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COMPARISON OF ACTIVE AND SEMI-ACTIVE SUSPENSION SYSTEMS USING ROBUST CONTROLLER

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ABSTRACT

Suspension system is used to fulfil the criteria of ride comfort and road handling. In this paper, a quarter car active & semi-active suspension systems are designed using Matlab/Script software. Comparison of active & semi-active suspension systems are done using robust control theory for the control targets suspension deflection, body acceleration and body travel. H infinity controller is selected to compare the two suspensions using time domain analysis. Finally the simulation result prove the effectiveness of the active suspension system by decreasing the body acceleration & sustaining the suspension deflection and body travel outputs.

Keywords- Active suspension system, semi-active suspension system, H infinity controller

I. INTRODUCTION

Semi-active suspension is one of the suspension that elastic parameter stiffness and shock absorber damping can adjust according to the need for adjustment and control. Skyhook semi-active suspension concept was proposed in1974. The spring stiffness tuning is very difficult, so semi-active suspension mainly by adjusting the shock absorber damping.

Semi-active suspension system has no specifically dynamic control components. It passed the velocity sensors data to the instrument ECU supervisor to calculate the required control force, and then adjust the shock absorber damping to attenuate shock of the automobile body. The study of semi-active suspensions are also focused on two aspects, one is on the designing of actuator, which is the damping adjustable shock absorbers; the other hand, the control methodology. Magneto rheological damper is the semi-active suspension latest technology and lots of researcher's exhibition great interests on this new technology. It has a fast response, which is lower than 1ms. Semi-active suspension also has its own advantages, such as its scheme amount and prix is greatly lower than the active suspension system.

The automotive active suspension, according to progress conditions and automobile load, controls their own operations status. Active suspension need to take effective control strategy to make the suspension to achieve the achievement required to achieve, therefore, the picks of control strategy for controllable suspension has a great demeanor of performance.

II. MATHEMATICAL MODELS

2.1 Active Suspension System Mathematical Model

Active suspension systems with hydraulic actuators to the passive components of suspension system as shown in Figure 1.

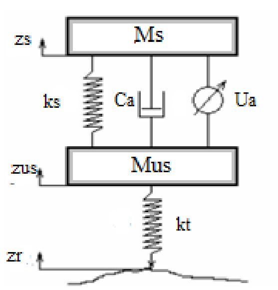

Figure 1: Quarter model of active suspension system.

The equations of motion are written as

$$M_s\ddot{z}_s + k_s\left(z_s - z_{us}\right) + c_a\left(\dot{z}_s - \dot{z}_{us}\right) - U_a = 0 \qquad (1)$$

$$M_{us}\ddot{z}_{us} + \left(z_{us} - z_s\right) + c_a\left(\dot{z}_{us} - \dot{z}_s\right) + k_t\left(z_{us} - z_r\right) + U_a = 0 \qquad (2)$$

Where uais the control force from the hydraulic actuator. It can be noted that if the control force ua= 0.

2.2 Semi-active Suspension System Mathematical Model

The design of the quarter car semi-active suspension system diagram is shown in Figure 2 below.

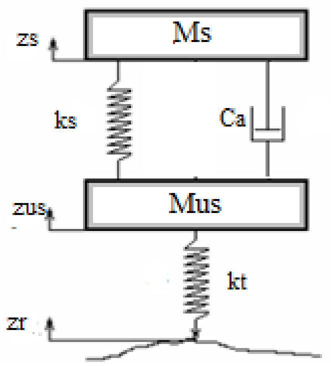

Figure 2: Quarter model of semi-active suspension system.

$$K_s\left(Z_{us} - Z_s\right) - C_a\left(\dot{Z}_{us} - \dot{Z}_s\right) = M_s\ddot{Z}_s \qquad (3)$$

$$-K_s\left(Z_{us} - Z_s\right) - C_a\left(\dot{Z}_{us} - \dot{Z}_s\right) + K_t\left(Z_r - Z_{us}\right) = M_{us}\ddot{Z}_{us} \qquad (4)$$

Where Zs is the position of the sprung mass, Zus is the position of the unsprung mass and Zr is the road displacement. These equations are solved numerically using MATLAB's dynamic system simulation software, SIMULINK

III. ROAD PROFILES

3.1 Random Road Profile

The random road disturbance input has a maximum peak of 15 cm and minimum peak of -15 cm as shown in Fig 3.

