Improving of the operation efficiency of the vehicle due to using of the neodymium magnets inside the vibration isolation devices

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Abstract. In this paper the isolation suspension with stiffness compensator based on neodymium magnets is suggested. It was found that the passive vibration isolators not completely sufficient of modern requirement of the vibration isolation. It was determined that the neodymium magnets with the same initial parameters are most effective in comparison with DC current electromagnets. The mathematical model of the vibration isolation suspension has been developed. In this research the traction characteristics for given magnets are presented. Also the design of the vibration isolation suspension with compensator of the stiffness based on neodymium magnets has been developed. This research has been performed under support of the President scholarship for young scientists under the order of Russian Federation Ministry of the education and science № 184 from 10 of March 2015.

Introduction
Nowadays the one of the problem in many areas of the industry, vehicle and agriculture is large level of the vibration which does not meet the sanitary standards. Vibration renders negative influence on the human body, environment, operation of the mechanisms and vehicles. Long influence of the vibration and noise leads to disturbance of the human body normal condition, causing the disturbances of the physiological condition, and so functional changing of the inner organs. The man reacts on vibration depends from common duration of its influence. The greatest impact of the overall vibration affects the vision system processes due to fluctuations of the eyeballs and head. Long term influence of the big enough intensity can negatively impact on the spine. In addition the vibration affect on normal course of the physiological processes, that causes varicose veins, coronary heart disease and hypertension. Excessive exposure of the local vibration can lead to the deceases of the blood vessels, nerves, muscles, bones and joints of the upper extremities.

Mechanical oscillations can cause malfunctions of the equipment operation, accumulations of the damages in materials, damages of the normal functioning of the different objects, defects of couplings, improper alignment of the motor with the driven machine, unbalance motor and machinery.

All these facts lead to necessity to found the way of the solutions directed on decreasing of the vibration levels, the transport industry is not an exception. The sources of the vibration in vehicles are electroengines, combustion engines, bad conditions of the roads, direct movement of the transport. At the present time the main methods of the protection can be separated in two groups. First group is directed on decreasing of the vibration inside of the vibration source. Prevention of the negative
influence of the vibration on the human organism, and also equipment operation, in that case it reduces to minimization of the mechanical vibration intensities and duration of its activity. At first we need to give an attention on the technique process, precisely on operation of the equipment, which cause of the vibration. Reduction of the level of the vibration from the rotating elements and mechanisms of transport, can be achieved whereby a precise fitting of the details and its operation: balancing, deskew, reducing to a minimum tolerances between the parts to be joined, timely lubrication components and assemblies. Second group, is directed on decreasing of the vibration parameters by the way of its elimination from the source to protected object. In that case for protection from vibration are applied the next methods: decreasing of vibration activity of the machines, the detuning from the resonance frequencies, damping, vibration isolation, vibration dampening. 

Nowadays the most promising way to reduce the vibration levels to be considered the application of the devices with floating area of the zero stiffness \[1,2,3\].

In paper \[4\] the authors presented the vibration isolation suspension with electromagnet compensator of the stiffness. Electromagnet compensator of the stiffness was made as two counter-connected DC current electromagnets. Compensator which was suggested has a several advantages in comparison with mechanical stiffness compensator, as the absence of the friction force, and as a consequence and the wear, the compensator has a fast response adjustment system which redistributes the voltage at the electromagnets under the load changes, provides zero stiffness.

However suggested system because of presence of the electromagnets supposes the using of the voltage regulator, position sensors and also supposes the tracking system, which finally leads to increasing of the system cost and also to necessity of periodic service. In practice the application of the suggested vibration isolation device is impeded with big enough mass-size parameters of the electromagnets stiffness compensator, despite their high ability to reduce the vibration.

In research \[5\] the design of the compensator based on supermagnets was suggested. Vibration isolators with supermagnets stiffness compensator are most practically applicable, efficiency of reducing of the vibrations is high enough, with the dimensions and weight is significantly less than when using electromagnetic stiffness compensators.

