Effect of magnetic permeability, shearing length and shear gap on Magnetic flux density of the Magnetorheological damper

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Abstract: The performance of the magnetorheological damper is determined based on the damping force obtained which will be used to reduce the vibrations in specific application .In this paper, a axisymmetric Magnetorheological damper model is analysed using ANSYS finite element analysis to simulate a distribution of the flux density of the applied magnetic field for the SA1018 and Aluminium materials in Magnetorheological damper for a given current in shear mode operation. The model which gives the maximum flux density is taken for further study the effect of shear gap and shearing length of the damper. Then the comparative study on the effect of variation of shear gap and effective length on magnetic flux density, where the damping force which is dependent on the magnetic flux density is obtained and by using the response surface methodology optimum values are obtained for maximum flux density.

1. Introduction

A magnetorheological (MR) fluid is a controllable fluid on which research is going on in various fields such as brakes, clutches, dampers and beams etc. MR fluid is a dispersion of micron sized magnetic particles in a base fluid such as silicone oil, hydraulic oil or water. Stabilizers are added to increase the time of magnetic particles suspension in the base fluid. When the current is supplied to the circuit, magnetic field is induced, the particles align into chain like structure such that the MR fluid behaves like semi solid with the increase in the dynamic yield stress due to this applied field.

The restriction to the flow of fluid in the fluid gap to increase the damping force is the principle of the suspension system which is also applicable for MR damper. The flow properties of MR fluid, such as dynamic yield stress and viscosity rise of the fluid when the external magnetic field is applied and MR fluids come to its original state when the field is taken off. The operational modes of these fluids are four modes they are valve mode, squeeze mode, shear mode and combined modes. The working mode can be chosen based on the required application.

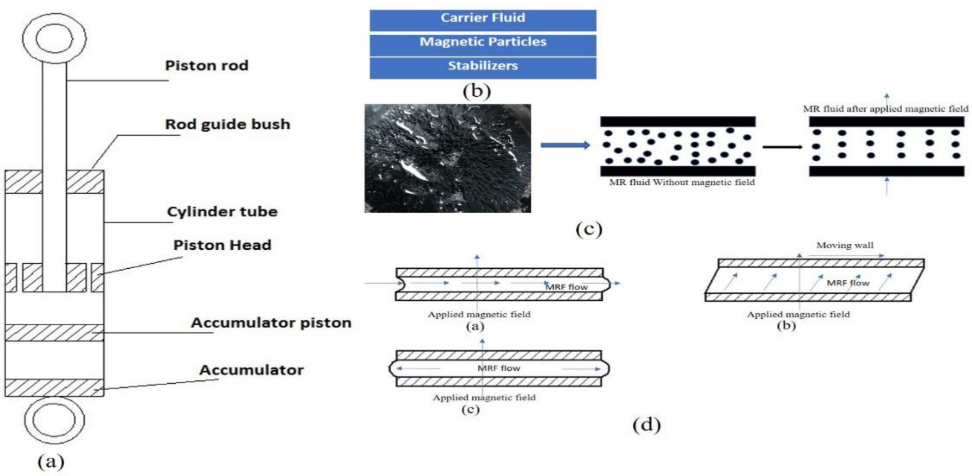


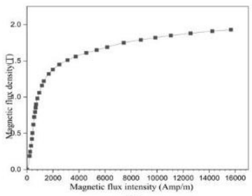
Fig 1: (a) MR Damper and parts (b) General constituents of MR fluids (c) Arrangement of particles when the field is applied (d) modes of operation of MR fluid .

The damping force can be calculated by employing the analytical models for dynamic yield stress [1]. Increase the width of the gap increases the pressure drop and the yield stress is dependency is predicted through FEMM analysis.[2]. In flow mode operation, the controllable pressure drops in both valve and orifice has been achieved through the magnetorheological valve and magnetorheological orifice magnetic simulations [3]. The stability and comfort of the vehicle can be drastically improved by active suspension systems which gives us more real time data analysis [4]. The model for double tube MR damper was developed mathematical through analytical method [5]. FEM based analysis can be compared with experimental results of damping force [6]. The damping coefficient decreases with the increase in the eccentric gap in the flow mode magnetorheological dampers [7]. The stability and comfort can be enhanced with various coil arrangements was proposed [8]. The comfort and stability of the vehicle with bypass hole to the MR damper can be increased [9]. Experimentally it is concluded that mixed mode MR damper gives high damping force when compared single mode [10]. Bingham model for mixed mode MR damper gives better experimental results and compared with the flow mode damper [11].The magnetic circuit can be optimised by using various algorithms which gives better results in real time application, the optimal design parameters of the MR damper was proposed based on the obtained results of the magnetic circuit [12].

