World Applied Sciences Journal 22 (Special Issue on Techniques and Technologies): 44-48, 2013
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2013.22.tt.22138

# Development of Spatial Vibration Protection Devices

*Elena Gennadevna Gurova, Vladimir Yuliusovich Gross,*
*Vladimir Sergeevich Kurbatov, Stanislav Vladimirovich Makarov,*
*Andrey Anatolyevich Sergeev and Nikolai Ivanovich Shchurov*

Novosibirsk State Technical University, Novosibirsk, Russia

**Abstract:** This work is to development of spatial vibration protection devices. The method of description of spatial vibration and vibration isolation is represented using mathematical tools-quaternions. The considered method is taking into account the stochastic vibration oscillations and describes it by the hypercomplex numbers. The theory supposes the development of 3D vibration isolation devices possessing power characteristics with a region of zero toughness. To obtain this region on the power characteristics of the spatial vibration isolators is presented resilient element and connected in parallel to toughness balance gear. The three-dimensional vibration isolator with electromagnetic balance gear of toughness, which eliminates vibration oscillations on all three axes of space simultaneously was developed using this method. Spatial vibration isolation device is a resilient element and the simultaneously connected of three-dimensional electromagnetic coils of toughness. Compensation coils of toughness are represented by two opposite-located electromagnetic dials. Each disc was represented by six electromagnetic (magnetic) coils isolated from each other and located along three space axes by two. The design of a one-dimensional vibration isolator with electromagnetic coils of toughness was developed. Three-dimensional vibration isolator can be used in any field of mechanical engineering and technics to eliminate vibration negatively affecting the human health and devices.

**Key words:** Vibration protection · Development work

## INTRODUCTION

In present, the noise and vibration control generated by machines and devices are the most important engineering problems. This problem is most important in the automotive, marine and locomotive production industry as well as defense, aircraft and space industries and other fields of technics. Harmful effect of vibration is their distribution and destroying the other cars and buildings, as well as influences the controlling equipment, adversely affect the performance and the reliability of devices and become a cause of accidents, etc. The vibration harmfully affects the human organism causing different diseases.

Today, there are many methods to reduce vibration such as passive vibration isolators (springs and dampers), vibration isolating devices with a floating section of zero toughness, active vibration protection systems, dynamic balancing of engines, etc. However, none of these methods correspond to the current requirements to the spatial vibration isolation because the most of these reduce vibration only along one space axis, or the effectiveness of vibration reduction is very low.

According these facts, the scientific studies are focused on the development of effective three-dimensional vibration isolator that will meet modern requirements of spatial vibration isolation.

In [1], a method for description of spatial mechanical vibrations was suggested to accurate consideration and elimination of vibration using this vibration isolation device. In most foreign and national studies, the vibration is simply considered as periodic harmonic process, but in reality, it is a stochastic process, i.e., arbitrary spatial variations. In one of the works, the Russian scientist [2] separately describes the technique of random vibration regards all three space axes of space representing to acceleration of vibration as frequency–amplitude characteristics. Matrix method [2, 3] was used for the mathematical representation and shows weak relation of vibrations along the axes, which may not accurately

**Corresponding Author:** Gurova, Novosibirsk State Technical University, prospekt Karla Marksa 20, Novosibirsk 630073, Russia.

describe random vibration and can not estimate the instantaneous changes of vibration vector in the whole space. Therefore, a method describing of stochastic process of fluctuations based on mathematical apparatus-quaternions [4-6] has been proposed. Hypercomplex numbers reveal the changes of sum vector of fluctuations in space and evaluate the instantaneous changes of vibration along all three axes using the following 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 $\bar{q}(t)$ –common vector of vibration in space; $u(t)$ –rate of change of position of the vibration vector; $x(t);y(t);z(t)$ –coordinate position of the vibration particle in space; $\bar{i};\bar{j};\bar{k}$ –unitary vectors (orts); $r(t)$ –amplitude of the vector in space; $\bar{e}$ – directing vector.

Equation (1) shows that implementation of quaternions allow simultaneous consideration of the position of the vibration vector regards to each axis and changing oscillation amplitude in any particle of space, as shown in Figure 1.

