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Design, Modelling and Study of Magnetorheological Dampers in Suspension System

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ABSTRACT

Nowadays different kinds of suspension systems are available. However, there is a necessity of a suspension system to reduce vibration much more. The main objective of this suspension system is to reduce the vibration. There are different types of dampers are used to reduce the shocks and vibrations. In this paper, we are using Magneto-Rheological fluid to arrest the vibration. It works with the help of electromagnet by producing the magnetic field. Analyze the properties of MR-fluid using advanced COMSOL software. It paved the way to increase the efficiency of the system. In future, it has more scope, and it will be the better suspension system for modern automobiles.

KEY WORDS: Suspension, Vibration, Magneto-Rheological Fluid, COMSOL.

1. INTRODUCTION

A suspension system usually consists of spring and dampers or other elements that can be modeled as spring and damper equivalents. The suspension system is classified into three types; they are active suspension system, semi-active suspension system, and passive suspension system. The different varieties of suspension system like a torsion bar, coil spring, rubber bush, leaf spring, air spring, etc. The various suspension systems were later modified into active and semi-active suspension system to meet the various requirements. This work deals with the development of a suitable suspension system with an electromagnetic damper that efficiently isolates vibration between the driver and the chassis. A Large number of researchers studied the different suspension systems and developed models to reduce the damping force created during the moving of vehicles. Experiments are carried out on the basis of numerical simulations, computational fluid dynamics concepts, and finite element analysis to determine the influence of the Magneto Rheological fluid. But COMSOL is one of the recently developed software for modeling and analyze all varieties of scientific and technological engineering problems. In this work, the magneto rheological suspension system is modeled by using COMSOL Multi physics software is used to accomplish the nature of the magnetic flux density developed.

This part of the paper mainly deals with the past experience of other researchers in developing the magneto rheological suspension models. Bogdan (2005) develop a real-time control of a magneto rheological shock absorber in the driver seat. MATLAB/Simulink was used to support the design of the controllers. Routhier (2011) were made an experimental clutch like setup has been designed to verify the SSE origins from force or displacement and if the phenomenon exists for thin layer of MRF like the one used in MRF clutches. Turczyn (2008) were investigated the basic properties of prepared MR fluids, as their response to an external magnetic field and their stability, for the preparation of model magneto rheological (MR) fluids. Moreover (furthermore) few results concerning the stabilizing effect of various additives are presented. Abigail has been investigated the usage of magneto rheological fluid in the active compliant actuator, for intended use in a stroke rehabilitation system. The proposed usage of the model is to perform an active exercise and increase the strength of the weakened hand of a human being due to stroke affected. By the end of the results it clearly indicates that the proposed model with the magneto rheological fluid is the opted solution. The viscosity of the magneto-rheological fluid is has been dynamically controllable. Bogdan (2013) made an experiment used a rotational rheometer with an extra chamber inside which a uniform magnetic field can be generated. Underlying the description of rheological properties of fluids is the Herschel-Bulkley's model of viscous-plastic substances. The aim of the experiment was to determine the shear stress, yield stress, the yield factor and the power-law exponent depending on the magnetic flux density, followed by the comparative study of rheological parameters of investigated fluids. Yancheng (2008) were investigating the effectiveness of PID control policies on large-scale magneto-rheological shock absorber subjected into impact force. In the present work, three pre-estimated controllers, which are PID controller, PI controller, and P controller, are developed to mitigate the peak shock response of magneto rheological shock absorber at peak impulsive load. An impulsive test rig that uses a fixed amount powder to produce the impact force is introduced. Comparative test results show that the P control has the best control results to restrain the peak response of damping force and the inner pressure of MR shock absorber. Ahmadian (2004) were studied the magneto rheological damper dynamic performance under impact and impulsive load. From the obtained result indicate that the influence of current cannot be control the damper performance. They designed and fabricated a compact MR damper for the protection of sensitive devices against high shock and impact by increasing the number of magnetically active volume using FEM analysis and, at the meantime, minimizing damper length. Sam (2013) was studied the influence of the magnetic field in the magneto rheological suspension system at the time of hard turning process and the obtained results indicated that the vibration of tool has been effectively reduced in the magnetic field direction on the magneto rheological suspension system, and performance of cutting is also increased. Butz (2002) were carried out a literature survey of electro and magneto rheological fluid properties and different models with their applications. The numerically simulated the vehicle suspension system with magneto rheological fluid. Zekeriya (2012) were optimally designed the magneto rheological damper to achieved the magnetic flux density maximally and damping force. The optimization of the parameters has been determined by using the computational fluid dynamics for magneto rheological fluid flow, finite element method and magnetic field by electromagnetic analysis. From the literature survey no other studies or investigation based on the simulation of maximum magnetic flux density produced in the magneto rheological suspension system. The ultimate objective of this paper is to design and develop a suspension system with MR fluid and simulate the model with the help of COMSOL software.

