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Review Article

A Review of half-car model vibration system using Magneto rheological Dampers

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Abstract

The suspension system is very crucial when considering the ride comfort of vehicle driver and passengers. Most of the research these days is based on the use of semi-active suspensions for vehicle suspension system. This system having a semi-active suspension with MR dampers is promising way of improving the ride comfort. This paper reviews the various ways of improving the ride comfort using various mathematical models, experimental work and gives an overall conclusion of why using a semi-active suspension system with MR dampers is better than using a passive system or an active system..

Keywords: *Semi-active suspension system, MR dampers*

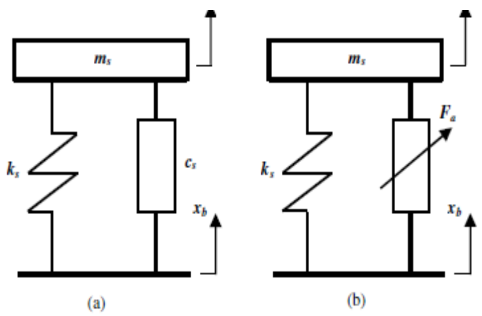
1. Introduction

Vehicle seat suspension systems play a very vital role in driver's and passengers' comfort. The primary function of the suspension system of a vehicle is to isolate the vehicle body from the road loads and to provide favorable handling by maintaining the road-tire contact[Anria Strydom , Sudhir Kaul , 2012]. The suspension can be achieved either by passive suspension or using active or semi-active suspension. Passive suspensions make use of oil dampers which can be used as it is economical and simple. But the performance is not improved efficiently. Seat suspension system is required to perform its function at lower frequencies because the vibration energy is produced at lower frequencies (generally less than 10Hz). Active suspension provides high performance improvement at any range of frequencies but the design is complex and costly as it requires high power requirement, variety of sensors and servo valves. Semi-active vibration isolation is intermediate between active and passive. The drawbacks are eliminated by semi-active suspension system which provides comparable performance to active suspensions but without the high cost[H. Metered , p. Bonello, s. O. Oyadiji,2009]. Semi-active devices like Magnetorheological Dampers can be used as they have the ability to provide adjustable damping. The fluid in these dampers has micron-sized magnetically polarizable particles suspended in a fluid with additives to take care of the settling, to enhance stability, improve lubrication and inhibit wear. These devices are preferable as the vehicle can generate voltage/current required to control the variable damping force. The voltage which the electromagnet receives can be directly controlled rather than the desired control force [Anria Strydom , Sudhir Kaul , 2012]. Hence, this suspension system is widely used for vehicle seat isolation. The potential application of MR damper in vehicle suspension system is reviewed.

2. Need of work

Vehicle suspension systems play a vital role in the comfort of the passengers. So , a lot of research is going on in the field of vehicle suspension to find an efficient and cost effective suspension system. It considers the isolation of vehicle seat from the road irregularities. From the 3 suspension systems viz. passive , semi-active and active , the semi-active suspension system is found to be cost efficient and effective. Hence , it is the most widely used suspension system.

3. Mathematical Modeling



(a)Passive (b) Semi-active

Fig.1 Vehicle seat suspension system

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Figure(1) shows passive and semi-active suspension models based on Single Degree Of Freedom (SDOF) The damper is represented by a controllable MR damper force, which is adopted in this study using the Modified Bouc-Wen model [H. Metered , p. Bonello , s. O. Oyadiji , 2009].

The governing equation of the motion of vehicle seat suspension is

$m_s x_s + k_s(x_s - x_b) + F = 0$

where ,

$F = c_s(x_s - x_b)$ *for passive suspension*

$= F_a$ for semi-active suspension

A suspension system in which there is a small relative displacement has high sprung mass acceleration while large relative displacement is observed to have low sprung mass aceeleration. Hence , the control is achieved such that the MR damper is switched to a high damping ratio as the relative displacement is higher than a specific value and a low damping value otherwise[Y. SHEN , M. F. GOLNARAGHI , G. R. HEPPLER , 2005]. This control is given by –

$$\Gamma s = \Gamma_{max} \qquad |x_s - y| \geq \delta$$
$$= \Gamma_{min} = 0 \qquad |x_s - y| < \delta$$

