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Analysis of Simply Supported Mr Fluid Sandwich Beam

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Abstract : The existence of vibrations in undesired parts of mechanical machinery, civil structures, aerospace and automotive components,will cause overall setback and efficiency reductions in processes when the above parts are used. Hence is advising to completely get rid of the unnecessary vibrations or reduce them to a minimum possible value. This experiment is an effort to reduce these vibrations using Magneto Rheological fluids. A Magneto Rheological fluid provides viscous damping. The damping factor increases when a magnetic field is applied and is multiplied as the strength of the magnetic field is more, also the natural frequency of the body under test changes from to a value which is different from the initial value. This technique was utilized and a three layered MR fluid sandwich beam was fabricated. This beam was subjected to testing and analysis under both undamped and damped conditions. The controllability of variations in the various dynamic parameters like natural frequencies, vibration amplitudes and damping factors were observed. A reduction is natural frequency of beam was obtained in the presence of MR fluid under magnetic field, from 550 Hz to 300 Hz.
Keywords: Magnetorheological fluid, MRFluid sandwich Beam, Natural frequency, Damping factor, Damping coefficient.

Introduction

Vibration is a mechanical phenomenon where by oscillations occurs about an equilibrium point. The detrimental effects of vibrations are undesirable wasting energy, creating unwanted noise, failure, discomfort and operational inefficiencies. Examples like vibrational motion of engines, electric motors and other mechanical devices in operations. Vibrations also occurs in various structures like building bridges etc and they are typically unwanted such vibrations can be caused due to various rotational and translational imbalances on uneven friction.Structural vibrations can be reduced in different ways the most common are stiffening, damping and isolation can be accomplished by magneto rheological fluid.Magnetorheological fluid belongs to group of smart materials consisting of highly polarizable magnetic particles with the size in the order of few microns dispersed in a carrier medium[1,2].These particles form chains in the presence of magnetic fields resulting in several orders of magnitude, modification in their rheological properties such as viscosity, plasticity and elasticity[3]. They exbhit a yield strength of 20-100kPa for applied 2-3 koe magnetic field levels. The viscosity varies from 0.2 to 0.3Pa-s at room temperature and their operational temperature range from -40^{0}C to +150^{0}C [4,5,6,] as shown in the fig(1).

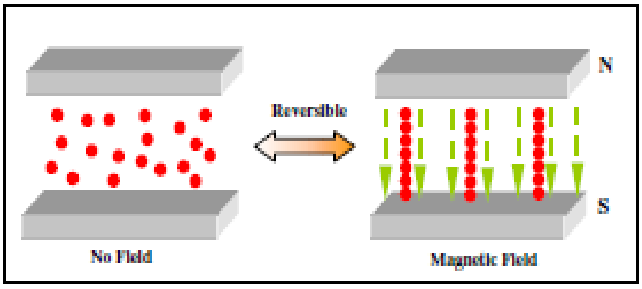

Fig.1. Chain like structure formation

A few literatures are available on MRFluid applications in the adaptive sandwich structures as the work carried out by researchers. Ross and his co-workers established the concept of using complex elastic moduli for the analysis of laminated sandwich beam[7], Experimental study investigates the controllability of vibration characteristics of magnetorheological cantilever sandwich beams. These adaptive structures are produced by embedding an MR fluid core between two elastic layers. The structural behavior of the MR beams can be varied by applying an external magnetic field to activate the MR fluid. The stiffness and damping structural characteristics are controlled, demonstrating vibration suppression capabilities of MR fluids as structural elements[8].

The complex modes can only exist when the beam is externally excited by specific "damped normal loadings" which are also complex and which are proportional to the local transverse inertia loading on the beam[9]. Use of these modes in the analysis of the forced vibration problem leads to a simple series form of solution. The orthogonality of these complex modes is briefly discussed and proved[10].

