Penerbit Akademia Baru

Journal of Advanced Research in Applied Mechanics

Journal homepage: www.akademiabaru.com/aram.html

ISSN: 2289-7895

Study of Magnetic Flux and Shear Stress of OEM Damper featuring MR Fluid

Open Access

M. H. Unuh[1,*], P. Muhamad[1], H. M. Y. Norfazrina[2], M. A. Ismail[1], Z. Tanasta[1]

[1] Intelligent Dynamics & System Research Lab, Malaysia-Japan International Institute of Technology, Universiti Teknologi Malaysia, 54100 Kuala Lumpur, Malaysia

[2] Department of Mechanical Engineering, Kulliyyah of Engineering, International Islamic University Malaysia, 50728 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 5 June 2017
Received in revised form 10 July 2017
Accepted 4 December 2017
Available online 12 March 2018

Keywords:
Finite element analysis, OEM damper, semi-active damper, MR fluid, Malaysian car

ABSTRACT

The applications of semi-active damper employing magnetorheological (MR) fluids keep increasing in fulfilling the demand to control undesired vibration effect. The aim of this study is to evaluate that the new design OEM damper can yield necessary magnetic flux and shear stress. In this study, a finite element model was built to analyse and examine the new design of OEM damper. The results show that the new design OEM damper can generate the necessary magnetic flux density to react with superior properties of MR fluid. The nodal solution illustrates the saturation of magnetic flux density. The magnetic flux density is directly proportional to applied current. The simulation results also verified the induced magnetic field can manifest the shear stress development in the MR fluid.

1. Introduction

Vibration becomes frequent concern in engineering practice as the undesirable vibration may cause imbalance gyrating parts, rough friction and gear teeth meshing. Automotive industry therefore set the aims to manufacture vehicle that is long lasting and as well give satisfaction in driving experience and also comfort desired by the passengers at the same time. Hence, researchers have narrowed down from a bigger subject which is the whole system vehicle itself into a more focused subject that is responsible for the vibration control of vehicle suspensions systems.

In extensive range of frequency, active suspensions are able to increase the performance of the suspension system more than passive suspensions can do. However, in the first months of 1980s, semi-active suspensions were suggested and seen as a better answer [1]. Semi-active suspensions are able to behave approximately as effective as fully active suspensions in ameliorate performance of driving while still work in passive condition when the control system fails. This system offers decent performance such as cost-effective, sustainable enough compared with passive suspensions

* *Corresponding author.*
E-mail address: hishamunuh@gmail.com (M. H. Unuh)

and higher power actuators where a large power supply is not needed [2]. In the beginning of application of these systems, the damping value can be tuned by modifying the orifice capacity in the oil-filled damper. This will alter the velocity of fluid flow and causes longer time settling. Hence, many researchers have recently investigated the possible applications of ER and MR fluids in the controllable dampers recently [3]. Although various researches have been done on the modelling and characterization of MR damper's behaviour, few works have been addressed towards the design of this type of damper. The geometric design of MR damper is an important issue to improve the damping performance. Even though the study of MR damper have flourished in many ways, it is seen that current research approaches mostly used custom made damper, omitting the original equipment manufacturer (OEM) that has the standardized geometry dimension with higher precision and accuracy. These dimensions are considerably vital in order to reengineer the most optimal damper design to be used in Malaysia vehicle which reacts effectively to smart fluid in real situations movement. There is surprising paucity of studies describing how magnetic flux affected the shear stress development of MR fluid in an actual OEM damper. The aim of this study was to evaluate that the new design OEM damper can yield necessary magnetic flux and shear stress. This study is the beginning for design revolution of Malaysia vehicle suspension system.

2. Design and Modelling of the Damper

The model of the new design of the OEM damper is developed using the three-dimensional computer-aided design (CAD) package in SolidWorks software. The modelling provides an overview of the new design equipped with precise and accurate dimension of original equipment manufacturer (OEM), the section view of parts and assembly of the design for simulation study to be carried out using ANSYS Mechanical APDL 15.0 software. The CAD modelling is as in Figure 1. Finite element analysis (FEA) tool in the software is employed to model the behaviour of the magneto rheological (MR) fluid that was exploited in the design during induction of electromagnetic force and simulating the wave of electromagnetic field.

