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DEVELOPMENT OF VIBRATION ISOLATOR USING MAGNETORHEOLOGICAL ELASTOMER

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Many vibration isolators, for example, passive vehicle mounting devices, have fixed rigidity. This article presents the development of an adjustable stiffness engine mount based on the magnetorheological elastomer (MRE) to reduce engine vibration. The development of the first MREs vibration isolator was to design the engine mounting, and then to simulate a magnetic circuit. The choice of housing material and the thickness of the MRE is considered to complement a sufficient and uniform magnetic field 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 for optimal magnetic field. Finite Element Method Magnetics (FEMM) software was used to demonstrate the effectiveness of electromagnetic circuits in generating magnetic fields through MRE samples. Finally, influenced by the various current input in the coil, the performance of the MRE vibration isolator is investigated. The input electric current whose value increases is more useful to change the increased stiffness value of the MRE-based isolator system.

Key words: magnetorheological, elastomer, vibration, isolator

INTRODUCTION

In the engineering field, there are many machines vibrate both on a small and large scale. Excessive vibration, under very high amplitudes, can cause the devices/machines/engines to fail. Many types of system can be used to reduce vibration or disturbance, for example, a passive system, a semi-active system, and also an active system [1]. In the conventional passive isolation system is simple, low cost, do not need external energy supply, system parameters are generally fixed, and they are chosen based on the design requirements of system. The selected choice of material in the passive system is natural rubber. Passive systems are solely practical for dampening vibrations in a very limited frequency, due to the permanent nature of material stiffness. If some other forces, then disturb the load, then it the load will oscillate up and down around its original position for some time. To solve these problems, many researchers have studied various active and semi-active systems both theoretically and experimentally. The semi-active isolation system has the ability to change the damping characteristics of system without using any actuators. The active isolation system differs from the conventional passive system in its ability to inject energy from external source into the system. The active system combines additional components such as sensors, actuators, electronics to provide controlled properties. The disadvantage of an active system is high energy consumption for activation [2]–[4]. Due to stability and reliability, it is preferred to choose the semi-active method for vibrations which can work for low and high frequencies. Low overall stiffness and low attenuation of vibration isolators are required for vibration at high frequencies, whereas the vibrations at low frequencies require high stiffness and high attenuation vibration isolators. Smart material magnetorheological elastomers (MRE), meanwhile, can be classified into a category of viscoelastic materials which undergoes mechanical and rheological changes under the application of magnetic fields. The MRE consists of soft ferromagnetic particles like pure iron and powdered carbonyl iron embedded within polymeric materials. The iron particles will be distributed randomly if no magnetic field is applied, but the influence of a magnetic field, a dipole moment parallel to the external magnetic flux lines is obtained by the iron particles and a chain is formed [5]–[10]. Many researchers have investigated an increasing the performance of vibration absorbers using MRE material [5], [8], [9], [11]–[13]. In order to study the performance of the vibration isolators, the results of magnetic field analysis, are used. A notable amount of researcher works has been performed to overcome the limitations of vibration dampening devices that are passive in reducing vibration frequencies. The MRE is an excellent potential candidate for smart devices used in a variety of engineering fields, especially in fields involving vibration isolations. Many researchers proposed many vibration isolators with MREs based [2], [5], [9], [12]–[14]. Previous studies have shown potential MREs applications for vibration isolation control. MREs can be used in the variable stiffness suspension system [2] or vehicle seat suspension system [1]. Researchers have developed various types of vibration absorbers based on a single-mode (shear or squeeze) elastomer or a shear compression mode [14]. The objective of this paper is to develop a vibration isolator using MRE material and optimize variable such as housing material selection. The development of the MRE vibration isolator is to design vibration isolator, type and wire size, and the amount of coil turns. A Finite Element Method Magnetics (FEMM)

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software, was utilized to simulate the system. After finding the optimum design, the last step was to fabricate a vibration isolator to demonstrate the effectiveness of the system to reduce vibration.

