Performance Evaluation and Optimal design of Active Suspension System of MR Fluid Shock Absorber - A Review

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Abstract

A suspension system or shock absorber is a mechanical device designed to smooth out or damp shock impulse or vibration and dissipate kinetic energy. In a vehicle, it reduces the effect of travelling over rough ground, leading to improved ride quality, and increase in comfort due to substantially reduced amplitude of disturbances. In this we improve the overall performance of shock absorber as an optimum solution. In this study we different study different fluids composition of fluids, controlling damping force and magnetic flux density of MR Fluid. To synthesize fluids by various optimization method and use CFD simulation software.

Keywords: Spring, Piston, Splendor, Fluid, transmissibility ratio, Performance Evaluation, Shock Absorber.

1. INTRODUCTION

Shock Absorber is consisting of three main parts that decide its performance. Spring, Piston cylinder arrangement of Damper (Dashpot), Fluid inside the cylinder. Shock Absorber absorb the shock coming from tire and gives comfortable ride to the passenger (rider).

Shock absorber design there is several shock absorber designs in use today:
1. Twin Tube Designs
2. Gas Charged PSD (position sensitive damping)
3. ASD (Acceleration Sensitive Damping)
4. Mono-Tube increased
5. Valve types: disc valve; rod valve; spool valve; Shim valve.

In order to improve the performance of MR valves and dampers, the optimal design of MR valves and dampers has been also considered. Rosenfeld and Wereley [15] proposed an analytical optimization design method for MR valves and dampers based on the assumption of a constant magnetic flux density throughout the magnetic circuit to ensure that one region of the magnetic circuit does not saturate prematurely and cause a bottleneck effect. Nevertheless, this assumption leads to a suboptimal result because the valve performance depends not only on the magnetic circuit but also on the geometry of the ducts through which the MR fluid passes. Nguyen et al [16] proposed an FEM based optimal design of MR valves constrained in a specified volume. This work considered the effects of significant dimensions of MR valves by minimizing the valve ratio calculated from the FE analysis. However, the control energy and time response of the MR valves was not considered in this research. Recently, Nguyen et al [17] have studied the optimal design of MR valves that satisfies specific operational requirements such as the pressure drop and inductive time constant with minimum control energy. It is noteworthy that in this study the power consumption of the valve was chosen as an objective function while the pressure drop and inductive time constant were treated as state variables with their constraints. Therefore, it is necessary to convert the optimization problem with constrained state variables to an unconstrained one. This increases the computation time and causes a low accuracy of optimal solutions. Moreover, no one has dealt with the vibration control of a suspension system which is equipped with the optimally designed MR dampers or MR valves [10].

Magneto rheological (MR) fluids have been investigated by many researchers as their material properties can be modulated through an applied electro- magnetic field. Specially, they are capable of reversibly changing from a linear Newtonian fluid to a semi solid with in a fraction of the milli seconds and the yield strength of this semisolid is controllable. The fluid causes the maximum yield stress of about 50 to 100 kPa. The magnetic field dependent shear strength of MR fluid depends on several factors including the size, composition, volume fraction of the particles and the strength of the applied magnetic field.
field. Systems that take advantage of MR fluids are potentially simpler and more reliable than conventional electromechanical devices. Sodeyama and Suzuki et al. have developed and tested an MR damper which provided maximum damping force of 300kN. Maher Yahya Salloom and Samad designed an MR damper for which simulation was carried out by magnetic finite element software (FEMMR). H. Yoshioka, J.C. Ramallo et al. constructed and tested MR fluid based damper on a base isolated two-degree-freedom building model subjected to simulated ground motion which is effective for both far- field and near- field earthquake excitations. Jansen and Dyke evaluated the performance of number of semi active control algorithms that are used with multiple MR dampers. Spancer and Dyke et al. Proposed a new model to effectively use as semi-active control device for producing a controllable damping force portraying the nonlinear behavior of MR fluid damper. N. Seetaramaiah and Sadak et al. have designed a small capacity MR fluid damper which achieved the requirements of dynamic range and controllable force. Lai and W.H Liao have found that MR fluids can be designed to be very effective vibration control actuators.

Magnetorheological (MR) fluids are materials that respond to an applied magnetic field with a dramatic change in rheological behaviour [1]. An MR fluid is in a free-flowing liquid state in the absence of a 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. The strength of an MR fluid can be described by shear yield stress [1]. Moreover, the change in viscosity is continuous and reversible, i.e. after removing the magnetic field the MR fluid can revert to a free flowing liquid. Using these characteristics of MR fluids, MR fluid devices have the ability to provide simple, quiet, rapid response interfaces between electronic controls and mechanical systems. Hence, scholars and industrialists have shown extensive interest in MR fluids and their applications.

