Design and Material Analysis of Regenerative Dispersion Magnetorheological (MR) Damper

Mohammad Abdul Aziz, Abd Halim Embong, MM Rashid, and Mhd Salim Saadeddin

Abstract— ***Magnetorheological (MR) dampers are widely applicable for vehicle suspension schemes, and MR fluid sedimentation is an indispensable problem of MR dampers. A Regenerative Dispersion MR Damper (RDMRD) under this research consists of a piston which contains piston and coil case cylinder, coil windings, piston rod, piston head cover, bobbin and one cylindrical tube to disperse MR fluids. In addition, external regeneration system has been added to generate electricity for the purpose of electricity supply in the piston. 2-D Axis symmetric model of RDMRD has been developed using Comsol Multiphysics in order to analyze power generation ability. Two magnetic field are generated inside the MR Damper, one internal piston coil and another external power producing coil. The induced magnetic field in the coil are evaluated for describing RDRMD power production capability.***

Keywords: MR Damper; MR Fluid; Power Generation; EMS, Finite Element.

1. INTRODUCTION

Magnetorheological (MR) dampers is a smart vibration mitigation device and its smart fluid (MR fluid) is being used for semi active-passive controllability system. During field off and field on damping operation MR fluid sediments on the bottom of MR damper. The sedimentation of the MR fluid leads to poor dispersion of the fluid in the damper which in turn reduces performance of the damper [1].

The application of the MR damper are vehicle suspension system [2-4], helicopters seat [5], civil structure base isolation [6-8], and railway transport [9, 10], unpredictable motion conditions and it is being capable of controlling larger payload condition. MR damper based system requires lower amount of power supply from external sources. The characteristics of the MR fluid has been changed by changing the useable current [11]. In addition to that, RDRMD can be an effective solution provider for sedimentation phenomenon. The potential possibility for removing fluid sediment from the bottom surface of the MR damper is to create bypass internal or external line for fluid pass. Although it was considered that the creating bypass line is the best solution for eradicating MR fluid sediment. The design and modification of MR damper has been done by several research group due to its importance and requirements in the technological sector. As MR damper requires accurate dispersion technique and this technique will eliminates all types of sedimentation problem. However, several group of researcher analyze and characterizes the self-power generation capabilities. Sapinski [12] proposed a power saving MR damper for power generation, where experimental design are considered in order to achieve accurate vehicle suspension system. Additionally, Hu and others has [13] mentioned an independent MR damper and it allows controllable damping force but requires power from external sources. Sun et al. [14] developed an independent pulsation absorber in order to operate vibration absorber. However, Chen and Liao [15] developed a regeneration technique for power production to the MR damper and it allows civil structure application. Bogdan Sapinski [16] analyze and construct an energy harvesting MR damper in order to provide self-sensing ability. In this paper, the development of regenerative dispersion MR damper design techniques are characterizes using several design materials.

2. DESIGN OF RDMR DAMPER

The dispersion MR damper consists of controllable cylinder-piston arrangement and piston moves in the line of electromagnetic arrangement. The regenerative bypass MR damper consists of controllable cylinder-piston arrangement, DC motor and regeneration unit for power production. The cylinder has an inner piston bypass hole although the fluid movements via annular fluid flow gap. The RDMR damper has a shear and valve mode operation in order to get proper dispersion inside the cylinder.

2.1 Materials selection for RDMR damper

The MR damper materials properties have an excessive effect on damping force due to its relative permeability and flux return impact from cylinder wall & flux distribution. In table 1 presents the RDMRD materials and properties.

2.2 MR fluid and its characteristics

Magnetorheological fluids change its characteristics for verity of magnetic field application. Rapid advancement of yield stress while without the application of applied electromagnetic effect to the MR fluid characteristics as

Revised Manuscript Received on March 10, 2019.

Mohammad Abdul Aziz, Department of mechatronics engineering, Faculty of Engineering, International Islamic University Malaysia, Jalan Gombak, 53100 Kuala Lumpur, Selangor, Malaysia.

Abd Halim Embong, Department of mechatronics engineering, Faculty of Engineering, International Islamic University Malaysia, Jalan Gombak, 53100 Kuala Lumpur, Selangor, Malaysia.

MM Rashid, Department of mechatronics engineering, Faculty of Engineering, International Islamic University Malaysia, Jalan Gombak, 53100 Kuala Lumpur, Selangor, Malaysia.

