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# Suspension System of Landing Gear using PID Controller with Genetic Algorithm

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***Abstract*— A landing gear suspension system absorbs the vertical energy at the time of touch down as well as when the aircraft is taxiing on uneven road profile, providing traveller and crew comfort with smooth ground ride before take-off, during landing and after landing. This paper explains the study of magneto rheological damper for suspension system of airplanes using PID controller with genetic algorithm. Two different disturbances namely step and random disturbances were given to the simulation model as the road profile. The performance of the simulation model was investigated in term fuselage displacement, velocity and acceleration. The results proved the PID controlled MR damper was better than MR damper and passive system in terms of the fuselage displacement, velocity and acceleration and takes considerably less time to stabilize the aircraft after landing impact happens. It significantly improves the fatigue life of the airplane fuselage and the components inside of landing gear system by reducing the vibration amplitudes.***

***Keywords*— MR damper, PID controller, genetic algorithm, semi-active suspension system, landing gear**

## I. INTRODUCTION

The most important phase of airplane flight is its landing.. The suspension system of an aircraft should absorb all the energy produced because of impact during touchdown and by excitations produced by aircraft taxing on an uneven surface [1, 2].

In today's airplane designs a conventional passive suspension system is employed [3]. The passive landing gear system does not have the ability to adapt different runway and landing conditions. Performance of an airplane landing can be greatly influenced by the factors such as excessive touchdown speed, approach speed, ground effects, cross winds, runway unevenness. When an airplane lands, large amplitude of vibrations is transmitted to the fuselage from the runway thereby causing passenger discomfort [4]. During worst landing conditions, the aircraft structure is unable to withstand such high impact loads and cause a possible flight failure [4,5]. Hence the vibrations need to be suppressed quickly. Findings [6-9] shows that when ground induced vibration fed into landing gear system minimize the fatigue and impact loads. This can be done by changing the damping and stiffness values of the system [6-9].

There are three types of control technologies namely passive, semi-active and active control [3]. In active control the hydraulic fluid properties can be changed by feeding information from ground induced vibrations [5].

This paper studies detailed nonlinear simulated model of two degree of freedom of a semi active suspension system. Based on derived dynamic equations SIMULINK model is created which helps us verify the performance of an semi active suspension system subjected to uneven road profile. SIMULINK control system simulation software is used to study stability of system [10]. The simulations allow comparison between PID controlled MR damper, MR damper and passive system. It has been verified that vertical displacement and impact loads are greatly reduced using an PID controlled MR damper and improvements are observed in landing gear and taxiing performance, landing gear and fuselage fatigue life, the ability to control airplane while ground operations by the pilot and crew and passenger comfort.

 

## II. MATHEMATICAL MODEL OF LANDING GEAR

An The 2 DOF mathematical model of landing gear consists of aircrafts body mass i.e. sprung mass $m_s$ and tire mass i.e. unsprung mass $m_t$. The spring stiffness $k_s$ and a damper with damping coefficient $c_s$ are representing the parameters of shock strut of landing gear. The spring stiffness $k_t$ and damping coefficient $c_t$ are the parameters of the tire mass. Here damping coefficient $c_t$ is neglected.

In Figure 1 $X_s$, $X_t$ are the vertical displacement of sprung mass and unsprung mass, W is the ground excitation produced by the uneven road profile. $F_{mr}$ is the force provided by MR damper at a given voltage and that voltage is controlled through PID controller. $F_{mr}$ force is used control the unbalance force in the system.

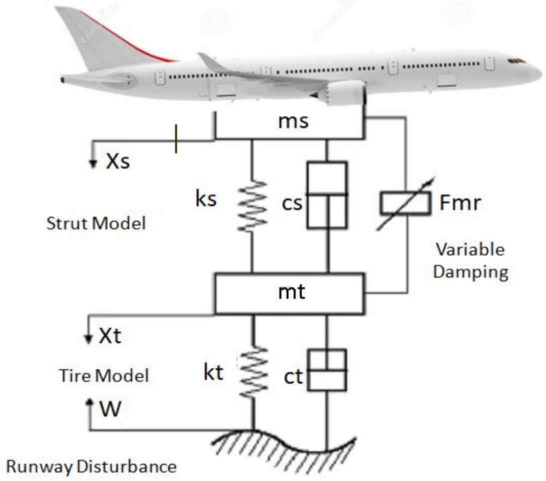


Figure 1. Model of 2 DOF Semi Active Suspension System

The dynamic equations can written as

(a) Passive suspension system (1-2)

$$m_s\ddot{X}_s = -c_s(\dot{X}_s - \dot{X}_t) - k_s(X_s - X_t) \quad (1)$$

$$m_t\ddot{X}_t = c_s(\dot{X}_s - \dot{X}_t) + k_s(X_s - X_t) + c_t(\dot{W} - \dot{X}_t) + k_t(W - X_t) \quad (2)$$