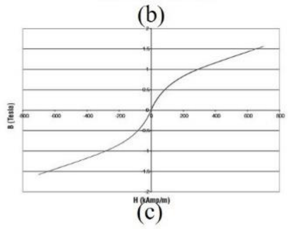
2. Basic parts and materials used for Analysis: The difference in variation of the magnetic field shall be seen by varying the dimensions and materials used for fabrication of the MR damper

Dampers parts & materials used	Damper 1 (Magnetic materials)	Damper 2 (Non-magnetic materials)
Piston core	SA1018	SA1018
Outercylinder	SA1018	Aluminium alloy
Piston rod	SA1018	Aluminium alloy
Copper coil	Copper coil	Copper coil
MR fluid	Lord 132DG	Lord 132DG

(a)



(b)

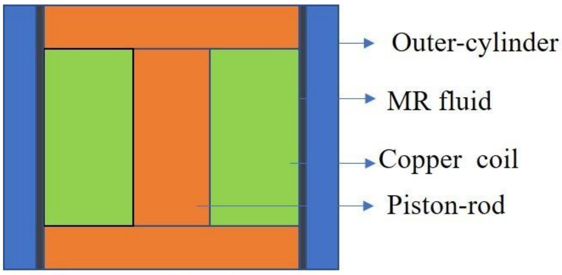


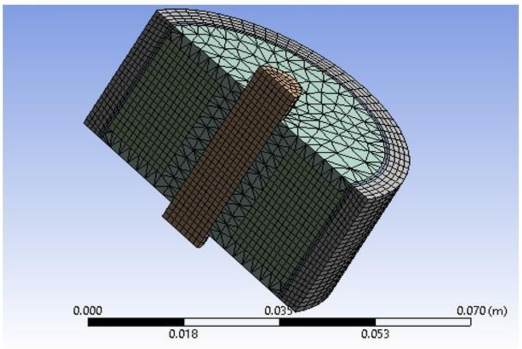
(c)

Table 1:(a) Materials used for Analysis, Fig 2(b & c): B-H curve for SA1018 and Lord 132DG respectively

3. Finite Element analysis of monotube MR damper

The damping force which is the output of the MR damper depends on the dimensions of electric circuit used for the piston core. When the current is passed to the copper coil, magnetic flux is produced in shear gap region. The flux lines induced through the effective length varies the yield strength of the MRF. The parameters which plays a important role are shear flow gap, effective length of shear, material selected for damper fabrication. The performance of the MR damper is changed when the parameters are varied. Under off state, the energy generated in the MR damper is dependent on the original MR fluid viscosity of the. Before going on to the actual damper fabrication the effect of cylinder material is studied and the parameters such as shear gap, shear length, applied currents, number of turns of coil all these parameters are to be obtained for their optimal conditions. In this paper, FE analysis is done for magnetic permeability of the outer cylinder by selecting SA1018 and aluminium materials. From this analysis whichever model gives high magnetic flux density in the shear gap is selected for the optimization of magnetic circuit by modelling the various damper models.



