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# Modeling And Fem Of Mr Fluid Damper For Structural Vibration Mitigation

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**ABSTRACT:** Magnetorheological (MR) Fluids are materials that respond to an applied magnetic field with a dramatic change in rheological behavior. An MR Fluid is a free-flowing liquid in the absence of magnetic field, but under a strong magnetic field its viscosity can be increased by more than two orders of magnitude in a very short time (milliseconds) and it exhibits solid-like characteristics. MR Fluid Dampers, based on MR Fluids, have been shown to be semi-active control devices that mesh well with application demands and constraints to offer an attractive means of controlling the intensity of vibrations in structures due to their mechanical simplicity, high dynamic range, low power requirements, large force capacity and robustness. The focus of this work is to design and analyze the MR Fluid Damper in order to suppress the structural vibrations. Following an overview of the essential features of MR Fluid Dampers, this paper discusses the design features of MR Fluid Damper i.e. hydraulic circuit and magnetic circuit and analyzes the same for structural vibration control.

**Key words:** *MR Fluids, MR Fluid Damper, Magnetic Circuit, Magnetic Flux, Structural Vibrations.*

## I. INTRODUCTION

Magneto-rheological (MR) fluids are the suspensions of micron sized, magnetisable particles (iron, iron oxide, iron nitride, iron carbide, carbonyl iron, chromium dioxide, low-carbon steel, silicon steel, nickel, cobalt, and combinations thereof [1]) in an appropriate carrier liquid (non-magnetisable) such as mineral oil, synthetic oil, water or ethylene glycol. The carrier liquid serves as a dispersed medium and ensures the homogeneity of particles in the fluid. A typical MR fluid consists of 20-40 percent by volume of relatively pure, 3-10 micron diameter iron particles, suspended in a carrier liquid [2]. They are field responsive in nature and the magneto-rheological response of these fluids lies in the fact that the polarization is induced in the suspended particles by the application of an external magnetic field. This allows the fluid to transform from freely flowing liquid state to solid-like state within milliseconds, because the magnetically dispersed particles attract each other to form fibril/chain-like structures along the direction of magnetic field. The chain-like structures resist the motion of the fluid and increase its viscous characteristics. Such behavior of MR fluid is analogous to Bingham plastics (non-Newtonian fluids) capable of developing a yield stress [3]. Fig.1 shows the synthesized MR fluids (Carrier fluid- Silicone Oil and Magnetisable particles- Carbonyl Iron of around 8 µm) inclusive of additives [4]

**Figure 1** MR Fluid

A favorable arrangement consists of particle chains aligned in the direction of the applied field and this, in turn, gives rise to a strong resistance to applied strains (Fig. 2).

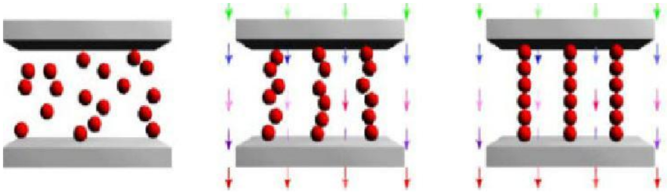

**Figure 2** Activation of MR fluid (Courtesy, Lord Corporation, USA)

The yield stress developed within the MR fluid is a function of the applied magnetic field. However, once this yield stress is exceeded, the behavior of the MR fluid deviates from that of a Bingham plastic. This is attributable to the breakdown of the chains of particles under the forces of the fluid flow, and results in a shear-stress/shear-rate characteristic that is highly non-linear. When used in a damping device, the result is a damper whose force/velocity characteristic is non-linear, but can be changed by the way the magnetic field is applied [5]. Recent devastating earthquakes around the world have underscored the tremendous importance of understanding the way in which civil engineering structures respond during such dynamic events. The magnitude 6.7 1994 Northridge Earthquake death toll was 57, and more than 9,000 people were injured, and more than 20,000 were displaced from their homes by the effects of the quake. In addition to earthquakes, strong winds can also result in unprecedented devastation along their path. The structures designed to support the high speed engines are subjected to inherent unbalance which causes vibrational problems. The unbalance may be due to faulty design or poor manufacture. Vibrations cause notable mechanical failures in turbines blade and disc vibrations are tough to control.

