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ACTIVE SUSPENSION USING PID CONTROL WITH MATLAB

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Abstract
This research paper proposes a PID controlled electromagnetic actuator design for active suspension system. In this method the ride profile is an unknown disturbance and we only measure the vertical displacement of the vehicle body caused by irregular ride profile. The simulation result show that proposed control can achieve better suspension performance and requires less information, also achieves better traction after encountering irregularities on the road.

Introduction

A suspension system consists of springs and dampers which connects the wheels and chassis and is responsible to absorb road bumps. The goal of suspension system is to increase the ride comfort, handling and stability.

Passive suspension compromises in all three criteria where as active suspension provides a common ground between the above three criteria by adding energy back to the system. An electromagnetic actuator incorporated in the suspension system adds energy into the vehicle body thus reducing its vertical acceleration and displacement. It is controlled by algorithm and sensor to provide real time adjustment. The sensor is responsible to measure vertical displacement and acceleration.

Since the 1990s the approach for best cost and performance has resulted in development of electronically controlled suspension which gives continuous and adjustable damping. It has resulted in massive development in servo/solenoid dampers made with co-operation of automobile companies (Ford, Volvo and GM) with control dampers suppliers like Sachs, Tenneco. Recent dampers are from Tenneco utilize magneto-rheological fluid which is non-Newtonian fluid that changes its properties in the presence of a magnetic or electric field. The dampers that utilize these fluids are called MR dampers and are more reliable than electromagnetic ones as they do not have any moving parts. In case of any irregularities on the road the fluid molecules under magnetic field forms a chain like structure absorbing all the forces caused by the bumps of the road.

Simulation

Modeling of Active Suspension of with Quarter Model of a Car

We use unknown and uneven road profile to compare both the suspension systems. The response of the control strategy used in active suspension is determined using Simulink toolbox which is then compared with passive suspension response. The quarter model of car shown below, is used for active suspension system with the marked elements.

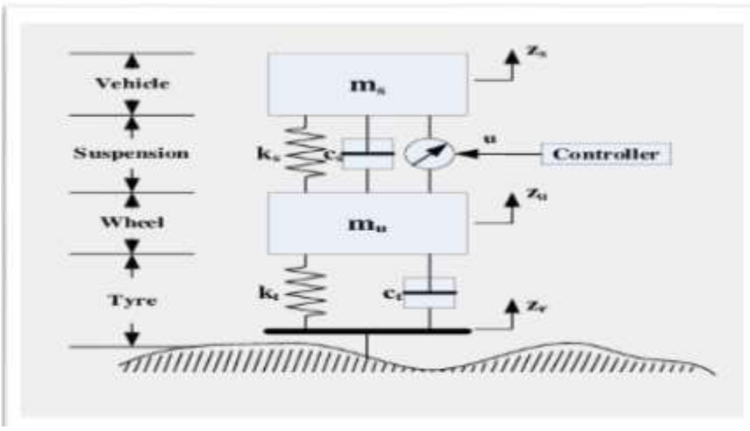

Figure1: Active Suspension System of a Quarter Model of Car

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Figure 1 demonstrates following quantities: -

- Ms: Sprung Mass (Car Chassis)
- Mu: Unsprung mass (Wheel Mass)
- Ks: Spring Stiffness
- Kt: Tire Stiffness
- Cs: Damper Force
- Ct: Tire Force
- U: Actuator Force
- Zs: Body Displacement
- Zu: Wheel Displacement
- Zr: Road Profile Displacement

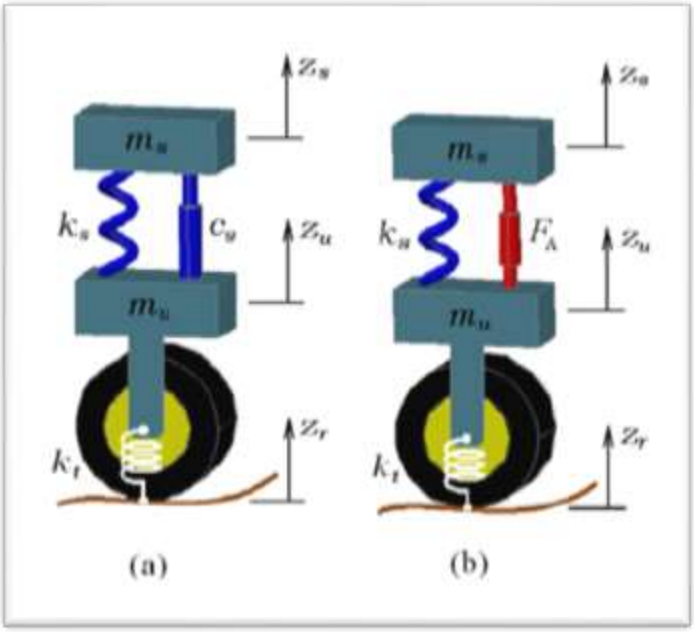

Figure 2: a) Passive Suspension b) Active Suspension

Mathematical model of active suspension

The damper is replaced by the actuator, results in suspension system with the spring. Thus, according to figure 2(b): -

