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ISSN: 2277-9655
[ICMTEST] Impact Factor: 4.116
IC™ Value: 3.00 CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

COMPARATIVE STUDY OF SEMI-ACTIVE CONTROL DEVICES USED IN AUTOMOBILE SUSPENSION

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ABSTRACT

The suspension system plays a main role in vehicle dynamic system. The semi-active suspensions are widely used in automobile industry with low price and low energy consumption. The design of vehicle suspension is very important to improve comfortableness and better performance. Suspension systems are classified into three types those are passive, semi-active, active suspension. This review paper involves comparative study of various semi-active control devices. Especially, some damper such as magneto-rheological (MR) damper, electro-rheological (ER) damper and piezoelectric-based friction damper are available in practice.

KEYWORDS: MR fluid, ER fluid, Electric field.

I. INTRODUCTION

There are three main types of vehicle suspensions: passive, semi-active and active suspensions which mainly improve seat and vehicle ride comfort, vehicle safety, road damage minimization and the overall vehicle performance [8]. Passive suspensions used in certain frequency range as they are effective only in a certain frequency range and no on line feedback is used. Active suspensions can improve the performance of the suspension systems over a wide range of frequency. However, active suspension has the one lack that is require more power supply that prevents this technique from being used extensively in practice [5].

Compared with active and passive suspension systems, the semi-active suspension system have advantages of both active and passive suspensions; i.e. it provides good performance compared with passive suspensions and is economical, safe and does not require higher-power actuators or a large power supply [10]. Semi-active suspensions were introduced in the early 1970s which can as effective as fully active suspensions in improving ride quality [1]. Since 1970s, semi-active suspensions have received much preference since they can get better performance than passive suspensions and consume much less power than active suspensions [10]. A damper (shock absorber) is a mechanical device designed to smooth out or damp shock impulse, and dissipate kinetic energy [2]. Especially, some controllable dampers, such as magneto-rheological (MR) dampers, electro-rheological (ER) dampers, and piezoelectric-based friction dampers are available in practice. Semi-active suspensions are more practical than ever in engineering awareness [5].

A.Q. Bhatti and H.Varum study the Effect of temperature on the damping properties and characteristics of the different vibration types. They found semi-active control is the best choice because the results of computer simulations indicate major improvements in displacement and force damping. Martin Orecny, Stefan Segla, Robert Hunady, Zelmira Ferkovab study the affectivity of a DA on seat suspend by a MR damper. The effect of the applied DA is negligible because the MR dampers reduced the maximal amplitudes to values that are almost unnoticeable for the operator situated on the seats [4]. Avinash B, Shyam Sundar S, K V Gangadharan was compared damping rate of the different fluid medium of a damper. MR fluid has much good damping properties compared to the silicon oil and air. Fluid can Increase their damping rate under the influence of magnetic field [8]. Abroon Jamal Qazi, Umar A. Farooqui, Afzal Khan, Farrukh Mazhar, Ali Fiaz demonstrated successful application of hybrid artificial intelligence techniques in designing a semi-active suspension system. The performance of semi-active control devices is much better in comparison with the passive system in terms of road handling and ride comfort [11]. B. Lafarge, C. Delebarre, S. Grondel, O. Curea, A. Hacal study the design and analyze piezoelectric vibrations harvesters located in a vehicle suspension for powering standalone systems, such as wireless transducers. The main advantage of using ambient energy converted by piezoelectric materials instead of batteries is to decrease the system installation price [12].

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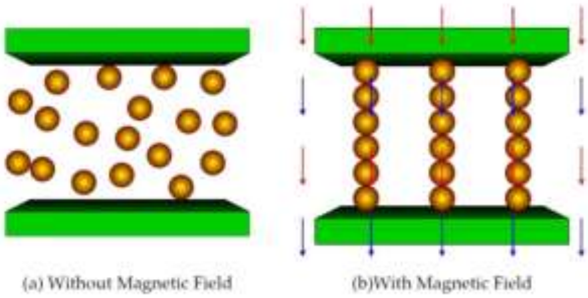
1. Magneto-rheological Damper
MR dampers have found considerable attraction in vibration reduction of vehicle seats and vehicle suspensions [15]. Magneto-rheological fluids have existed for over fifty years. Now, they are stable and have many attractive features such as high yield stresses and low viscosity. They have many applications such as automotive damping. Magneto-Rheological Fluid technology has been successfully established in various automotive applications like in vehicles seat suspension [9].

2. Electro-rheological Damper:
A variable damper is constructed with ER (Electro- Rheological) fluid. A bilinear optimal control is applied to regulate the viscosity of the fluid. ER fluid supply an effective control method and provide a practical useful control system for vibration of vehicles [7].