## II. DESIGN FEATURES OF MR DAMPER

### 2.1. Hydraulic Circuit Design

The MR fluid damper devices operate in pressure driven flow mode (PDF). During motion of the MR damper piston, fluids flow in the annular gap between the piston and the cylinder housing. For quasi-static analysis of MR fluid dampers, assume that:

1) MR dampers move at a constant velocity; 2) MR fluid flow is fully developed; 3) a simple Bingham plasticity model may be employed to describe the MR fluid behavior. In an analogous fashion the pressure drop developed in a device based on pressure driven flow mode is commonly assumed to result from the sum of a viscousPcomponent η and a field dependent induced yield stress component pressure may be approximated by:

$P \square P \square P \square ^{12.\eta.Q.L} \square ^{c.\tau_0.L}$

$\eta, \tau, g^3 \cdot w, g$

P

τ . This

(1)

### 2.2. Magnetic Circuit Design

The typical design process for a magnetic circuit is as follows:

(1) Determine the magnetic induction $B_f$ in the MR fluid to give desired yield stress $\tau_y$

For $\tau_y$ □ 46.5kPa, $B_f$ =0.85T.

(2) Determine the magnetic field intensity $H_f$ in the MR fluid. For $B_f$ =0.85T, $H_f$ =250kA/m.

(3)The total magnetic induction flux is given by $\Phi = B_f A_f$ , where $A_f$ is effective pole area including the fringe of magnetic flux. Because of the continuity of magnetic induction flux, the magnetic induction $B_s$ in the steel is given by

$$B_s \square \frac{\Phi}{A_s} \square \frac{B_f \cdot A_f}{A_s} \qquad (2)$$

$A_f = 1.4702\times10^{-3}$ m², $A_S$ □ 0.628 □$10^{-3}$ m² and $B_s$ =1.135T.

(4) Determine the magnetic field intensity $H_s$ in the steel using. For $B_s$ =1.135T, $H_s$ =0.8kA/m.

(5) By using Kirchoffs's Law of magnetic circuits, the necessary number of amp-turns (NI) is

$$NI = \sum H_i L_i \square H_f g \square H_s L \qquad (3)$$

Where L= length of steel path which is equal to $L_s$ □ $L_c$ .

NI is calculated as 159 amp-turns. Taking I=2A, yields N=80.

## III. ANALYSIS OF MR DAMPER

The MR damper was designed using SolidWorks Fig.3 and the model was meshed using Hypermesh.

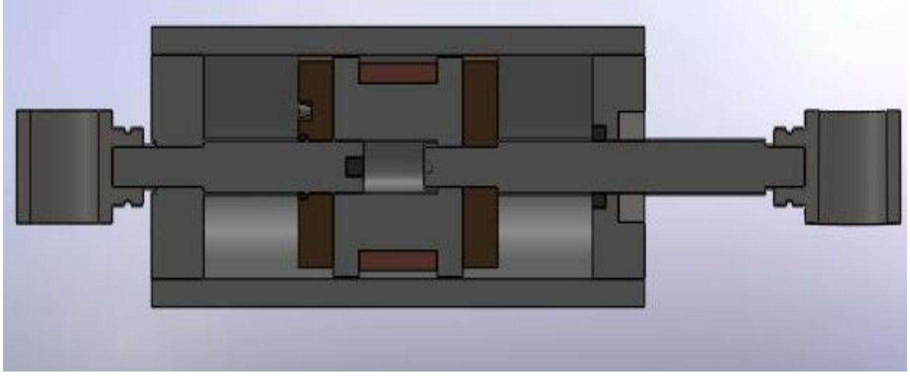

**Figure 3** Sectional View of Damper

### 3.1. Structural Analysis

Analysis of the MR damper was done using ANSYS 16.0 and various results were obtained. The structural analysis of MR damper is important for predicting the behavior of the damper under various load conditions as well as internal pressure changes. The MR damper is made of low-carbon steel whose youngs modulus is 210 GPa and density of 7850 kg/m³ .The MR fluid is MRF-132DG, produced by the LORD Corporation, USA.

