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Review Article

Semi-Active Suspension system with M.R. Damper for car seat vibratio n- A Review

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Abstract

The paper throws light on advancement done in order to increase ride comfort of driver in an automobile.These road vibrations are measured in form of pulses and according to it relations are plotted against damping force required for stability of passenger seat.. This work investigates propagation of shock pulses from road conditions by presentic different mathematical models of quarter car semi active suspension system. A 2DOF system is first studied, which was then modified to three degrees of freedom with fuzzy control of quarter car system and afterwards 2 additional degrees of freedom were added to a quarter car model. A skyhook system was then introduced which used with two different sensors to measure two different masses. Finally a critical comparative study was conducted at end of each model to compare performance characteristics of passive (classical type) damping system and semi active suspension system with MR damper employed to quarter car system.

Keywords: *Magneto-Rheological fluid, Semi-Active control, Driver seat, Quarter car model.*

1. Introduction

Suspension system amongst automobile has vital role to be played in vehicle stability. They are also called as shock absorbers as they absorb the bumps and jerks coming to car passengers from various road conditions. Depending on effectiveness and performance in providing stability to automobile suspension systems can be classified in three types namely Passive or uncontrolled suspension system, Active damping system, Semi-active suspension system. Passive seat suspension have been demonstrating their results as they have single degree of freedom[SDOF]suspension system. Insufficient damping provides poor resonance control and good high frequency isolation whereas on the other hand large damping results in good resonance at expense of high frequency isolation.(Ayman,F.Z,El,GamalH.A,ElSouhily B.M,2014)
Passive suspension system has limited range of operating conditions whereas Semi active suspension system overcomes this limitation by performing equally over wide range of operating conditions. Several researchers have studied these systems for driver seat damping (Saikat Dutta, SangollaNarahari, Goutam Chakraborty, Dec 18-20 2013). Semi Active suspension with MR (Magneto-Rheological Damper) consist of MR fluid cylinders which helps in reducing road shocks. The performance related to damping parameters of semi-active systems is directly proportional to the selected and implemented control strategy. There were many different already established control strategies which researchers had studied such as preview control. Linear optimal control .sliding mode control, skyhook, ground hook and hybrid control , model-following sliding mode control , nurofuzzy control, gain scheduling control, H∞ control, on–off sky-hook, continuous sky- hook, on– off balance, continuous and adaptive damping control, fuzzy logic control and human-simulated intelligent control for the development, testing, performancecomparison and implementation of necessary mechatronics based devices using semi-active technology.(Devdutt, M. L. Aggarwal,2014)

2. Need of Work

Ride Comfort is very important as far as well being of vehicle operator is concern. Thus a lot of efforts are being taken to increase ride comfort. RIDE COMFORT is directly related to seat mounting as seat mounting is the ultimate connection of passenger and road conditions. Therefore efforts are to be made to isolate vehicle seat from road conditions. This control strategy is found to best suitable for a quarter car model. Semi active suspension technology deals with vibration problems related to comfort at wider frequency range as compared to passive which was used earlier.(Hiroaki RYUJIN7, August 1-6, 2004)

3. Types of Papers

3.1 Original Paper

Various papers which reports technically original research output, which has academic and/or industrial

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contributions. Original papers conducts full peer review. These papers mainly have their focus on experimentation and research of the topic on which they are being published.

3.2 Review Paper

A brief evaluation of a current technology in driver seat isolation system and application of product in quarter car system. It also throws light on potential area of developments and various conclusions and variable factors related to it.

4. Mathematical Modeling

4.1 Quarter car Model (Bouc-Wen equation)

The equation of motion of quarter car model with MR Damper is modeled mathematically as Modified Bouc-Wen model can be expressed as:

The schematic diagram for quarter car model is given in given fig.1: (Saikat Dutta, SangollaNarahari, GoutamChakraborty, Dec 18-20 2013)

$m_1\ddot{x}_1+k_{11}(x_1-x_2)+f_{MR}=0$

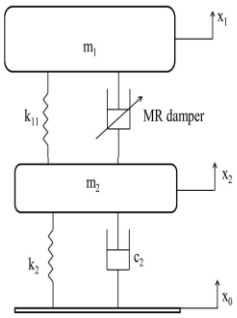

Fig.1 Schematic diagram quarter car model.(Saikat Dutta, SangollaNarahari, GoutamChakraborty, Dec 18-20 2013)

4.2 Quarter car Model (Spancer Model)

This mathematical model of Semi-active suspension for quarter car system considers driver seat has two degree of freedom i.e. rotary motion as well as vertical motion. The Two masses of wheel and unsprung mass are having vertical displacement. (Mahmoud El-Kafafy, Samir M.El-Demerdash,2012). By application of Newton's second law of motion to the quarter car model, the equations of both the masses can be obtained. The damping force in MR damper is derived as:

