# Smart material magnetorheological elastomer-based to reduce vibration

Gigih Priyandoko[1,*], Purbo Suwandono[2], Muhammad Ilman Nur Sasongko[2]
[1]*Department of Electrical Engineering, Faculty of Engineering, Universitas Widyagama Malang, Indonesia*
[2]*Department of Mechanical Engineering, Faculty of Engineering, Universitas Widyagama Malang, Indonesia*

**Abstract:** This article describes the creation of an adjustable stiffness vibration isolator that employs magnetorheological elastomer (MRE) - a smart material - to reduce undesirable vibration. The initial phase involved the design of the vibration isolator, followed by magnetic circuit simulation. Finite Element Method Magnetics (FEMM) software was subsequently used to demonstrate the generation of magnetic fields within the vibration isolator by MRE samples. The selection of the housing material and the MRE thickness is deemed necessary to complement a sufficiently strong and homogenous magnetic field, which alters stiffness. The magnetic circuit design is innovative and takes into account factors such as the wire type, size, and coil turns for the optimal magnetic field. Lastly, the performance of the MRE vibration isolator is examined through analyses of the various current inputs in the coil. The increase in the value of the input electric current is more effective in modifying the raised stiffness value of the MRE-based isolator system.
**Keywords:** Magnetorheological Elastomer,Smart Material, Isolator, Vibration,

## I. INTRODUCTION

A passive system conforms to a range of principles such as being straightforward, inexpensive, and requiring no external power source. Parameters are chosen based on design requisites; the material utilized is typically natural rubber [1]–[3]. As this substance is permanently rigid, it is suitable to attenuate vibrations at restricted frequencies, making passive systems highly practical. When external forces disturb the load, it will move up and down from its initial position for some time. To overcome this challenge, numerous researchers have explored active and semi-active systems theoretically and experimentally [4]–[9]. A semi-active isolation system can modify the reducing properties of the system even without an actuator.

The active isolation system's capacity to inject energy from an external source into the system sets it apart from the conventional system. Such a capability leads to controlled properties in the active system. The system combines additional components such as electronics, actuators, and sensors [10]. The use of an active system has a drawback, specifically the high power consumption required for activation. This is why, in the case of vibrations, a semi-active method is preferred due to its effectiveness with both low and high frequencies, as well as its superior stability and reliability. For high-frequency vibrations, it is necessary to use isolators with low stiffness and attenuation, while for low-frequency vibrations, isolators with high stiffness and attenuation are required [2], [7]. In this investigation, magnetorheological elastomers (MRE) are used as vibration isolators due to their elastic and damping properties, which can help to reduce unwanted vibrations when subjected to an external magnetic field. This smart material is effective in mitigating the effects of vibrations. Viscoelastic materials are one of the types of smart materials that respond to magnetic fields by changing mechanically and rheologically [1]–[3]. Smart materials come in different types and viscoelastic materials are one of them. These materials respond to magnetic fields by changing mechanically and rheologically[1]–[3]. This material consists of gentle magnetic particles and is a powder compound like pure iron and powdered carbonyl iron that are combined with plastic materials. Filler ingredients and elastomers are blended in a particular ratio to make the composite substance. The filler particles remain in a specific area within the elastomer after the MRE has been dried and set. The MR phenomenon occurs when a magnetic field causes a particle to form a chain structure, resulting in certain mechanical properties. This was first discovered by Jobob Rabinow in 1948. Alterations in rigidity provide another indication of the MR effect. Therefore, we have tried different approaches by changing several factors, such as the matrix material, additives and size, percentage content, type, and shape of the fillers. The aim is to develop an MRE that can maximize the MR effect [1], [3]–[5], [11]–[15].

Many experts have researched how to enhance the effectiveness of vibration dampers by utilizing MRE materials [6], [8], [16]–[19]. They investigate performance by employing magnetic field analysis. Numerous academic papers have been published by scholars in an attempt to overcome the restrictions of passive vibration-damping tools in reducing vibration frequency. MRE material has the potential for use as clever tools in various areas of engineering, specifically those focusing on reducing vibrations.Many researchers[9], [20],

  

[21] have suggested various vibration isolators using MRE in multiple stiffness suspension systems or vehicle seat suspension systems. Many researchers have suggested various vibration isolators using MRE in multiple stiffness suspension systems or vehicle seat suspension systems. Many researchers have suggested various vibration isolators using MRE in multiple stiffness suspension systems or vehicle seat suspension systems. MREs have great potential for vibration isolation, as shown in past studies. Elastomers that use shear or compression modes or shear compression modes have produced various vibration dampers. By using MRE material and optimizing variables like the selection of housing material, wire type and size, and number of coil turns, this research aims to create a vibration isolator. The vibration isolator will demonstrate the effectiveness of the vibration-damping system.This research aims to develop a device that reduces vibrations using MRE material and will be tested different variables such as the type of housing material, wire size, and the number of coil turns to increase effectiveness. We will demonstrate the effectiveness of this vibration-dampening system by creating a prototype.

