ANALYSIS OF SEMI ACTIVE SUSPENSION SYSTEM WITH THE HELP OF FUZZY LOGIC CONTROL AND QUARTER CAR TEST RIG

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Abstract*—This paper makes study on fuzzy logic controlled semi active suspension system. Quarter Car Model (2-DOF) is developed and simulation models are prepared in MATLAB/SIMULINK software. Input parameters for model simulation are taken from literature available and disturbances required checking for performances used here are step input, sine input from literature. Simulation of passive suspension and semi active suspension is done and their performances are compared by comparing displacement, velocity, acceleration, ride/comfort, handling plots. Fuzzy logic control is applied for semi active suspension to reduce compromise between ride and handling. Different membership function and rules are decided to get effective fuzzy control performance.

Keywords: Suspension System, Quarter Car, Fuzzy Logic, Step Input, Sine Input, MATLAB/SIMULINK.

I. INTRODUCTION

Suspension system is mechanism that physically separates the car body from the wheels of car. The purpose of suspension system is to provide the good ride comfort and stability of vehicle. Suspension systems are classified into three categories such as passive, Semi active and Active. This classification is done on the basis of performance of suspension system when vehicle is traveling. Passive suspension system have fixed value spring stiffness and damping coefficient which are fixed at designed stage, so passive suspension system can give good ride comfort at certain speed and frequency. Even though passive system has advantage of being cheap it has several drawbacks. Active suspension system uses actuators which externally apply force to vehicle body and give better ride comfort and vehicle handling. But active suspension system required complicated arrangements of actuators, control system; external power source which increases overall cost of system so application of active suspension system is limited to costly vehicles. On other hand semi active suspension system uses controllable damper in which Magneto Rheological (MR) fluid is used. Magneto rheological fluid changes its damping coefficient under the action of external magnetic field. Semi active suspension gives good ride comfort and vehicle handling as compared to passive suspension system. [1] Semi active suspension system is very simple in construction and cheaper than active suspension system. Due to these reasons semi active suspension system attracted many researchers to contribute in this field.

II. SUSPENSION SYSTEM MODELS

For different dynamical performance with suspension system different models for car can be understand. They may have different degrees of freedom, with which car models can be classified as Quarter car model (2 DOF, 3 DOF), Half car model (4DOF Roll model, 4DOF Pitch model), Full car model (7 DOF).[2]

III. CONTROL STRATEGIES FOR SEMI ACTIVE SUSPENSION SYSTEM

Large number of control strategies had been studied in past such as Skyhook control, Groundhook control, Hybrid control, PID control etc.

Skyhook control

Skyhook control strategy was presented by Karnopp in 1974. The damper is connected to Sky (a fixed y-axis). If the suspension damper is expanding and damper is moving towards the sky then skyhook controller turns the damper on and damper pulls down on the sprung body. The difference between passive and Skyhook control is that Skyhook controller varies the damping force. Skyhook control strategy improves the ride comfort but decreases road holding ability. [3]

Groundhook control

The Groundhook controller differs from Skyhook controller model. In Groundhook control damper is connected to unsprung mass unlike Skyhook control. The logic of Groundhook policy is similar to skyhook but only difference is that Groundhook controls unsprung mass and Skyhook controls sprung mass. Groundhook control strategy improves the vehicle handling but decreases ride comfort. [3]

Hybrid control

Hybrid control system combines both Skyhook and Groundhook control strategies to take advantage of both. Logic is exactly same as Skyhook and Groundhook control. Hybrid control improves both ride comfort and vehicle handling. [3]

PID controller

PID controller is placed between sprung and unsprung mass for controlling the viscosity of MR damper by varying the current supply to the MR damper.

PID controller is defined by equation,

Uc is the current input from the controller, Kp is the proportional gain, Ti and Td is the integral and derivative time constant of the PID controller respectively. Zegler Nicols proposed rules for determination of proportional gain Kp, integral time Ti and derivative time Td based on the transient response characteristics given by the system. PID controller improves both ride comfort and road holding. [4]

Fuzzy Logic Controller

Even if semi active suspension system have many attractive features it is very difficult to control the suspension system due to highly nonlinear and hysteretic characteristics of MR damper. So for development of good semi active suspension system, design of control strategy is most crucial part. [5]

Fuzzy logic controller can be used for controlling the current supplied to the MR damper similar as PID controller.