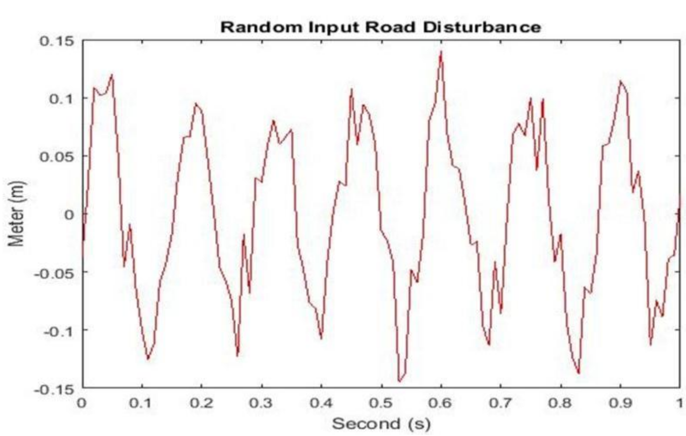

Figure 3: Random road profile

3.2 Sine Road Profile

The sine road disturbance input has a maximum peak of 10 cm and minimum peak of -10 cm as shown in Figure 4.

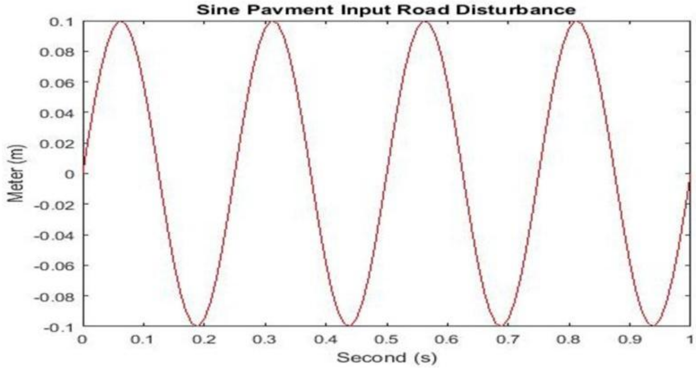

Figure 4: Random road profile

IV. THE PROPOSED CONTROLLER DESIGN

4.1 Active Suspension Design

The active suspension system with H∞ controller witha third order hydraulic actuator system block diagram is shown in Figure 5.

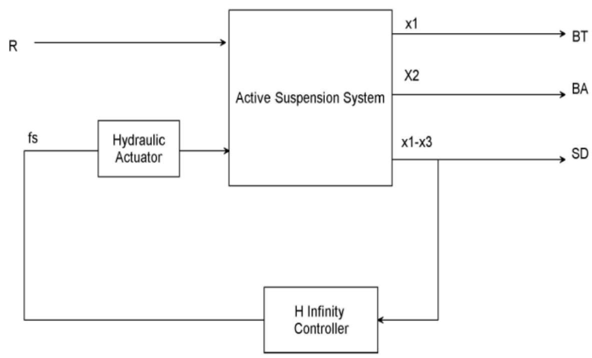

Figure 5: Active suspension system with H∞ controller system block diagram

The hydraulic actuator model is a third order transfer function defined as:

$$actuator = \frac{s^2 + 2s + 1}{s^3 + 5s^2 + 6s + 4} \qquad (5)$$

4.2 Semi-active Suspension Design

The semi-active suspension system with H∞ controllersystem block diagram is shown in Figure 6.

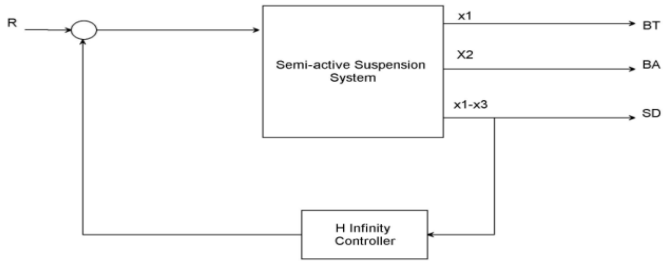

Figure 6: Semi-active suspension system with H∞ controller system block diagram

V. RESULT AND DISCUSSION

The quarter car active and semi-active suspension system parameter values are shown in Table 1.