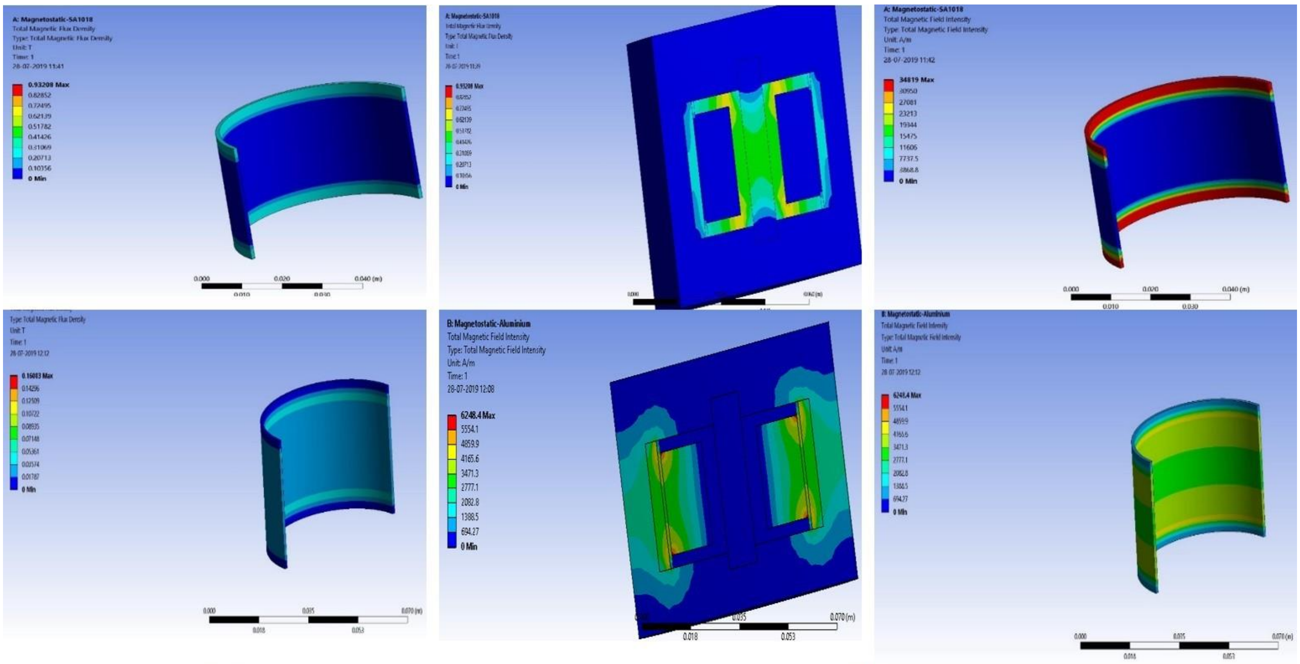


Effective length(mm)	3
Shear height(mm)	1
Piston diameter(mm)	10
Outer cylinder(mm)	4

Fig 3: Damper nomenclature, Meshed model and Dimensions of MR damper model

4. Result and discussion

The material used for fabrication plays a significant role in the performance of the MR damper. When SA1018 steel which is magnetic is used for analysis outer cylinder and piston rod, the magnetic flux which was obtained in the shear gap is 0.38T and when the aluminium alloy was used for the same outer cylinder and piston rod the magnetic flux density obtained was 0.05T. The other important result obtained is, there is leakage of magnetic flux to the atmosphere when the non-magnetic material is used for simulation Fig 4 (a & b) shows the variation of magnetic flux density in the gap and magnetic flux leakage into the atmosphere. The shear gap and shearing length are the important parameters in analysis of the damping force in the MR damper. When there is a increase in shear gap and shear length, drastic decrease in the flux density of the applied magnetic field in the shear gap and shear length is seen in fig 6(a,b,c) which decreases damping performance of the MR damper. Through response surface method the optimal values are obtained in table 2.



(a) (b)

Fig 4: (a) Flux density of the MRF (SA1018, Aluminium) (b) Magnetic Flux intensity of MRF (SA1018, Aluminium)