2.1 Design and Prototype

The new design innovation provides an improvement of original equipment manufacturer (OEM) damper with a straightforward construction and lower manufacturing cost. The main feature of the innovation is the involvement of magnetorheological (MR) fluid which can alter its shear stress characteristic within milliseconds under the influence of magnetic induction. The typical MR damper is usually in monotube design which coil is integrated with the piston of the damper. In response to the force applied, the monotube approach obliges the piston to travel only within fixed distance of cylindrical reservoir. The electrical wire connected pass through the channel in the piston rod which is created using perforation techniques. This approach will cause the wire to flex as it is experiencing continuous movement as the piston gives response to any vertical direction force. In the long run, it will result in breakage of the wire causing no magnetic flux can be induced to react with MR fluid. In addition, some problems may occur such as introduction to the channel may decrease the strength of the damper generally, the piston rod specifically to sustain and be tolerant to larger load. Hence, the new design promotes the use of twin-tube. Referring to Figure 1, a piston assembly is disposed in the inner cylinder and has an outer cylinder as protection for the new design damper's inner part. The coil is hold at stationary with respect to one of the housing which is the inner cylinder to increase the dependability of the electrical connection to the coil and solve the strength problem. It also acts as a valve control for a flow passage between the inner and outer cylinder and capable of generating a magnetic field across at least a portion of the flow gap. A pair of ferromagnetic rings is provided for directing the magnetic field or flux through the flow gap.

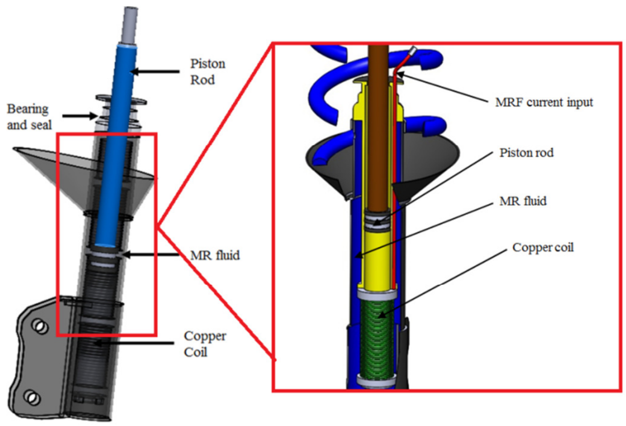

Fig. 1. Sectional view of the new design [4]

2.2 Finite Element Modelling

2-D axisymmetric model of the control valve in the new design damper is analyzed using finite element method. The goal of this approach is to determine the magnetic flux generated with given current and as pioneer evidence that the design damper can fulfilled the main requirement of utilizing the MR fluids. Schematic representation of the 2D axisymmetric model of MR control valve of design is shown in Figure 2.

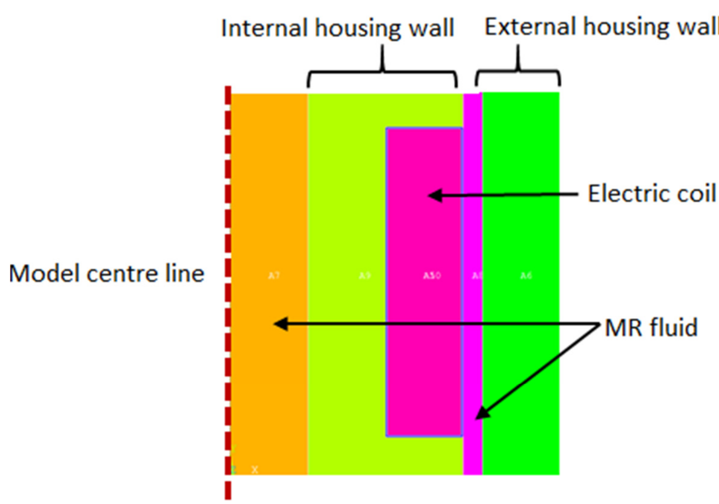

Fig. 2. 2D axisymmetric model of MR control valve

2.2.1 Approach and assumption

The analysis is simplified to a single iteration analysis. Outside of the model parameter is presumed not experiencing any flux leakage and saturation of the material does not ensue. The ramification of flux leakage is demonstrated by creating a layer of air bordering the iron. The maximum radius of the iron shall be equal or smaller than the air layer. ANSYS Mechanical APDL version 15.0 obliges user to insert the input in the form of current density for electromagnetic nodal analysis. The current density is defined as:

$$JS = \frac{NI}{A} \quad (1)$$

where, N is the number of turns, I the current input and A is the coil area. The number of turns used for the finite element modelling is 450 turns. The current is ranging from 0.2A to 2.0A while the coil area is $1.4253 \times 10^{-3} m^2$. The flux will work parallel to the surface of the model parameter in congruence with the assumption. The model is surrounded with the flux parallel boundary condition. A Maxwell stress tensor and a virtual work computation employed to recapitulate the forces generated in the model.

