

# Design of Electro-Hydraulic Suspension System

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**ABSTRACT:** The suspension system is designed for passengers comfort in automobiles. The suspension of road vehicle is usually designed with two objectives; to isolate the vehicle body from road irregularities and to maintain contact of the wheels with road way. The design of suspension system allows vehicle engineers to achieve an exceptional combination of ride and handling performance. This research is intended for modern electric dampers for variable loads consisting from different suspension setups in vehicles. The research will provide an effective suspension model where in the variable loads will be counter-reacted by auto stiffness circuit in the ECU. This circuit can be manualised using control levers or otherwise will decide the road surface integrity for any unbalance force using electronic sensors. In this model there is also a provision for application of the primary MR fluid which is been used in the standard model.

**KEYWORDS:** Modern electric dampers, ECU, MR Fluid

## I. INTRODUCTION

The comfort for any automobile comes from suspension system that it is put on with. The suspension system defines the cabin force and absorbs the shock to provide a very comfortable ride. There are different suspension systems based on two types of road conditions that is city road condition and off road condition. It defines two types of suspension system based on this two road conditions i.e. soft setup (stiffness factor is less) & Stiff setup (stiffness factor is high). Generally the soft setups are of lower costs and stiff setups are of high costs. There is no middle ground available for the market which will define the both comfort levels. Or we can say those which are available are of very high costs. So we introduced a new design of suspension system which will satisfy both soft and stiff condition. This design can be used for various automobile applications under different road conditions.

## II. LITERATURE REVIEW

Ayman A. Aly et al. [1] had described the model and controller used in the study and discusses the vehicle response results obtained from a range of road input simulations.

Bhuwaneshwar Chandekaret al. [2] had design an active Electro Hydraulic suspension which will give a good road handling or driving safety and passenger comfort than passive suspensions.

GadhiaUtsavD et al. [3] had represented design and problem identification for existing car's suspension system in this paper.

Mert SEVER et al. [4] had designed an optimal state derivative feedback controller is proposed by employing the linear matrix inequalities framework. In order to demonstrate the effectiveness of the proposed controller, a two-degree-of-freedom quarter vehicle suspension model equipped with an electro hydraulic actuator is preferred.

Muhammad Zahir Hassan et al. [5] had reported the numerical analysis technique to investigate the influence of spring stiffness in automotive suspension towards improving the vehicle ride and performance.

S. Elizabeth Premalatha et al. [6] had prepared MR fluids, composed of iron particles and analyse their flow behaviour in terms of the internal structure, stability and magneto rheological properties.

Arne Lind et al. [7] had proposed latest developments in vibration control of structures and structural components using magnetorheological fluids.

Mr. Vinayak D. Dabade et al. [8] had presented paper on basic properties of the magneto rheological fluids (MR) and their development in recent years.

K. Rama Raju et al. [9] had proposed latest developments in vibration control of structures and structural components using magnetorheological fluids.

James Sathya Kumar et al. [10] had reviewed the challenges in methods of preparation, difficulties encountered in storage and use, and possible solutions to overcome the challenges.

Mark R. Jolly et al. [11] had compared properties of different MR Fluid by computing the results.

A. Roszkowski et al. [12] had determined the coefficient of viscosity of a magneto-rheological fluid for different values of the magnetic field and to determine parameters at which the flow of the fluid through a capillary is stopped.

C. Wu et al. [13] had proposed the performance dynamic test for both of MR damper and fluid damper are carried on by INSTRON 8800 test machine according with theories of structural dynamics and electromagnetic. Dampers with various sizes are tested and simulated by modified Bouc-Wen modal according to the proper test data.

V. Krithika et al. [14] had proposed damper system application, MR fluid is used as the hydraulic oil instead of standard SAE oils.

Henri GAVIN et al. [15] had developed smart adaptive suspension system that dynamically varies the damping coefficient to achieve better control and improve the ride quality of an automobile.