$F_d=C_1(\dot{y}-\dot{x}'_w)+k_1\{(x_B-x_W)-x_0\}$…….. (Mahmoud El-Kafafy, Samir M.El-Demerdash,2012)

4.3 Bingham Model for quarter car system

Controller generates the voltage 'v' in the MagnetoRheological damper which modifies the force *for* semi active suspension. By Referring to fig.2 we could see Bingham model for quarter car system. The motion equations of the car body and wheel of this model are as follows

$\mathbf{f_a= f_c.sgn_{\dot{x}}'+ c_0\dot{x}'+ f_0}$ (Amit et al)

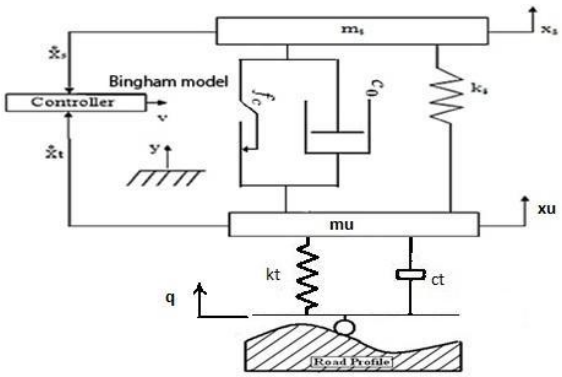

Fig.2 Schematic Diagram for bingham model Amit et al

4.4 Fuzzy logic Control for quarter car

This method was first proposed by LotfiZadeh (Zadeh L.A.,1965). This method uses the algorithmic fuzzy logic control fordamping of road shock Pulses. This method has been proved of great Significance in control of mechatronics application. Two inputs which are provided to this algorithm are driver seat velocity (V_p) and secondary suspension system velocity (V_{rel}) to get desired output damping force. These variables are designated as PL (Positive Large), PM (Positive Medium), S (Small), NM (Negative Medium) and NL (Negative Large) respectively. And these relationship of input and output variables are plotted against each other. As shown in fig.3 (Devdutt, M. L. Aggarwal,2014)

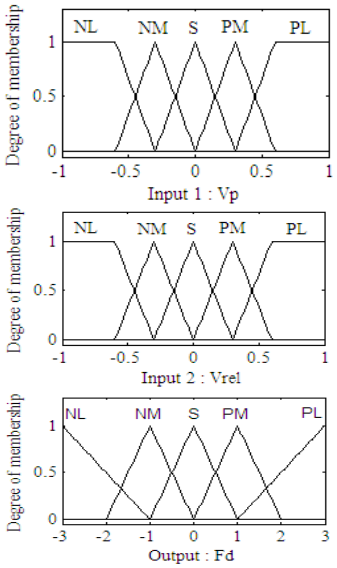

Fig.3 Membership function curves for FLC (Devdutt, M. L. Aggarwal,2014)

4.5 4DOF model (4 degree of freedom)

To design a fully efficient seat suspension system for quarter car model, wholly knowledge of actual actuator is essential. Consider a quarter car model system as shown in fig.4As vehicle is moved along a bumped road, shocks are transmitted through tires, axle & primary suspension of vehicle. This filters major portion of road shocks. Remaining portion of shock is available as input to seat suspension. If seats are just bolted to the body of the vehicle a quarter car seat isolation model can be added to the system.(Mark G. Malvoki,June 2000).

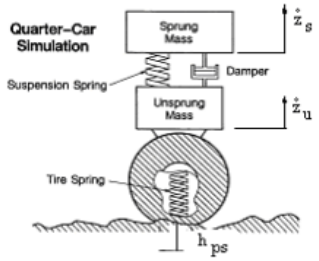

Fig.4 Quarter car model

Resulting 4DOF system is shown in fig.5 this introduces two additional degrees of freedom to consider effect of seat cushioning and primary suspension of the vehicle (Nishimura,H., Okumura,Y.and Shimodaira, S.2002).

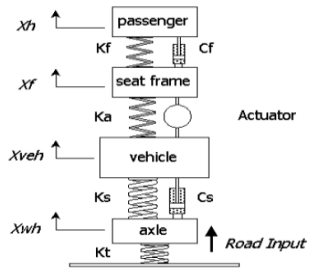

Figure 3.1: Four Degree Of Freedom Model

Fig.5 4DOF Model

The analysis may either be done by considering rigid seat without cushioning for weight reduction requirement. Thus vertical model serves well in determining vehicle forces and damping forces. The notations for vertical positions are given by x_h for the human passenger, x_f for the seat frame, x_{veh} for the vehicle (sprung mass) and x_{wh} for the wheels and anxle (unsprung mass). Thus equation can be written in the state space according to following equation. (Mark G. Malvoki,June 2000)

$\dot{x} = F_x + G_u$
$_y = H_x + j_u$

Where
x= State vecrot
u= Control vector
y= Output vector
F= State matrix
G= Input matrix
H= Output matrix
J= Feed forward Matrix

4.5 Sky-Hook control for semi active suspension

Xubin Song (Xubin Song,2009) designed cost effective skyhook control for driver seat semi-active suspension applications. In skyhook controlthere are two sensors adapted to measure sprung mass acceleration and relative displacement. A change observed is made by eliminating one sensor rather than using two.