3. Piezoelectric friction based Damper
Piezoelectric based fiction damper have only recently been introduced to be used in vibration control system. However, the development of such a device is still in its beginning [13].

II. MAGNETO-RHEOLOGICAL FLUID
Major components of MR fluid are oil and iron particles which vary in percentages according to the applications and properties. Iron particles are coated with anti-coagulant materials. When this combination of fluid is in inactive state, it acts as typical natural oil [9]. These magnetic particles may be iron particles that can measure 3-10 microns in diameter [15]. The particles will be formed into chain-like fibrous structures in the presence of a high electric field or a magnetic field. When the electric field strength or the magnetic field strength reaches a certain value, the suspension will be solidified and has high yield stress; conversely, the suspension can be liquefied once more by removal of the electric field or the magnetic field. The process of change is very quick, less than a few milliseconds, and can be easily controlled [10]. With absence of applied magnetic field (off state), MR fluids behave as a Newtonian-fluid. Applying an external magnetic field through the fluid activates MR fluids, causing the micron-sized particles to form magnetic dipoles along the magnetic lines of force [9].



III. ELECTRO-RHEOLOGICAL FLUID
The principle of ER damper is to utilize the characteristic that the viscosity of fluid changes with voltage charged on [7]. This fluid contain of micro-powder particles dispersed in a non-conductive liquid. When subject to an electric field, the viscosity and yield shear stress of the liquid increase with the electric field to such an extent that the liquid may become plastic, and when electric field is removed, the plastic is quickly turned into liquid again. Its response time is very less about few milliseconds. It is easy to control, fast to respond, simple to install and versatile. The controllable rheological nature of this versatile material has been evaluated for a huge range of application concepts. Hence, ER fluid has a high potentiality for industrial development, such as clutches, seals, bearings, chucks, hydraulic control valves, couplings, shock absorbers and dampers of vibration system [14].

ER and MR fluid dampers enable active and semi-active vibration control systems with reaction times in the range of milliseconds and, additionally, low power requirements when using MR fluids [1].

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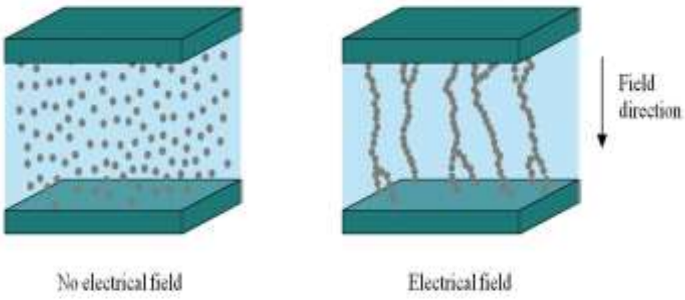


Table 1: Typical properties of some electro- and magneto-rheological fluids [1]

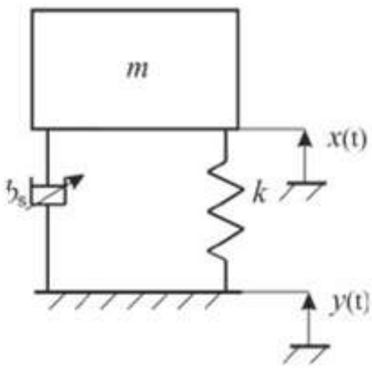
Property	ER Fluid	MR Fluid
response time	Milliseconds	Milliseconds
plastic viscosity h (at 25 _C)	0.2 to 0.3 Pa. s	0.2 to 0.3 Pa. s
operable temperature range	+10 to +90ºC (ionic; DC) -25 to +125ºC (non- ionic; AC)	- 40 to 150 ºC
power supply (typical)	2 to 5 kV, 1 to 10 mA, (2 to 50 watts)	2 to 25 V, 1 to 2 A, (2 to 50 watts)
maximum yield stress	2 to 5 kPa (at 3 to 5 kV/mm)	50 to 100 kPa (at 150 to 250 kA/m)
maximum field	ca. 4 kV/mm	ca. 250 kA/m
Density	1 to 2 g/cm3	3 to 4 g/cm3

IV. COMPARISON OF ER AND MR FLUID

Due qualitatively similar behaviour phenomenological models of ER and MR fluid devices can mostly be applied to either material. ER and MR fluid consist of micron-sized polarisable or magnetisable solid particles dissolved in a non-conducting liquid like mineral or silicone oil [1]. Some properties of electro- and magneto-rheological fluids are provided in Table 1. Show about the same response time and plastic viscosity h, MR fluids are less sensitive to impurities, such as water. They have a larger operating temperature range, and they can be controlled within lower voltage supply. Often iron is used as a solute, the density of MR fluids is significantly higher than for typical ER suspensions. A greater variety of materials is available for ER fluids, and electric fields are often more suitable for complex geometries and small dimensions.