Yalcintus[11] investigated externally applied magnetic field level over the MRFluid layer. The stiffness and damping can be varied, these variations in the damping and stiffness properties can be use to tune the vibration characteristics of adaptive beams such as natural frequency, vibration amplitudes mode shapes and loss factors.Viscoelastic materials (VEM) are added to structures. In order to enhance the damping effects of the VEM, a constraining layer is attached, creating a passive constrained layer damping (PCLD) treatment. When this constraining layer is an active element, the treatment is called active constrained layer damping (ACLD). Recently, the investigation of ACLD treatments has shown it to be an effective method of vibration suppression [12]. WeiKe-Xiong[13], investigated the vibration responses of sandwich beam with respect to intensity of magnetic field and excitation frequencies and result shows that sandwich beam with elastomers cores have the capability of shifting of natural frequencies and vibration amplitude decrease with variation of intensity of external magnetic field of MRF.Sun[14], investigated the dynamic response of MR sandwich beam analytically using energy approach and compared the results with experimental results. Experiments were also performed to estimates the relationship between the applied magnetic field and the complex shear modulus of the MRFluid using oscillatory rheometry technique.[15],introduced an analytical model for MR structures based on the Kelvin - Voigt model and Hamilton principle. The relationship between the magnetic field and the complex shear modulus of MR sandwich beam in the pre-yield region is developed.[16],investigated the vibration response of partially treated multilayered beam with MRFluid as sandwich layer between the two layers of continuous elastic structure has been analyzed.[17], find the change in the location of magnetic field towards the direction of free ends of beams results in an increase in damping effect. Up to date there is no complete research work on MR adaptive space structures.[18], find the active segment of MRfluid layer is placed in various parts of plate and the optimal positions of active segment for selected modes of vibration are determined.

[19], finds the structural behaviour of the MR beams can be varied by applying an external magnetic field to activate the MR fluid. The stiffness and damping structural characteristics are controlled, demonstrating vibration suppression capabilities of MR fluids as structural elements.[20],investigated the dynamic properties of a MR sandwich beam using finite element and Ritz formulations and compared the results using experimental investigations. A free oscillation experiment was also performed to estimate the complex shear modulus of the MRFluid.[21], optimal configurations of A partially treated MR sandwich beam where subsequently identified to achieve maximum model damping factor corresponding to the first five flexural modes, considered either individually or simultaneously.

[22], findMagnetorheological (MR) elastomers are used to construct a smart sandwich beam for micro-vibration control. The micro-vibration response of a clamped–free sandwich beam with an MR elastomer core and a supplemental mass under stochastic support micro-motion excitation is studied. The dynamic behavior of MR elastomer as a smart viscoelastic material is described by a complex modulus which is controllable by external magnetic field[23,24].

The main objective of this study is to provide vibration mitigation device in the form of simply supported sandwich beam whose stiffness and damping properties can be easily controlled by means of MRFluid effect.

Design and Manufacture of Sandwich Beam

The details of fabrication of each type of beam is explained in the following sections

Fig.2(a). Prepared MR Fluid Sandwiched beam

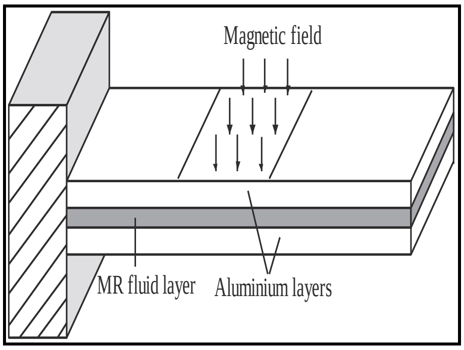

Fig. 2(b). Schematic representation of ME Fluid sandwiched beam

Fig. 2(c).Arrangements of aluminium sandwich beam

Fabrication of aluminium sandwich beam:

Material: Aluminium
No of Layers: 3
Top layer: 600x100x3 mm (Al)
Cavity dimensions: 400x60x3mm (MRFluidmiddle layer)
Bottom layer: 600x100x3mm (Al)
Density of aluminium: 2700Kg/m^3
Siliconrubber two layers.

Process

The preparation of MR fluid is complex process, in which high observation is needed to obtain required MR fluid. Here in this preparation process we try to suspend the fine carbonyl iron powder particles (4-9μm)[25], in carrier oil (silicon oil). The carrier oil of high viscosity is used so that the suspension of iron particles becomes uniform throughout the fluid. For our preparation we used silicon oil as carrier oil and fine white lithium grease as the surfactant.