Comparison between active and passive control system can be clearly seen from following fig.6

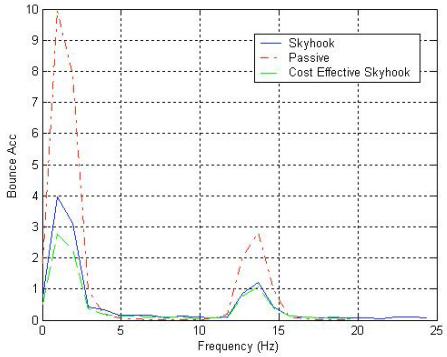

Fig.6.1 Comparisons of Bounce acceleration

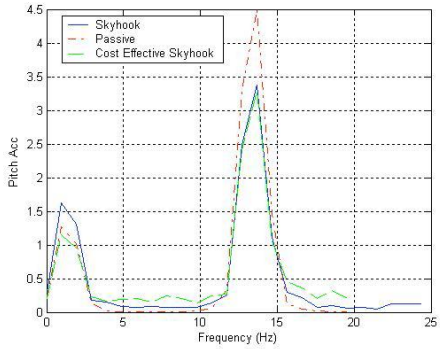

Fig6.2 Comparisons of Pitch acceleration

In automobile industry, both cost and reliability are of big concern. They are primary objectives for every design. It is engineer's duty and challenge to him to develop more cost-Effective control algorithms but maintain a high quality for production. (Xubin Song,2009)

Conclusions

Ride comfort is very important as far as well being of vehicle operator is concern. Thus a lot of efforts are being taken to increase ride comfort. Ride comfort is directly related to seat mountings, thus efforts are

being made to isolate vehicle seat from road vibrations. MR-Damper reduces more amplitude for same velocity of vehicle than classical type. It produces more efficient operation with less consumption of power as only power source required in this case is voltage applied across MR damper, which is substantially less as that of required by conventional passive suspension system. At first spancer model emphasizes 2DOF system, suspension is achieved reduction of impacts on seat by application of 2 state dampers. Time for which vehicle is unsteady is less in MR damper. Amplitude of voltage is directly proportional to voltage provided to damper. Thus vehicle experiences small accelerations with MR damper.(Ayman,F.Z,El,GamalH.A,ElSouhily B.M,2014) MR damper system is found to work better under sinusoidal road conditions.In case of sinusoidal road pulses, the control strategy works more efficiently for low frequency excitations. At high frequency excitation, the control strategy does not perform as effectively as before and needs to be improved.(Saikat Dutta, SangollaNarahari, GoutamChakraborty, Dec 18-20 2013) Although it has seen that damper performs to its optimum capacity for cosine roads efforts needs to be taken for different road pulses rather than cosine road to improve performace. It has been observed tha MR fluid works efficiently under wide range of conditions as that compared to conventional system. And to get optimum result of damping through semi-Active suspension it is required that internal friction in the system need to be kept low and electromagnet used should be capable of producing high frequency magnetic field.(M. Unsal, C. Niezrecki, C. Crane III) However the problems associated with fluid system pops in this application such as viscosity of polarized MR-fluid may be affected by different temperature conditions, leakage may occure due to wear of damper piston rings. In Skyhook concept to study damping capacity, it is assumed that damping force required to be should be exactly equal and opposite to the reference force. (Mahmoud El-Kafafy, Samir M.El-Demerdash,2012) This approximation made in skyhook control strategy may lead to errors. Due to rapid on-off of damping force may cause short high frequency sounds near switching point. Introduction of dead band around switching point could be used as remedy to the problem. Further the study elaborates that how accurate analysis can be made by increasing degrees of freedom by even considering the cushioning effect of seat. (Mark G. Malvoki,June 2000).

Paper systematically presents the established research in the concern work and how it is being developed over the period of time. Vehicles withsemi-active controlled system represent better designs over car models with passive dual rate dampers, which in turn exhibit a better performance than models with linear suspension dampers, and provide more comfort to driver. Thus objective is completed to a large extend. (G. Verros ,S. Natsiavas,2005)

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