The purpose of this paper is to present Fuzzy logic algorithm for Quarter car model of two degrees of freedom semi active suspension system for improvement in ride comfort and vehicle handling. Also to compare semi active suspension system with passive system.

IV. MODELLING OF SUSPENSION SYSTEM

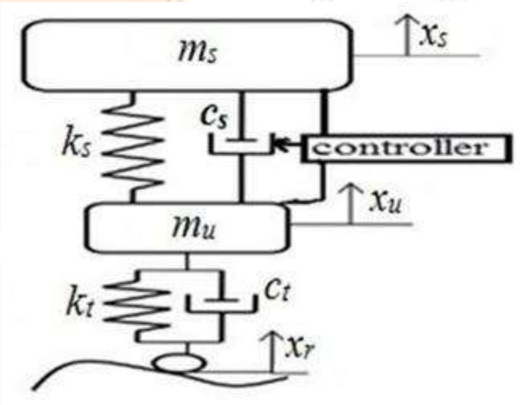

Figure 1:Semi active Quarter Car Model

A typical semi active suspension system can be modelled as shown in fig. 1. Since the model represents single suspension from one of the four corners of the vehicle. This two DOF system generally referred as the Quarter car model which includes unsprung mass representing the wheels and associated components. Sprung mass represents the vehicle body and is the portion the vehicle mass that is supported above the unsprung mass.

The parameters used in the simulation of this model are shown in table 1.

Table 1. Parameters for Simulation [6]

Parameter	Symbol	Value	Unit
Sprung mass	m_s	535	Kg
Unsprung mass	m_u	40	Kg
Damping coefficient	c_s	3002.3	Ns/m
Tyre damping	c_t	300	Ns/m
Spring stiffness	k_s	96000	N/m
Tyre stiffness	k_t	350000	N/m

V. CONTROLLER DESIGN

In this work fuzzy logic algorithm is used for designing control system for semi active suspension. Fuzzy logic algorithm is developed by Lotfi Zadeh which is very powerful tool for control system applications. Fuzzy logic controller is assembled between sprung mass and unsprung mass are inputs to fuzzy logic controller and desired damping coefficient is the output from the controller.

Triangular and trapezoidal membership functions are used for designing this system in which five linguistic grades are taken into account as: HN (High Negative); NN (Negative); ZZ (Zero); PP (Positive); HP (High Positive). Fuzzy rule base is shown in table 2.

Table 2: Fuzzy Rule Base

		Input 1 Relative Velocity				
		HN	NN	ZZ	PP	HP
	HN	HD	BD	BD	BD	MD
	NN	BD	BD	MD	MD	MD
	ZZ	BD	MD	MD	MD	GD
	PP	MD	MD	MD	GD	GD
	HP	MD	GD	GD	GD	LD

Here Mamdani method [7] is used for fuzzy inference system. For defuzzification i.e. transformation of resultant linguistic data into mathematical numerical Centroid method is used.

VI. SIMULATION RESULTS

MATLAB/Simulink software is used to evaluate the performance of designed Quarter car model semi active suspension system.[7] For measuring performance of suspension system, sinusoidal input is given to system because road surface is conventionally modelled as sinusoidal, step, bump inputs. [8]

Selected sinusoidal road profile has frequency of 1.88Hz and amplitude 0.1m. At resonance condition any system vibrates with highest amplitude. [9] One of the natural frequencies of Quarter car model is 1.88Hz; hence sinusoidal input is designed for 1.88Hz frequency. Figure 2 shows the sinusoidal input road profile of frequency 1.88Hz and amplitude 0.1m.