V. MR DAMPER MATHEMATICAL MODEL

MR damper technology was originally developed by General Motors for use in the Cadillac and Chevrolet Corvette in 1998 [2]. The operator seat will be considered as a simple suspended mass. The suspension is realized by a coil spring and a magneto-rheological (MR) damper [4].



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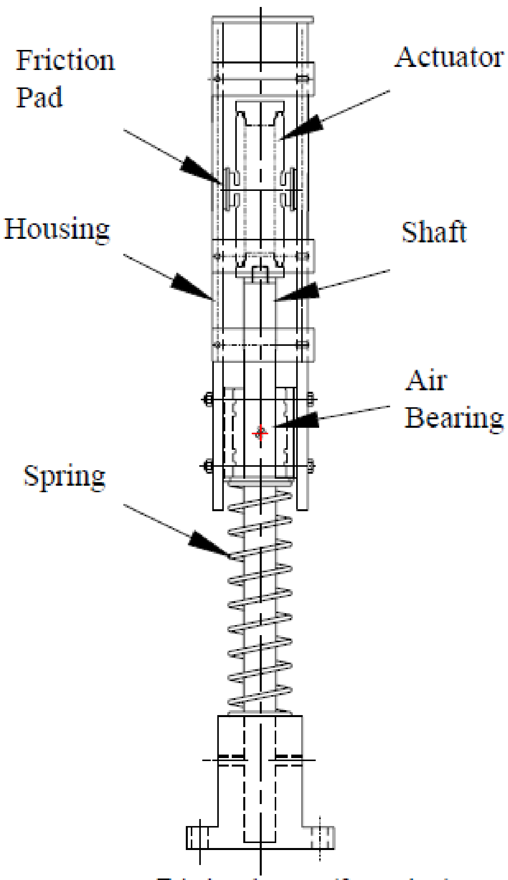
The equation of motion of the first investigated model is as follows:

$$M\ddot{x} + Fs + k\,(x+y) = 0.$$

The magneto-rheological damper used in the study is RD 1097-01 manufactured by Lord Corporation. This type of damper is appropriate for cases where a high degree of controllability is needed. As is known the MR dampers have their hysteresis. The generated MR damper force Fs is in this case dependent on two parameters. The first one is a velocity and the second is an applied electric current on the MR coil [4].

VI. PIEZOELECTRIC FRICTION DAMPER

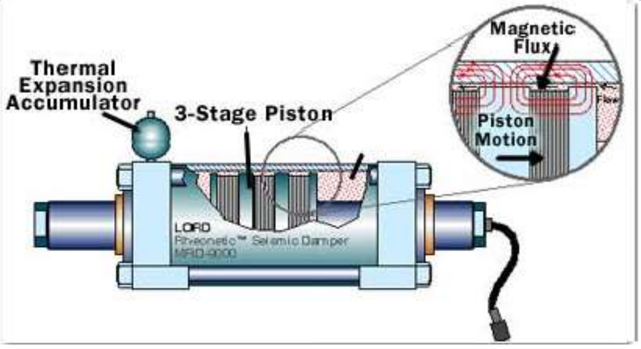
The friction damper consists of many moving and fixed components as shown in Figure. The moving components consist of the outer housing and the air bearing. The outer housing also comes in contact with the friction pads as it vibrates. The friction pads are fixed to both sides of the actuator so that the normal force that the actuator applies is symmetrical. The normal force provided between the friction pads and the outer housing induces a frictional load, which retards the motion of the outer housing. Within this damper, there is also a spring, which connects the moving housing to the stationary base. With the frictional pads not engaged, the air bearing provides a relatively frictionless contact surface [13].



Friction damper (front view)

VII. SKY HOOK CONTROL

Damper of the seat was controlled by the well known sky hook control strategy. The strategy was set as an on-off control. The current of the damper in the off state is 0 A. In the on state the current is at a maximal set value 0.4 A.



VIII. CONCLUSION

In this paper we have studied the application of semi-active suspension for the vibration reduction in a class of automotive systems by using various dampers. By theoretical comparison between the above semi-active suspension system and fixed damping settings it seems that MR damper is more preferable in practical use. As reduction of vibration using an idealized semi active suspension with a dynamic absorber in magneto-rheological damper improved the reduction of vibration only for about 7%. ER and MR fluid dampers enable semi-active vibration control systems with reaction times in the range of milliseconds and, plus, low power requirements when using MR fluids. So MR damper is more preferable.

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