MAGNETORHEOLOGICAL ELASTOMER MATERIAL

Material plays an important part in fabricating the MREs sample. Materials selection are Carbonyl Iron Powder (CIPs) low magnesium and manganese compound was supplied by Sigma-Aldrich. Silicon oil Dow Coring Corporation 200® fluid, viscosity 0.06 (m2/s) (25 oC) was supplied by Sigma-Aldrich. Clear RTV Silicon (100% silicon rubber) was supplied by Permatex. The conventional process to develop MRE consists of three steps [15], as shown in Figure 1. Firstly, silicon rubber, silicon oil and micro-sized magnetic carbonyl iron particles are mixed at room temperature. Secondly, the dispersed carbonyl iron powder (CIP) is mixed into the polymer matrix. The air bubbles must be removed from the sample. Lastly, the mixture is poured into a mold and allowed to cure ranging from several minutes to several hours depending on the polymer curing time. The mixture of material is injected into the mold and polymerized at high temperature (200-500 0C) for two to three hours or even up to 24 hours at room temperature. During the final polymer cure process, if the solidification process is completed with a magnetic field applied to the composite matrix continuously treating ferrous particle to form chains. MREs has two kinds of the structure according to their particle distribution after polymerization, namely isotropic (random arrangement of CIPs) and anisotropic (chain of CIPs) [13], [16].

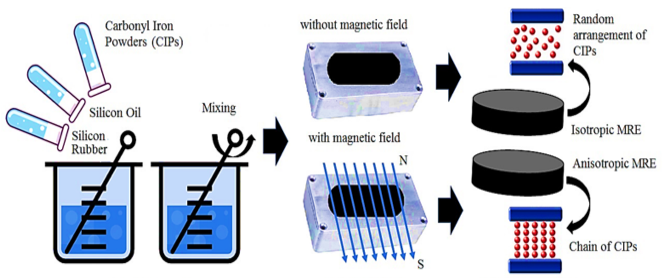


Figure 1: Fabrication of MRE.

1. Three raw materials mixing: silicone rubber, silicon oil and CIPs, 2. Polymerization: allow polymerization of the suspension within a mould either in the absence or presence of a magnetic field. 3. After-polymerization: two types of MREs are isotropic and anisotropic

DESIGN AND SIMULATION

Finite Element Method Magnetics (FEMM) is a software package that is open-source and is used in solving electromagnetic problems for finite element analysis. The 2D planar and 3D axisymmetric linear and nonlinear harmonic low frequency magnetic are addressed by the program, as well as the magneto-static problems and linear electrostatic problems. The FEMM software was integrated to assist in designing the magnetic circuit in the multi-sandwich vibration isolator which is done in different types of conditions and parameters by simulating the magnetic field [15]. A cross-sectional drawing of a vibration isolator shown in Figure 2. The FEMM simulation results are given in Figure 3a below. Figure 3b below shows the results of the FEMM which elaborates the contour plot of magnetic flux density. For each component, the material selection was considered to change the stiffness using the equipped ample and uniform magnetic fields. The block properties of housing and platform using A1020 Steel, and Aluminium-6061 is used for a coil. The innovative magnetic circuit design to determine the type of wire, size of the wire, the turn numbers 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. The vibration isolator was designed using FEMM 4.2 software, as shown in Figure 3a. The software meshed the nodes after the block properties and materials for each part are defined, to begin the magnetic circuit simulation in the design, as seen in Figure 4. The effective region where the MRE was located was where the highest magnetic flux density concentration is presented, which was the main goal of this design.