**Figure 4** Meshed Damper

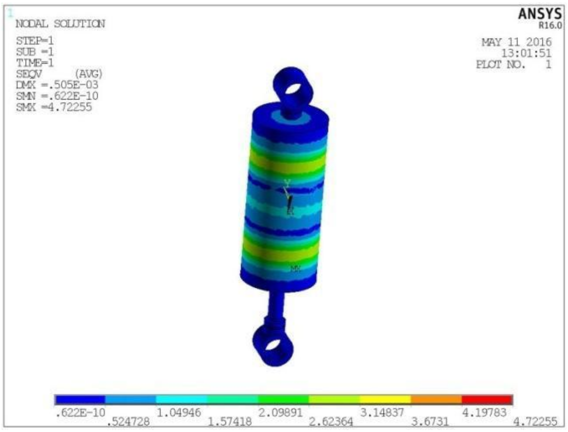

**Figure 5** Von-Mises Stress in Damper

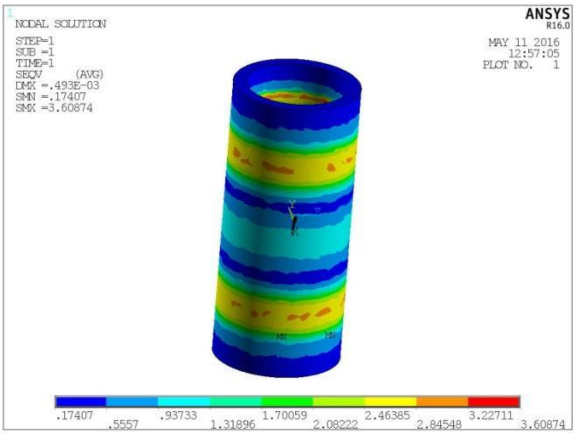

**Figure 6** Von-Misis Stress in Cylinder

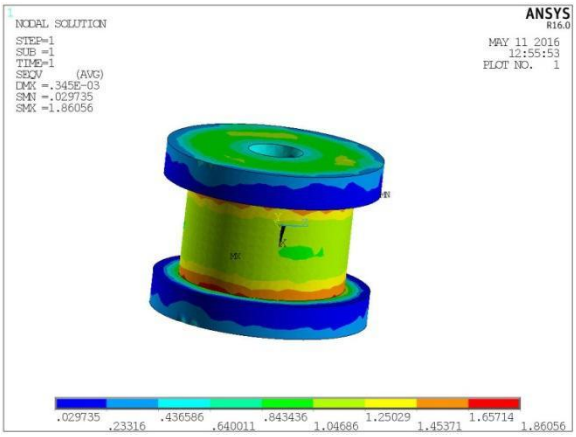

**Figure 7** Von-Mises Stress in Piston

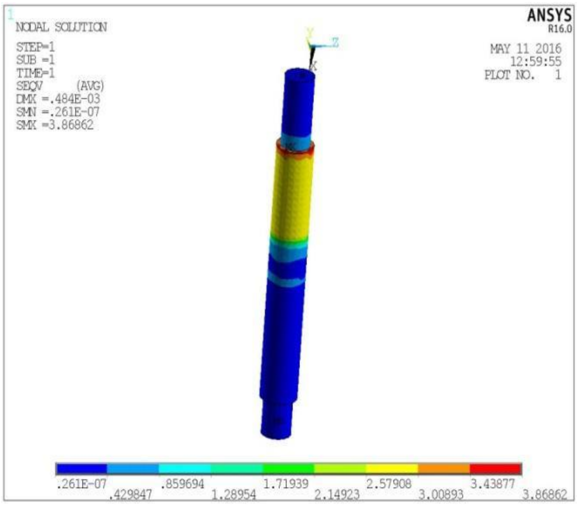

**Figure 8** Von-Mises Stress in Piston Rod

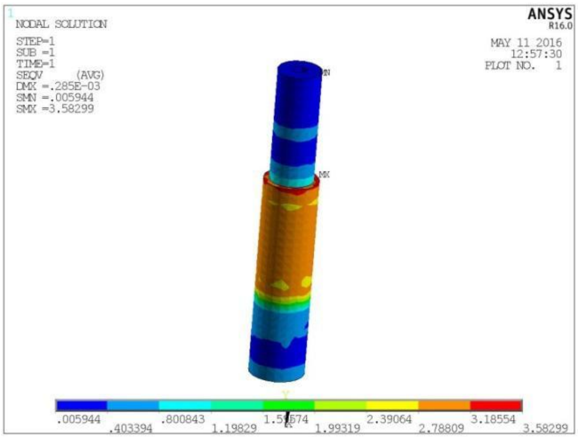

**Figure 9** Von-Mises Stress in Hollow Rod

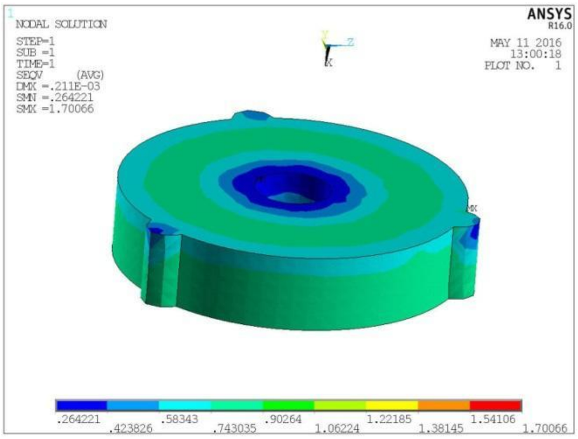

**Figure 10** Von-Mises Stress in Bronze Plate

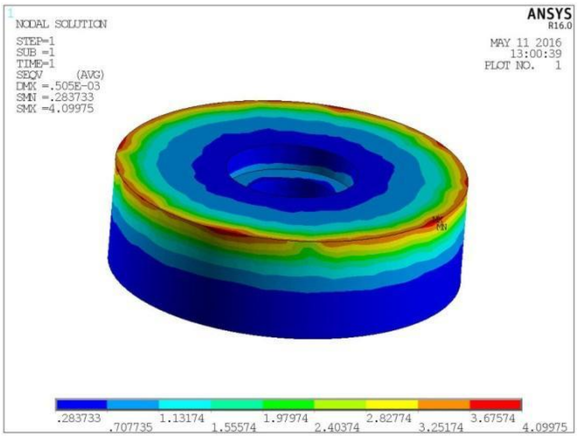

**Figure 11** Von-Mises Stress in Cover Plate

### 3.2. Magnetic Analysis

The magnetic analysis of the damper is done to verify the magnetic field strength of the coil, for the designed air gap of 0.4mm and optimal results were obtained.

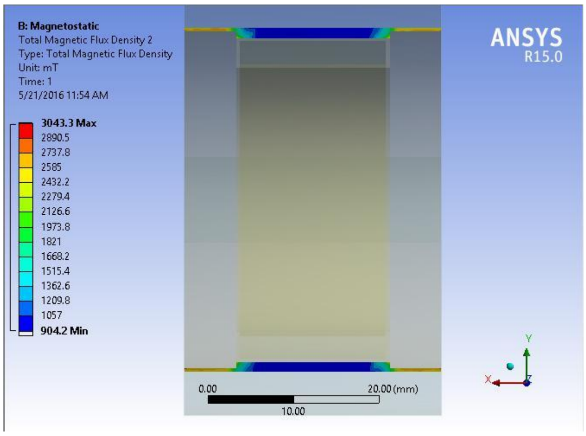

**Figure 12** Magnetic Flux Density in Air Gap

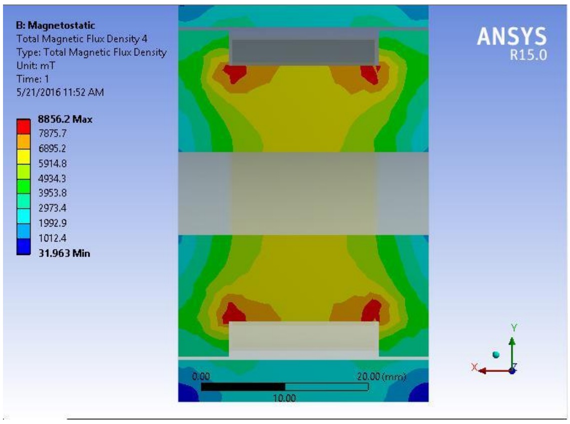

