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Macromodel of Mechanical Processes in the Amortized Electronic Devices

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Abstract: In the research shows the importance of protecting electronic devices from the effects of vibration in terms of their stability and durability. The task of volume 6-stage vibration insulation taking into account rotary fluctuations of a design of electronic devices round axes of the Cartesian system of coordinates is set. Systems of the equations on which the topological model of mechanical processes in system of depreciation of the block of the electronic device is constructed are received. Possibility of connection of macromodels with various number of levels of cascade system of vibration insulation and different quantity of internal elements on each of them is shown. Total accelerations on printing knots and on separate electronic components allow to estimate mechanical stability and durability of electronic devices.

Key words: Vibroinsulators, electronic device, vibration influences, vibroprotection, stability, reliability, design durability, mechanical modeling, system of vibration insulation

INTRODUCTION

All types of the Electronic Devices (ED) are affected by external vibration loadings which indulge in each Electronic Component (EC) and each detail of the bearing design. Mechanical influences take place in the working ED if it is established on mobile object or at its transportation in a non-working state. Thus, even stationary ED and also mobile ED when moving from a production place to a place of operation are exposed not to continuous but short-term transport shaking.

At design of ED it is necessary to provide vibration stability (Kofanov, 2011), i.e., ED properties at the set vibration to carry out the provided functions and to keep values of the output characteristics in the set limits. It will be in that case when accelerations of EK on exceed maximum permissible values with necessary stocks. Ensuring vibration durability of the bearing designs is characterized by tension in materials which should not exceed strength also with necessary stocks (Crede, 1963).

For any form of vibration exposure arise resonant phenomena in which the mechanical acceleration EC and mechanical stresses in the materials have high values. The most dangerous is usually the first resonant frequency when these values are increased by several orders of magnitude and may exceed the maximum allowable value. When dangerous resonant frequencies can not bring constructive measures for the operating frequency range, it is necessary to apply vibration isolation (Ilyinsky, 1982). For this purpose, various types of vibration isolators-additional damping devices mounted between the EC and the objects of their installation.

MATERIALS AND METHODS

Technique: Methodical approach to design of ED with vibration insulation provides mathematical modeling of the system including from 4-10 and more vibroinsulators located not only on the basis of the block or a case of ED but also on other walls of the case. Thus, it is possible to reduce acceleration of vibrations on all three axes of volume influences. Unevenness of an arrangement of internal EC and details of the bearing designs leads to emergence of torques of a design of ED round three axes of coordinates (Denavit and Hartenberg, 1955). Therefore in this research the task of modeling of 6-stage vibration that is distinctive feature of the considered task is set. The technique of modeling is constructed on electromechanical analogy that allows not to develop the special computer program for vibration modeling and to use widespread programs of modeling of electric chains (OrCAD PSpice, MicroSim, etc.).

The main part: Vibroprotection using vibration isolators is one of the main ways to protect the units, cabinets, racks ED from mechanical effects (Crede, 1963; Kamaev, 2000).

The main requirement to system of vibroprotection is the exception of possibility of resonant fluctuations of ED

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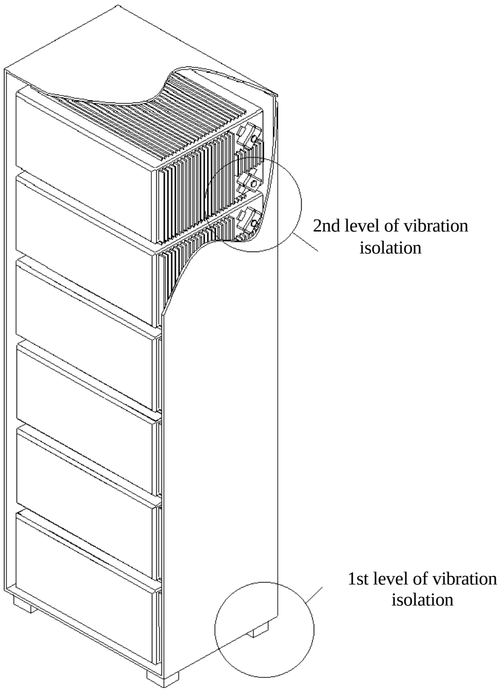