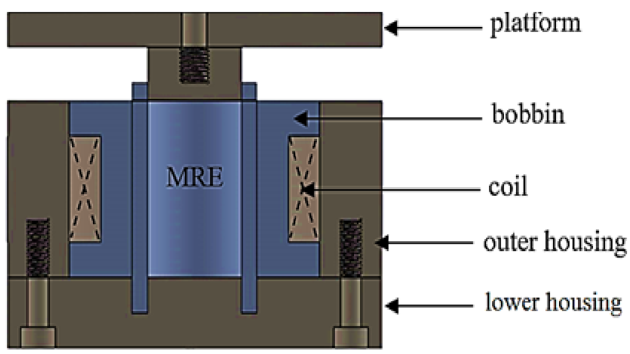
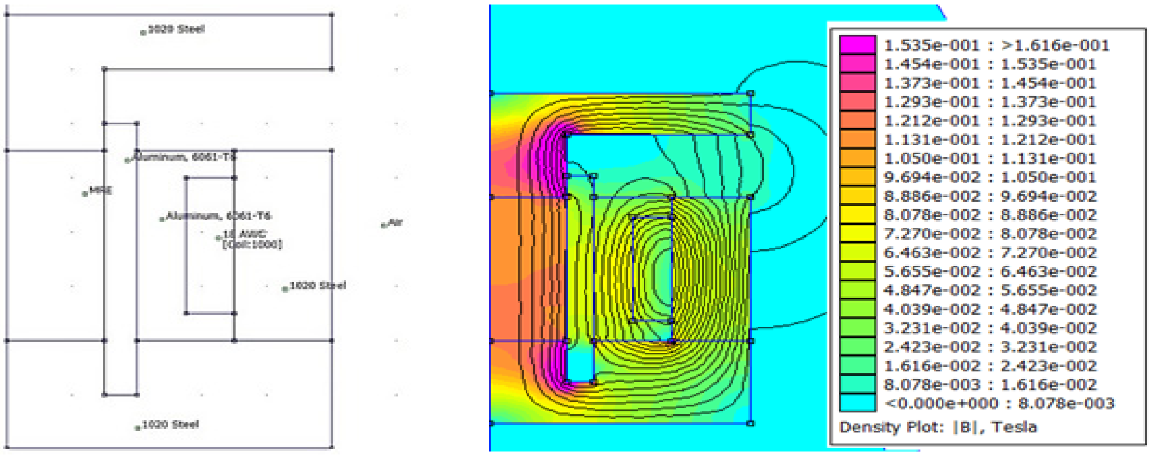


Figure 2: A cross-section view of the vibration isolator

In order to obtain better results, vibration isolator modification is needed. To create a kind of sandwich plate device, the steel plates inserted between the MREs dragged the magnetic field into the active area. 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 generate magnetic fields. 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



a) b)