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1.1 Need of MR damping devices

1. Automobile suspension mostly influence the vehicle ride quality and safety
2. Need of real-time performance adjustment based on road situation and vehicle operation state.
3. Conventional dampers such as hydraulic and spring dampers have constant setting throughout their life.
4. MR dampers due to the apparent viscosity of magnetic fluids can operate in semi-active conditions.

1.2 Characteristics:

1. Under a strong magnetic field its viscosity can be increased by more than two orders of magnitude in a very short time (milliseconds). Hence, very low response time.
2. The change in viscosity is continuous and highly reversible.
3. Yield strength of up to 50-100 kPa.
4. Insensitivity to contaminants.
5. Low voltage (12-24 V) required for operation.
6. Broad working temperature range: -40º C to 150º C.

1.3 Types of MR dampers:
1. Mono tube
2. Twin tube
3. Double ended MR damper
4. MR-Hydraulic hybrid damper

1.3.1 Mono tube MR damper:
A monotube MR damper is one that has only one reservoir for the MR fluid and also has some way to allow for the change in volume that results from piston rod movement. In order to accommodate this change in reservoir volume, an accumulator piston is usually used. The accumulator piston provides a barrier between the MR fluid and a compressed gas (usually nitrogen) that is used to accommodate the necessary volume changes.

![Figure 1. Monotube MR damper section view.](image)

1.3.2 Twin tube MR damper:
The twin tube MR damper is one that has two fluid reservoirs, one inside of the other. This configuration has an inner and an outer housing. The inner housing guides the piston/piston rod assembly just as the housing of a mono tube damper does. This inner housing is filled with MR fluid so that no air pockets exist. To accommodate changes in volume due to piston rod movement, an outer housing that is partially filled with MR fluid occurs. In practice, a valve assembly called a “foot valve” is attached to the bottom of the inner housing to regulate the flow of fluid between the two reservoirs. As the piston rod enters the damper, MR fluid flows from the inner housing into the outer housing through the compression valve that is attached to the bottom of the inner housing.

The amount of fluid that flows from the inner housing into the outer housing is equal to the volume displaced by the piston rod as it enters the inner housing. As the piston rod is withdrawn from the damper, MR fluid flows into the inner housing through the return valve. In order for a twin-tube MR damper to function properly, the compression valve must be stiff relative to the pressure differential that exists between either sides of the piston when it is in operation [4]. The return valve must be very unrestrictive so that as little resistance to fluid flow as possible is provided. The damper should function properly as long as the following conditions are met:
(1) The valving is set up properly;
(2) MR fluid settling is not a problem; and
(3) the damper is used in an upright position.
With this type of MR damper, keeping the iron particles (which are an integral part of MR fluid) in suspension is a major concern since these iron particles can settle into the valve area and prevent the damper from operating properly. All MR dampers are affected by MR fluid settling, but this problem is particularly prevalent in the twin tube variety.

Figure 2. Twin tube MR damper.

There are some limitations on MR Fluid are setting up stability of fluid, relative cost and durability of devices on damper.

Zhu et al. (2012) and Kumbhar et al. (2015) presented MR fluid characterization, synthesis, and its application. An MR damper contains a type of smart fluid called a magnetorheological fluid (MRF). Changes in the applied excitation current vary the strength of the magnetic flux density of the electromagnets and consequently vary the rheological properties of the MR fluid. Such fluids contain micron-sized magnetic particles (5–50 μm) such as iron, suspended in a carrier fluid, usually a kind of oil. Without an applied magnetic field, the MRF behaves as a conventional fluid and its viscosity is independent of the flow rate. However, the application of a magnetic field creates a dipole moment aligned to the field in the iron particles, and the particles form linear chains parallel to it, as shown in Figure 3.

Figure 3. MRF magnetic particles chain-like formation with applied magnetic field

From the above discussions, it is concluded that Magneto rheological (MR) fluids have been investigated by many researchers as their material properties can be changed through an applied electromagnetic field. Specially, they are capable of reversibly changing from a linear Newtonian fluid to a semi solid with in a fraction of the milliseconds and the yield strength of these semi solids controllable. No one in his study developed shock absorber damper to improve the performance of semi active suspension system to optimize the MR damper parameter and synthesis the MR fluids properties to absorbers the energy and control shock of valve, seal and piston scratch geometric parameter of shock absorber damper by combing effect finite element methods as thermal analysis and C.F.D. analyses of flow simultaneously.

