Determination of traction characteristic of stiffness compensator for vibroisolation device

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Abstract. In this paper the electromagnetic traction characteristics of the vibration isolator stiffness compensator are presented. In designing of the power characteristics must take into account the characteristics of the position with respect to each axis, the equation derived to describe the characteristics of each axis based on stiffness. Compensator of the stiffness characteristic of each axis can be described by a polynomial of n-th order, for example third order. It should be noted that the total quaternion characteristics of the compensator can be described with taking into account its tilt with respect to each axis, and characteristics of the stiffness.
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Introduction

Nowadays the main problems of mechanical engineering are noise and vibrations of working machines and mechanisms. This engineering issue is most acute in automotive, shipbuilding, locomotive building, and industry and in other areas. Vibrations make sufficient negative influence on reliability and operability of different devices. Especially those vibrations are dangerous for human caused different diseases. Despite on many types of the vibroprotection and vibroisolation devices [1, 2, 3, 4], most distribution took shock absorbers AASS (АКСС), springs and other passive devices of vibroprotection. However, having a simple structure and low cost, they are not enough effective, and often do not even reduce vibration levels to sanitary standards. In [2, 3] the most efficient vibroisolators with stiffness compensators, which can work with zero-stiffness effect [2, 3], are presented.

Methods

As is well known, vibration is spatial arbitrary oscillations. In [5,6] the describing method of chaotic vibration relatively of three spatial axis separately was suggested. For mathematical describing of the oscillations in that research the matrix method is used. This method has species when there is weak coupling oscillations axis. Because of this fact faster method of describing of the spatial vibrations with using of the quaternions is suggested. Hypercomplex numbers allow us to obtain the sum spatial vector of the vibrations and estimate the instantaneous value of the vibrations relatively three axis only with one equation:

$$\bar{q}(t) = u(t) + x(t)\cdot\bar{i} + y(t)\cdot\bar{j} + z(t)\cdot\bar{k} = u(t) + \bar{r} = u(t) + r(t)\cdot\bar{e} \quad (1)$$

where $\bar{q}(t)$ - is common vector of the vibration in the space; $u(t)$ - is rate of the position changing for vibration; $x(t); y(t); z(t)$ - are coordinates of vibration point in the space; $\bar{i}; \bar{j}; \bar{k}$ - are unit vectors (orts); $r(t)$ - is amplitude of the vector in the space; $\bar{e}$ - is the direction vector.

In [7, 8, 9] with help of quaternions the value of the stiffness can be taken to account respectively to each axis and amplitude of oscillations in each point of space. The application of the mathematical apparatus for the description of the vibrations in the space allows developing the methods of the calculation and designing of 3D vibration isolation devices.

Characteristics of the 3D stiffness compensator can be described by one common equation:

$$F\left(x; y; z\right) = 0 \quad (2)$$

On the basis of (1) and (2) we can write spatial force characteristic of 3D compensator:

$$\begin{aligned} &a_n\cdot(x-x_0)^n + b_m\cdot(y-y_0)^m + c_k\cdot(z-z_0)^k + \\ &+ a_{n-2}\cdot(x-x_0)^{n-2} + b_{m-2}\cdot(y-y_0)^{m-2} + c_{k-2}\cdot(z-z_0)^{k-2} + \\ &+ \ldots + a_1\cdot(x-x_0) + b_1\cdot(y-y_0) + c_1\cdot(z-z_0) = 0 \end{aligned} \quad (3)$$

where *n, m, k* – are odd values;

$a_n, b_m, c_k, a_{n-2}, b_{m-2}, c_{k-2}, a_1, b_1, c_1$ - are approximation coefficients (for taking to account design species of 3D stiffness compensator; value of connected to electromagnets coils voltage; value of the interpolar gap); x_0, y_0, z_0 - are coordinates of the working point.

Equation (3) of stiffness compensator characteristic is equation of the surface is shown on Fig.4.

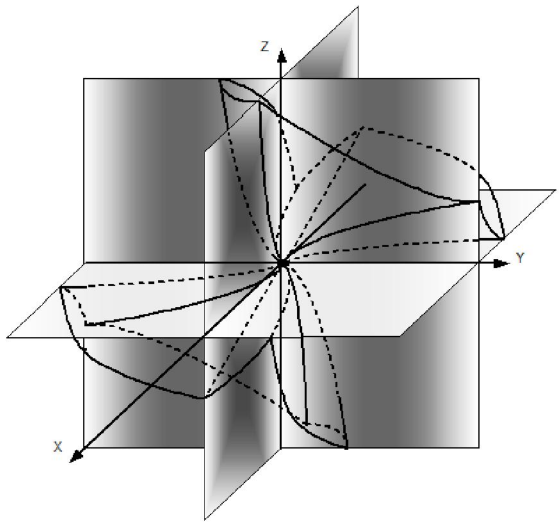

Figure 4. Force characteristic of 3D stiffness electromagnetic compensator

Force characteristic of 3D electromagnetic stiffness compensator, which has been obtained with quaternions [9, 10] mathematic method:

$$q(t)=u(t)+x(t)\cdot\cos\alpha(t)\cdot\bar{i}+y(t)\cdot\cos\beta(t)\cdot\bar{j}+z(t)\cdot\cos\gamma(t)\cdot\bar{k} \quad (4)$$

where $u(t)$ is component, which takes to account amplitude of the vibration vector.

$x(t)$ is force characteristic of the stiffness compensator relatively *Ox* axis.

$y(t)$ is force characteristic of the stiffness compensator relatively *Oy* axis.

$z(t)$ is force characteristic of the stiffness compensator relatively *Oz* axis.

$\cos\alpha(t)$; $\cos\beta(t)$; $\cos\gamma(t)$ are coefficients (angles) of the tilt characteristic of the compensator relatively *Ox, Oy, Oz* axis.

Projections relatively each axis can be described by third-degree polynomials:

$$x(t)=a\cdot t^3+b\cdot t, \quad (5)$$

$$y(t)=c\cdot t^3+d\cdot t, \quad (6)$$

$$z(t)=e\cdot t^3+f\cdot t, \quad (7)$$

Conclusion

The method for calculation and simulation of spatial vibroisolation was presented. Spatial vibroisolators can be used in any areas of engineering and technology, and can be very effective to protect human from vibrations, which are generated by power mechanisms of the transport.

Appendix

Stiffness characteristic of the compensator of each axis can be described by a polynomial of n-th order, for example third order. It should be noted that the total quaternion characteristics compensator can be described with taking into account the tilt with respect to each axis, and stiffness characteristics.

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