# Magneto-rheological Fluid Assisted Vibration Damping in Bi-directional Composite Beam

Dr. Biju B  
Professor  
Department of Mechanical Engineering  
Mar Athanasius College of Engineering Ernakulam, Kerala, India

Rajendraprasad P  
B. Tech Student  
Department of Mechanical Engineering  
Mar Athanasius College of Engineering Ernakulam, Kerala, India

Roshin Mathews George  
B. Tech Student  
Department of Mechanical Engineering  
Mar Athanasius College of Engineering Ernakulam, Kerala, India

Tony Varghese  
B. Tech Student  
Department of Mechanical Engineering  
Mar Athanasius College of Engineering Ernakulam, Kerala, India

## Abstract

In systems having mechanical vibrations, the amplitudes may vary from few nanometers to meters depending upon the system. Detrimental effects of vibration may be system failure, operational inefficiencies etc. Structural vibrations can be mitigated by different methods like stiffening, damping, isolation etc. The damping characteristics of a bi-directional composite beam subjected to vibration damping using magneto-rheological fluid are studied. Composite materials are made from two or more constituent materials with different properties, that when combined, produce a material with entirely different characteristics. By choosing appropriate combination of matrix and reinforcement material a new material can be made that exactly meets the requirement of a particular application. Magneto-rheological fluid (MR fluids) is colloidal suspension which can change from liquid to quasi-solid phase under the influence of external magnetic field. Small sized, magnetisable, ferrous particles contained in low permeability oil constitute a MR fluid. When external field is removed phase changes from solid to liquid. This behavior is used in damping. Magneto-rheological fluid layer is sandwiched between two composite beams and is properly sealed. It is then subjected to free vibration analysis considering the beam as cantilever. The natural frequencies of the beam corresponding to different modes are determined experimentally. The MR fluid sandwiched beam is subjected to magnetic field at different locations on the beam and the variations in natural frequencies are studied. It is observed that the maximum relative change in natural frequency is observed when the field is applied on both sides at the centre as well as the clamped end of the beam.

**Keywords:** Magneto-rheological fluid, natural frequency, damping, finite element

## I. INTRODUCTION

In the systems having mechanical vibrations, amplitudes may range from a few nanometers to meters depending upon the type of system. Vibrations can lead to detrimental effects such as system failure, discomfort, and operational inefficiencies. Various methods of vibration suppression include active, passive and semi-active vibration control systems. Active vibration control systems are known to yield enhanced vibration suppression of structures and to adapt to changes in excitation and structural properties, but they are expensive and require a lot of power. In passive methods, viscoelastic layers are employed in sandwich structures, but they are not suitable for applications where the stiffness and damping properties must be altered [1].

Semi-active control devices possess the advantages of active and passive control devices. These devices include controllable fluids such as electro rheological (ER) and magneto rheological (MR) fluids. These fluids are widely used in various semi-active vibration control applications owing to their controllable rheology and damping properties.

Various researches have used ER fluids which are activated in the presence of an electric field. ER fluids have low yield strength, require high voltage, and are more sensitive to common impurities. MR fluids, on the other hand exhibit higher yield strength under the influence of magnetic fields [2]. This study deals with using MR fluid to reduce the vibrations in a cantilever beam. MR fluids are colloidal suspensions which exhibit large reversible changes in flow properties such as apparent viscosity when subjected to sufficiently strong magnetic fields. Presence of magnetic field leads to the formation of chain-like structures aligned parallel to the applied magnetic field. When magnetic field is removed the phase again changes back to liquid. The quick response, good reversibility and controllable performance of MR fluids make them suitable for use in various devices.
The objective of this study is to analyze experimentally, the controllability of cantilever MR sandwich beam under an external magnetic field. The maximum relative change in natural frequency, and therefore in stiffness, obtained by applying the magnetic field is referred as controllability.

II. NATURAL FREQUENCY EVALUATION OF ALUMINIUM BEAM USING ANSYS

Dimension of the aluminium beam considered for analysis is 300mm x 30mm x 3mm. The natural frequency was found out experimentally, was validated using ANSYS software. The results obtained are very close which implies the methodology used is correct. The comparison of ANSYS value and experimental values is shown in table 1. Figure 1 shows the natural frequencies along with mode shapes obtained from ANSYS.

<table>
<thead>
<tr>
<th>Aluminium beam</th>
<th>First mode (Hz)</th>
<th>Second mode (Hz)</th>
<th>Third mode (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSYS</td>
<td>0.8716</td>
<td>5.4583</td>
<td>15.285</td>
</tr>
<tr>
<td>Experimental</td>
<td>0.93</td>
<td>5.20</td>
<td>15.43</td>
</tr>
</tbody>
</table>

Table 1: Comparison of Ansys and Experimental Results

Fig. 1: (a) First Mode, (b) Second Mode, (c) Third Mode of Aluminium Beam

III. METHODOLOGY

The experiment is conducted using the facilities in the vibration lab. The study is conducted using MR sandwich cantilever beam. The beam is formed by three layers: two composite beams and an MR fluid core. An external magnetic field controls the rheological properties of the fluid, hence the dynamic characteristics of the structure. The core layer has a thickness of 4mm. The two beams are sealed together using a mixture of m-seal and araldite. One end of the sandwich structure was kept open to facilitate the filling of MR fluid. The MR fluid was injected using a hypodermic syringe. Once the gap between the beams was fully filled, the opening was also sealed and allowed to dry.