Fig. 1: Sketch of a design of a six-storied case with cascade system of vibration insulation

in the range of frequencies determined in the specification on design of ED. Borders of this range depend on device service conditions and in certain cases can be very wide. Admissible level of accelerations at various types of mechanical influences is defined on EC, proceeding from requirements of specifications for reliability taking into account coefficients of stocks. For constructive materials the admissible level of resonant amplitude of fluctuations is defined, proceeding from the settlement mechanical tension which are compared to strength of materials. Thus, the formulation of the problem of modeling a 6-power vibration is formulated as follows.

It is set object of vibroprotection ED design with cascade vibration insulation consisting of the case and blocks located in it (Fig. 1). A source of fluctuations of the ED carrier a surface on which ED is located. It is possible to understand the ship as the carrier. The design of ED is connected to the vibrating ship case surface by means of case vibroinsulators (for example, AKSS-120IH). Blocks are connected to case walls other vibroinsulators (for example, AKSS-25IH). Fluctuations of blocks and walls of a case influence at each other.

It is required to define mechanical accelerations on walls of ED blocks which are used for calculation of mechanical accelerations in places of fastenings of the Printing Knots (PK) located in blocks and mechanical accelerations of EC established on printed-circuit boards subsequently.

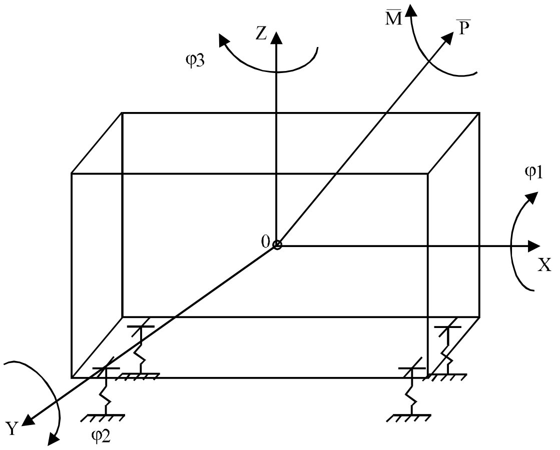

Fig. 2: The sketch of a design of the electronic device on vibroinsulators

In the course of modeling the following assumptions are accepted (Vachenko *et al*., 2012; Uvaysov *et al*., 2011):

- The case represents a box with deformable walls in which there are blocks
- Each block has a parallelepiped appearance with the walls deformed at vibration in which printing knots with ED are rigidly fixed
- The case is connected to a carrier surface elastic communications which parameters are defined by vibroinsulators
- Blocks are connected to a case elastic communications which parameters are defined by other vibroinsulators

Influences the mechanical accelerations arising in places of fastening of a case to the ship case. Consider modeling unit installed inside the enclosure of the cabinet on vibroinsulators.

At calculation of the block on vibroinsulators it is considered how the weight established on the elastic communications connecting the block to a case. Such system (Fig. 2) has six degrees of freedom. They are defined by shifts of the center of masses 0 along axes X, Y, Z and angles of rotation concerning these axes.

By drawing up the equations of the compelled fluctuations of the block as systems with six degrees of freedom, it is necessary to consider all revolting forces and forces of inelastic resistance (Roberson and Schwertasser, 1988). Generally, the revolting forces operating on the block can be any both in size and in the direction. Having led these forces to the center of mass of system, we will receive equally effective main a vector and the main moment (Fig. 2). We will designate their projections to axes of coordinates of X, Y, Z through P1 (t), P2 (t), P3 (t) and M1 (t), M2 (t), M3 (t), t, the current time.