**Simulations**

Based on the mathematical description, taken in \[5\], we can assemble the set of the equation for the suspension:

\[
\begin{align*}
\frac{d^2 x}{dt^2} + c \cdot x - F_k &= F(t); \\
F_k &= (ax^3 + cx) - F_p; \\
F_p &= f(t) \cdot (ax^3 + cx) \cdot x.
\end{align*}
\]  

On the basis of the set of the equations (1) is composed block diagram of the vibration isolation suspension with regulator (see figure 1).
The model of the vibration isolation suspension has been composed on the basis of this block diagram (see figure 2).

Simulation of the vibration isolation suspension with nonlinear regulator was carried out in Simulink. For presented model the input signal is sine (Sine Ware) with parameters: amplitude is 1; frequency, another parameters is 0. The step signal (Step) is used as the load. On the oscilloscope (“Scope”) the reaction of the system on sinusoidal impact is shown. Results of the simulation of the vibration isolation system without correction link are shown on figure 3.
Figure 3. Oscillogram of the vibration isolator operation with tuning system without correction link

The model of the designed stiffness vibration isolator, which has been done in AutoCAD is shown on figure 4.

![Model of the developed stiffness vibration isolator](image)

Figure 4. Model of the developed stiffness vibration isolator
1- protected base; 2- basis for resilient element; 3- resilient elements (springs); 4- duralumin rods; 5-vibroisolation base; 6- stock; 7- duralumin disk; 8-anchor; 9-mounting place for neodymium magnets; 10- duralumin basis

2-
Magnetic compensator of the stiffness is mounted in parallel to resilient element, which has been made as four springs 3, which are mounted with help of duralumin bases 2 for resilient element by one
side to vibrating base 5 and by another side to protected base 1. Magnetic compensator is the two disks 7, one of them is rigidly mounted on the vibration base 5 through duralumin base 10, and another disk 7 is mounted on the vibration base 5 with help of duralumin rods 4. Stock 6 is rigidly coupled with protected element 1. Neodymium magnets are mounted on the bottom and top disks 7 inside the deepenings 9, and so on the both sided of the anchor 8. Magnets are placed in plane of the anchor and sides of the disk have different polarity. In that case, the total stiffness of the vibration isolator will be sum of all the stiffness’s of each resilient element (spring) and magnetic stiffness compensator. Thus the stiffness can be reduced to zero, and this provides ideal vibration isolation.

Principle of operation is based on movement of the anchor with changing of the magnitude of the external force, so the power characteristic became falling, that provide the zero-stiffness of all vibration isolator.

Supermagnets, which are used in suggested compensator, are produced from alloy of rare-earth material neodymium (Nd). Main advantage of such magnets is big traction forces under the small sizes. The traction characteristic of the used neodymium magnet is shown on the figure 5.

Magnet characteristics are laid on the stage of the production of the magnet and can not be changed further. Main parameters of the magnets are residual magnetic induction and stability to demagnetization (coercivity force). Neodymium magnets can be produced in shape of the disk, cube, rail, cylinder, rod, ring, sector or ball. The view of the used neodymium magnets is presented on figure 6. Basic characteristics of the magnets have been summarized in table 1.

It is necessary to know the characteristics of the given neodymium magnets for calculation of the vibration isolation suspension with compensator of the stiffness based on the neodymium magnets. These characteristics are shown in table 1.
Table 1 – Characteristics of the magnet

| Type       | N42         |
|------------|-------------|
| Shape      | disk        |
| Height (h) | 8 mm        |
| Diameter (D) | 12 mm      |
| Tolerance  | +/-0,1 mm   |
| Properties | $B_r > 1170$ mT; $H_{ch} > 868$ kA/m; $H_{cj} > 955$ kA/m; $(BH)_{max} > 263$ kJ/m$^3$; $T_w < 80^\circ$C |
| Coating    | Nickel (Ni) |
| Max temperature | 80 °C      |
| Direction of the magnetization | axial |

Neodymium magnets are placed thus that there are two magnets on each axis (see figure 7). This is due to the fact that the all vibration isolation supports must have not less 6 degrees of freedom. The duralumin disk with supermagnets inside the mounting places is shown on the figure 8.

Figure 7. Layout of the neodymium magnets
Conclusion
The represented vibration isolator is based on compensator of the stiffness with supermagnets can be used in engineering and vehicle area. The suggested solution can be efficient in prevention of negative influence of the vibration on the human body and in improving of the efficiency of the exploitation of the vehicle.

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