Figure 3: a) Simulation design and b) a contour results of vibration isolator

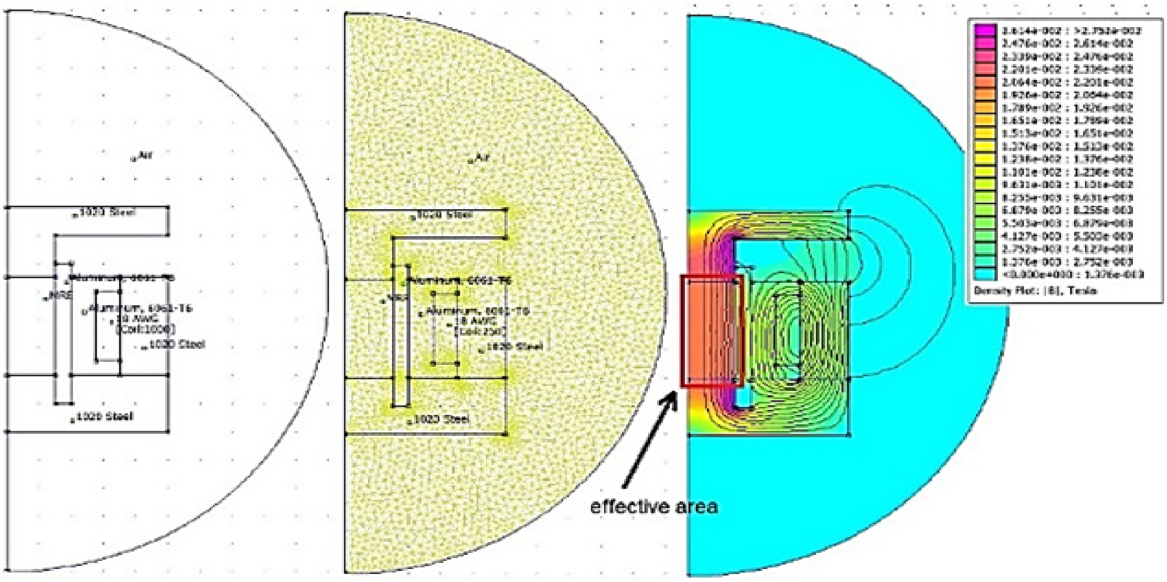


Figure 4: Design, meshing and simulation results using FEMM software

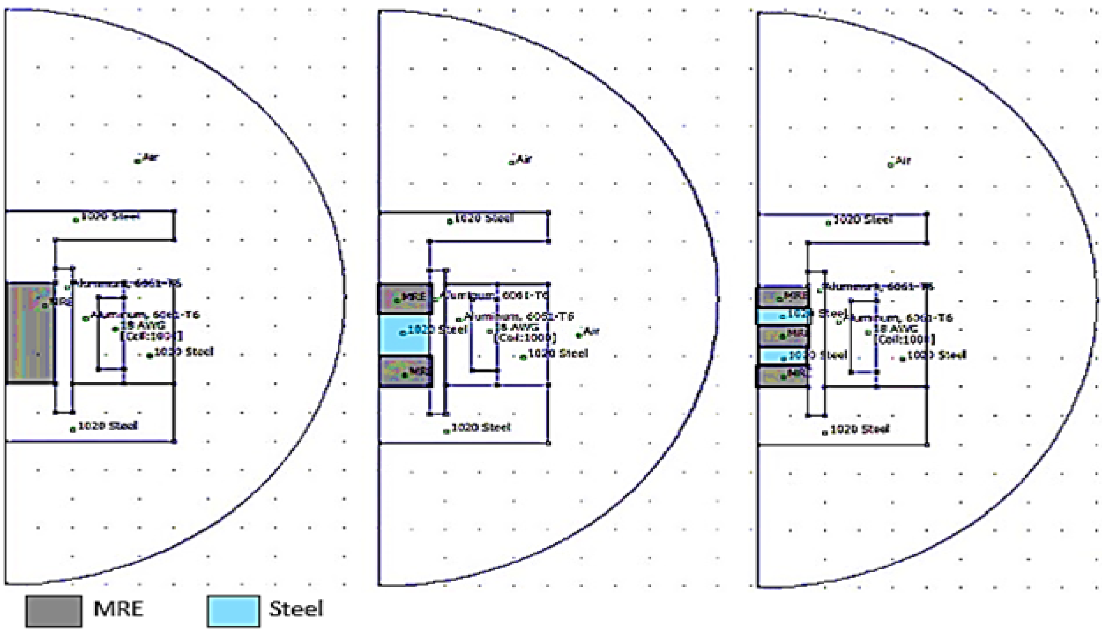


Figure 5. One and two steel plates inserted in between the MREs

compared to the others. Such that, the AWG 18 wire type with 1000 turn number is selected to develop a coil. Figure 6c shows that one layer (no steel plate inserted), three layers (one steel plate inserted), five layers (two steel plates inserted) is sandwiched in between MRE performance to generate magnetic fields. The simulation results show that five layers are the best performance compared with the others. The last simulation is a 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.