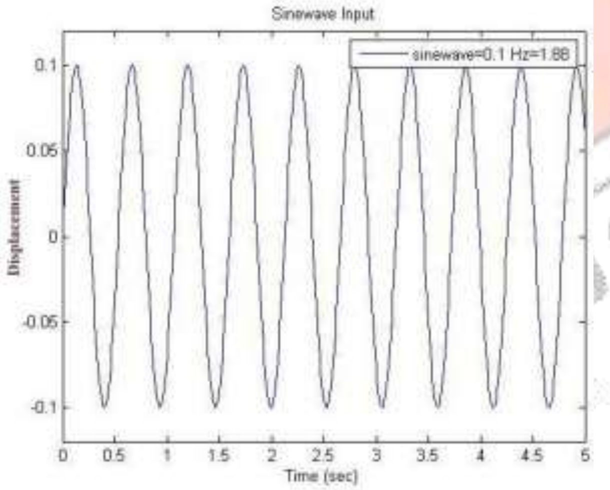

Figure 2. Sine wave of 0.1m and 1.88Hz

Simulation results are shown by output response curves of sprung and unsprung mass under the given inputs. Root Mean Square (RMS) values of displacements, velocities and accelerations are taken for comparison of performance of semi active and passive suspension system. Output response of passive system is shown by green colour and output response of semiactive system (i. e. fuzzy logic system (FLC)) is shown by blue colour.

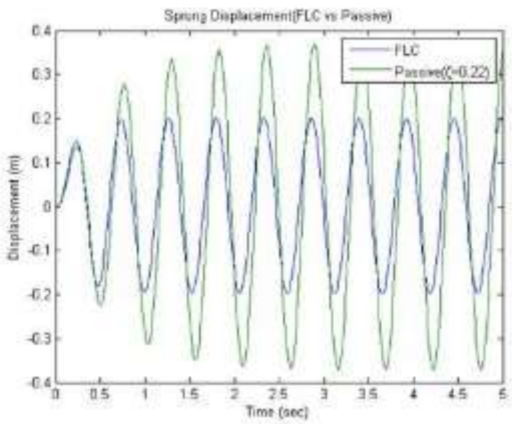

Figure 3. Sprung mass displacement

Figure 3 shows output displacement response of passive and semiactive system for sprung mass. From figure RMS displacement of passive system is 0.2252m and of FLC is 0.1092m. There is reduction in RMS displacement in case of FLC by 51.51% as compared to passive system.

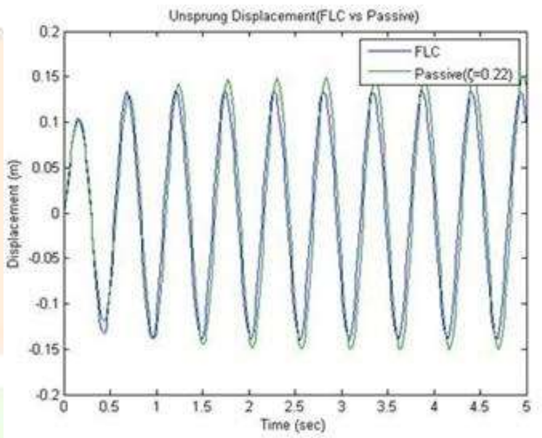

Figure 4. Unsprung mass Displacement

Figure 4 shows output displacement response of passive and semiactive system for unsprung mass. From figure RMS displacement of passive system is 0.0960m and of FLC is 0.0747m. There is reduction in RMS displacement in case of FLC by 22.19% as compared to passive system.

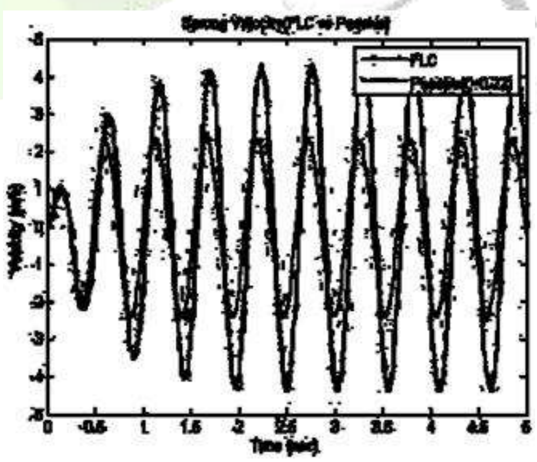

Figure 5. Sprung mass Velocity

Figure 5 shows output velocity response of passive and semiactive system for sprung mass. From figure RMS velocity of passive system is 2.6501m/s and of FLC are 1.2839m/s. There is reduction in RMS velocity in case of FLC by 51.55% as compared to passive system.