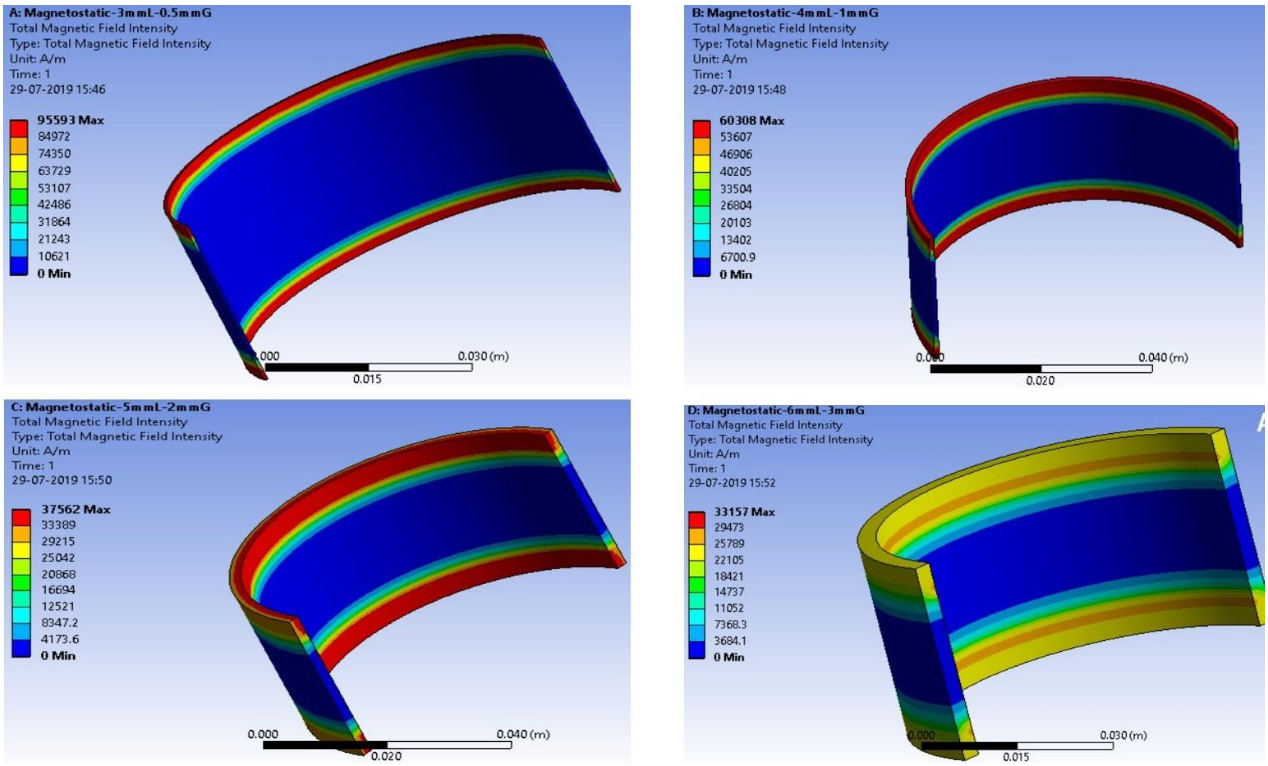


Fig 5: Flux intensity of the applied Magnetic field at various shear length and shear gap

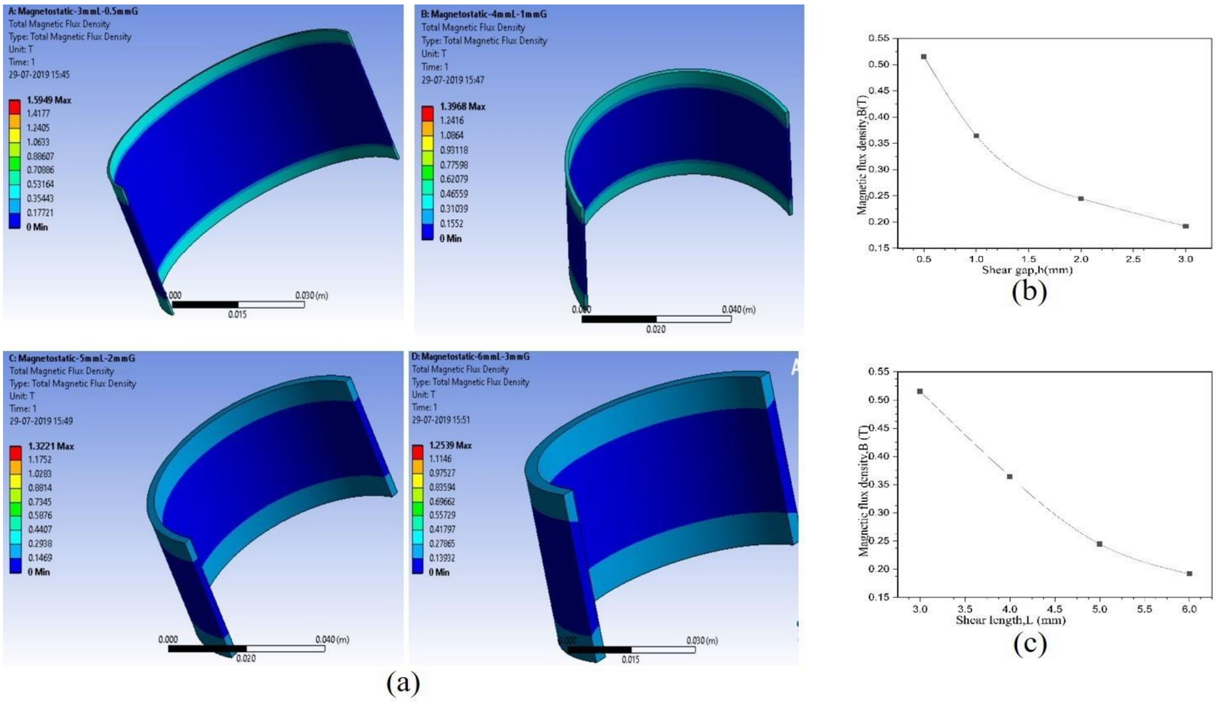


Fig 6(a,b,c): Decrease in the flux density of the applied magnetic field when shear gap and shear length is increased

Shear gap(mm)	Shearing length(mm)	Magnetic flux density(T)
0.5	3	0.5232
1	4	0.3537
2	5	0.24317
3	6	0.18167