$$Ms.\ddot{Zs} + Ks(\mathrm{Zs} - \mathrm{Zu}) = Fa$$

$$\mathrm{Mu}.\ddot{Zu} - \mathrm{Ks}(\mathrm{Zs} - \mathrm{Zu}) + \mathrm{Kt}(\mathrm{Zu} - \mathrm{Zr}) = -\mathrm{Fa}$$

Mathematical model of passive suspension

According to figure 2(a): -

$$Ms.\ddot{Zs} + Cs(\dot{Zs} - \dot{Zu}) + Ks(\mathrm{Zs} - \mathrm{Zu}) = 0$$

$$Mu.\ddot{Zu} - Cs(\dot{Zs} - \dot{Zu}) - Ks(\mathrm{Zs} - \mathrm{Zu}) + Kt(\mathrm{Zu} - \mathrm{Zr}) = 0$$

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Mathematical Model of Active and Passive suspension using Simulink Toolbox

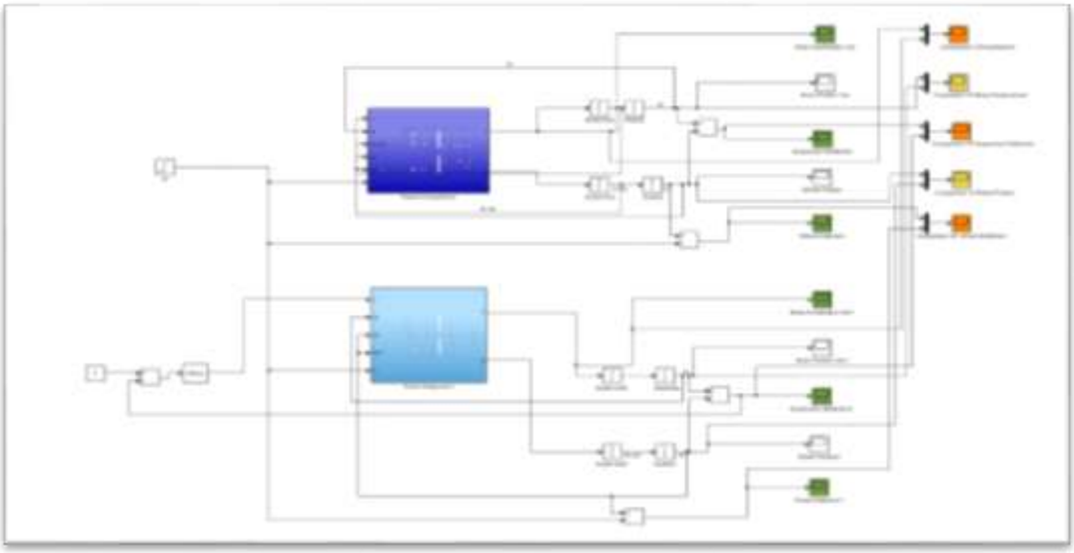

Figure 3: Comparison of Passive and Active Suspension

In Figure 3 Simulink model is made using mathematical model of passive and active suspension system. Purple subsystem in figure denotes passive suspension model and blue subsystem denotes active suspension model.

Following below are the constant values taken: -

Constant Values	Value
Ms: Sprung Mass	282 kg
Mu: Unsprung Mass	45 kg
Ks: Spring Stiffness	17900 N/m
Cs: Damper Force	1000 Ns/m
Kt: Tire Stiffness	1657900 N/m
Zr: Road Profile Displacement	1
Proportional(P)	1
Integral(I)	100
Derivative(D)	5000

Table 1. Vehicle suspension system parameters for a quarter-car model

Simulation Results are Shown below. When compared to its passive equivalent(yellow), the active vehicle suspension system(blue) exhibits a high level of vibration attenuation.