## II. SIMULATION

A readily available free open-source software called Magnetic Finite Element Method (FEMM) is available online. It enables solving electromagnetic problems for finite element analysis [22]–[25], as well as linear magnetostatic and electrostatic issues. FEMM can also address the linear and nonlinear harmonic low-frequency magnetic problems of 2D and 3D colorimetry. The application is designed to assist in achieving optimal magnetic circuit design for vibration isolators composed of MRE. The program simulates different combinations of MRE composition materials.To achieve the most effective reduction of vibrations, the magnetic field simulation requires careful consideration of numerous parameters and conditions. To induce magnetorheological elastomers (MRE), a multi-sandwich arrangement of MRE and pure iron is utilized, with an optimal magnetic field achieved by attaching a specific number of turns to the coil.The study involved simulating the use of MRE in the middle of a vibration isolator without a pure iron plate. The aim was to investigate whether using one or two steel plates, placed in opposite directions, would create a maximum magnetic field. Figure 1 illustrates the proposed design drawings and fabricated vibration isolator sections.The material for the parts of the vibration isolator is selected for its ability to create the most powerful magnetic field, which alters the stiffness of the MRE by inducing a uniform cross-sectional area. Pure iron, which is an excellent conductor of magnetic fields, is preferred for making the housings for vibration isolators. The materials will undergo simulation to determine the most effective conductor for conducting a simulated magnetic field. We test the wire type, size, coil turns, and current to create the most innovative magnetic field generator circuit that minimizes system vibrations. The main goal of this study is to find the best position for the MRE, which is where magnetic flux density is highest. Figure 2 displays this information in a contour plot of magnetic flux density on the vibration isolator, created using the FEMM software. The main goal of this study is to find the best position for the MRE, which is where magnetic flux density is highest. For optimal outcomes, adjust the vibration isolator accordingly.

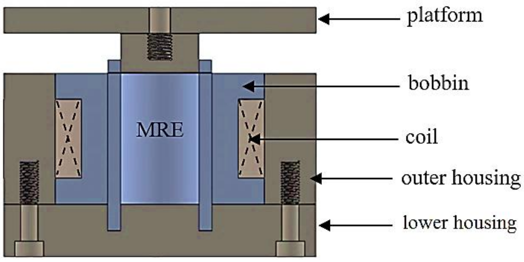


Figure 1. A cross-section view of the vibration isolator design

## III. RESULTS AND DISCUSSION

The experiment collects information on vibration dampers made with MRE materials. Figure 3 displays the testing setup. The trial employs a SIRIUS mini SIRIUSm-4xACC DAQ system, a piezo-electronic accelerometer PCB®, and a laptop computer. Software and hardware interface connects the DAQ to laptops and piezoelectric accelerometers to transmit vibration signals. A power source supplies energy to the electromagnetic coil of a device that reduces vibrations.An electric motor, also mounted on the device, produces vibrations for testing. The motor operates as a generator of vibrations.

  