Table 2: Magnetic flux density values at different shear gaps and shearing lengths

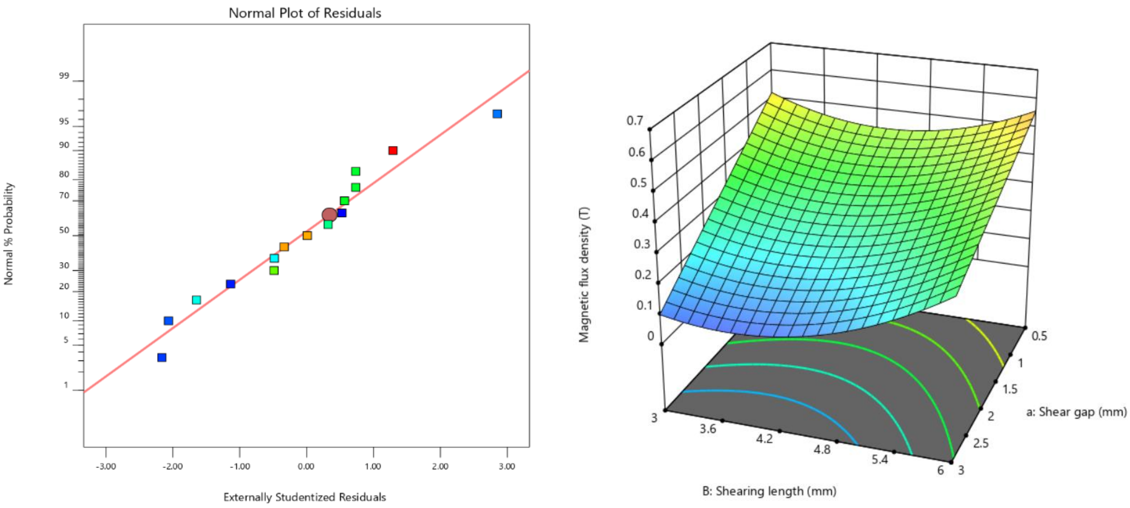


Fig 7: Normalized plot and 3D Surface plot

Shearing gap	Shearing length	Current	Magnetic flux density
0.691mm	3.927mm	1.928A	0.4931T

Table 3: Optimum Values selected from FE Analysis

$$\text{Magnetic flux density} = +0.440579-0.097295*(\text{Shear gap}) -0.311122*(\text{Shearing length}) +0.918366*\text{Currents}+0.021714*(\text{Shear gap} * \text{Shearing length}) -0.074844*(\text{Shear gap} * \text{Currents}) -0.024351*(\text{Shearing length} * \text{Currents}) -0.011661*\text{Shear gap}^2 + 0.037142*\text{Shearing length}^2 - 0.195981*(\text{Currents}^2)$$

Table 4: Regression model equation

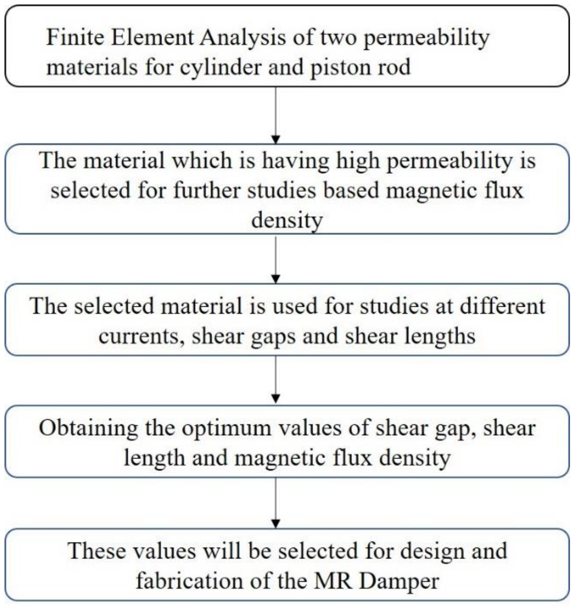


Fig 8: Flow chart for arriving at optimum values through FE analysis

5. Conclusion

- The materials used for analysis of damper model plays a significant role in delivering required output force. For better performance of the MR damper, the magnetic materials having high permeability used for analysis give good results compared to less magnetic permeability materials.
- The FE analysis of the MR damper shows that, there should be a optimum shearing length and shear gap to get the required flux density of the applied magnetic field which increases the performance of the MR damper.
- From the response surface methodology optimum values and regression model equation and the optimum value of magnetic flux density was obtained.

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