Composition and properties of MR fluid

Composition:

Silicon oil (68% by wt) whose viscosity ranges from 0.340Pas, density is 0.9659gm/cm^{-3}.

Carbonyl iron powder (32%by wt) particles varies from 4-9μm as BASF norms.

Fine white lithium grease (12% by wt) as surfactant.

Chemical properties:

A regular MR fluid consists of 20-40% of carbonyl iron particles by volume. Size of the iron particles may vary from 4-9μm as BASF norms[carbonyl ironpowderparticlesmade CN, BASF, chemical composition (wt%) :> 99.5%Fe, <0.04%C, < 0.01%N, 0.2%O : the average particle size was about 6μm]. The suspension oil/carrier oil liquid liquid may be of mineral oil, synthetic oil, and water of glycol. Here synthetic (silicon oil) oil is used as carrier oil. And surfactant is used to discourage gravitational settling and promote iron particles. There are many kinds of surfactants are available in market such as oleic acid, steric acid, foamed silica, fine lithium grease etc. We made use of fine white lithium grease as surfactant in our work, sometimes surfactant act as lubricant in the system.

Physical properties:

All typical MR fluids exhibits high yield strength values in excess of 50MPa, when magnetic field is applied yield values are of 150-250KAm^{-}1over 150 MPa at saturation. A working/active temperature of MRfluid varies from -40^{o}C to +150^{o}C.

Process

Primarily silicon oil and white lithium grease is added together and stirred with the help of an electric stirrer about 2-3hours. Later we will observe whitish kind of fluid which ensures us the proper blending of grease in to the silicon oil. This state of fluid will be eligible for further process.

Fig.3.Silicon mixed with grease.

After the solution is prepared as seen above the required weighed iron powder is then poured into it , in parts while the stirring is carried out. As the iron powder falls into the container it gets mixed along with the solution and becomes highly viscous and appears to be black in colour. After the entire amount is poured in to the silicon grease solution, it is again stirred for a while so that uniform and proper mixing of the solution is done. This stirring is carried out for about 2-3 hours and the end result obtained is MR Fluid.

Fig .4. Prepared MR Fluid

Experimental setup and connections:

Components of experimental setup and connections

1) Heavy frame with beam clamping provision
2) Beam
3) Stand and Magnet holder Neodymium ferrous boron (NDFBE)
Number of magnets used: 12
Sensitivity 100.2 mVper gram Strength: 0.3 Tesla per magnet
SN 2081637 Grade 32
4) Accelerometer(Make-kisler) ±50g
5) Gauss meter
6) MRFluid
7) Striking Hammer
8) Data acquisition system NI9234
9) LabviewsoftwareLABVIEW (Laboratory Virtual Instrumentation Engineering (Work Bench) From NI 2010

Experimental procedure:

Setup and connections

Place the frame to hold the beam in an open area.Place the beam on the frame and tighten the clamps so that the beam is rigidly held on the frame.In initial condition do not fill MR Fluid into the beam.Place accelerometer on the beam by applying some gum solution onto it.Connect the accelerometer with data acquisition system.Also connect the impulse hammer with the data acquisition system.Connect data acquisition system with the laptop with the help of USB connector.

Fig.5. Self made Experimental setup

Results and discussions

Experimentation with MRfluid without applying magnetic field(undamped conditions)

Pour the MRFluid in to the cavity of the beam. Close the top layer and screw the nuts of beam tightly such that no leakage of beam takesplace. Clamp the beam on the frame. Attach the accelerometer.Hammer the beam with impulse hammer and note down the frequency,amplitude and time values.Find out the natural frequency from the graph.

Experimentation with mrfluid with applying magnetic field(damped conditions)

Place the electromagnet/permanent magnet below the beam carefully. Connect the electromagnet with power source in cae used.Calibrate the gaussmeter using zero for chamber.Place the sensor on the top of electromagnet and note down the value of magnetic field produced.Measure the airgap between the electromagnets/magnets to the bottom plate of the beamMaintain the air gap as minium as possible.Hammer the beam with impulse hammer and note down the frequency,amplitude V/S Frequency from obtained values.Find out the natural frquency from the graph.