RESULTS AND DISCUSSION

The block macromodel on vibroinsulators described by system of the equations of Lagrange (Nikravesh, 1984; Homenko, 2012) is nonlinear as the Coefficients of Mechanical Losses (CML) of vibroinsulators along axes X, Y, Z, depend on tension and on temperature. For reduction of time of calculations there are analytical expressions for calculation of CML which aren't depending obviously on tension or amplitudes of movements. We will make in Lagrange's equations consistently differentiation on each of six coordinates and it is applicable a complex form of record of the generalized revolting loadings for each of them. Considering kinematic nature of excitement, we will receive the following system of the equations at impact of harmonious vibration:

$$\begin{cases} -\beta_{11}\omega^2\overline{A}_1 + (1+j\gamma_1)(\alpha_{11}(\overline{A}_1 - \overline{A}_{01}) + \alpha_{15}(\overline{A}_1 - \overline{A}_5) + \alpha_{16}(\overline{A}_1 - \overline{A}_6)) = 0; \\ -\beta_{22}\omega^2\overline{A}_2 + (1+j\gamma_2)(\alpha_{22}(\overline{A}_2 - \overline{A}_{02}) + \alpha_{24}(\overline{A}_2 - \overline{A}_4) + \alpha_{26}(\overline{A}_2 - \overline{A}_6)) = 0; \\ -\beta_{33}\omega^2\overline{A}_3 + (1+j\gamma_3)(\alpha_{33}(\overline{A}_3 - \overline{A}_{03}) + \alpha_{34}(\overline{A}_3 - \overline{A}_4) + \alpha_{35}(\overline{A}_3 - \overline{A}_5)) = 0; \\ -\beta_{44}\omega^2\overline{A}_4 - \beta_{45}\omega^2(\overline{A}_4 - \overline{A}_5) - \beta_{46}\omega^2(\overline{A}_4 - \overline{A}_6) + (1+j\gamma_{2,3})(\alpha_{24}(\overline{A}_4 - \overline{A}_2) + \\ +\alpha_{34}(\overline{A}_4 - \overline{A}_3) + \alpha_{44}(\overline{A}_4 - \overline{A}_{04}) + \alpha_{45}(\overline{A}_4 - \overline{A}_5) + \alpha_{46}(\overline{A}_4 - \overline{A}_6)) = 0; \\ -\beta_{45}\omega^2(\overline{A}_5 - \overline{A}_4) - \beta_{55}\omega^2\overline{A}_5 - \beta_{56}\omega^2(\overline{A}_5 - \overline{A}_6) + (1+j\gamma_{1,3})(\alpha_{15}(\overline{A}_5 - \overline{A}_1) + \\ +\alpha_{35}(\overline{A}_5 - \overline{A}_3) + \alpha_{45}(\overline{A}_5 - \overline{A}_4) + \alpha_{55}(\overline{A}_5 - \overline{A}_{05}) + \alpha_{56}(\overline{A}_5 - \overline{A}_6)) = 0; \\ -\beta_{46}\omega^2(\overline{A}_6 - \overline{A}_4) - \beta_{56}\omega^2(\overline{A}_6 - \overline{A}_5) - \beta_{66}\omega^2\overline{A}_6 + (1+j\gamma_{1,2})(\alpha_{16}(\overline{A}_6 - \overline{A}_1) + \\ +\alpha_{26}(\overline{A}_6 - \overline{A}_2) + \alpha_{46}(\overline{A}_6 - \overline{A}_4) + \alpha_{56}(\overline{A}_6 - \overline{A}_5) + \alpha_{66}(\overline{A}_6 - \overline{A}_{06})) = 0, \end{cases} \tag{1}$$

Where:

j = Imaginary unit

A_{01-03} = Amplitudes of vibromovements of the basis on axes X, Y, Z, respectively

A_{04-06} = Amplitudes of turns of the basis concerning axes X, Y, Z, respectively

The discussion of Eq. 1 given below step by step:

- Circular frequency of excitement
- The generalized rigidity coefficients depending on temperature and representing single reactions of communications in i-volume the direction when moving system to k-volume the direction (thus =)
- Weight, moment of inertia or centrifugal moment
- Coefficients of mechanical losses when moving along axes X, Y, Z, respectively
- Accepts value or depending on coefficient
- Complex amplitude of shift on i-that coordinate