2. MATERIALS AND METHODS

The magneto-rheological fluid damper is a damper of ferrite particles in the carrier fluid. Additional additives improve its stability and other parameters. Carbonyl iron particles are essentially used for the preparation of MR fluid. Dimensions of ferrite particles are between 0.5 and 5 µm. Synthetic oil is mainly used as a carrying fluid. By applied the magnetic field into the magneto rheological fluid, a chain like structure is formed and within a fraction of a second the suspension was acted like a semi-solid material. The magneto rheological fluid has been acted as a Non-Newtonian fluid varying viscosity at the time of the magnetic field. But at the time of neglecting the magnetic field in the suspension system the magneto rheological fluid acted like a Newtonian fluid. Yield stress is caused by the chain form of the magneto rheological fluid and which resist the flow of fluid. By applied force in the chain formation in terms of magnitude and magnetic field the shape is changed. Properties of the MR Fluid as tabulated in the below table. When magnetic flux appears, apparent viscosity, defined as a ratio of a shearing stress and a shearing rate, changes. The application of magneto rheological suspension system has been developed to improve the suspension rate in automobiles.

Table.1.Properties of the MR Fluid

Representative feature	Typical MR Fluid
Maximum yield stress	50-100kPa
Power supply	2-24 V at 1-2 A
Response time	10 millisecond
Operational field	Up to 250 kA/m
Energy density	0.1 J/cm3
Stability	Good for most impurities
Operational temperature	-40C up to +150 C

For designing the damper 1018 low-carbon steel is used for the piston, piston rod & cylinder. AISI 4340 steel is used for sleeve, copper for the coil and air for air medium. A magnetic field has to be applied to the piston, piston rod, iron powder & cylinder. The multi-turn coil has to be given to coil. The material used for designing the coil is copper. The designed and developed magneto-rheological fluid suspension system is shown in Fig. 1.

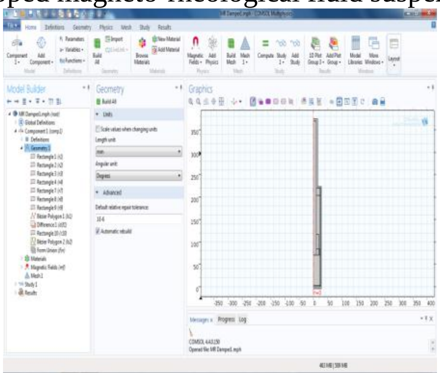

Fig.1.Geometry of damper

The material properties like Relative permeability, Electrical conductivity, Relative permittivity, Coefficient of thermal expansion, Heat capacity at constant pressure, Density, Thermal conductivity, Young's modulus and Poisson's ratio are assigned for this particular suspension design is tabulated in the below tables. The utilized temperature is 293.15 K, and the absolute pressure is 1 atm.

Table.2.Properties of steel AISI 4340 for the proposed design

Property	Value
Relative permeability	1
Electrical conductivity	4.032e6 S/m
Relative permittivity	1
Coefficient of thermal expansion	12.3e-6 1/K
Heat capacity at constant pressure	475 J/(kg*K)
Density	7850 kg/m^3
Thermal conductivity	44.5 W/(m*K)
Young's modulus	205e9 Pa
Poisson's ratio	0.28

Table.3.Properties of low carbon steel 1018 for the proposed design

Property	Value
Relative permeability	1
Electrical conductivity	8.41 MS/m
Relative permittivity	1

Table.4.Properties of copper for the proposed design

Property	Value
Relative permeability	1
Electrical conductivity	5.998e7 S/m
Relative permittivity	1
Surface emissivity	0.5
Heat capacity at constant pressure	385 J/(kg*K)
Density	8700 kg/m^3
Thermal conductivity	400 W/(m*K)
Reference resistivity	1.72e-8 ohm*m
Resistivity temperature coefficient	3.9e-3 1/K
Reference temperature	273.15 K