The beam under consideration can be operated in three different modes: valve mode, shear mode and squeeze-flow mode [3]. The present study employs squeeze-mode.

IV. EXPERIMENTAL SET UP

Various devices used for conducting the experiment included- a rigid frame for clamping the cantilever beam, permanent magnets, impact hammer, accelerometer, data acquisition system. It also included software –DEWETRON- to analyze the vibration response and thus determine the natural frequencies. Once the beam is excited using impact hammer, the accelerometer measures its vibration response. The data acquisition system collects the signals from the impact hammer and the accelerometer and sends them to the dynamic signal analyzer software. Finally, the signals are processed and Fourier transformed to get the natural frequencies of the beam. The vibration response was obtained in the frequency domain, where natural frequencies and amplitudes of vibration were presented in the output. Figure 2 shows the experimental set up. MR fluid used for the study has yield strength of 35 KPa. Glass epoxy based bi-directional composite beam was used. The beam dimension used for the analysis was 250 mm x 50 mm x 8mm. The density of the material is 1050 kg/m³. The Young’s Modulus of the material is 5.5 GPa.
V. RESULTS AND DISCUSSIONS

Natural frequencies of MR sandwich beam are determined experimentally with and without the presence of magnetic field are shown in figure 3 and figure 4 respectively.

Fig. 2: Cantilever Bi-directional Beam Test set up

Fig. 3: Natural frequencies of the beam determined in the absence of magnetic field.

Fig. 4: Natural frequencies of the beam determined in the presence of magnetic field.
The comparison of natural frequencies of the beam in the absence of magnetic field and in the presence of magnetic field along positions is shown in table 2. The analysis was carried out for various positions of the magnetic field.

Table 2
Comparison of Natural Frequencies of the Beam in the Absence and Presence of Magnetic Field

<table>
<thead>
<tr>
<th>Position of magnets</th>
<th>Mode 1 (Hz)</th>
<th>Mode 2 (Hz)</th>
<th>Mode 3 (Hz)</th>
<th>% variation of first natural frequency from corresponding value in the absence of magnetic field</th>
<th>% variation of second natural frequency from corresponding value in the absence of magnetic field</th>
<th>% variation of third natural frequency from corresponding value in the absence of magnetic field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without field</td>
<td>91.48</td>
<td>1517.42</td>
<td>2625.82</td>
<td>~</td>
<td>~</td>
<td>~</td>
</tr>
<tr>
<td>1</td>
<td>96.44</td>
<td>1614.99</td>
<td>2833.66</td>
<td>5.42</td>
<td>6.43</td>
<td>7.92</td>
</tr>
<tr>
<td>2</td>
<td>97.05</td>
<td>1599.12</td>
<td>2813.11</td>
<td>6.09</td>
<td>5.38</td>
<td>7.13</td>
</tr>
<tr>
<td>3</td>
<td>97.05</td>
<td>1614.99</td>
<td>2800.29</td>
<td>6.09</td>
<td>6.43</td>
<td>6.64</td>
</tr>
<tr>
<td>4</td>
<td>97.05</td>
<td>1613.77</td>
<td>2819.82</td>
<td>6.09</td>
<td>6.35</td>
<td>7.39</td>
</tr>
<tr>
<td>5</td>
<td>97.05</td>
<td>1638.18</td>
<td>2817.99</td>
<td>6.09</td>
<td>7.96</td>
<td>7.32</td>
</tr>
<tr>
<td>6</td>
<td>97.05</td>
<td>1614.99</td>
<td>2807.01</td>
<td>6.09</td>
<td>6.43</td>
<td>6.9</td>
</tr>
<tr>
<td>7</td>
<td>96.44</td>
<td>1633.9</td>
<td>2819.21</td>
<td>5.42</td>
<td>7.68</td>
<td>7.36</td>
</tr>
<tr>
<td>8</td>
<td>97.66</td>
<td>1624.15</td>
<td>2765.50</td>
<td>6.76</td>
<td>7.04</td>
<td>5.32</td>
</tr>
<tr>
<td>9</td>
<td>97.66</td>
<td>1605.83</td>
<td>2820.43</td>
<td>6.76</td>
<td>5.83</td>
<td>7.41</td>
</tr>
</tbody>
</table>

The various positions of the magnets are explained below.
1) Single magnet is placed below the beam on the extreme left end of beam
2) Single magnet is placed above the beam on the extreme left end of beam
3) Single magnet is placed below the beam on the extreme right end of beam
4) Single magnet is placed above the beam on the extreme right end of beam
5) Magnets are held above and below the beam on extreme left end of beam
6) Magnets are held above and below the beam on extreme right end of beam
7) Magnets are held above and below centre of the beam
8) Magnets are held above extreme left and below extreme right ends of the beam
9) Magnets are held below extreme left and above extreme right ends of the beam

VI. CONCLUSION

Vibration damping of sandwich beam was carried out. The vibration characteristics were studied by operating the beam in squeeze-flow mode. Initially the methodology was proven using an aluminium beam. It can be observed that, on the application of magnetic field, the natural frequencies of the beam increased for different positions of the applied field. On the application of the magnetic field, the apparent viscosity of MR fluid increases, thus increasing the stiffness of the MR sandwich beam which causes increase in natural frequencies. It is observed that relative change in natural frequency is greater for higher modes. It is observed that the maximum relative change in natural frequency is observed when the field is applied on both sides at the centre as well as the clamped end of the beam. Relative change in natural frequency is comparatively lower when magnetic field is applied only on one side of the beam.

REFERENCES