Mhd Salim Saadeddin, Department of Manufacturing Engineering, Faculty of Engineering, International Islamic University Malaysia, Jalan Gombak, 53100 Kuala Lumpur, Selangor, Malaysia.

Table 1: RDMRD materials and properties

Name of the component	Materials
valve coil	10# steel[2]
valve body	10# steel[2]
MR valves	Low carbon steel [3]
Porous valves	Magnetic steel beads [4]
MR valves	Pure iron (#DT3)[5]
outer housing	Aluminum, hollow steel[6]
yoke sleeve , piston	Magnetic soft materials or pure iron[7]
Shielding sleeve	Nonmagnetic materials or aluminum [7]
Permanent magnets	NdFeB[7]
Bobbin	Permalloy steel[8]
MR valve	Permalloy steel[8]
Valve core	Alloy (No 10)[9]
Nonmagnetic bobbin	Alloy (No 10) [9]
Magnetic disc	Alloy (No 10) [9]
Valve housing	Alloy (No 10) [9]
Electrical coil	Copper [9]
Magnetic circuit	AISI 12L14[10]
Support ring	Stainless steel[11]
Inner shaft	Cobalt steel alloy[12]
Bobbin	Low carbon steel [13]
bobbin shaft	Steel [13]
Inner and outer valve	Steel [13]

Newtonian fluid and this phenomenon also called Bingham plastic behavior (yield strength) [14, 15]. The commercial MR fluid flows through annular valve section [3, 8, 16]. In table 2 commercial MR fluid composition characteristics are presented [17, 18]. The characteristics of MR fluid in the existence of electromagnetic pitch works likely non-Newtonian fluid and G. Yang proposed that for design consideration, parallel plate is more efficient and appropriate in annular gap[16]. Hideo Fujitani studied that, under the fixed velocity condition the resistance of force become constant and more accurate than Bingham model [19]. However, MR fluid greatly influenced by the porosity and tortuosity of outside valve and to minimizes viscous force under affordable range, the valve area chosen lower than critical Reynolds(Recr) number [4]. Holger Bose found that, under the application of 2.5 A current, the maximum damping force 3.3kN while 25 vol. % in iron particle in MR fluid region [20].

Table 2: Commercial MR fluid composition characteristics

Commercial MR fluid	Iron% (volume)	Carrier fluid	Density (g/ml)
MRX-126PD	26	Hydrocarbon oil	2.66
MRX-140ND	40	Hydrocarbon oil	3.64
MRX-242AS	42	Water	3.88
MRX-336AG	36	Silicone oil	3.47

3. RESULTS

FINITE ELEMENT ANALYSIS OF RDRMD

In the MR damper, the magnetic field is produced through magnetic coil. The COMSOL simulation version shows that, the wound coil is measured, and the magnetic field delivered by this coil is essential to motivate the MR fluid. Different current via the electrical coil, the magnetic flux mass could be different, and the MR fluid can be invigorated appropriately. In COMSOL MR damper version, the DC current is used in the form of current density i.e. current in the coil zone. In simulation, the electricity has been analyzed through equation 1.

$$J_e = \frac{NI_{coil}}{A} e_{coil} \qquad (1)$$

In Equation 4.1, is the total amount of rolls, is the current, A is the coil region, is the current flow mass and direction followed by the current. Figure 1 and represents the plot of 2D axisymmetric model and mesh analysis of RDRMD.

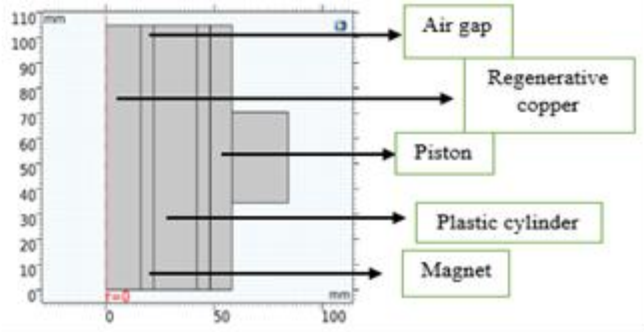

Fig. 1: 2-D axisymmetric model of RDRMD.