We will consider receiving coefficients α_{ik} and β_{ik}. Coefficients α_{ik} for system share with six degrees of freedom on the following four groups: The linear:

$$\alpha_{11} = \sum k^X,\ \alpha_{22} = \sum k^Y,\ \alpha_{33} = \sum k^Z$$

Linearly-rotary:

$$\alpha_{15} = \sum k^X z,\ \alpha_{16} = -\sum k^X y,\ \alpha_{24} = -\sum k^Y z,\ \alpha_{26} = \sum k^Y x,\ \alpha_{34} = \sum k^Z y,\ \alpha_{35} = -\sum k^Z x$$

The gyroscopic:

$$\alpha_{45} = -\sum k^Z xy,\ \alpha_{46} = -\sum k^Y zx,\ \alpha_{56} = -\sum k^X yz$$

The tortional:

$$\alpha_{44} = \sum (k^Y z^2 + k^Z y^2),\ \alpha_{55} = \sum (k^Z x^2 + k^X z^2),\ \alpha_{66} = \sum (k^X y^2 + k^Y x^2)$$

Where:

$k^{x\text{-}z}$ = Coefficients of rigidity of elements of communication along the corresponding axes
x-z = Coordinates of fastening of vibroinsulators concerning the center of mass of the block

Coefficients share on three groups:

- For linear shifts: $\beta_{11} = \beta_{22} = \beta_{33}$ = m body weight
- For turns: $\beta_{44} = J^X$, $\beta_{55} = J^Y$, $\beta_{66} = J^Z$ the moments of inertia of a body concerning axes X, Y, Z
- For communication of linear shifts and turns: $\beta_{45} = -J^{XY}$, $\beta_{46} = J^{XZ}$, $\beta_{56} = -J^{YZ}$ the corresponding centrifugal moments

After receiving as a result of the decision of system of the Eq. 1 movements of the block, it is possible to define accelerations of the block and mechanical tension in vibroinsulators. Amplitude of vibration acceleration is defined by multiplication of amplitude of vibromovement by a square of circular frequency of vibration:

$$\bar{a} = \bar{A} \times \omega^2 \tag{2}$$

For creation of topological macromodel of the block (Kofanov, 2011) on vibroinsulators, we will divide the left part of system of the Eq. 1 into jω and having grouped factors relatively A1, A2, A3, A4, A5, A6, A01, A02, A03, A04, A05, A06, we will receive:

$$\left\{\begin{array}{l}
\left(-\frac{\beta_{11}\omega}{j} + \frac{\alpha_{11}}{j\omega} + \frac{\alpha_{11}\gamma_1}{\omega} + \frac{\alpha_{15}}{j\omega} + \frac{\alpha_{15}\gamma_1}{\omega} + \frac{\alpha_{16}}{j\omega} + \frac{\alpha_{16}\gamma_1}{\omega}\right)A_1 - \left(\frac{\alpha_{15}}{j\omega} + \frac{\alpha_{15}\gamma_1}{\omega}\right)A_5 - \left(\frac{\alpha_{16}}{j\omega} + \frac{\alpha_{16}\gamma_1}{\omega}\right)A_6 = \\
= \left(\frac{\alpha_{11}}{j\omega} + \frac{\alpha_{11}\gamma_1}{\omega}\right)A_{01} \\
\left(-\frac{\beta_{22}\omega}{j} + \frac{\alpha_{22}}{j\omega} + \frac{\alpha_{22}\gamma_2}{\omega} + \frac{\alpha_{24}}{j\omega} + \frac{\alpha_{24}\gamma_2}{\omega} + \frac{\alpha_{26}}{j\omega} + \frac{\alpha_{26}\gamma_2}{\omega}\right)A_2 - \left(\frac{\alpha_{24}}{j\omega} + \frac{\alpha_{24}\gamma_2}{\omega}\right)A_4 - \left(\frac{\alpha_{26}}{j\omega} + \frac{\alpha_{26}\gamma_2}{\omega}\right)A_6 = \\
= \left(\frac{\alpha_{22}}{j\omega} + \frac{\alpha_{22}\gamma_2}{\omega}\right)A_{02} \\
\left(-\frac{\beta_{33}\omega}{j} + \frac{\alpha_{33}}{j\omega} + \frac{\alpha_{33}\gamma_3}{\omega} + \frac{\alpha_{34}}{j\omega} + \frac{\alpha_{34}\gamma_3}{\omega} + \frac{\alpha_{35}}{j\omega} + \frac{\alpha_{25}\gamma_3}{\omega}\right)A_3 - \left(\frac{\alpha_{34}}{j\omega} + \frac{\alpha_{34}\gamma_3}{\omega}\right)A_4 - \left(\frac{\alpha_{35}}{j\omega} + \frac{\alpha_{35}\gamma_3}{\omega}\right)A_5 = \\
= \left(\frac{\alpha_{33}}{j\omega} + \frac{\alpha_{33}\gamma_3}{\omega}\right)A_{03} \\
\left(\frac{\alpha_{24}}{j\omega} + \frac{\alpha_{24}\gamma_{2,3}}{\omega}\right)A_2 + \left(\frac{\alpha_{34}}{j\omega} + \frac{\alpha_{34}\gamma_{2,3}}{\omega}\right)A_3 + \left(\begin{array}{l} \frac{\alpha_{44}}{j\omega} + \frac{\alpha_{44}\gamma_{2,3}}{\omega} - \frac{\beta_{44}\omega}{j} + \frac{\alpha_{24}}{j\omega} + \frac{\alpha_{24}\gamma_{2,3}}{\omega} + \frac{\alpha_{34}}{j\omega} + \frac{\alpha_{34}\gamma_{2,3}}{\omega} + \\ + \frac{\alpha_{45}}{j\omega} + \frac{\alpha_{45}\gamma_{2,3}}{\omega} - \frac{\beta_{45}\omega}{j} + \frac{\alpha_{46}}{j\omega} + \frac{\alpha_{46}\gamma_{2,3}}{\omega} - \frac{\beta_{46}\omega}{j} \end{array}\right)A_4 + \\
+ \left(\frac{\alpha_{45}}{j\omega} + \frac{\alpha_{45}\gamma_{2,3}}{\omega} - \frac{\beta_{45}\omega}{j}\right)A_5 + \left(\frac{\alpha_{46}}{j\omega} + \frac{\alpha_{46}\gamma_{2,3}}{\omega} - \frac{\beta_{46}\omega}{j}\right)A_6 = \left(\frac{\alpha_{44}}{j\omega} + \frac{\alpha_{44}\gamma_1}{\omega}\right)A_{04} \\
\left(\frac{\alpha_{15}}{j\omega} + \frac{\alpha_{15}\gamma_{1,3}}{\omega}\right)A_1 + \left(\frac{\alpha_{35}}{j\omega} + \frac{\alpha_{35}\gamma_{1,3}}{\omega}\right)A_3 + \left(\frac{\alpha_{45}}{j\omega} + \frac{\alpha_{45}\gamma_{1,3}}{\omega} - \frac{\beta_{45}\omega}{j}\right)A_4 + \\
+ \left(\begin{array}{l} \frac{\alpha_{55}}{j\omega} + \frac{\alpha_{55}\gamma_{1,3}}{\omega} - \frac{\beta_{55}\omega}{j} + \frac{\alpha_{15}}{j\omega} + \frac{\alpha_{15}\gamma_{1,3}}{\omega} + \frac{\alpha_{35}}{j\omega} + \\ \frac{\alpha_{35}\gamma_{1,3}}{\omega} + \frac{\alpha_{45}}{j\omega} + \frac{\alpha_{45}\gamma_{1,3}}{\omega} - \frac{\beta_{45}\omega}{j} + \frac{\alpha_{56}}{j\omega} + \frac{\alpha_{56}\gamma_{1,3}}{\omega} - \frac{\beta_{56}\omega}{j} \end{array}\right)A_5 + \left(\frac{\alpha_{56}}{j\omega} + \frac{\alpha_{56}\gamma_{1,3}}{\omega} - \frac{\beta_{56}\omega}{j}\right)A_6 = \left(\frac{\alpha_{55}}{j\omega} + \frac{\alpha_{55}\gamma_3}{\omega}\right)A_{05} \\
\left(\frac{\alpha_{16}}{j\omega} + \frac{\alpha_{16}\gamma_{1,2}}{\omega}\right)A_1 + \left(\frac{\alpha_{26}}{j\omega} + \frac{\alpha_{26}\gamma_{1,2}}{\omega}\right)A_2 + \left(\frac{\alpha_{46}}{j\omega} + \frac{\alpha_{46}\gamma_{1,2}}{\omega} - \frac{\beta_{46}\omega}{j}\right)A_4 + \left(\frac{\alpha_{56}}{j\omega} + \frac{\alpha_{56}\gamma_{1,2}}{\omega} - \frac{\beta_{56}\omega}{j}\right)A_5 + \\
+ \left(\frac{\alpha_{66}}{j\omega} + \frac{\alpha_{66}\gamma_{1,2}}{\omega} - \frac{\beta_{66}\omega}{j} + \frac{\alpha_{16}}{j\omega} + \frac{\alpha_{16}\gamma_{1,2}}{\omega} + \frac{\alpha_{26}}{j\omega} + \frac{\alpha_{26}\gamma_{1,2}}{\omega} + \frac{\alpha_{46}}{j\omega} + \frac{\alpha_{46}\gamma_{1,2}}{\omega} - \frac{\beta_{46}\omega}{j} + \frac{\alpha_{56}}{j\omega} + \frac{\alpha_{56}\gamma_{1,2}}{\omega} - \frac{\beta_{56}\omega}{j} + \right)A_6 = \left(\frac{\alpha_{66}}{j\omega} + \frac{\alpha_{66}\gamma_3}{\omega}\right)A_{06}
\end{array}\right. \tag{3}$$

