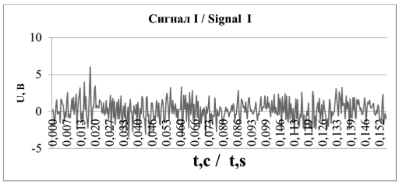

Fig.6. A graph of the signal I recorded by the recording equipment for an embodiment that the metal balls are placed inside the sensor housing

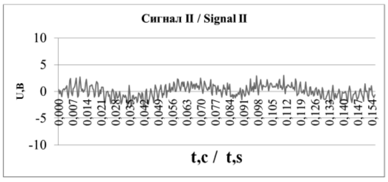

Fig.7. The signal plot II recorded by the recording equipment for the case that there is no metal balls are inside the sensor housing

The fact of registering a useful signal is confirmed by the statistical significance of the difference between the signal I recorded from the sensor with inertia elements (Fig. 6) and the signal II recorded from the sensor without inertia elements (Fig. 7), based on Smirnov's homogeneity criterion with significance level $\alpha = 0.05.$. Fig.8 shows the histograms of the relative frequencies for samples X and Y.

Figure 9 shows the empirical distribution functions corresponding to the samples X and Y. The abscissa represents the points that determine the intervals for grouping the values of the signals at the instants of time, and the ordinates represent the relative frequencies that correspond to the intervals of the grouping.

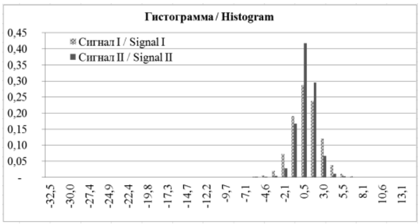

Fig.8. The histogram of the relative frequencies for signal I and signal II

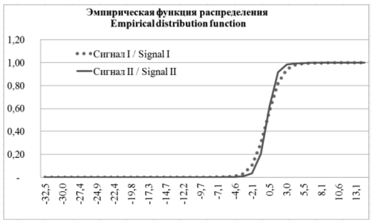

Fig. 9. Empirical distribution functions for signals I and signals II

The Smirnov homogeneity criterion (the Kolmogorov-Smirnov test) showed that the H_0 hypothesis is rejected (H_0 is the hypothesis of the homogeneity of signals I and signals II, the corresponding statistics $S = \sqrt{mn/(m+n)} \cdot D_{m,n} \approx 2.87$ exceeds the critical value $S_{0.05} = 1.36$ corresponding to the significance level $\alpha = 0,05$, m, n - is the sample sizes, $D_{m,n} = \sup\left|F_n^*(y) - G_m^*(y)\right|$ is the characteristic of the difference between the empirical distribution functions $F_n^*(y)$, $G_m^*(y)$, for samples *X* and *Y*).

IV. Registration of the forms of motion of elements in model problems depending on parameters.

The signal generated by the sensor based on the motion of the "model medium" depends on the characteristics of the elementary "specimens" of the medium and their number. By selecting the number of elements of the "model medium" and the shape of the sensor housing, it is possible to obtain a signal with various characteristics, which, in particular, can be the average value or the standard deviation from the mean. Of interest are the features of functional dependences between the main characteristics of the signal.

Fig. 10 and Fig.11 represent graphs of typical signals from sensors with 2 and 22 elements of "model media", respectively.

The presented variants of signals reflect a process conventionally called "quasi-beats" and characterized by a periodic increase in the oscillation amplitude of control points of the model vibration table in accordance with Fig. 10 and Fig. 11. The same technological process is reflected by different graphs of signals from sensors of one schematic diagram, but with different numbers of the "model medium" elements.

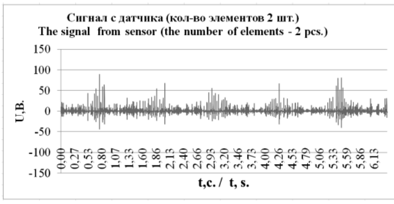

Fig.10. The signal is recorded from a sensor that contains 2 balls inside the housing

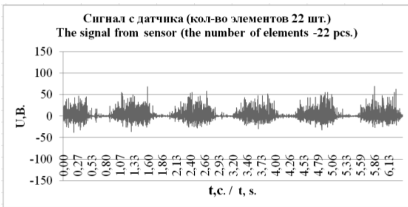

Fig.11. The signal is recorded from a sensor that contains 22 balls inside the housing

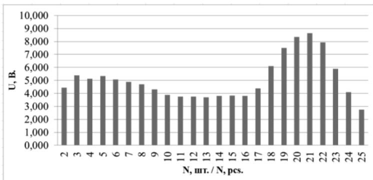

Fig. 12. The average signals from the sensors, depending on N – the number of elements of the inertial body (averaging is over the nearest points)

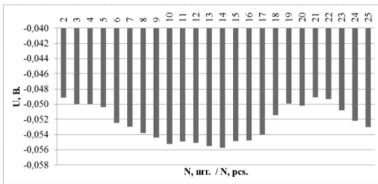

Fig. 13. Mean-square deviation of signals from sensors, depending on N – the number of elements of the inertial body (averaging is over the nearest points)

Fig. 12 and 13 show the histograms of the functions of mean values and root mean square deviations for sensor signals when the number of elements of the model medium changes from 0 to 27 (the data are averaged).

Conclusion.

The constructive diversity of sensors generates a variety of signals reflecting the dynamic processes of interaction of the "operating medium" with the vibrating surface of the technological machine. The "model medium" and sensor design serve as factors that form the relationships between the dynamic interaction of the "operating medium" of the vibrating machine and the "model medium" of the sensor. To determine the significant constructive factors of the relationship between the "model medium" - "operating medium" - the vibrating surface, the method of determining the statistical significance is used. The number of elements of the "model medium" is an important factor affecting the quality of recording dynamic effects that are implemented in the "model medium", reflecting the effects of the dynamics of modes in the process of the vibratory technological machine operation.

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