Development of Vibration Isolator Magnetorheological Elastomer Based

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Abstract. Most of the vibration isolator has fixed stiffness, such as a passive vehicle mounting system. This article presents the development of the adjustable stiffness engine mounting magnetorheological elastomers (MREs) based to reduce vibration. The development of MREs vibration isolator is to design of engine mounting first step, for next step is to simulate the electromagnetic circuit. The housing material selection and MREs thickness were considered to provide ample and uniform magnetic fields to change the stiffness. The innovative magnetic circuit design includes the type and size of the wire and the number of turns of the coil to obtain the best magnetic fields to eliminate vibration. Finite Element Method Magnetics (FEMM) software was used to show the effectiveness of the electromagnetic circuit to generate magnetic fields through the MREs. Finally, the varies current input influence to the MREs vibration isolator is investigated. The higher current input is more useful to eliminate vibration using MREs isolator system.

Keyword: magnetorheological; elastomer; vibration isolator

1. Introduction

In the engineering field, there are many machines vibrate both on a small and large scale. Excessive vibration can cause the engine to fail under very high vibrations. Various methods and materials have been proposed by experts to reduce excessive vibration. The tool to reduce vibration usually called as a passive, semi-active, or active system [1].

The passive system uses natural rubber as the material of choice. Passive systems are only useful for dampening vibrations in a very narrow frequency range, due to the permanent nature of material stiffness. The active system combines additional sensors, actuators, electronics with controlled
properties. The disadvantage of an active system is high energy consumption for activation. The semi-active method combines the use of sensors and actuators to vary the properties of the insulator system [1]-[2]. The semi-active method is preferred because of its stability and reliability for low and high-frequency vibrations. High frequencies require low stiffness and low attenuation vibration isolators, whereas vibrations at low frequencies require high stiffness and high attenuation vibration isolators.

Meanwhile, smart material MRE can be classified into a group of rheological materials that undergo rheological changes under the application of magnetic fields. These materials consist of soft ferromagnetic particles such as pure iron and carbonyl iron powder. If no magnetic field is applied, the iron particles will be distributed randomly, but if given the influence of a magnetic field, the iron particles will obtain a dipole moment that is parallel to the external magnetic field and forms a chain [3]–[8].

Many researchers have researched increasing the performance of vibration absorbers using MREs material [3], [5], [9]–[12]. The results of magnetic field analysis, whose value depends on magnetic circuit design, are used to verify the performance of vibration isolators. Significant work of researchers has been done to overcome the limitations of vibration dampening devices that are passive in reducing more extensive vibration frequencies. So that the MREs is an excellent potential as a smart device is used in a variety of engineering fields, especially in fields involving vibration isolation. Many researchers proposed many vibration isolators with MREs based [5], [6], [9]–[11], [13].

The objective of this paper to develop vibration isolator use MREs material and optimise variable such as housing material selection. The development of MREs vibration isolator is to design of engine mounting first step, type and size of the wire and the number of turns of the coil. The effectiveness of the system, a Finite Element Method Magnetics (FEMM) software was used.

2. Magnetorheological Elastomer

Magnetorheological elastomers (MREs) are a type of rubber-active composite material that is reinforced with rubber particles with soft particles, whose physical or mechanical properties can be changed based on the application of magnetic fields. MREs can be made by mixing micron-sized magnetic particles into a matrix such as rubber that is not magnetic. If a magnetic field is applied, the MREs shows a magnetorheological effect that provides physical properties that depend on the field. In magnetic field appearance, permeable micron ferrous particles within MREs are magnetised and attracted each other to form columns and chains in the direction of magnetic flux, and the phase becomes semi-solid in milliseconds. When the magnetic field is deleted, MRE will reclaim their original and natural property. However, MREs has distinct drawbacks such as particle settling due to density mismatch between particles and a carrier fluid [2], [3], [10].

MREs has two kinds of the structure according to its particle distribution, namely isotropic and anisotropic [9]. During the final polymer cure process, the magnetic field applied to the composite matrix treats ferrous particle to form chain until the solidification process is completed. This treatment called as anisotropic MREs. Conversely, isotropic MREs can be obtained without applying the magnetic field during the final cure process.