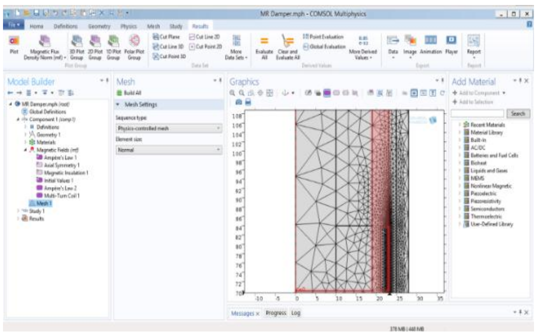

Fig.2.Meshing the model

2.1. Analysis Using COMSOL Software: For modeling and analyzing the different types of scientific and engineering quandaries COMSOL Multi physics software is one of the best solutions. Designing the suspension system, a small annular gap is provided at the head of the piston for the effective suspension fluid channel. Whenever the piston moves upward and downward, the suspension fluid is passed through that effective gap with shear rate. The automatic shape order is selected for component defines, and the specific material is selected to develop the model. The designed suspension system has 300 numbers of turns of the copper coil with the wire diameter of 0.25 mm. For selecting the magnetic field, the full field is used. The model is meshed before analyzed and which is shown in the below figure 2. All the parameters, boundaries, fluid domains, edges, expressions, and points are applied independently on the computational mesh. The number of degrees of freedom solved is 98658.

3. RESULTS AND DISCUSSION

The meshed model has been compiled, and the obtained results are shown in Figs.3 and 4. The viscosity of the magneto-rheological fluid varies based on the magnetic field produced inside the piston cylinder. The distributions of magnetic flux density from the figure 4 3D view have different colors. At the maximum magnetic flux density area the color should be red. These results clearly show the distribution of Magnetic flux density due to the application of magnetic field. The viscosity of the magneto-rheological fluid is directly proportional to the magnetic field produced in it. So the viscosity is varied at different stages and has a capacity of controlling the vibration developed in it.

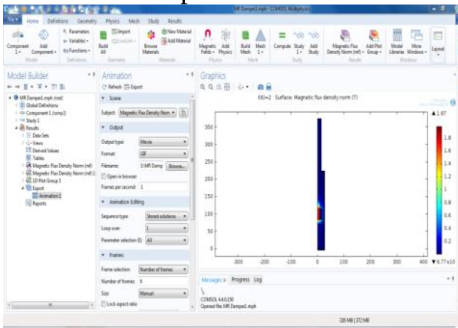

Fig.3.Result based on 2d view

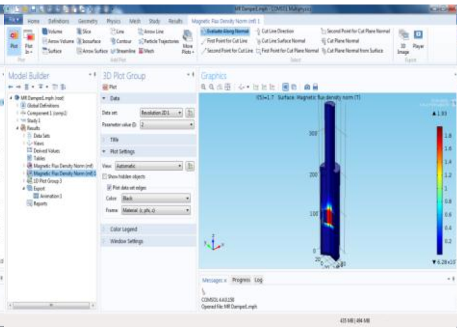

Fig.4.Result based on 3d view

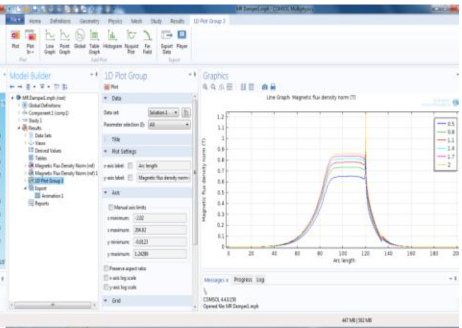

Fig.5.Magnetic flux density VS Arc lengths

Fig. 5 shows the line graph plot between the arc length and the magnetic flux density norm. The X-axis stands for arc length, and the Y-axis represents the magnetic flux density norm (T). The maximum limit in the arc length is 204.02, and the maximum magnetic flux density norm (T) is 1.24299.

4. CONCLUSIONS

In this paper a Magneto rheological fluid damper and electro magnets are used as external power sources for an active control suspension system. Results from the analysis clearly shows that the distribution of Magnetic flux density due to the application of magnetic field. Based on the analysis result the proposed model make good effect in real time control and will be a good option for improving automotive ride comfort of passengers in near future.

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