**Figure 13** Magnetic Flux Density in Piston

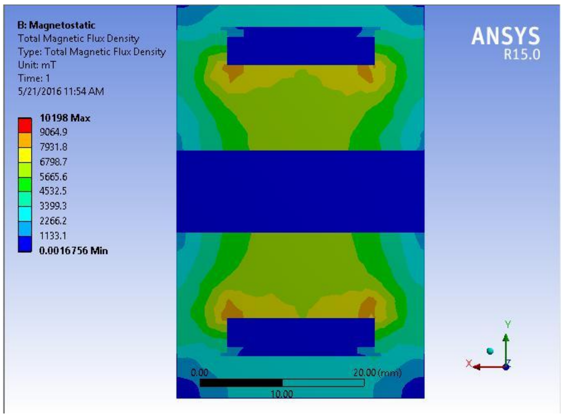

**Figure 14** Magnetic Flux Density in Damper

Finite element model of the MR damper is created by using element type Solid45. Pressure analysis of the model is carried out for the maximum pressure of 4MPa which is applied on the internal surface of the cylinder and all DOF constraints are given on the eye nuts.

## IV. CONCLUSIONS

The structural (pressure) analysis for the proposed MR damper is presented. It is clear from the Figure 5-11 that the stress developed in the damper is well with-in the limit of the material. Figure 12 shows that the magnetic flux density is maximum at the air gap. Hence it can be concluded that the dimensions and various parameters calculated for the development of the damper are safe and the MR damper can be used for mitigation of structural vibrations.

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