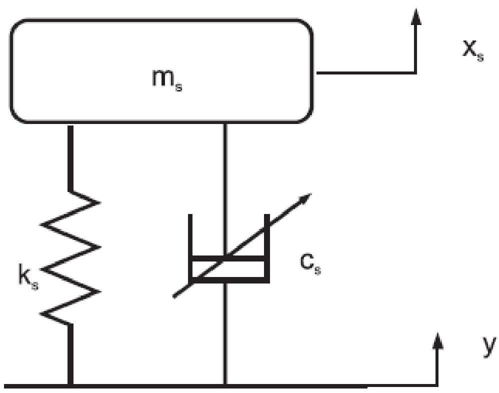


Fig.2 1DOF suspension system

According to skyhook working principle , the semi-active law for on-off control is –

$$\Gamma_s = \Gamma_{max} \qquad x_s(x_s - y) \geq 0$$
$$= 0 \qquad x_s(x_s - y) < 0$$

Figure(2) is a 2-DOF vehicle using a MR damper. The dynamics of the damper are modeled using Bingham model (the first model used to study the behaviour of MR damper)[R N Yerrawar , Dr.R.R.Arakerimath , Patil Sagar Rajendra , Walunj Prashant Sambhaji , 2014].

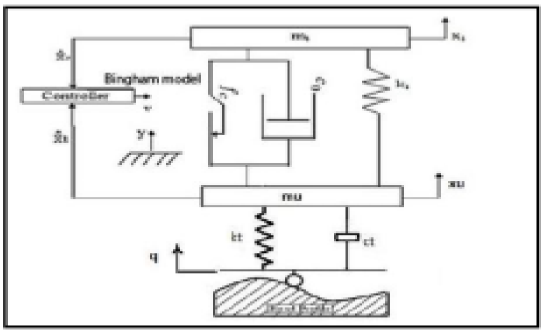


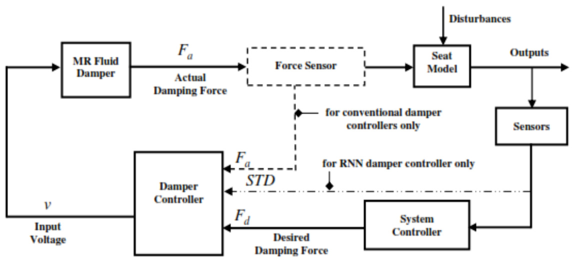
Fig.3 Car model with MR damper

The motion equations of the car body and wheel of this model are given as

$$m_s x_s = -[k_s(x_s - x_u) + f_a]$$
$$m_u x_u = -\{-[k_s(x_s - x_u) + f_a] + [k_t(x_u - q) + c_t(x_u - q)]\}$$

4. Semi-active control using MR dampers

The following figure describes the block diagram of the semi-active suspension system using an MR damper[H. Metered , p. Bonello , s. O. Oyadiji , 2009]. The system has 2 nested controllers, one system controller and one damper controller. The system controller is used to calculate the desired damping force using the dynamic response of the seat suspension mathematical model. The damper controller adjusts the voltage applied to the damper so that it can track/compare the actual force to the desired force. The output of this damper is fed to the Modified Bouc-Wen model.



This figure shows the semi-active system for a vehicle seat in which an MR damper is used. The inverse RNN controlled dampers are preferred over the conventional control dampers because the conventional damper controllers need to be fed by calculating the actual force from a force sensor shown in the figure. This sensor is required to be connected in series with each MR damper which reduces the reliability and increases the cost. The inverse RNN damper controller measures the Seat Travel Displacement (STD) which is already available from the sensors used by the system controller.

5. Experimental Work

This setup is used to collect the data in order to build the BLS and LMS models [Anria Strydom , Sudhir Kaul , 2012].

