# Maintainable isolator based on MR material

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**Abstract.** Use of isolators made of MR material in vibration protection systems is determined by the following three factors: reliability, cost price and design efficiency. Division of a complex and multifunctional system of an isolator into constituent elements based both on functional and on design features could be one of the possible methods to solve the set problem. It will give an opportunity to create independently a vibration insulation system, an impact protection system and a positioning system which combines an offtake device and an isolator neutral position adjustment. Synthesis of each of the mentioned elements which were developed and advanced independently into a full design will allow elaborating a maintainable isolator with advanced technical and economical characteristics.

**Key words:** isolator, maintainability, MR material, division, synthesis, versatility, quality.

**Introduction.** During the last 50 years all-metal isolators based on MR material became widely used in the practice of vibration and impact protection for various devices [1, 2, 3].

MR material is a non-woven wire structure which has equivalent elastic and dissipative characteristics as elasomeric materials do but surpassing the same in regard to durability, damping and persistence both under normal operation conditions and under extreme ones, namely high and low temperatures, corrosive and cryogenic media, solar radiation, humidity [6]. Being characterized by unique properties the products from MR material have found the widest usage in the aviation and space engineering. Application of MR materials in the national economy industries is being restricted due to manufacturing complexity requiring special equipment as well as high labor intensity and high cost of materials.

The framework for designing maintainable isolators from MR material is being set up towards two directions.

1. Division of a complex function of an isolator as a whole into the constituent elements: a vibration insulation system, an impact protection system and a positioning system. Each of the systems is autonomous to the maximum extent and is made of easy workable primitive elements which do not require special equipment and tools for their manufacture.

2. Repetitive multiple use of the constituent elements after isolator reassembly (repair). Each system of an isolator in the course of its operation bears uneven mode and time load. It is possible to improve each system in accordance with its load. In case the set problems are solved both an insulator cost could be reduced and its quality improved.

**Methods.** Structural design of an insulator with divided functions based on MR material is given on Figure 1. The vibration insulation system consists of four rectangular elastic damping elements 6, one end face of which rests on a movable pin 3 and the other on a case 1. The system operates inside a special loading pattern, the elements experience complex work strain. The positioning system consists of a spring 11, a damping element 9 and a stack of adjusting shims 10. The impact protection system consists of a supporting elastic damping element 7, a limiter for Y direction 4 and four damping elements 5 taking impact loads along X-Z axes. The whole assembly is enclosed in the case 1 and is fixed by a cover 2. At time of operation the isolator is mounted onto a basement (foundation) with surface A and a unit which is going to be protected from vibration is mounted onto surface C.

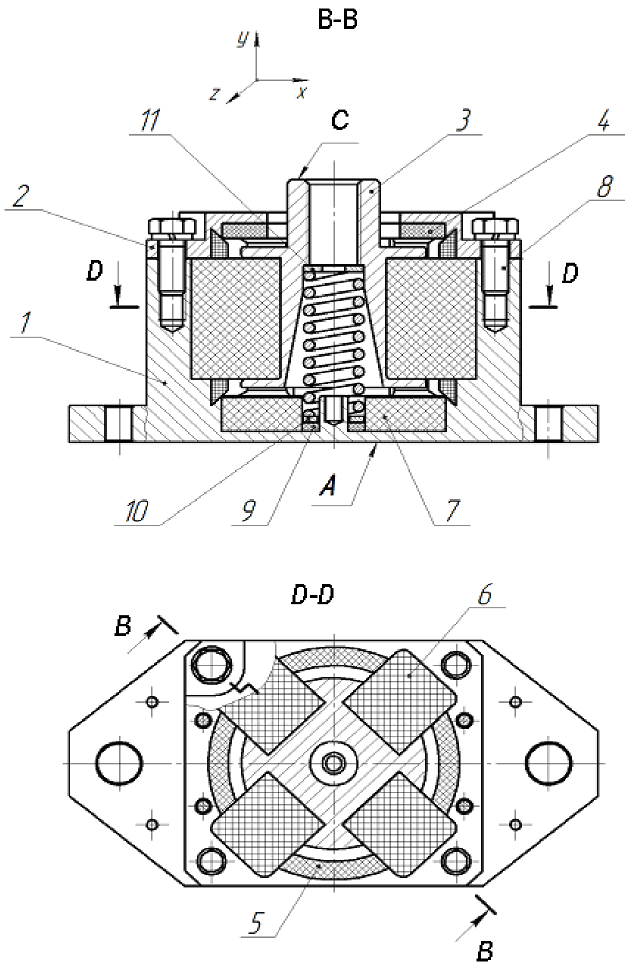


Figure. 1. Structural design of an isolator with divided functions based on MR material