Usually the MRF contains 20%–40% by volume of pristine soft iron particles, mixed with mineral oil synthetic oil, water, or glycol. Various additives are usually included to minimize the settling problem of iron particles, enhance lubricity, modify viscosity and inhibit wear (Yang, 2001; Newton, 2009). One of the major and most important applications of MRF is in the development of MR dampers.

From above revived paper the limitations of commonly used liquids have motivated exploration of sunflower oil as an alternative carrier liquid for said application. After comparing properties of various alternative carriers like soybean oil, sunflower oil, honge oil; edible vegetable oil like Sunflower oil, which is bio-degradable, environmentally friendly, and abundantly available in many parts of India. Selected as a carrier liquid in the present work. Past literature has not reported use of the same as MRF carrier liquid; hence, samples will synthesized with sunflower oil, soybean, and edible oil as a carrier fluid. Hence there scope for improvement in change in propertied fluid to get efficient fluid to absorb shock and give comfort for active suspension system.
From above paper the magnetic flux densities obtained, at different current inputs, the output torques are calculated so their scope improvement in flux density of MR shock Absorber to maximum output torque.

2. Approach
The approached is used to satisfy stated objective function of MR Shock Absorber will be used to design and develop the setup of shock absorber to test and synthesis to fluid properties for active and semi active suspension system. Twin tube MR Shock Absorber is used to design and optimize the parameter of piston valve and seal to improve various geometric parameter of shock twin tube damper. The approach is also will be optimize the damping force to control yield stress. To reduce cost and weight of existing design of shock absorber damper.

3. Scope of the Study
Magneto rheological (MR) fluid technology has been proven for many industrial applications like shock absorbers, actuators, etc. Among the various shock absorber damper systems, MR Fluid and Twin tube type’s shock absorber Systems are noticed to more energy absorbing and controlling devices in domestic and industrial applications. Hence this research work is focused to address the needs of made more of the energy efficient and controlled shock absorber damper system in terms of economic loading conditions and identified for better performance enhancement technique with MR Fluid Synthesis by changing the properties of fluids, characteristics of damper and Heat reduction methods. The present work aimed to improving the shock absorber with some changes in spring and damper to enhance the performance. The present work can be extended to adjustable compression damping & rebound damping for various track & driver requirement.

The present work can be extended for light weight & optimization of shock absorber by using material Titanium, Beryllium.
By replacing normal hydraulic fluid we replace with MR fluid to improve performance of shock absorber.
Main scop of this study is to Improvising the performance of shock absorber for bycle having 0.7 transmissibility ratios that means maximum or more force transmitted to the passenger which cause discomfort (Fatigue).

4. Objective of Project Work
To improve shock absorber performance in such a way that it will provide sufficient comfort to the passenger. It should fit in available space so easy to adjust. The weight should be as low as possible. The cost should not exceed the available budget. To study MR fluid for its suitability as fluid for active suspension system. To synthesis the MR Fluid and test its suitability for particular application. To design and conduct test on damper with synthesized MR fluid.

Optimize the design to the possible extent without affecting the performance.

5. Methodology

6. Experimental Procedure:
To test various characteristics of shock absorber damper on damper test rig. For calculation of damping factor and damping coefficient, damping force for fluid properties. Also use FFT Analyzer and validate result with CFD simulation software.

7. Stock Shock Absorber Experiment:
To found out various characteristics of twin type bycle damper (original damper).
Specifications and observations:
1. Cam dia. With Lobe = 45mm
2. Cam Base diameter = 50mm
3. Cam Lift = 20mm
4. Stiffness of spring = 18000N/m
5. Load on Absorber = 45kg

**7.1. Observation from experimental reading**

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**Table 1:** Observation table

**7.2. Splendor spring specifications**
- Coil diameter = 7mm
- Mean diameter = 42.3mm
- Total free length = 220mm
- Number of coils = 18.5
- Number of active coils = 16.5
- Equivalent stiffness = 18.09 N/mm
- Pitch 1st part = 10mm
- 2nd part = 15mm

**7.3. Designed spring specifications**
- Coil diameter = 7mm
- Mean diameter = 50mm
- Total free length = 220mm
- Number of coils = 12
- Number of active coils = 10
- Stiffness 1st part = 25 N/mm
- 2nd part = 43 N/mm
- Equivalent stiffness = 15.4 N/mm
- Pitch 1st part = 13.5mm
- 2nd part = 17mm

**Figure 4:** Stock shock absorber spring (splendor)
3. Analysis Results:

Result 6: deformation of splendor spring

Result 7: Deformation of designed spring

2.3. Conclusion:

From above experiment it is found that the transmissibility for the shock absorber is very large that is about 0.8 and therefore our main aim will be to decrease the transmissibility (force transmitted to the chassis or passenger) so that force transmitted to passenger will be less and passenger can get comfortable ride.