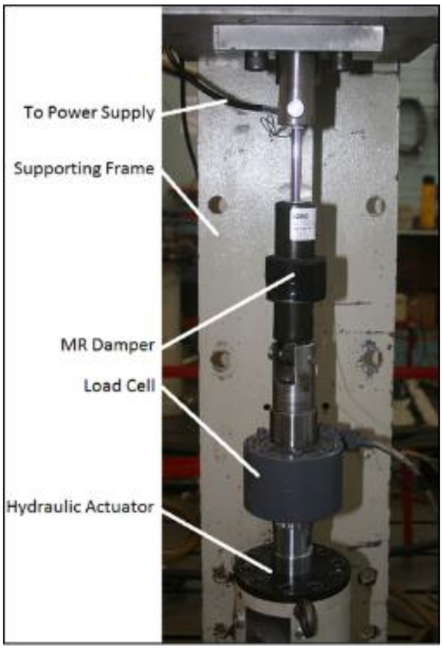


Fig.4 Damper characterization setup

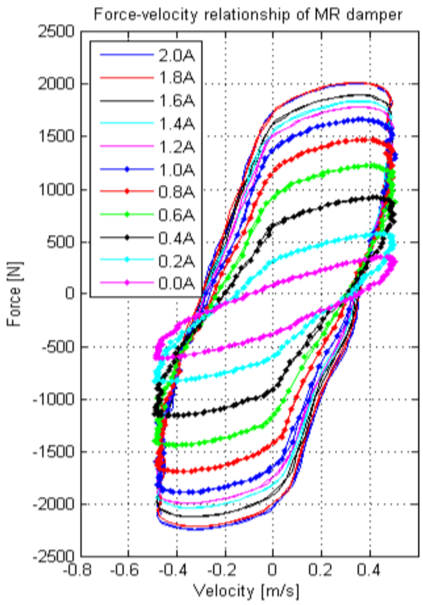


Fig.5 Measured data at 10mm amplitude and 8Hz

The Root Mean Square (RMS) error is used to find out the accuracy of the models.

$$RMS\ Error = \frac{\sqrt{\sum_{i=1}^{n}[\hat{f}_i(t) - f_i(t)]^2}}{n}$$

The experimental work helps to determine the dependence of vibration isolation transfer coefficient of external vibration frequencies. The following figure shows the dependence of vibration isolation transfer coefficient of the frequency of external vibrations[Alexey m. Bazinenkov , valery p. Mikhailov , 2015].

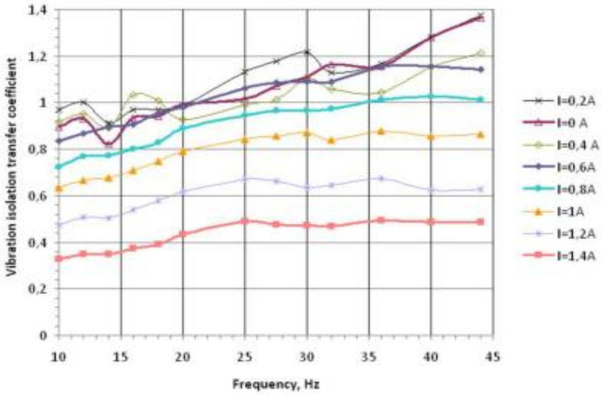


Fig.6 Experimental diagram of dependence of the vibration isolation transfer coefficient from the frequency of external vibrations

Figure 7 shows the suspension testing machine which is used to verify the efficacy of the various control methods.

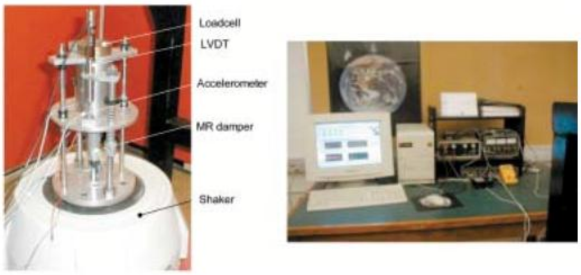
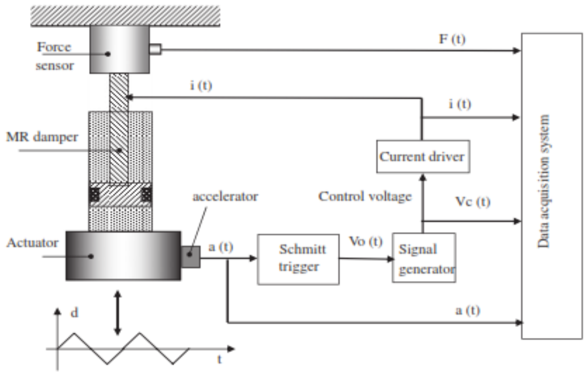


Fig.7 Car model suspension test rig

3 sensors are present to calculate the response of the system. A load cell is used to measure the damping force on the sprung mass , an LVDT is used to measure the relative displacement of the sprung mass and 2 accelerometers are used to measure the acceleration of the sprung mass and the base[Y. Shen , m. F. Golnaraghi, g. R. Heppler , 2005].

