Realization of The Adjusting System in Stiffness Compensator Based on Permanent Neodymium Magnets

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Realization of The Adjusting System in Stiffness Compensator Based on Permanent Neodymium Magnets

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Abstract In this paper one of the cases of adjusting system for the stiffness compensator based on permanent magnets with changing of the axial distance between magnets has been described. The dependency of the traction force from value of the rotation angle of the anchor relatively basis in stiffness compensator has been described. Research & Development is under the scholarship of the President of Russian Federation, order No 184 from 10th of March 2015.

Introduction
In recent time, the level of the vibration from power installations has been increased up to high values. The negative impact of the vibration from vibrating installations influences on design, the equipment, electronics and people, which are using of these installations.

As practice shows, the most promising means of fighting vibration is the inclusion of the vibration isolators, that is, suspension of the equipment with source of the vibration [1, 2, 4, 11, 17- 20, 21]. This method allows us significantly reducing of the vibration level. However, vibration isolators are less effective against low-frequency oscillations, which are caused by imperfection of their design.

The use in the vibration isolator design of the vibration isolator will significantly increase the efficiency of the suspension device [2, 3, 12-16, 22]. The vibration isolator has a traction characteristic having a negative slope, but in absolute value equal to the characteristic of the elastic element, which is included in the vibration isolation suspension.

In [6, 8, 9, 10], the authors proposed the installation of a vibration isolator which is equipped with the stiffness compensator based on electromagnets. In [6, 7], the issue of reducing the size of the device, the authors has been proposed the replacement of the electromagnetic coils with permanent neodymium magnets. However, a necessary condition of the absolute vibration isolation is a adjusting system, which allows the adjustment of the stiffness compensator to the external impact to provide full vibration isolation under different initial conditions.

It should be noted that the adjustment system of the stiffness compensator which has electromagnets as the basis, was easy to realization, as it is possible to regulate the power supply of electromagnets and to change the traction caused by their interaction. As for the neodymium compensator, its adjustment system remains far from obvious. It is necessary to choose the most suitable way to adjust the stiffness compensator.

Calculation and simulations
In this paper the authors have been proposed to use the adjustment system of the stiffness compensator based on neodymium magnets with rotation anchor with magnets. The core of this approach is the...
transmission of the position sensor signal of the protected and oscillated objects to device that drives the stock with anchor. The anchor with installed magnet is rotating and changes the distance between the centers of the magnets because of that the force of the interaction between the magnets of the anchor and basis of the stiffness compensator is changed.

In this paper the characteristic of the traction force is obtaining in the stiffness compensator with in dependency with the anchor rotation angle has been considered. From the equation presented in [10], the force of the interaction between the magnets from its shift is possible to define from next dependency:

\[ F(r) = \frac{\pi}{2\mu_0} B_0^2 R^4 \sum_{i,j=0}^1 \frac{(-1)^{i+j}}{(x+h(i+j))^2} \left( 1 - \frac{3}{2} \frac{r^2}{(x+h(i+j))^2} \right) \]  

(1)

The (1) shows the dependency of the traction force form axial distance between two magnets.

Three counter directed magnets are supposed to use in design of the stiffness compensator. The magnets are placed to attract to each other (see figure 1).

Dependency of the force arises inside of the stiffness compensator with shift of the magnets:

\[ F(r) = \frac{\pi}{2\mu_0} B_0^2 R^4 \sum_{i,j=0}^1 \frac{(-1)^{i+j}}{(x+h(i+j))^2} \left( 1 - \frac{3}{2} \frac{r^2}{(x+h(i+j))^2} \right) \cdot \frac{(-1)^{i+j}}{(b-x+h(i+j))^2} \left( 1 - \frac{3}{2} \frac{r^2}{(b-x+h(i+j))^2} \right) \]  

(2)

where \( r \) is distance between center of the magnets;
\( B_0 \) is residual magnetic induction of the magnet;
\( R \) is radii of the magnet;
\( h \) is height of the neodymium magnet;
\( x \) is magnitude of the gap between of the anchor and the basis.

The compact dependency is obtained by this way is sum of the double series [10, 12], that is the sums of the set of the numbers to the elements of which the positive integers \( i \) and \( j \) are assigned.

\[ 0 < r < \delta - h \]

\[ 0 < b - x - h(i+j) < \delta - h \]

\[ x < \delta - h \]

\[ \delta - h < 2R \]

\[ \delta - h < h \]

\[ \delta - h < \delta - h \]

\[ \delta - h < \delta - h \]

\[ \delta - h < \delta - h \]

Figure 1. The sketch of the placement of the anchor and basis of the stiffness compensator
Figure 2. The sketch of the placement of the magnets from the top

It can be seen from figure 1 that the magnets 1 and 2, are placed in the base of the stiffness compensator are interacting with movable anchor of the device through the magnet 3. Thus, starting from the triangle ABC the dependency of the distance between the magnets from rotation angle of the device anchor can be establishing.

The distance between the magnets has dependency from rotation angle of the anchor accordingly the cosine theorem:

$$r(\alpha) = \sqrt{2R_y(1-\cos(\alpha))}$$  \hspace{1cm} (3)

where $R_y$ is the radii of the placement of the anchor magnets.

It is useful to note that all magnets of the device impact on the anchor magnets. However the design of the vibration isolator has been made to minimize impact from the neighbor magnets on each other, and because its impact can be neglected. As can be seen on figure 1 the strongest impact on anchor magnet with some rotation angle are made two neighbor magnets of the basis 1 and 2 in the moment of its placement. Thus, it is necessary to take into account this impact on the anchor.

Starting from the condition that magnets which placed in anchor and basis have the same characteristics, it is possible to write the force of its impact on the anchor magnet.

The dependency of the traction force between magnets from the anchor shift angle:

$$F(\alpha) = \frac{\pi}{2\mu_0}B_0^2R^4 \sum_{i,j=0}^{1} \frac{(-1)^{i+j}}{(x+h(i+j))^2} \left( 2 - \frac{3R_y(2-\cos(\alpha)-\cos(60-\alpha))}{(x+h(i+j))^2} \right) - \frac{(-1)^{i+j}}{(b-x+h(i+j))^2} \left( 2 - \frac{3R_y(2-\cos(\alpha)-\cos(60-\alpha))}{(b-x+h(i+j))^2} \right).$$  \hspace{1cm} (4)

Accordingly (4) the dependency of the traction force is acting on the anchor magnet from rotation angle has been drawn:
It can be seen from figure 3 the max value of the angle is angle between two magnets in the basis of the stiffness compensator (60°). Max values of the force of the interaction of the anchor and the basis of the stiffness compensator are angles (0° и 60°) where the magnets of the anchor and the basis are placed on the same axis. Also from this plot can be seen that the minimum force achieves by the magnets when the magnets of the anchor are placed between magnets of the stiffness compensator basis. Thus, it can be concluded that minimum force between the magnets is almost half less than maximum achieved force.

Conclusion

From results of this dependency it was established that when the rotation angle changes it is possible to change the traction force and consequently the slope of the traction characteristic of the stiffness compensator. It is allowing the vibration isolation system to adjust to the level of the oscillations and thus allow the effectively isolate it. Further research the proposed adjustment system can be realized in design of the vibration isolator.

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