The application of the mathematical apparatus allowed the development of an accurate method to describe the vibration in space, formulate the laws of chaotic changes of vibration oscillations. Stochasticity of mechanical vibrations depending on numerous of random factors allows implementation of developed method using probability theory [5].

The method describing arbitrary vibratory oscillations in space has been developed [5]. Probability theory, which considers the most of the random factors affecting its character, was applied for analysis of stochastic vibration. the mathematical apparatus-quaternions [4, 6] which allow to track the position of the vibration vector in space and evaluate the instantaneous changes of oscillation amplitude and positions regards to all three axes using a single equation were used for accurate and fast description of spatial vibration oscillations [4, 6].

The technique for description of vibration isolation in space [7, 8] to theoretical maximum elimination of the spatial vibration and to development of a device according to the state standards regulating the vibration protection systems has been suggested.

In majority of foreign and Russian studies, the theory of vibration protection is separately considered relatively to each axis of the space. In the study [2], a theory of ideal vibration isolation of material particle and absolutely solid body and separate vibration along axes OX, OY and OZ [8] is eliminated, was suggested. This method does not suggest the simultaneous spatial vibration isolation. Therefore, the method for description of the ideal vibration isolation in space was suggested using mathematical tools-the quaternions and the concept of a vector space. Hypercomplex numbers allow forming and describing the conditions and requirements to the ideal vibration isolation in space.

Ideal spatial vibration isolation of material particle is ensured if the vector sum of all forces affecting this particlet is zero at any time moment [5, 8]:

$$m\cdot\bar{a}=\sum\bar{P}\,, \quad (2)$$

where $m$ – mass of a particle; $\bar{a}$ – acceleration of particle; $\sum\bar{P}$ – sum of the forces affecting a particle ($\sum\bar{P}=\bar{q}_P$).

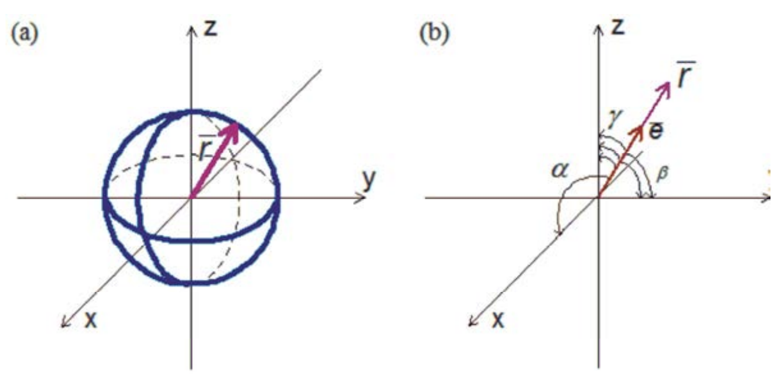


Fig. 1: A graphical representation of the vibration vector in space.
(a) motion path; (b) axes decomposition

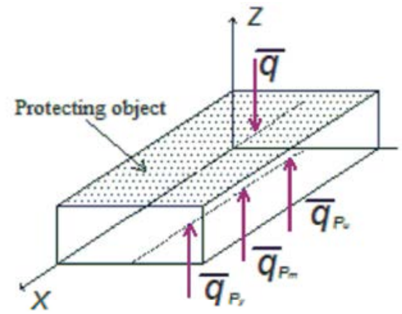


Fig. 2: The general case of the force effect on the protected object for arbitrary spatial oscillations

Ideal vibration isolation in the space of a absolutely solid body from arbitrary oscillations is ensured (Fig. 2), if the sum of the forces and moments affecting the body will be balanced, i.e., the sum vector and the total time will be zero at any time:

$$\sum \overline{q}_P = \overline{q} + \overline{q}_{pn} + \overline{q}_{pt} + \overline{q}_{pi} = 0 \,,\ \sum M(\overline{q}_P) = 0 \,, \qquad (3)$$

where $\overline{q}$ – power transmitted through the protected to vibrating object $\overline{q}_{pn}$ – resilient interaction forces of vibrating and protected objects; $\overline{q}_{pt}$ – dissipative forces of interaction of these objects; $\overline{q}_{pi}$ – intertial forces of intermediate links connecting vibrating and protected objects. Each of these conditions (3) is the sum of the projections to the arbitrary axes and sum of their moments regards to these axes.