Hui Pang et al. [16] had proposed a novel variable universe fuzzy control design for vehicle semi-active suspension system with magnetorheological (MR) damper through the combination of fuzzy neural network (FNN) and particle swarm optimization (PSO).

Krishnan Unni R et al. [17] had designed the magneto-rheological damper to maximize the damping force with the measured geometric constraints for the all Terrain Vehicle.

ItthisekNilkhamhang et al. [18] had concerned with stable adaptive schemes for semi-active control of suspension systems, which can deal with uncertainties in a nonlinear model of MR damper.

Arjon Turnip et al. [19] had investigated numerical aspects of a sensitivity control for the semi-active suspension system with a magneto-rheological (MR) damper.

Jian Wu et al. [20] had handled the non-linearities of MR dampers with a piece wise modelling method, and the vibration attenuation is realised by designing a static piecewise-affine (PWA)  $H_\infty$  controller.

### III. CONVENTIONAL SUSPENSION SYSTEM

An active suspension system possesses the ability to reduce acceleration of sprung mass continuously as well as to minimize suspension deflection, which results in improvement of tire grip with the road surface, thus, brake, traction control and vehicle maneuverability can be considerably improved.[1]

One of the performance requirements is advanced suspension systems which prevent the road disturbances to affect the passenger comfort while increasing riding capabilities and performing a smooth drive. While the purpose of the suspension system is to provide a smooth ride in the car and to help maintain control of the vehicle over rough terrain or in case of sudden stops, increasing ride comfort results in larger suspension stroke and smaller damping in the wheel hop mode [1]. Many control methods have been proposed to overcome these suspension problems. Many active suspension control approaches such as Linear Quadratic Gaussian (LQG) control, adaptive control, and non-linear control are developed and proposed so as to manage the occurring problems[1].

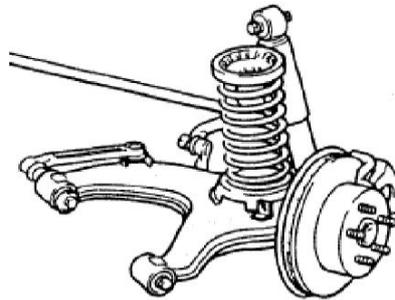


Fig1.Schematic of Quarter Car Suspension System[1]

In this study of Ayman A. Aly, an automatic suspension system for a quarter car is considered and an intelligent controller is designed when the vehicle is experiencing any road disturbance (i.e. pot holes, cracks, and uneven pavement), the vehicle body should not have large oscillations, and the oscillations should dissipate quickly (see Fig.1). The road disturbance is simulated by a step input as a soft road test and rough road as a simulated to real way and the distance between the body mass and simulation mass is output of the system[2].

According to his study, Suspensions control is highly a difficult control problem due to the complicated relationship between its components and parameters. The researches were carried out in suspensions control systems cover a broad range of design issues and challenges[3-4].

#### IV.MR FLUID

Magnetic functional fluids are able to change their rheological properties when it is placed in an external magnetic field. Magnetorheological fluid (MRF) are the suspensions of these micron size polarisable particles in a magnetically neutral fluid. Silicone oil or mineral oil is usually used as magnetically neutral fluid. In MR fluid, some small additives are added, which affect the polarization of the particles and also stabilization of the structure of the suspension to resist settling of particles. MR fluids contain the magnetisable particles, non-magnetisable suspending fluids and additives. MR fluids response to an applied field and have ability to change from a linear viscous fluid with free floe to a semi-solid state. When the field is cut off, the MR fluid comes to original state.MR fluid behave like Newton fluid in zero magnetic field. When certain amount of magnet field is applied, the magnetic particles form chain cluster due to dipole-dipole interaction between particles[6-7].