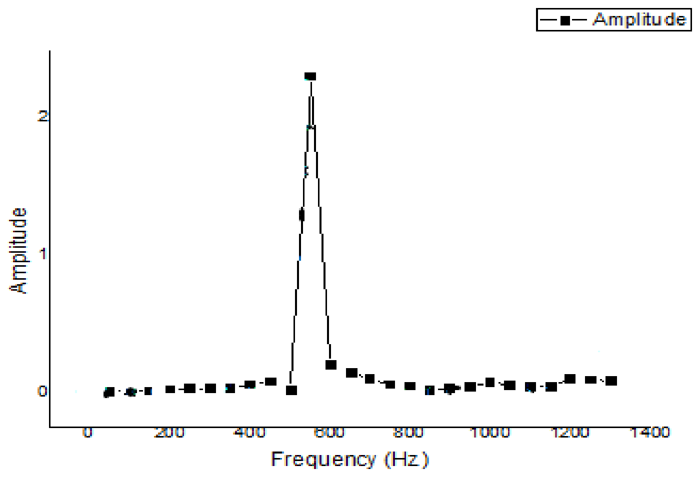

Fig.6.Graph of Undamped Condition

From the graph:
Natural frequency (f_n) =550Hz
Angular frequency (ω_n) =2π f_n (1)
=34555.75Hz

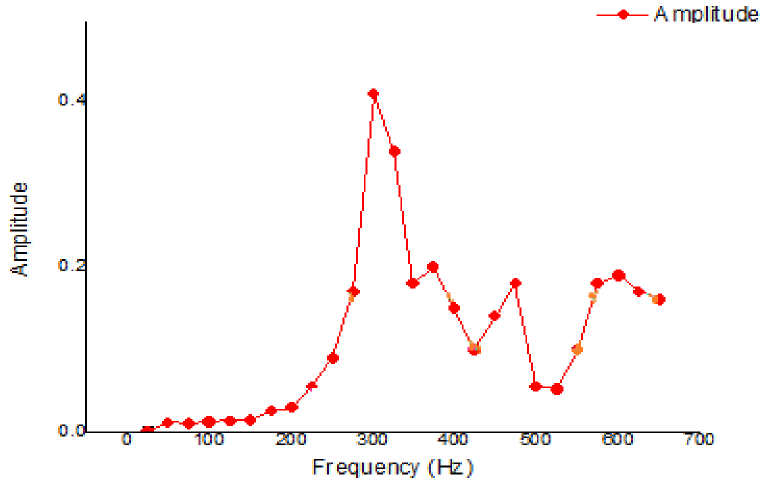

Fig.6.Graph of Damped Condition From graph

Natural frequency (f_d) =300Hz
Angular frequency (ω_d) =2π f_d (2)
=1885.2Hz
Now damping coefficient(C) of the system can be calculated as -
First we have to find damping factor (ξ) can be calculated using the relation
$\omega_d = \omega_n\sqrt{1-\xi^2}$ (3)
$1885.2=3455.75\sqrt{1-\xi^2}$
Damping factor (ξ) =0.83809
Then
$C/Cc=\xi$ (4)
Cc-Critical damping coefficient

$C=2m\ \omega_n=2x0.0776x3455.75=5374.38Ns/m$

0.83809=C/5374.38

Damping Coefficient (C) =4504.236Ns/m

Results are as

Undamped natural frequency (f_n) =550Hz
Damped natural frequency (f_d) =300Hz
Damping factor (ξ) =0.83809
Damping Coefficient(C) =4504.236Ns/m

Conclusion:

The natural frequency of beam drops from 550Hz for undamped to 300Hz for damped condition, this is due to the presence of MRFluid in the beam under magnetic field and it has really good damping effect.

It can be seen that the presence of MRfluid in the beam under the magnetic field creates a good damping effect because the damping factor (ξ) is 0.83809.

Thus the property of particle alignment in magnetorheological fluid can be caused against unwanted vibrations, wherein the fluid provides internal damping and occupies much less space than external dampers. Hence MRFluid is not only prove effective in reducing vibrational forces but also safe inexpensive and compact with effective innovation. This field can revolutionize methods of damping in civil structures, automobiles and mechanical machines.

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