This theory supposes the development of 3D vibration isolation devices with power characteristics and a region of zero toughness. To obtain this region on the power characteristics, the spatial vibration isolator is presented as an resilient element and connected parallel balance gear of toughness. Power characteristics of the resilient element have a positive toughness coefficient along all three axes and the balance gear-a negative toughness coefficient, equal in modulo to the toughness of the resilient element regards to each space axis. To ensure the fusion of zero toughness region at the operating load, the balance gear is supplied by system restructuring, which tracks the relative position of the vibrating and protected objects and holding the balance gear work items in the area of operating movements.

Implementation of the mathematical apparatus-quaternions, stochastic and vector spaces has allowed: identify and describe the method of the spatial vibration isolation of a solid body from the spatial oscillations; study of requirements and conditions of absolute vibration isolation of material particle and absolute solid body in space; represented graphically ideal vibration isolation of absolute solid body from arbitrary spatial oscillations and determine power characteristics of vibration isolation devices in space.

A three-dimensional version of the vibration isolation device with toughness balance gear [1, 7, 10], which almost entirely eliminates 3D-vibration and meets all the requirements for vibration protection devices has been developed using the methods described above. The characteristics and properties of spatial balance gear were also described.

The foreign and Russian scientists consider passive resilient elements such as springs as one of the few devices that can be attributed to the devices, which eliminate vibration in space. However, the efficiency of vibration reduction is quite low and, as practice shows, the installation of these devices hardly reduces vibration even to sanitary standards. One of the most effective vibration protection devices are developments of foreign scientists (France, Germany and United States)-active vibration isolators, but they eliminate the vibration only along single axis. Therefore, the variant of vibration isolation device with toughness balance gear that significantly meets the requirements of ideal vibration isolation in space has been suggested.

Spatial 3D-vibration isolator is a resilient member with the parallel connection of three-dimensional electromagnetic balance gear of toughness. Both components are located between two bases (vibrating and protecting). Resilient element as springs is fixed between vibrating and protecting bases that the base is located in space. Electromagnetic balance gear of toughness is two opposite electromagnetic dials. Balance gear is hard fixed on the vibrating base. Each disc is composed by six electromagnetic (magnetic) coils isolated from each other and located by two along three axes in space. Each coil is supplied separately from the power source. Balance gear of toughness is equipped by control unit to control the change relatively to vibrating and protecting objects and redistributing the voltage on the coils to prevent vibration. Common anchor of electromagnetic disks is firmly connected to the protecting base through a rod. The rod is the main guide for the anchor of electromagnetic balance gear of toughness. Figure 3 shows the vibration isolator relatively one axis [11].

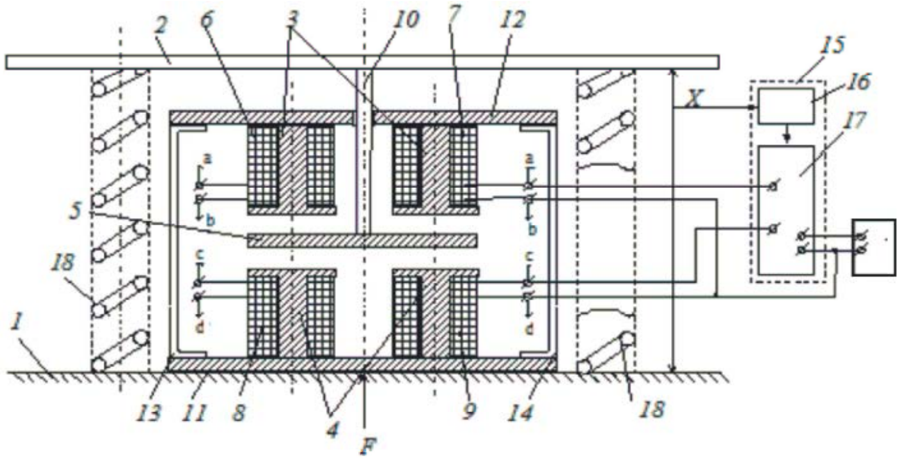


Fig. 3: Vibration isolating suspension arm with electromagnetic balance gear of toughness: 1 – vibrating object; 2 – protecting object; 3 – direct current electromagnets; 5 – common anchor; 6, 7, 8, 9 – coils (coils 6, 8 receive the power series with coils 7, 9 of electromagnets through the connections a, b, c, d); 10 – rod; 11, 12 – electromagnet magnetic conductor; 13, 14 – fixing cramps; 15 – controller; 16 – detector of relative position of vibrating and protecting objects; 17 – potentiostat; 18 – resilient member; 19 – electric power supply.