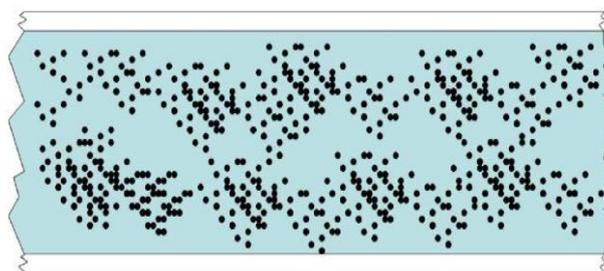


Fig.2.(a).Free flowing MR fluid[7]

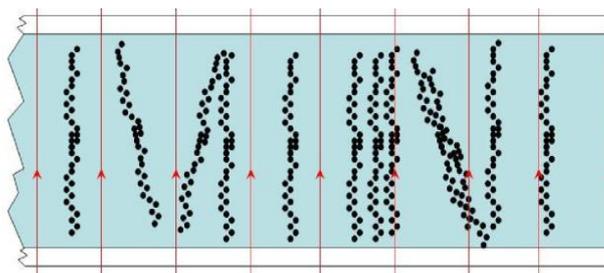


Fig.2.(b).Magnetic field applied to an MR fluid[7]

**Performance parameters of MR Fluid[7-8]**

Energy Consumption [J/cm <sup>3</sup> ]	0.1
Max Field Intensity [kA/m]	250
Max Shear Stress [kPa]	50~100
Apparent Viscosity [Pa·s]	0.2~1.0
Suitable Temperature [°C]	-50 ~ +150
Impurities Sensitivity	Insensitive
Density [g/cm <sup>3</sup> ]	3 ~ 4
Input Voltage [V]	2~25
Appearance	Dark Gray Liquid
Solids Content by Weight, %	72
Flash Point, °C (°F)	>150 (>302)

The MR fluids can be widely used in designing damping devices such as shock absorbers, clutches, surface polishing machine parts and vibration dampers[9].

**Problems associated with MR Fluid[10-11-12]**

1. Clumping effect
2. Fluid particle separation
3. Oxidation of particles
4. Stability
5. Temperature effects
6. Sealing issues
7. Interior wall incrustation

**V. CONVENTIONAL MR DAMPER**

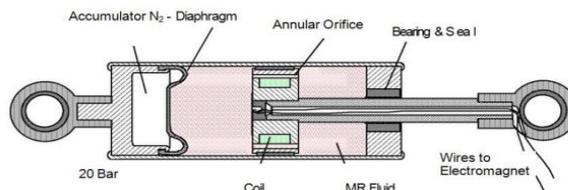


Fig.3.Commercial Linear MR Fluid-based Damper[8]

The MR fluid damper contains MR fluid, bearing & seal, annular orifice, coil, diaphragm and accumulator. For accumulator, there is nitrogen gas with pressure 20-bar acting on the damper. The diaphragm is used to separate the nitrogen and the MR fluid[13]. Also, the coil produces the electromagnetic field by the current passing through it. The annular orifice allows the MR fluid passing up and down. And also, the bearing & seal is used to prevent the friction. The MR fluid valves and associated magnetic circuit are fully contained within the piston. These magnetically controlled valves regulated the flow of MR fluid within the damper[14]. Current is carried to the electromagnetic coil via the leads through the hollow shaft. When the current through the valves the MR fluid will change the state into solid. Then the damping force will increase. By changing the current, the damping force can be changed so that the damping can be controlled.[15]

For the smart adaption, ultrasonic transceiver is used which consists of an ultrasonic wave generator and receiver. The ultrasonic wave generator generates the sound waves which are transmitted to a particular distance assuming the surface to be flat. The time is taken for the reflected wave to be detected caught in the reference or base time. If there

are any irregularities on the surface, the time required for the reflected wave to be detected obviously changes<sup>2,3</sup>. Based on the time difference, we change the stiffness factor of the suspension system[14].



Fig.4.MRDamper[14]

MR device installed on Land Rover Aurora 2016 Sport Utility Vehicle (SUV) car, which is composed of MR fluid, piston, conducting coil, floating plug and spring[16].