The process to develop MRE consists of three steps [14] as shown in Figure 1. Firstly, silicon rubber and micro-sized magnetic iron particles are mixed in one bucket and stirred until mixed. Secondly, the dispersed iron powder is mixed into the polymer matrix. If air bubbles occur, they must be removed from the sample volume to get an excellent result. Lastly, the mixture of material injected into the mould and polymerised at temperature 200-500°C for two to three hours.

3. Design Concept

Finite Element Method Magnetics (FEMM) is an open-source finite element analysis software package for solving electromagnetic problems. The program addresses 2D planar and 3D axisymmetric linear and nonlinear harmonic low frequency magnetic, and magneto-static problems and linear electrostatic problems. The FEMM software was used to help in to design the magnetic circuit in the multi-sandwich vibration isolator by simulating the magnetic field in different types of conditions and
parameters [14]. A cross-sectional drawing of a vibration isolator shown in Figure 2. The FEMM simulation results, as shown in Figure 3a. The contour plot of magnetic flux density can be shown in the results of the FEMM, as shown in Figure 3b.

![Fabrication of MRE](image1)

**Fig. 1. Fabrication of MRE**

![Vibration isolator cross-sectional](image2)

**Figure 2. A vibration isolator cross-sectional**

![Simulation design and a contour results of vibration isolator](image3)

**Figure 3. Simulation design and a contour results of vibration isolator**

The material selection for each part was considered to provide ample and uniform magnetic fields to change the stiffness. The block properties of housing and platform using A1020 Steel, and Aluminium 6061 is used for a coil bobbin. The innovative magnetic circuit design to determine the type wire, size...
of the wire, the number of turns of the coil and current applied to the coil to obtain the best magnetic fields to eliminate vibration. American wire gauge (AWG) 16 and 18 wire types are compared to develop a coil to get the best results in magnetic fields (B) generation. After the type of wire known, apply various a turn number the coil which is 250, 500 and 1000. Lastly, apply various current to the coil, which is 0.5, 1, 1.5 and 2 amperes, respectively.

4. Results and Discussion

Vibration isolator was designed using FEMM 4.2 software, as shown in Figure 3a. After defining the block properties and materials for each part, the software can begin meshing the nodes to start simulating the magnetic circuit in the design, as shown in Figure 4. The highest concentration of magnetic flux density was at the affective area where the MRE was located, which was precisely the aim of this design was.

![Figure 4. Design, meshing and simulation results using FEMM software](image1)

![Figure 5. One, two and three steel inserted in between the MREs](image2)

In order to obtain better results, vibration isolator modification is needed. The steel plates inserted in between the MREs to make a kind of sandwich plate system to drag the magnetic field into the active
The simulation was used to simulate no plate, one plate, and two plates steel insert is sandwiched between MREs to generate maximum magnetic fields, as shown in Figure 5.

Results for various wire type of the coil are the AWG 16 and 18, as shown in Figure 6a. It can be seen that the AWG 18 type result is better than AWG 16 type. Such that AWG 18 type is chosen to develop a coil. Figure 6b shows the results of AWG 18 type was used with different turn number, which is 250, 500 and 1000, respectively. The result shows that a 1000 turn number of the coil is the best performance compare for the others. Such that, the AWG 18 wire type with 1000 turn number is selected to develop a coil. Figure 6c shows that two plates steel or five layers are the best performance compared with the others. The last simulation is different current applied to the vibration isolator, which is 0.5, 1, 1.5 and 2 amperes. It can be seen in Figure 6d, 2 amperes applied to the system generate the highest magnetic fields in the MRE part.

**Figure 6.** Various parameter values of vibration isolator simulation results

**5. Conclusion**

It can be concluded to develop vibration isolator MREs based on the simulation results in above, the vibration isolator was used housing and platform material is a 1020 Steel. An aluminium 6061 was chosen for the coil bobbin. The best innovation for magnetic circuit design, the vibration isolator used
AWG 18 types of wire with 1000 number of turns, and 2 amperes of currents applied to the system to generate maximum magnetic fields in the effective area of MREs.

6. Acknowledgement
The authors would like to thank the Ministry of Research, Technology and Higher Education, the Republic of Indonesia for their support in the research work. This research was fully supported by a DRPM research grant under PDUPT Widyagama University.

7. References
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