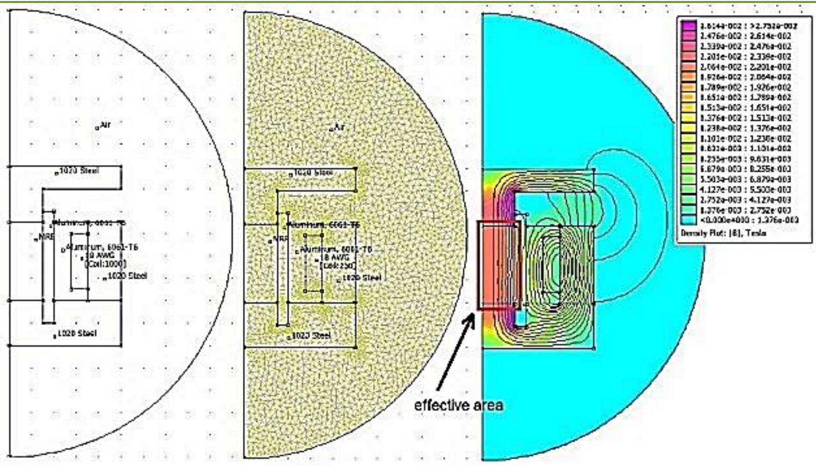


Figure 2. A contour plot of magnetic flux density

Figure 3. Testing setup

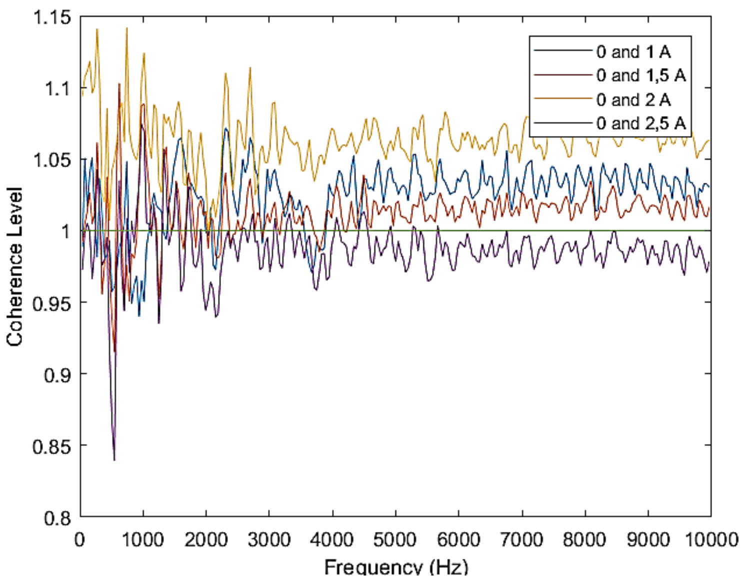


Figure 4. The coherence level for the vibration signal

  

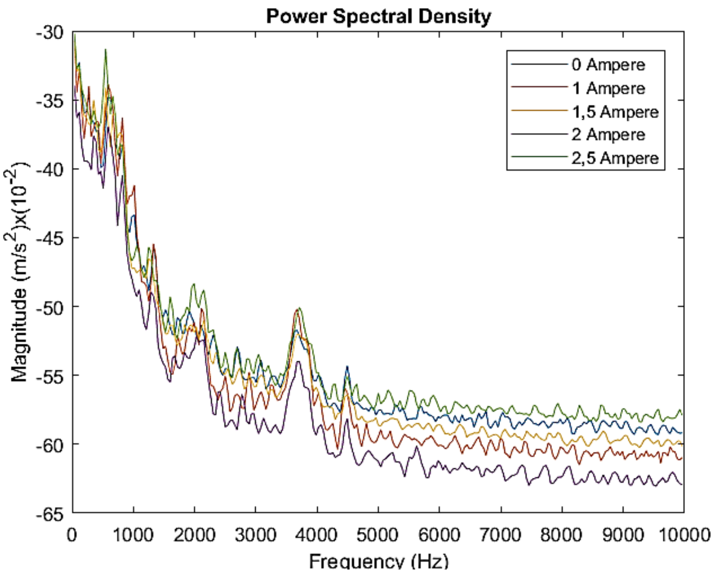


Figure 5. The power spectral density for the vibration signal

The motor operates as a generator of vibrations. During the experiment, the electromagnetic coil receives currents of 0.0, 1.0, 1.5, 2.0, and 2.5 amperes in turn. As the electricity going to the coil gets stronger, the strength of the magnetic force in the isolator where vibrations are stopped goes up. The stiffness of the MRE rises when the carbonyl iron particles react, which then reduces the vibrations that come from the 4, 6, and 8 VDC motors to the MRE isolators. Figures4-5 display the information gathered from graphs of time responses for power distribution and coherence levels. It also provides an investigation into the disparities in vibration amplitudes of affected isolators.In Figures4-5, you can see the coherence levels for two separate signals representing different currents passing through the vibration oscillator coil. Coherence measures the degree of linear dependence between the signals by comparing their frequency components. If the frequencies of both signals are coordinated, their coherence magnitude is equal to 1. However, if they are unrelated, their coherence magnitude will be 0. The MRE shows the strongest vibration when a current of 2.5 amps is applied to the vibration isolator coil, indicating high stiffness. By examining the graph, we can see that an increase in current causes an increase in vibration difference.To create a magnetic field, the vibration-isolating coil utilizes five different types of current. It has been observed that the coherence level between 0 amps and 2.5 amps demonstrates the weakest value as compared to other signal coherence levels. This indicates that an increase in current applied to the vibration isolator coil results in the fading and amplification of the magnetic field. Consequently, the MRE stiffness is also elevated.

## IV. CONCLUSION

From this study, it is apparent that a vibration isolator based on MRE has been developed. The DC motor operates as a disturbance generator installed above the vibration isolator features. The current provided to the coil fluctuates. As the current sent to the vibration isolation coil increases, the power spectral density graph and signal coherence level show an increase in the magnitude value for the accelerated amplitude. This proves that altering the MRE properties is possible by adjusting the stiffness of the vibration isolator, which is done through an external magnetic field generated by sending an electric current to the vibration isolator's coil.

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