Having made replacement:

$$m_{ij} = j\beta_{ij}\omega,\ k_{ij} = {}^{\alpha_{ij}}\!\!\diagup_{j\omega},\ d_{ij} = {}^{\alpha_{ij}\gamma_i}\!\!\diagup_{\omega}$$

We will write down system of the Eq. 3 in a matrix form Eq. 4. It is possible to notice that the system of Eq. 4 represents the description of a mechanical chain made by means of a method of nodal potentials. Having excluded from it sources of external influences, we will receive the topological macromodel of fluctuations of the block represented in Fig. 3 in the form of an equivalent chain.

$$\begin{bmatrix}
\left[\begin{matrix} m_{11}+k_{11}+d_{11}+ \\ +k_{15}+d_{15}+k_{16}+d_{16} \end{matrix}\right] & 0 & 0 & 0 & [-k_{15}-d_{15}] & [-k_{16}-d_{16}] \\
0 & \left[\begin{matrix} m_{22}+k_{22}+d_{22}+ \\ +k_{24}+d_{24}+k_{26}+d_{26} \end{matrix}\right] & 0 & -[k_{24}+d_{24}] & 0 & -[k_{26}+d_{26}] \\
0 & 0 & \left[\begin{matrix} m_{11}+k_{11}+d_{11}+ \\ +k_{15}+d_{15}+k_{16}+d_{16} \end{matrix}\right] & -[k_{34}+d_{34}] & -[k_{35}+d_{35}] & 0 \\
0 & -[k_{24}+d_{24}] & -[k_{34}+d_{34}] & \left[\begin{matrix} k_{44}+d_{44}+m_{44}+ \\ +k_{24}+d_{24}+k_{34}+d_{34}+ \\ +k_{44}+d_{44}+m_{44}+ \\ +k_{44}+d_{44}+m_{44} \end{matrix}\right] & -[k_{44}+d_{44}+m_{44}] & -[k_{44}+d_{44}+m_{44}] \\
-[k_{15}+d_{15}] & 0 & -[k_{35}+d_{35}] & -[k_{45}+d_{45}+m_{45}] & \left[\begin{matrix} k_{55}+d_{55}+m_{55}+ \\ +k_{15}+d_{15}+k_{35}+d_{35}+ \\ +k_{45}+d_{45}+m_{45}+ \\ +k_{56}+d_{56}+m_{56} \end{matrix}\right] & -[k_{56}+d_{56}+m_{56}] \\
-[k_{16}+d_{16}] & -[k_{26}+d_{26}] & 0 & -[k_{46}+d_{46}+m_{46}] & -[k_{56}+d_{56}+m_{56}] & \left[\begin{matrix} k_{66}+d_{66}+m_{66}+ \\ +k_{16}+d_{16}+k_{26}+d_{26}+ \\ +k_{46}+d_{46}+m_{46}+ \\ +k_{56}+d_{56}+m_{56} \end{matrix}\right]
\end{bmatrix}
\begin{bmatrix} A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \\ A_6 \end{bmatrix}
=
\begin{bmatrix} (k_{11}+d_{11})A_{01} \\ (k_{22}+d_{22})A_{02} \\ (k_{33}+d_{33})A_{03} \\ (k_{44}+d_{44})A_{04} \\ (k_{55}+d_{55})A_{05} \\ (k_{66}+d_{66})A_{06} \end{bmatrix}$$