2.2.2 Material properties

Each material in the model is defined under the option of constant relative permeability. Table 1 shows the properties of material involved in the model. However, ANSYS material library does not contain any data for MR fluid. Thus, the properties are specified using B-H curves graph shown in Figure 3.

Table 1
Properties of material involved

Model Area	Constant Relative Permeability μ_x
Internal housing wall	75
External housing wall	75
MR fluid	B-H Curve graph
Coil element	1
Air Gap	0.005

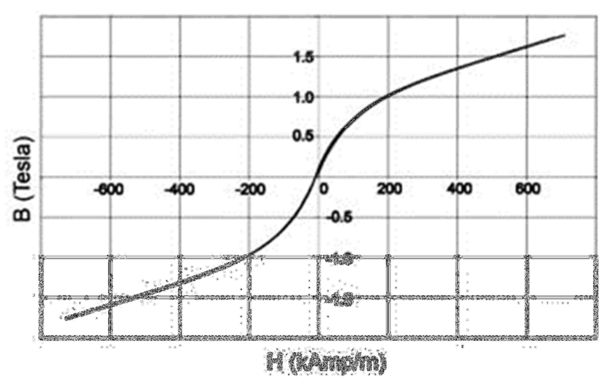

Fig. 3. MR fluid B-H curve [5]

2.2.3 Magnetic flux density and shear stress strength

The finite element model simulates the magnetic flux density on the area where MR fluid is stored as illustrated in Figure 4. The average magnitude of magnetic flux density of a particular applied current can be calculated by simply dividing the summation of the highest value and the lowest value generated in the solution by two as indicated. Linear analysis approach permits the formulation to be used. A new set of result is obtained from a new set of electric current value. The analysis is repeated by keeping the number of turns of coil constant. The results are tabulated in Table 2 and a scattered graph is plotted using MATLAB (see, Figure 5). It can be concluded that the magnetic flux density is directly proportional to applied current. From the data set of current-magnetic flux density, a new data set of shear stress can be computed. The expression of the equation was in the form of fourth order polynomial.

$$\tau_y = 6.298\, B_f{}^4 - 25.824 B_f{}^3 + 26.639 B_f{}^2 - 0.438 B_f \quad (2)$$

The equation expresses the magnetic flux density as a function of the fluid shear stress. The data set of magnetic flux density and shear stress is tabulated systematically also in Table 2 and graph showing the relationship of those two is plotted using MATLAB and shown in Figure 6.

The new design with MR control valve is capable of generating magnetic flux density greater than 1 Tesla using the selected MR fluid (MRF-122 EG 0011369535). The MR fluid has achieved its maximum shear stress and saturation has occurred when the magnetic flux density was applied beyond 0.9 Tesla as seen in the figure. Hence, any addition to the value of applied current beyond this value will not take effect.