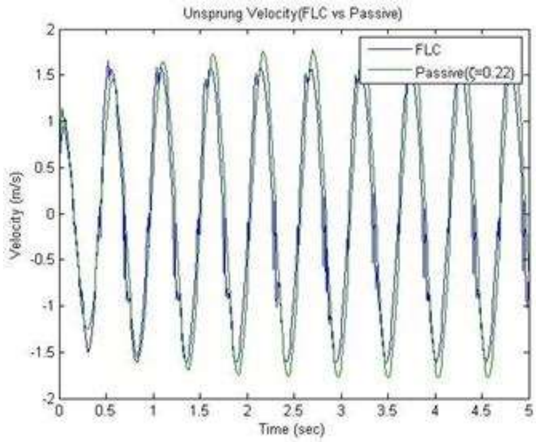

Figure 6.Unsprung mass Velocity

Figure 6 shows output velocity response of passive and semiactive system for unsprung mass. From figure RMS velocity of passive system is 1.1166m/s and of FLC are 0.8764m/s. There is reduction in RMS velocity in case of FLC by 21.51% as compared to passive system.

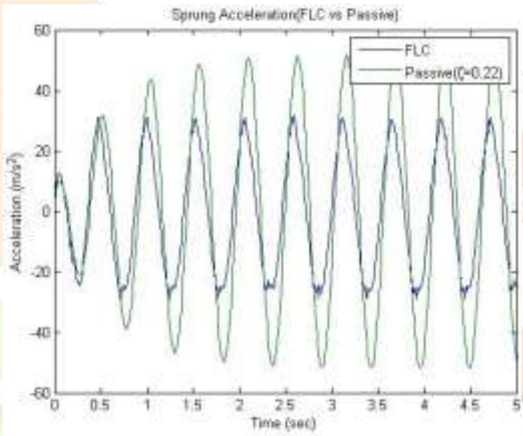

Figure 7. Sprung mass Acceleration

Figure 7 shows output acceleration response of passive and semiactive system for sprung mass. From figure RMS acceleration of passive system is 31.4186m/s^2 and of FLC are 15.6505m/s^2. There is reduction in RMS acceleration in case of FLC by 50.17% as compared to passive system.

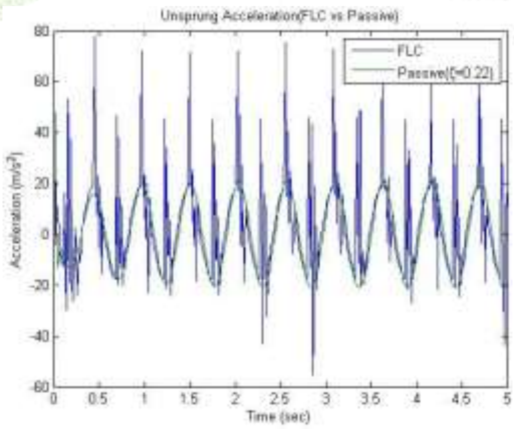

Figure 8. Unsprung mass Acceleration

Figure 8 shows output acceleration response of passive and semiactive system for unsprung mass. From figure RMS acceleration of passive system is 15.807m/s^2 and of FLC are 13.4183m/s^2. There is reduction in RMS acceleration in case of FLC by 17.26% as compared to passive system.

VII. CONCLUSION

Passive suspension transfer more disturbances to the passenger or cargo materials and there is compromise between ride comfort and handling due to its fixed parameters such as damping coefficient and stiffness. While semi active suspension has advantage of varying its damping value by controlling its viscosity due to applied current to MR damper. In case of semi active suspension system sprung mass parameters like displacement, velocity, and acceleration are decreased by 51.51%, 51.55%, and 50.17% respectively as compared to passive suspension system which denotes that there is increment in ride comfort. Similarly in case of semi active suspension system unsprung mass parameters like displacement, velocity, and acceleration are decreased by 22.19%, 21.51%, and 17.26% respectively as compared to passive suspension system which denotes that there is increment in road holding ability.

VIII. REFERENCES

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