Table 1: Parameters of quarter vehicle model

Model parameters	symbol	symbol Values
Vehicle body mass	M_s	415 Kg
Wheel assembly mass	M_{us}	53 Kg
Suspension stiffness	k_s	10,500 N/m
Tire stiffness	k_t	130,000 N/m
Suspension damping	c_a	900 N-s/m

5.1 Control Targets Output Specifications

The control targets output specifications of the quarter car active & semi-active suspension system is shown in Table 2 below.

Table 2. Control targets output specifications

No	Control Targets	Output
1	Body travel	Minimum
2	Body acceleration	Minimum
3	Suspension deflection	Same as Road Profile

5.2 Simulation of a Random Road Disturbance

The body travel, body acceleration and suspension deflection simulation result of the active and semi-active suspension system with H∞ controller for a random road disturbance is shown in Figure 7, Figure 8 and Figure 9 respectively.

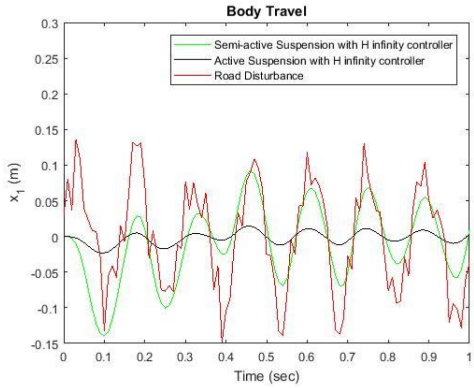

Figure 7: Body travel for random road disturbance

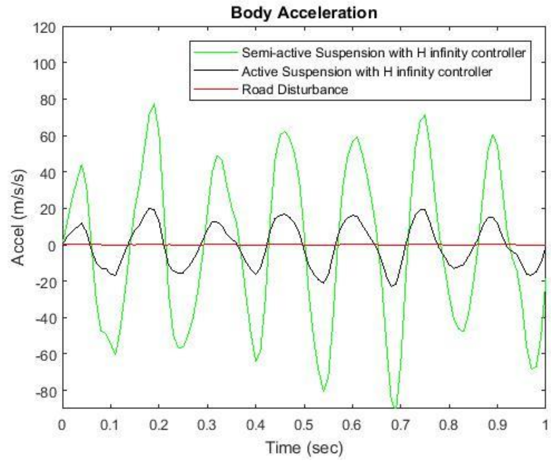

Figure 8: Body acceleration for random road disturbance

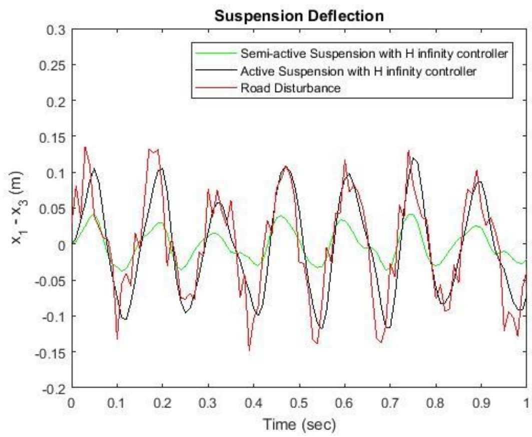

Figure 9: Suspension deflection for random road disturbance

5.3 Simulation of a Sine Input Road Disturbance

The body travel, body acceleration and suspension deflection simulation result of the active and semi-active suspension system with H∞ controller for a sine road disturbance is shown in Figure 10, Figure 11 and Figure 12 respectively.