Figure 8 shows the test setup for measuring the time response and damping force of the magneto rheological damper.



The damper is actuated by material test system frame. The force change due to the velocity makes the analysis complicated as we are only concerned with the change in force due to the control input.

The figures indicate the response of the step-up input and the step-down input [Miao Yua, , X.M.Donga, S.B.Choib, C.R.Liaoa , 2008].

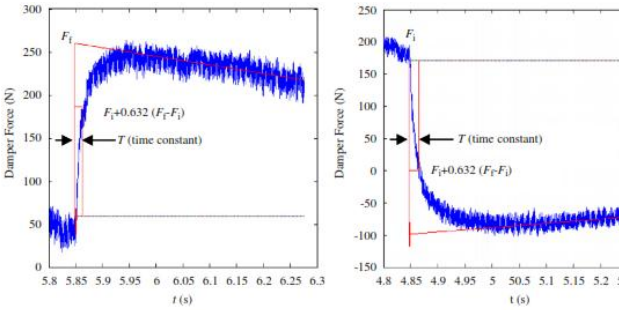


Fig.8 Time response of the damping force under step current input

Figure 9 shows the responses of MR dampers at frequency of 1Hz for five constant electric currents. When the applied electric current is increased , the damping force increases considerably , but if the current exceeds 0.75A then the change in the damping force is not significant[G.Z. Yao , f.f. Yap, g. Chen , w.h. Li , s.h. Yeo , 2001].

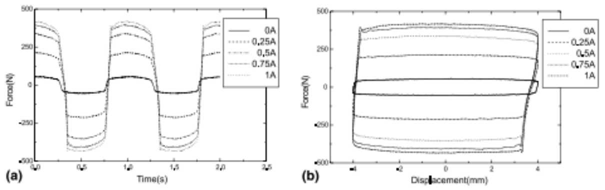


Fig.9 Comparison of estimated responses with corresponding experimental responses

6. Conclusion

The semi-active suspension system is reviewed and the following important conclusions are noted. The control methods viz. the R-S control and the MSK control method have more vibration control capabilities than by applying a constant current/voltage to the MR damper of the system. Hence , these control methods are preferred over the methods which use constant current/voltage. As the semi-active suspension system is able to vary its properties more freely than the passive suspension , it is being preferred over the passive suspension system. While studying the fundamental principles of the semi-active suspension system, several critical criteria such as weight , size , shape center of gravity , types of dynamic disturbances must be considered for proper result . If these important criteria are not considered , the design may fail or the system will not function properly. The preliminary simulation of the 2-degree-of-freedom model in which magnetically suspended vehicle is used showed that significant improvements related to the constant-damping linear suspension are possible using semi-active suspensions When compared to the seat suspension using the passive hydraulic dampers , the seat suspensions in which self-powered MR dampers are used reduced the values of the peak acceleration and RMS acceleration]. These values of peak and RMS acceleration are not reduced significantly in case of passive suspensions. The MR fluid dampers provide considerable scope to achieve better compensation of shock and vibration attenuation performance of suspension seats. It can be also seen that the power consumed by the controlled MR damper system is very much less than the system in which a constant voltage is provided]. The semi-active suspensions with new control strategies are more effective than the passive or semi-active suspensions with current neural network control]. These systems are developed by using Recurrent Neural Network (RNN) which increases the system reliability. The response of the vehicle which is modeled by the Modified Bouc-Wen model shows that the performance of the MR suspension can be improved by using the preview information and it is better than the performance of the passive suspension. If the variable damping coefficient is considered , the system which has a damping coefficient limit of 4000 N.s/m is the best when ride comfort is considered]. If the damping coefficient exceeds this value , it may reduce the ride comfort. The MR damper has a very large range of changeable damping force under the magnetic field and can be controlled by changing the applied voltage/current. Considering all these factors , the semi-active suspension system using MR dampers can be used for vehicle seat isolation as it is the most efficient and cost effective method and this provides the scope for further research.

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