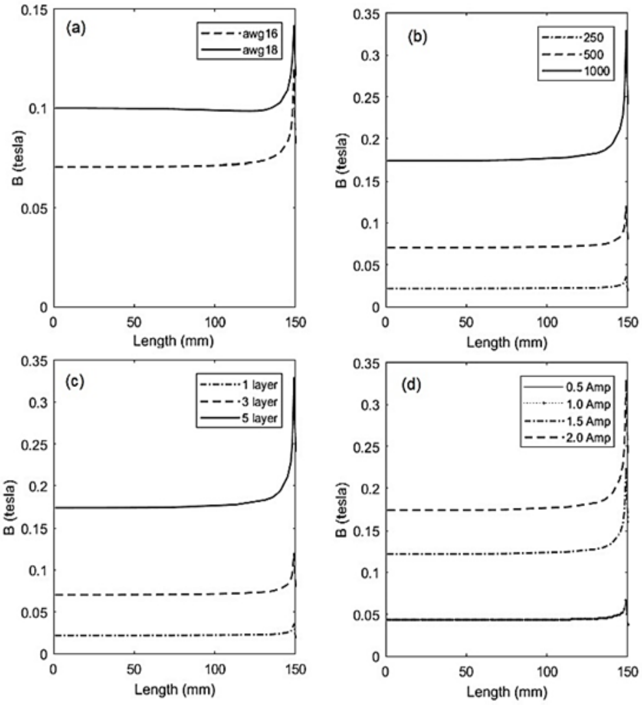


Figure 6: Various parameter values of vibration isolator simulation results, a. American Wire Gauge (AWG) 16 and 18 used for a coil, b. 250, 500 and 1000 turn number used for a coil, c. 1 layer (no steel plate inserted), 3 layer (1 steel plate inserted) and 5 layers (2 steel plates inserted) between the MRE performance, d. 0.5 Amp – 2.0 Amp current applied to the coil performance

EXPERIMENTAL RESULTS

The experimental test rig utilized to obtain the test of the vibration data on the MRE vibration isolator is displayed in Figure 7 below. Equipment's used in the experiment are 4-Kanal SIRIUS mini SIRIUSm-4xACC Dewesoft DAQ System, PCB® Piezotronic accelerometer, and laptop. To send the vibration signals to the laptop for processing, both the laptop as well as the piezoelectric accelerometer were connected with the DAQ. The DC power supply supplies the DC motor and the electromagnetic coil with current within the vibration isolator. Throughout the experiment, a constant 8 VDC was supplied for the DC motor whilst mounted on top of the vibration isolator is used as disturbance generator. The electromagnetic coil was supplied with 0.0, 1.0, 1.5, 2.0 and 2.5 Amperes respectively each time the experiment was performed. The material used consisted of steel and the number of turns the coil is 400 of AWG 18 wire type.