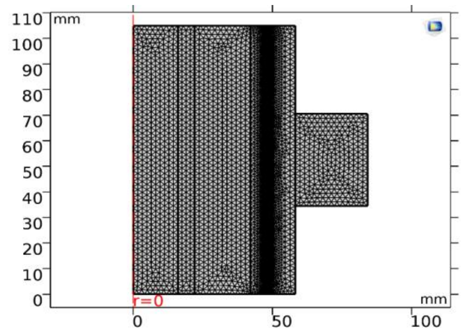

Fig. 2: Mesh Analysis of RDRMD

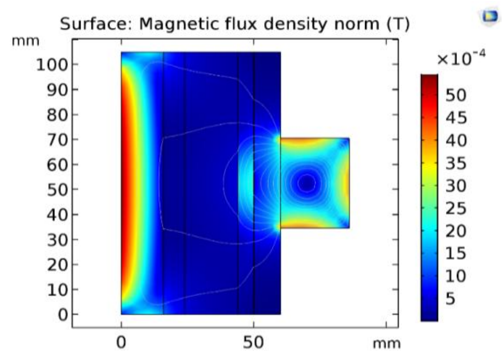

Fig.3: Magnetic flux density norm (T) for 4 mm air gap surface plot.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

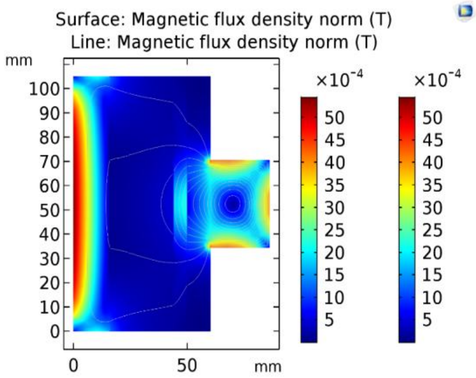

Fig. 4: Magnetic flux density norm (T) for 4 mm air gap surface and line plot

Chronologically currents are applied for producing magnetic flux mass and preferred position view of RDRMD is shown in fig. 3. Fig. 4 presents for both surface and line plot, while the air gap is 4 mm. outer regenerative parts shows the magnetic flux density and inside parts are piston coil head which produces magnetic flux density for gap surface, line plot and contour plot with addition of 4 mm air gap. The gap surface, line plot and contour plot has mentioned in figure 5 and magnetic flux mass represented by Tesla (T). The currents applied from various range (0.1-1.5) A. The materials used for making RDRMD are Alloy Steel AISI 4310, PVC 40% plasticizer, copper and Neodymium magnet.

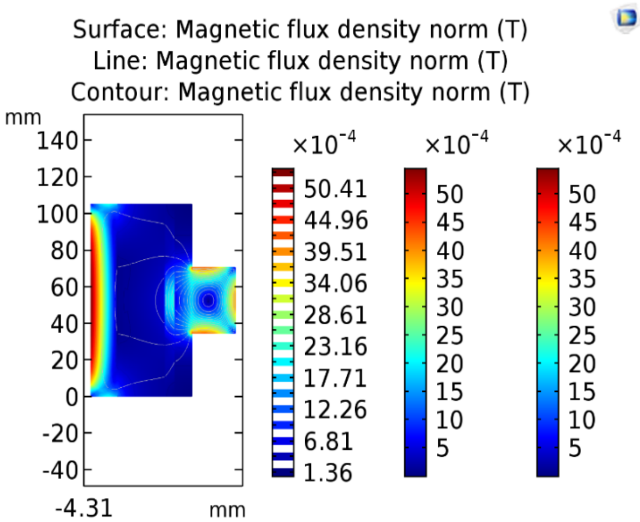

Fig. 5: Magnetic flux density norm (T) for 4 mm air gap surface, line plot and contour plot

4. CONCLUSION

The regenerative MR dispersion damper design for higher damping force and self-power generation capability. Dispersion system added due to the problem of sedimentation during field off and field on damping force. This proposed dispersion system also includes DC motor for rotating MR fluid in the bottom of the MR damper for bypassing MR fluid throughout the cylinder. Moreover, self-power generation capability provides required currents for MR damper will get high damping capability and controllability. The Comsol Multiphysics created finite element analysis done for characterizing magnetic propagation during field on and filed off damping process and it also characterizes the energy production capacity of the proposed regenerative MR damper. In addition, magnetic flux propagation and production ability is checked in this research.