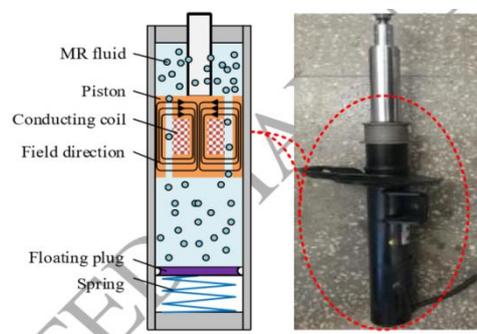


Fig.5.MR Shock Absorber[16]

## VI. CONCLUSION

In this paper, we had studied the different conventional suspension systems. Such type of conventional suspension systems can work either in soft or stiff condition nor both. To overcome this problem we had designed new model of suspension system consisting of MR damper. For this, we studied different properties of MR fluid along with their advantages and respective problems. We also studied the current design of conventional MR Damper and we had tried to improve that design.

## REFERENCES

- [1] Ayman A. Aly, and Farhan A. Salem, " Vehicle Suspension Systems Control: A Review "
- [2] Bhuwaneshwar Chandekar, Hemant D. Lagdive, "Design of Electro-Hydraulic Active Suspension System for Four Wheel Vehicles"
- [3] Gadhia Utsav D., Prof. Sumant P. Patel, " Design and Problem Identification of Wagon-R car's Rear Suspension"
- [4] Mert SEVER, Hasan Sefa SENDUR, Hakan YAZICI, M. Selçuk ARSLAN, " Electro hydraulic suspension system design with optimal state derivative feedback controller"

- [5] Muhammad Zahir Hassan, MohdKamarulHafis Abdul Aziz, Frank Delbressine and Matthias Rauterberg, "Numerical Analysis of Spring Stiffness in Vehicle Design Development Stage"
- [6] S.ElizabethPremalatha, R. Chokkalingam, M. Mahendran, "Magneto Mechanical Properties of Iron Based MR Fluids"
- [7] Arne Lind, "Semi-active suspension systems using magneto-rheological fluids"
- [8] Mr.Vinayak D. Dabade, Prof. Y. R. Patil, Prof.M.V.Kharade, Prof. P.R. Patil, "smart material: magneto rheological fluid"
- [9] K. Rama Raju and D. VineethVarma, "Developments in vibration control of structures and structural components with magnetorheological fluids"
- [10] James Sathya Kumar, P. Sam Paul, GirishRaghunathan and Divin George Alex, "A review of challenges and solutions in the preparation and use of magnetorheological fluids"
- [11] Mark R. Jolly, Jonathan W. Bender, and J. David Carlson, "Properties and Applications of Commercial Magnetorheological Fluids"
- [12] A. Roszkowski, M. Bogdan, W. Skoczynski, B. Marek, "Testing Viscosity of MR Fluid in Magnetic Field"
- [13] C. Wu, Y.C. Lin and D.S. Hsu "PERFORMANCE TEST AND MATHEMATICAL MODEL SIMULATION OF MR DAMPER"
- [14] V. Krithika, C. Subramani and A. Geetha "Smart Adaptive Suspension System using MR Fluid"
- [15] Henri GAVIN, Jesse HOAGG and Mark DOBOSSY "OPTIMAL DESIGN OF MR DAMPERS"
- [16] HuiPang, Fan Liu, ZerenXu "Variable universe fuzzy control for vehicle semi-active suspension system with MR damper combining fuzzy neural network and particle swarm optimization"
- [17] Krishnan Unni R, N. Tamilarasan "Design and analysis of a magneto-rheological damper for an all terrain vehicle"
- [18] ItthisekNilkhamhang, Tomoaki Mori, Akira Sano "Direct and Indirect Stable Adaptive Control for Suspension Systems with MR Damper"
- [19] Arjon Turnip, Keum-Shik Hong\* and Seonghun Park "Control of a Semi-Active MR-Damper Suspension System: A New Polynomial Model"
- [20] Jian Wu, Hongliang Zhou, Zhiyuan Liu, MingqinGu, "A Load-dependent PWA- $H_\infty$  controller for semi-active suspensions to exploit the performance of MR Dampers"