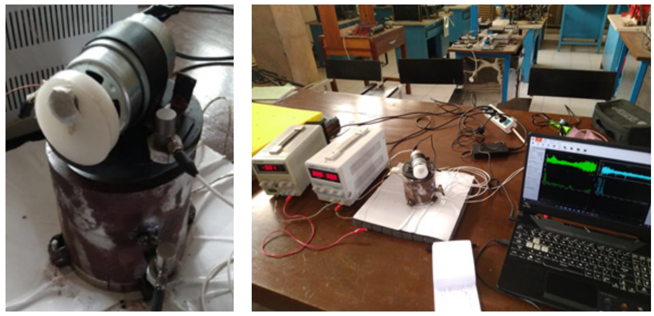


Figure 7: The experimental setup

The density of the magnetic flux in the effective area of the vibration isolator also increases as the current applied to the electromagnetic coils increases. Carbonyl iron particles contained within the MRE react and increase the MRE's stiffness, which, as a result, reduces the vibration generated by the 8VDC motor on the MRE vibration isolator. Figures 8-9 are the collected data results which are taken of both the graphs of coherence level time response and power spectral density, as well as analyzing the difference in vibration amplitude when the isolator is disturbed. Figure 8 show power spectral density for vibration signal at vibration isolator if five type current 0 Ampere, 1 Ampere, 1.5 Ampere, 2.0 Ampere, and 2.5 Ampere applied to the vibration isolator coil, respectively. It can be seen that the magnitude signal when current 0 Ampere applied to the coil is lowest magnitude values, that mean stiffness of the MRE is lowest value compare to the other. When the current 2.5 Ampere is applied to vibration isolator coil, the MRE has highest acceleration magnitude value or high stiffness value of the MRE. It was inferred from the graph that increase differences existed in the vibration amplitude for each current increment applied.

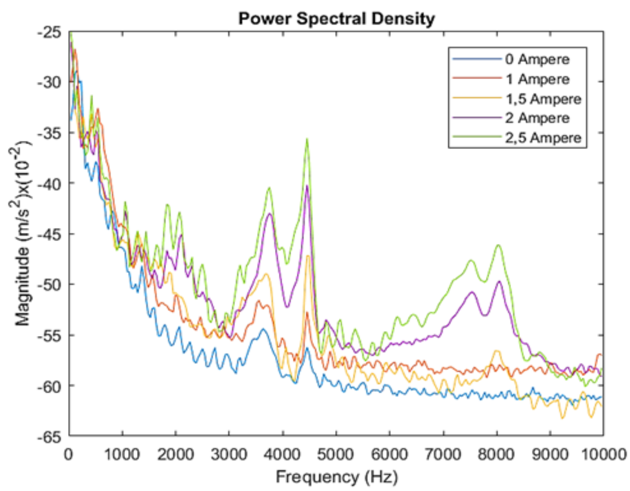


Figure 8: Power Spectral Density

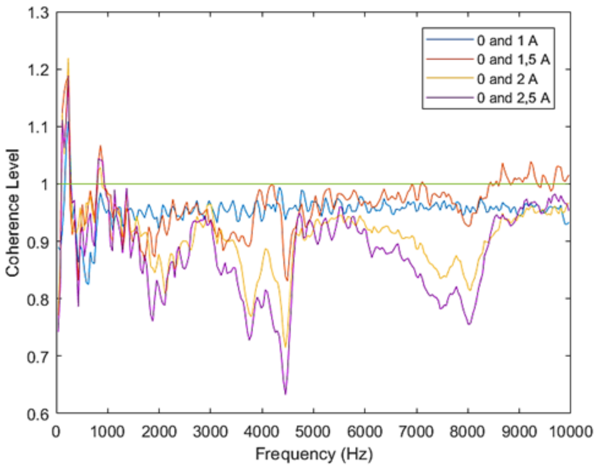


Figure 9: Coherence level signal

Figure 9 shows the coherence level for two different signals as a result of two different currents applied to the vibration isolator coil. Coherence measures the degree of linear dependency of two signals by testing for similar frequency components. If two signals correspond to each other perfectly at a given frequency, the magnitude of coherence is 1. If they are totally unrelated coherence will be 0. Five types of current applied to the vibration isolator coil to generate magnetic fields. It can be seen that coherence level 0 Ampere to 2.5 Ampere have smallest values compare to other coherence level signals. That means an increase in the current applied to the coil of the vibration isolator, causes the magnetic field to increase and so the stiffness of the MRE also increases.

CONCLUSIONS

In this work, MRE-based vibration isolators have been developed. The material used consisted of steel and the number of turns the coil is 400 of AWG 18 wire type. The DC motor whilst mounted on top of the vibration isolator is used as disturbance generator. The experimental results show based on the power spectral density and the signal coherence level graphs, that the increasing magnitude value for the amplitude acceleration is observed when the current applied to the vibration isolation coil is increased. This shows that the characteristic of MRE can be modified by the stiffness of isolating vibrations when controlled by an external magnetic field, by applying an electric current to the coil in the vibration isolation system.

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