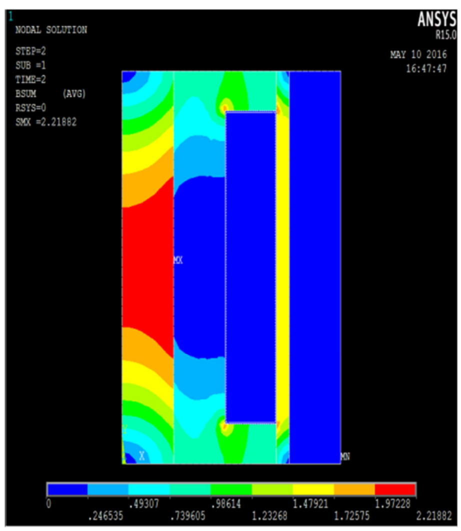

Fig. 4. Magnetic flux density

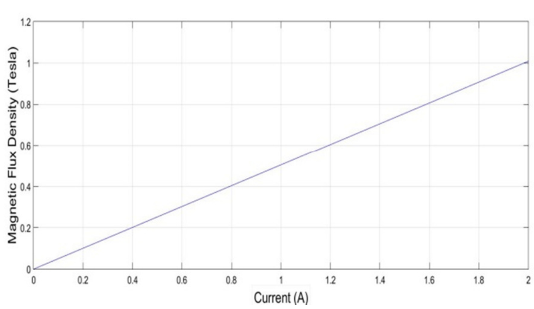

Fig. 5. Magnetic flux density against current

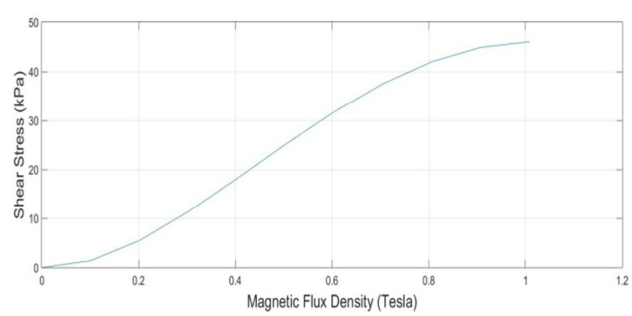

Fig. 6. Shear stress against magnetic flux density

Table 2
Summary of magnetic flux density and computed shear stress

Current (A)	Magnetic Flux Density (Tesla)	Shear stress (kPa)
0.0	0.00000	0.00000
0.4	0.20160	5.46910
0.8	0.40342	18.13370
1.2	0.60513	31.79790
1.6	0.80684	42.01276
2.0	1.00855	46.04897

2.2.4 Magnetic Flux Line

Zooming to the flux path where MR fluid is stored in the Figure 7, the flux lines concentration increases as the distance between one flux lines to its adjacent becomes closer. For this reason, it is demonstrating the influence of MR fluids rheology properties on the electrical coil generally and to the generated magnetic field for a more focused subject. In addition, Figure 8 illustrated the direction change of magnetic flux lines in vectors form once they entered the area storing MR fluid. Thus, the highest value of magnetic flux density was recorded along the area where MR fluid is stored. At the moment MR fluid becomes saturated however, these magnetic flux lines concentration will decrease.

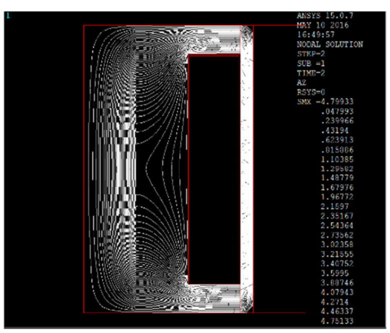

Fig. 7. Magnetic flux lines

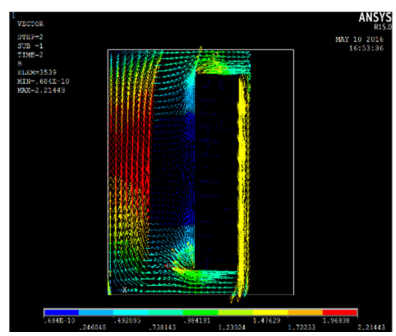

Fig. 8. Magnetic flux lines in vector form

3. Conclusion

The new design of OEM damper had gone through finite element analysis extensively as an analytical work. The finite element analysis was carried out with varied electric current to induce different strength of magnetic field. It is discovered that magnetic field lines became concentrated as they approached the region area of the MR fluid. The region area of MR fluid had also recorded the highest magnetic flux density. Correspondingly, the simulation results showed that by increasing the strength of an applied magnetic field will increase the yield stress generated by the MR fluid. The results from finite element modelling proved that the proposed design has the capability to yield necessary magnetic field to correspond with superior characteristic of the MR fluid used. The simulation results also verified the induced magnetic field can manifest the shear stress development by polarizing the suspended particle in the MR fluid. The gradient of shear stress response decreased at highest shear stress and eventually become plateaus as the MR fluids saturated completely.

References

[1] BalaMurugan, Loganathan, and Jeyaraj Jancirani. "An investigation on semi-active suspension damper and control strategies for vehicle ride comfort and road holding." *Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering* 226, no. 8 (2012): 1119-1129.

[2] Savaresi, Sergio M., Charles Poussot-Vassal, Cristiano Spelta, Olivier Sename, and Luc Dugard. *Semi-active suspension control design for vehicles*. Elsevier, 2010.

[3] Rashid, Muhammad Mahbubur, Nasrudin A. Rahim, Mohammed Azlan Hussain, and M. Azizur Rahman. "Analysis and experimental study of magnetorheological-based damper for semiactive suspension system using fuzzy hybrids." *IEEE Transactions on Industry Applications* 47, no. 2 (2011): 1051-1059.

[4] bin Ismail, Mohamad Amiruddin, Pauziah Binti Muhamad, and Aminudin bin Abu. "Magneto Rheological for Motorcycle Suspension Using Bouc-Wen Model." In *Applied Mechanics and Materials*, vol. 534, pp. 111-116. Trans Tech Publications, 2014

[5] Kim, Keun-Joo, Chong-Won Lee, and Jeong-Hoi Koo. "Design and modeling of semi-active squeeze film dampers using magneto-rheological fluids." *Smart Materials and Structures*17, no. 3 (2008): 035006.