ACKNOWLEDGMENT

This work has been carried out at the International Islamic University Malaysia. Authors would like to thank for their financial assistance of this research.

REFERENCES

1. Rashid MM., Aziz M. A., and Khan M. R., "An Experimental Design of Bypass Magneto-Rheological (MR) damper," in IOP Conference Series: Materials Science and Engineering, 2017, p. 012021.
2. Hu G., Long M., Huang M., and Li W., "Design, analysis, prototyping, and experimental evaluation of an efficient double coil magnetorheological valve," Advances in Mechanical Engineering, vol. 6, p. 403410, 2014.
3. Kubík M. and Mazůrek I., "Design of Semi-active Magnetorheological Valve," in The Latest Methods of Construction Design, ed: Springer, 2016, pp. 51-56.
4. Hu W., Robinson R., and Wereley N. M., "A design strategy for magnetorheological dampers using porous valves," in Journal of Physics: Conference Series, 2009, p. 012056.
5. Guo C., Gong X., Zong L., Peng C., and Xuan S., "Twin-tube-and bypass-containing magneto-rheological damper for use in railway vehicles," Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, vol. 229, pp. 48-57, 2015.
6. Zhu X., Jing X., and Cheng L., "Magnetorheological fluid dampers; a review on structure design and analysis," Journal of Intelligent Material Systems and Structures, vol. 23, pp. 839-873, 2012.
7. Zhang H., Liao C., Yu M., and Huang S., "A study of an inner bypass magneto-rheological damper with magnetic bias," Smart Materials and Structures, vol. 16, p. N40, 2007.
8. Yoo J.-H. and Wereley N. M., "Design of a high-efficiency magnetorheological valve," Journal of Intelligent Material Systems and Structures, vol. 13, pp. 679-685, 2002.
9. Wang D., Ailon H., and Liao W., "A magnetorheological valve with both annular and radial fluid flow resistance gaps," Smart Materials and Structures, vol. 18, p. 115001, 2009.
10. Facey W. B., Rosenfeld N. C., Choi Y.-T., Wereley N. M., Choi S. B., and Chen P., "Design and testing of a compact magnetorheological damper for high impulsive loads," International Journal of Modern Physics B, vol. 19, pp. 1549-1555, 2005.
11. Mao M., Hulon W., Choi Y.-T., and Wereley N. M., "A magnetorheological damper with bifold valves for shock and vibration mitigation," Journal of Intelligent Material Systems and Structures, vol. 18, pp. 1227-1232, 2007.
12. Goldasz J., "Study of a magnetorheological fluid damper with multiple annular flow gaps," International Journal of Vehicle Design, vol. 62, pp. 21-41, 2013.
13. Guo N., Du H., and Li W., "Finite element analysis and simulation evaluation of a magnetorheological valve," The international journal of advanced manufacturing technology, vol. 21, pp. 438-445, 2003.

14. Jolly M. R., Bender J. W., and Carlson J. D., "Properties and applications of commercial magnetorheological fluids," in 5th annual international symposium on smart structures and materials, 1998, pp. 262-275.
15. Jolly M. R., Carlson J. D., and Munoz B. C., "A model of the behaviour of magnetorheological materials," Smart Materials and Structures, vol. 5, p. 607, 1996.
16. Yang G., Ramallo J., Spencer Jr B., Carlson J., and Sain M., "Large- scale MR fluid dampers: dynamic performance considerations," in Proceedings of International Conference on Advances in Structure Dynamics, 2000, pp. 341-48.
17. Jolly M. R., Bender J. W., and Carlson J. D., "Properties and applications of commercial magnetorheological fluids," Journal of Intelligent Material Systems and Structures, vol. 10, pp. 5-13, 1999.
18. Corporation L.. Available: http://www.lord.com/
19. Fujitani H., Sodeyama H., Hata K., Komatsu Y., Iwata N., Sunakoda K.,"Dynamic Performance Evaliation of 200kN Magneto- pheological Damper," Technical Note of National Institute for Land and Infrastructure Management, vol. 41, pp. 349-356, 2002.
20. Böse H. and Ehrlich J., "Magnetorheological dampers with variousdesigns of hybrid magnetic circuits," Journal of Intelligent Material ystems and Structures, vol. 23, pp. 979-987, 2012.