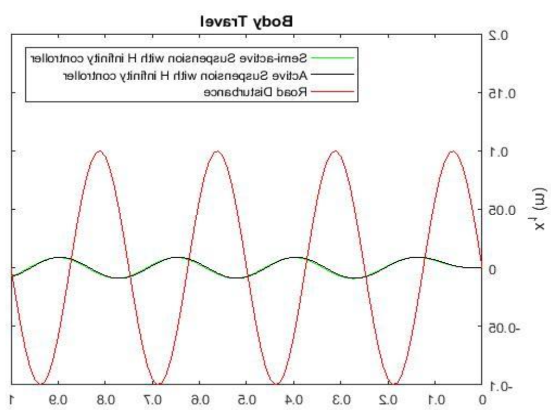

Figure 10: Body travel for sine road disturbance

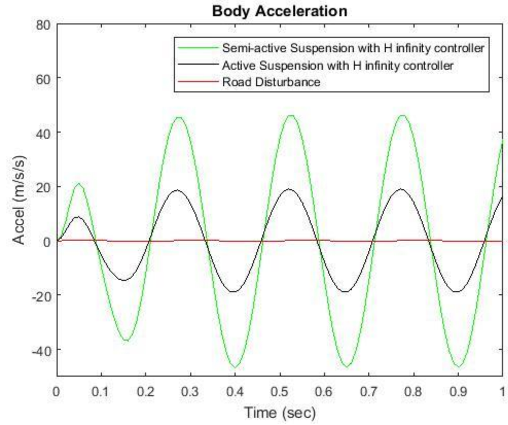

Figure 11: Body acceleration for sine road disturbance

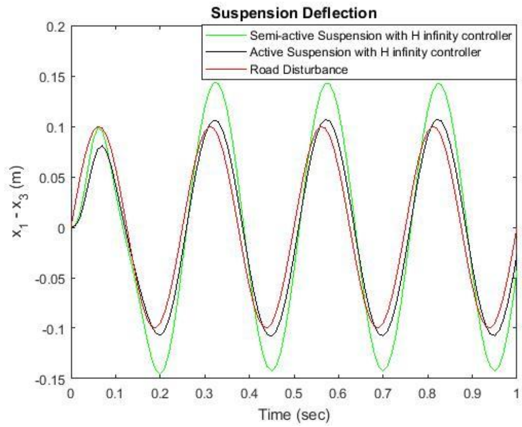

Figure 12: Suspension deflection for sine road disturbance

5.3 Numerical Values of the Simulation Outputs

The numerical result of the simulation of body travel, body acceleration and suspension deflection is shown in Table 3, Table 4 and Table 5 bellow.

Table 3: Numerical values of the body travel simulation result

No	Systems	Random	Sine
1	Road Profile	0.15m	0.1m
2	Semi-active	0.09m	0.01m
3	Active	0.01m	0.01m

Table 2 shows us the active suspension system with H∞ controller have the minimum body travel amplitude in the random road profile and equal amplitude in the sine road profile.

Table 4: Numerical values of the body acceleration simulation output

No	Systems	Random	Sine
1	Road Profile	5 m/ s 2	2 m/ s 2
2	Semi-active	80 m/ s 2	45 m/ s 2
3	Active	20 m/ s 2	18 m/ s 2

Table 3 shows us the active suspension system with H∞ controller have the minimum body acceleration amplitude in the random and sine road profile.

Table 5: Numerical values of the suspension deflection simulation output

No	Systems	Random	Sine
1	Road Profile	0.14m	0.1m
2	Semi-active	0.05m	0.1m
3	Active	0.14m	0.1m

Table 4 shows us the active suspension system with H∞ controller have the suspension deflection amplitude the same as the road profile input in the random and sine road profiles.

VI. CONCLUSION

The methodology was developed to design an active suspension for a passenger car by designing a controller, which improves performance of the system with respect to design goals compared to semi-active suspension system. Mathematical modelling has been performed using a two degree-of-freedom model of the quarter car model for active and semi-active suspension system considering the three control targets to evaluate the performance of suspension with respect to various contradicting design goals. H infinity controller design approach has been examined for the comparison of the active & semi-active suspension systems. The potential for improved ride comfort and better road handling using H infinity controller for the design of the active & semi-active suspension systems is examined. The objectives of this project have been achieved. Dynamic model for linear quarter car suspensions systems has been formulated and derived only one type of controller is used to test the systems performance which is H infinity controller. Finally the simulation result prove that the active suspension system has better performance.

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