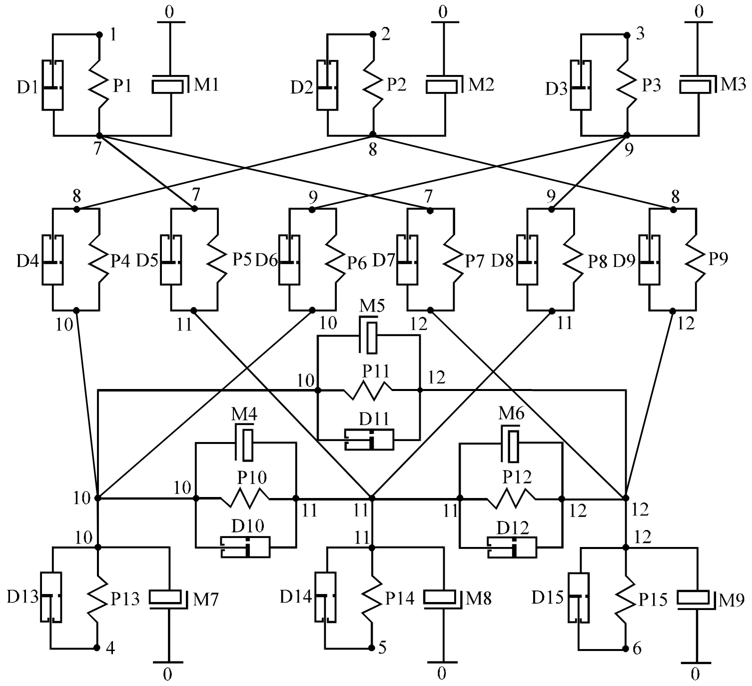

Fig. 3: Topological model of mechanical processes in the ED block

Table 1: Parameters of elements of macromodel of mechanical process

Elements of a chain and parameters					
M	Parameters	D	Parameters	P	Parameters
M1	β_{11}	D1	$\omega/(\alpha_{11}\gamma_1)$	P1	$1/\alpha_{11}$
M2	β_{22}	D2	$\omega/(\alpha_{22}\gamma_2)$	P2	$1/\alpha_{22}$
M3	β_{33}	D3	$\omega/(\alpha_{33}\gamma_3)$	P3	$1/\alpha_{33}$
M4	β_{45}	D4	$\omega/(\alpha_{24}\gamma_{24})$	P4	$1/\alpha_{24}$
M5	β_{46}	D5	$\omega/(\alpha_{15}\gamma_{15})$	P5	$1/\alpha_{15}$
M6	β_{56}	D6	$\omega/(\alpha_{34}\gamma_{34})$	P6	$1/\alpha_{34}$
M7	β_{44}	D7	$\omega/(\alpha_{16}\gamma_{16})$	P7	$1/\alpha_{16}$
M8	β_{55}	D8	$\omega/(\alpha_{35}\gamma_{35})$	P8	$1/\alpha_{35}$
M9	β_{66}	D9	$\omega/(\alpha_{26}\gamma_{26})$	P9	$1/\alpha_{26}$
		D10	$\omega/(\alpha_{45}\gamma_{45})$	P10	$1/\alpha_{45}$
		D11	$\omega/(\alpha_{46}\gamma_{46})$	P11	$1/\alpha_{46}$
		D12	$\omega/(\alpha_{56}\gamma_{56})$	P12	$1/\alpha_{56}$
		D13	$\omega/(\alpha_{44}\gamma_{44})$	P13	$1/\alpha_{44}$
		D14	$\omega/(\alpha_{55}\gamma_{55})$	P14	$1/\alpha_{55}$
		D15	$\omega/(\alpha_{66}\gamma_{66})$	P15	$1/\alpha_{66}$