The results of laboratory dynamic tests showed that the time of operation of an individual vibration insulation system complies with the specified life of an isolator (N). The specified life is time of failure-free operation of an isolator. The impact protection system along Y axis exceeds the specified life and makes 1.25 N. The specified life of the impact protection system along X-Z axes makes 1.5 N. The specified life of the positioning system makes 2.5 N. Basic parts wear for 4 N period was within the specified norms. Therefore the elastic damping elements (EDE) 6 are a “weak link” in the isolator.

In order to evaluate durability capabilities the process parameters calculation was done with use of a definite isolator under the real operation conditions. Calculations were performed in the respect of modification 1 of the maintainable isolator based on MR material under the following conditions: vibration-isolated mass M – 27.5 kg; amplitude of vibration displacement of affecting vibration – $A_0 = 0.5 \cdot 10^{-3}$ m; rated resonance frequency – $f_r$ = 13 Hz; transfer factor during resonance $\eta_r = 4$. The isolator has the initial geometrical, connection and mounting dimensions and mass, fitted in the volume designated for its positioning on the unit.

**Static performance.** Amplitude of vibration displacement of vibration-isolated mass,

$$\grave{A} = \grave{A}_0 \cdot \eta_r = 2 \cdot 10^{-3} m,$$

absorption (dissipation) factor and hardness,

$$\psi = \frac{2\pi}{\sqrt{\eta_r^2 - 1}} = 1.62,$$

$$\tilde{N} = \frac{\grave{I} \cdot f_r^2}{250 \cdot \left( \frac{1}{\eta_r^2 - 1} + 1 \right)} = 17.4 \cdot 10^{-2} \, N/m .$$

Coefficients of similitude of the isolator hysteresis loop determined by means of the system of transcendental equations [7]

$$\psi = 4 \left\{ \frac{(n-1)^2 + (n+1) \cdot \left[ 1 - \left( 1 - \frac{Y_0}{A} \right)^n \right]}{(n+1)^2 + 4n - 2 \cdot (n+1) \cdot \left[ 1 - \left( 1 - \frac{Y_0}{A} \right)^n \right]} \right\},$$

$$C = \frac{2.5 \cdot T_0}{A \cdot \left[ 1 - \left( 1 - \frac{Y_0}{A} \right)^n \right]} \times$$

$$\times \left\{ \frac{5+4n}{20} - \frac{6}{(n+1)\cdot(n+2)\cdot(n+3)\cdot(n+4)} - \frac{1}{7} \left[ (n+1) - 2 \cdot \left( 1 - \frac{Y_0}{A} \right)^n \right] \right\},$$

$$n = 0.6 \cdot \left( \frac{A}{Y_0} \right)^{-0.05} \cdot e^{-0.07 \cdot \frac{A}{Y_0}} .$$

After substitution of the values of energy dissipation factor ψ, hardness C, vibration displacement amplitude A and solution of the system of equations, the coefficients of similitude of the isolator hysteresis loop can be determined as follows: $Y_0 = 0.75 \ 10^{-3}$m, $T_0 = 75$ N.

**Selection of MR material parameters [8]**. Taking into account that the problem requires to ensure minimum geometrical dimensions and mass of EDE, relative tension shall be set at the level of

$$\overline{\Delta}_0 = \frac{\Delta_0}{Y_a} = 0.3,$$

where $Y_a$ – admissible deformation of EDE, $\Delta_0$ – tension.