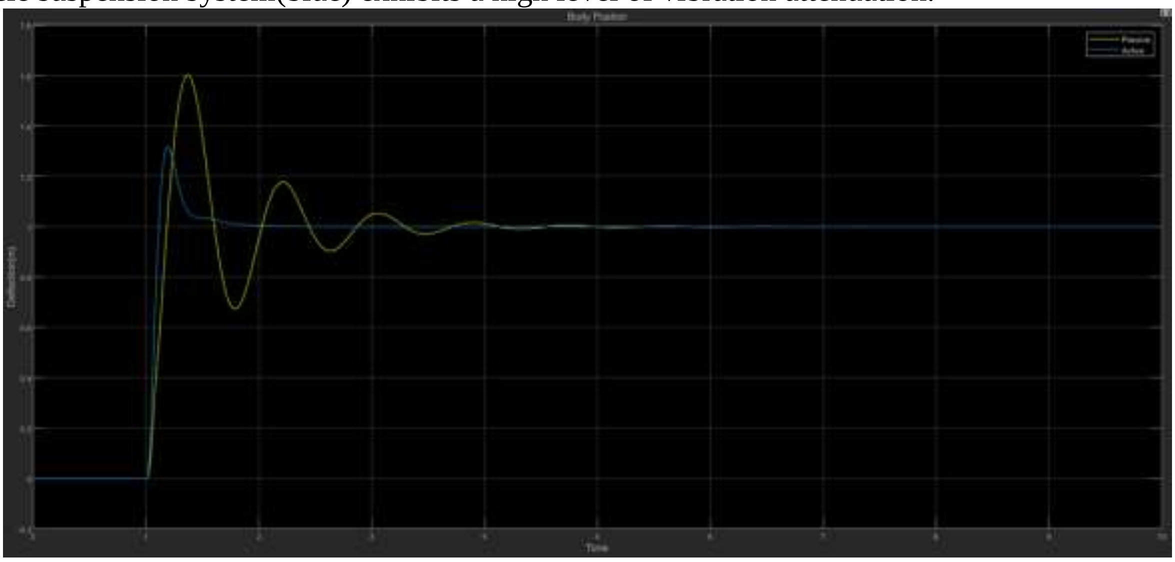

Figure 4: Comparison of Body Position versus Time

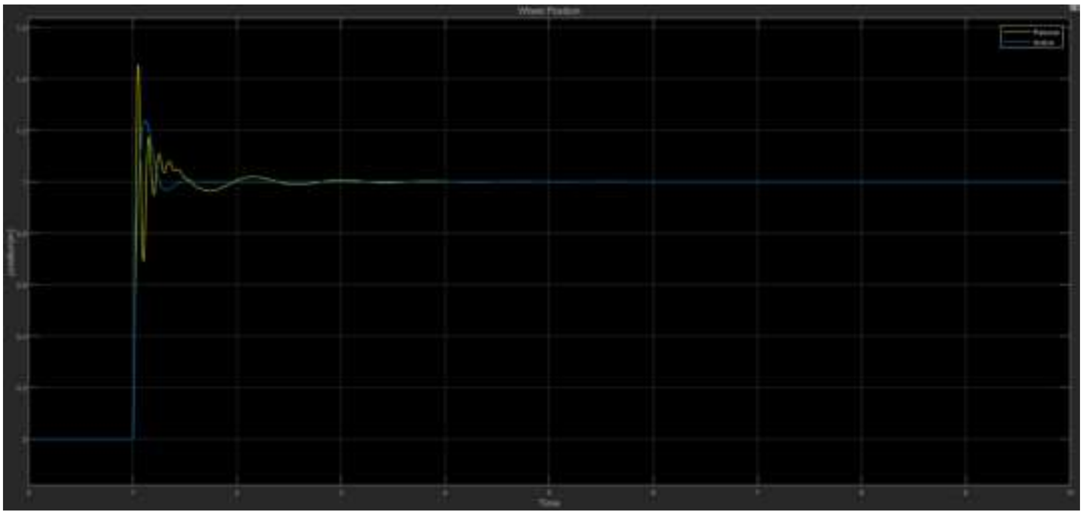

Figure 5: Comparison of Wheel Position versus Time

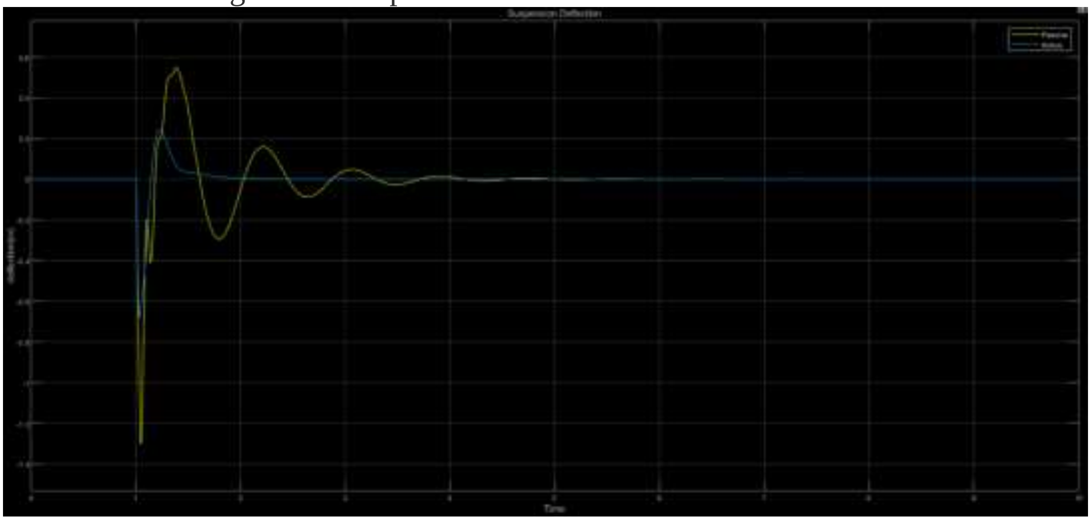

Figure 6: Comparison of Suspension Deflection versus Time

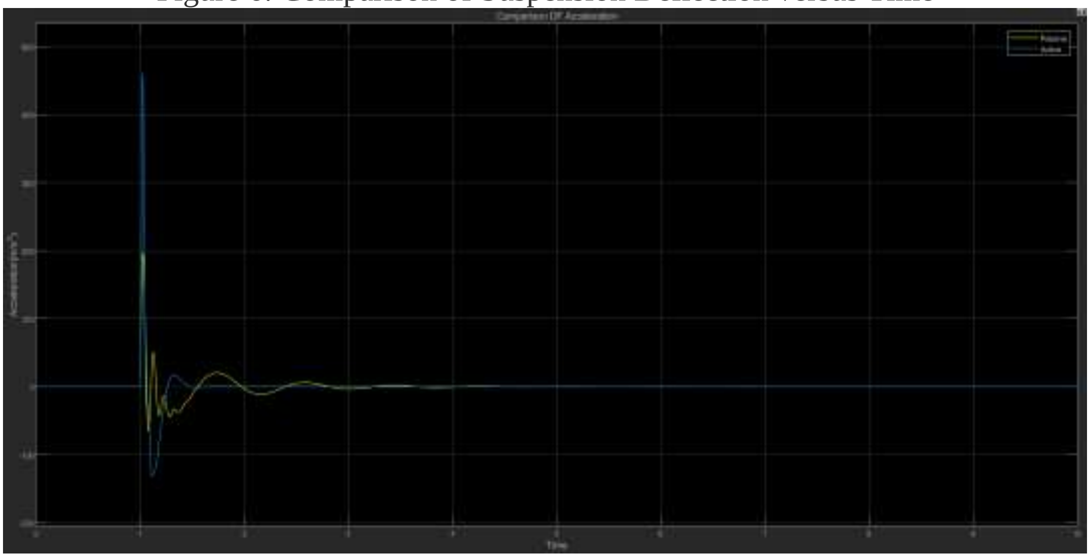

Figure 7: Comparison of Acceleration versus Time

Simulation Results

In the above figures road disturbances are assumed as the input for the system. Parameters the are taken into observation are body position, wheel position, suspension deflection and comparison of acceleration.

No	Parameters	Passive	Active	Reduction
1	Body Position	1.6m	1.3m	18.75%

2	Wheel Position	1.47m	1.21m	17.68%
3	Suspension Deflection	0.58m	0.21m	63.793%
4	Acceleration	$199 m/s^2$	$460 m/s^2$	-131.15%

Table 2: Comparison table between active and passive suspension

Table 2 shows reduction in body wheel and suspension travel when compared to a step input for Zr=0.1. When compared to acceleration the reason active suspension has higher acceleration value is because it has better opportunity for traction as bumps are absorbed by the suspension.

Conclusion

The suspension system proposed only responds to the position of the car body and tire and is independent of road profile, this factor is the main advantage of the system. The simulation findings demonstrate that it takes less time than passive suspension to stabilise the vertical position of the quarter of the car. The choice to utilise an active suspension system should be based on the trade-offs involved as it leads to higher costs, more complexity and leads to more maintenance requirements.

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