Developed spatial vibration isolator is used as follows. At constant external force acting between the protecting and vibrating objects and vibrations of the latter regards to all three axes of space, the towing performance of the balance gear has the same incline in absolute value as the power characteristics of the appropriate resilient element, which eliminates toughness in affected region relatively to each axis in the space, i.e., exclude the transmission of dynamic forces to protecting object caused by oscillations of vibrating object. The change of the efforts relatively to any of the axes of the space causes the changes of the relative position of the vibrating and protecting objects along appropriate axis in space that triggers the control unit and, therefore, change the output voltage supplied to appropriate coils of electromagnetic balance gear of toughness. The voltage on the coils is redistributed that at the new position of vibrating and protecting objects, the incline of traction towing characteristics relatively to each axis of electromagnetic balance gear of toughness remained unchanged. This provides zero–dimensional toughness of whole vibration isolator and thus, eliminating the transmission of dynamic forces at different values of the external force.

As the result, we have developed a version of the construction of three-dimensional vibration isolator with electromagnetic balance gear of toughness, which eliminates vibration in the whole space and meets the requirements for ideal vibration isolation.

Implementation of the developed vibration isolation device will allow further development of the new methods of calculation and designing of three-dimensional vibration isolation devices at following steps of our study. The proposed vibration isolation device can be used in any field of engineering and technology to reduce the vibration levels.

This work was conducted in the framework of the State Contract no. 9884r/14275 on 11.01.2012 within "Cl.M.N.I.K" program.

## REFERENCES


1. Gurova, E.G., 2012. Development of three-dimensional vibration isolation device: A report on state contract No. 9884r/14275 on 11.01.2012 within "Umnik" Program. Novosibirsk.
2. Baranovskiy, A.M., 2000. Theoretical principles of efficient vibration isolation on the ships, Doctoral Sci. (Tech.) Dissertation, Novosibirsk, pp: 40.
3. Babakov, I.M., 2004. Theory of Oscillations: Study Manual, Ed. Ponkratov B.V. Moscow: Drofa, pp: 591.
4. Berezin, A.V. and Yu.A. Kurochkin, 2003. Quaternions in Relativistic Physics. Ed. Fedorov, F.I. Moscow: Editorial, pp: 200.
5. Gurova, E.G., 2011. Study and Description of Spatial Vibration. In Proceedings of International Anniversary Scientific–Technical Conference, May 10–12, 2011. Novosibirsk: Novosibirsk. Gos. Akad. Vod. Trans., 1: 243-244.

6. Kantor, I.L., 2009. Hypercomplex Numbers. Moscow: Nauka, pp: 145.
7. Gurova, E.G., 2011. Design of Spatial Vibration Isolator. In Proceedings of International Anniversary Scientific–Technical Conference, May 10–12, 2011. Novosibirsk: Novosibirsk. Gos. Akad. Vod. Trans., 1: 244-245.
8. Zuev, A.K. and O.N. Lebedev, 1997. High Performance Vibration Isolation of Ship Power Equipment. Novosibirsk: Novosibirsk. Gos. Akad. Vod. Trans., pp: 19.
9. Gurova, E.G., 2008. Vibration isolation suspension arm of ship power equipment with nonlinear electromagnetic balance gear of toughness. Cand. Sci. (Tech.) Dissertation, Novosibirsk.
10. Gurova, E.G., 2011. Three-dimensional Vibration Isolator. V Mire Nauchnykh Otkrytiy, 2: 182-183.
11. Gurova, E.G. and V.Yu. Gross, 2010. Patent RF No. 2010121808/11 (031010): Vibration isolator with electromagnetic balance gear of toughness.