In order to ensure steadiness of the form and geometrical dimensions of EDE, density of MR material and a blank part shall be set as follows: $\rho_c = 0.85 \cdot 10^3$ kg/m$^3$; $\rho_{bp} = 0.2 \cdot 10^{-3}$ kg/m$^3$.

The requirement of EDE workability predetermines the following diameters of spring and wire: d = $1.05 \cdot 10^{-3}$ m; δ = $0.09 \cdot 10^{-3}$ m. In order to ensure anti-corrosion properties and capabilities to withstand high and low temperatures the wire brand EI-708 with the below specified characteristics is selected: density $\rho_u = 8 \cdot 10^{-3}$ kg/m$^3$; yield point $\sigma_y = 90 \cdot 10^{-5}$ N/m$^2$; elastic modulus $E_u = 1.5 \cdot 10^{-1}$ N/m$^2$.

**EDE geometrical dimensions.** Free height

$$H_f = \frac{Y_0}{K_1 \overline{\sigma}_Y \left( 1.125 + 0.2\overline{\Delta}_0 - 0.9\overline{\Delta}_0^2 \right) \cdot \left( 0.64 - \overline{\rho}_c \right) \cdot \left( 0.2 - \overline{\rho}_{bp} \right) \cdot \left( 20 + \overline{d} \right)} = 31 \cdot 10^{-3} m,$$

where $\overline{\sigma}_Y = \dfrac{\sigma_Y}{E_U};\ \overline{\rho}_c = \dfrac{\rho_c}{\rho_U};\ \overline{\rho}_{bp} = \dfrac{\rho_{bp}}{\rho_U};\ \overline{d} = \dfrac{d}{\delta}$.

EDE area

$$S = \frac{T_0}{K_2 \cdot \sigma_{YU} \cdot \left(0.8 - 2.3 \cdot \overline{\Delta}_0 + 5.4\overline{\Delta}_0\right) \cdot \left(\overline{\rho}_c - 0.03\right) \cdot \left(\overline{\rho}_{bp} + 0.2\right) \cdot \left(23 - \overline{d}\right)} = 1 \cdot 10^{-3} m^2;$$

elastic element is selected subject to the best pressing of a blank part in a rectangular form with the sides of $25 \cdot 10^{-3}$ m, $40 \cdot 10^{-3}$ m (in plan).

Admissible deformation of EDE

$$Y_a = \frac{Y_0}{K_3 \cdot 10^{-2} \cdot \left(1.125 + 0.2 \cdot \overline{\Delta}_0 - 0.9 \cdot \Delta_0^{-2}\right)} = 12.5 \cdot 10^{-3} m,$$

where $K_1$, $K_2$, $K_3$ – adjustment coefficients.

Pretension between EDE

$$\Delta_0 = \overline{\Delta}_0 \cdot Y_a = 3.75 \cdot 10^{-3} \text{ mm.}$$

EDE operating height

$$H_o = H_f - \Delta_0 = 27.25 \cdot 10^{-3} \text{ m.}$$

Final isolator characteristics: weight of an object to be damped – 27.5 kg; resonance frequency – 13 Hz; transfer factor during resonance – 4. Weight of the set of EDE makes 0,1kg.

**Conclusion.** Analysis of the results of calculation and optimization of the process parameters of elastic damping elements of the vibration insulation system shows that its improvement allows increasing the elements lifetime only by 25%. In the meantime a simple modernization of the impact protection system by optimization of technology may ensure increase of its life by 80%. Heat treatment of the spring results in increase of the positioning system life by 70%. Basic parts have high coefficient of lifetime so they do not require improvement. Therefore replacement of the elastic damping elements at time of an isolator repair may significantly extend service life of the isolator based on MR material, increase its reliability and reduce cost price.

**Discussion.** On the authors' opinion the set problem to develop a maintainable isolator based on MR material was solved to the full extent. Meanwhile the further development of this subject is of concern [4, 5]. For example, elaboration of other structural designs of isolators with various arrangements of the elastic damping elements. Development of an assortment of maintainable isolators varying both in the magnitude of weigh (mass) loads and in the range of resonance frequencies. The further individual improvement and perfection of each of the component systems: vibration insulation, impact protection and positioning for various operational needs.

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