Parameters of elements of a chain are calculated according to Table 1. Entrance impacts on the block are set by means of sources of movements along axes X, Y, Z and turns of rather same axes. Sources are connected in hubs 1-6 of macromodel (Fig. 3), respectively.

After calculation of the macromodel containing sources of entrance influences, we receive values of movements and turns of the center of mass of the block concerning axes X, Y, Z as potential variables of hubs 7-12, respectively.

Now, we will pass to consideration of more difficult design when in the case standing on vibroinsulators there is a block in turn connected to case walls by means of vibroinsulators. We will call such system as a system with cascade vibration insulation. As it was described above in this system it is necessary to consider dynamic nature of impacts of a case on the block which is in it.

At calculation of the block which is in a case the mass of all PK are considered. The case is connected by elastic communications with a surface of its installation and the block to a case. The system has six degrees of freedom.

From the theoretical point of view of fluctuation of a case and the block can be described by the same equations therefore their general topological model contains two identical fragments (macromodel) similar represented in Fig. 2. We will designate the model knots corresponding to a case, numbers with an index "Sh" (ish, i = 1...12) and the knots corresponding to the block, the same numbers but with an index "B" (ib, i = 1... 12). According to the interrelations which are available in the considered system, to knots of a case 1-3Sh it is necessary to connect the sources modeling movements of the basis along axes X, Y, Z, respectively and to hubs 4-6Sh turns of the basis of rather same axes. Communications between a case and the block are established as follows: hubs 7-12Sh (movements and turns of the center of mass of the block) connect to hubs 1-6B (entrance impacts on the block), respectively.

Parameters of macromodels of the body of a case and the block located in it should be set as follows. For case macromodel weight is set as the mass of an empty case without the mass of the blocks which are in it. The center of gravity of a case corresponds to the center of gravity of an empty case. Concerning it coordinates of fastening of the vibroinsulators connecting a case and a surface of installation are set.

For the block a given mass of the case and all of its component PK and structural elements. The center of gravity of the block is defined also with all constructive elements which are its part. Coordinates of fastening of the vibroinsulators connecting the block to a case are set concerning the center of mass of the block.

Calculation allows to define movements and turns of the center of mass of a case concerning axes X, Y, Z and also movements and turns of cent of mass of the block located in a case. For transition from movements to accelerations it is necessary to use a Eq. 2.

Connecting macromodels in this way, it is possible to receive models of designs with various number of levels of cascade system of vibration insulation and different quantity of internal elements on each of them. Besides, similarly the PK macromodels being its part can be connected to the knots describing movements of the block that expands possibilities of modeling even more.

Findings: In the offered method of complex modeling the macromodel of vibration processes in the amortized ED block is developed. Thus, the arising tortional fluctuations of ED round axes of coordinates are considered. The model is presented in the form of an equivalent chain similar to an electric chain and ready to realization in any computer program of modeling of electric chains (Kamaev and Yakovlev, 2006).

CONCLUSION

The actual problem of ensuring high reliability of the electronic devices subject to big vibration influences (Kofanov, 2011; Chen, 2014) demands the models suitable for designs like electronic cases and blocks with application of cascade installation of vibroinsulators. For the solution of the specified problem in this study it is developed, approved and the model for the analysis of vibration impacts on electronic cases and blocks with possibility of repayment with vibroinsulators of resonant peaks is recommended to practical application. Investigating various options of an arrangement of vibroinsulators, it is possible to pick up such option which will give the chance to meet requirements for reliability of the electronic devices installed on mobile objects.

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