The Performance of shock absorber damper properties of seal, valve of shocks piston scratch and damper fluid properties of vehicle suspension system with alternative Fluids (Mixture of two fluids) has been measured with above methodology discussed and best combination with suitable energy absorbing and control fluid properties fluid will be selected. From above calculated values minimize the weight of damper as function of percentage of Nano Particle. Effect of magnetic field by using different proportions of fluids on MR fluid will be calculated. Due fluid heating Effect of temperature calculated by CFD. Speed is used to control a damping force. Experimental result may be obtained closure to result obtained by CFD analysis of MR Shock Absorber and Compared with optimization method to find optimal solution.
8. LITERATURE REVIEW

1. Gaurav Vaidya, Pranay Kanoje, Nikhil Tidke [international Journal of engineering technology science and research, IJETSR] Various types of suspension system for vehicles from low end applications to high end applications are studied, September 2017

2. F.G. Guzzomi, P.L. O’Neill, A.C.R. Tavner [Reasearchgate] Investigation of Damper valve dynamic using parametric numerical method. In this, the dynamic performance of automotive hydraulic damper valve is check for particular damper i.e. the flow simulation was performed on software, January 2007

3. Dheeman Bhuyan, Kaushik Kumar. Design and analysis of base valve of twin tube Dampers. In this the monotube shock absorber has been replaced by twin tube to check the performance and the effect of the fluid pressure on valve diaphragm and spring, February 2016

4. Ismail Gerdemeli, A.Engin Cotur, Eren Kayaoglu, and Adem Candas. Computer aided valve design of shock absorbers used in Vehicles. The valve of twin tube shock absorber has been studied and analyzed by computer DR program, July 2011

5. Automotive department, Transylvaniauniversity of Brasov. About the preliminary design of the suspension spring. In this they prepare the basic structure to start the design of suspension spring and shock absorber, October 2018

6. P.R. Jadhav1, N.P.Doshi2, U.D.Gulhane3. Analysis of Helical Spring in Mono suspension System Used in Motorcycle. In this they find the behavior of helical spring in shock absorber application and analysis that spring in ansys, June 2017.

7. Dong Guan etal,(2019) reviewed the research work done on: Test and simulation the failure characteristics of twin tube shock absorber. In this paper, the dynamic performance of a twin-tube shock absorber is investigated by experiment and simulation.

8. R. Jeyasenthil, S.B. Choi (2018) reviewed the research work done on: A novel semi-active control strategy based on the quantitative feedback theory for a vehicle suspension system with magneto-rheological damper saturation. In order to improve damper performance, researchers are introduced a robust controller for a semi-active suspension system with actuator saturation.

9. Sadak Ali Khana, A.SureshbN. (2014) reviewed the research work done on: Principles, Characteristics and Applications of Magneto Rheological Fluid Damper in Flow and Shear Mode. This work presents a Magneto rheological (MR) fluid has been attracting great research attention because it can change its characteristics very rapidly and controlled easily in the presence of an applied magnetic field.

10. Ryszard Jabłoński, Tomas Brezina (eds.) et al. (2016) reviewed the research work done on: Evaluation of damping characteristics of a damper wit magneto-rheological fluid. This paper presents experimental investigations carried out to study, the parametric modeling technique for MR shock absorber analysis will be use. The applications of magneto-rheological (MR) damping devices, utilizing their properties of simple damping control under the application of a magnetic field.

11. M. Ashtiani, S. H. Hashemabadi, et al. (2014) reviewed the research work done on: A Review on the Magnetorheological Fluid Preparation and Stabilization. Magnetorheological fluids (MRFs) are one of the categories of smart materials, whose viscosity increases considerably in the presence of a magnetic field. These fluids are prepared by dispersing magnetizable micro size particles into a carrier fluid with stabilizer additives. The main feature of these fluids is their ability to change from liquid to semi-solid state with controllable yield stress just a few milliseconds after applying a magnetic field.

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REFERENCES