(b) Semi Active suspension system (3-4)

$$m_s\ddot{X}_s = -c_s(\dot{X}_s - \dot{X}_t) - k_s(X_s - X_t) - F_{mr} \quad (3)$$

$$m_t\ddot{X}_t = c_s(\dot{X}_s - \dot{X}_t) + k_s(X_s - X_t) + c_t(\dot{W} - \dot{X}_t) + k_t(W - X_t) + F_{mr} \quad (4)$$

## III. SIMULINK MODEL OF LANDING GEAR

### A. *Passive Model of 2DOF Landing Gear*

The simulink model of passive or traditional suspension system is shown in the Figure 2.

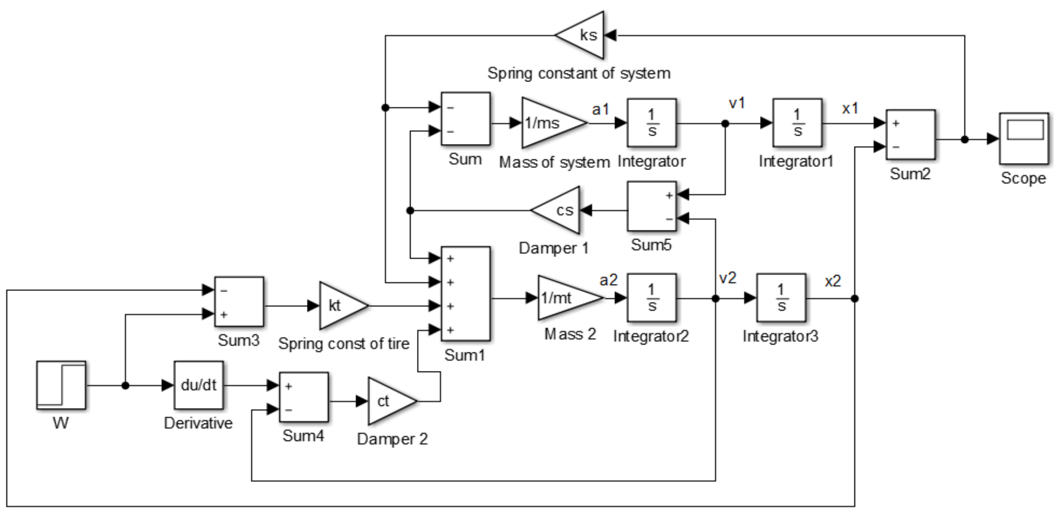


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Figure 2. Simulink model of passive suspension system

B. *Passive Model with MR Damper*

To simulate and identify parameters of MR damper, various models of MR damper are formulated, namely:

1) Bouc Wen Model
2) Dahl Model
3) Bingham Model
4) Lugre Model

During comparison between all four models it was found that Bouc Wen model is performing well and has minimum settling time.

1) Bouc Wen Model: The pictorial view of Bouc Wen model of an MR damper is depicted by the Figure 3 The hysteresis loop has an internal variable y that represents hysteresis behavior and satisfies the expression (5) . The model equation of Bouc Wen model is expressed by the following.

$$\dot{y} = -gamma * |\dot{z}| * y * |y|^{n-1} - beta * z * |y|^{n} + A * \dot{z} \quad (5)$$

Where y is internal variable that can vary its value according to hysteresis loop

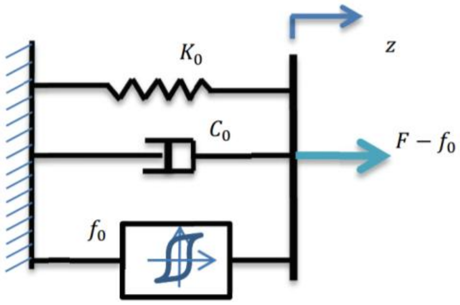


Figure 3. Bouc Wen MR damper

The force exerted by MR damper is the function of the relative displacement z and $\dot{z}$ and the parameter alpha defined by the control voltage v, and is given by equation (6)

$$F_{mr} = C_0 * \dot{z} + k_0 z + alpha * y + f_0 \quad (6)$$

Where $k_o$ is the stiffness of the spring element of the MR damper. The coefficients $C_0$ and alpha have a linearly relationship with the control voltage v is given by eq (7-8)

$$C_0 = C_{0a} + C_{0b} + v \quad (7) \; ; \; alpha = a_{0a} + a_{0b} * v \quad (8)$$

The simulink model of Bouc Wen MR Damper using above equation is shown in the Figure 4

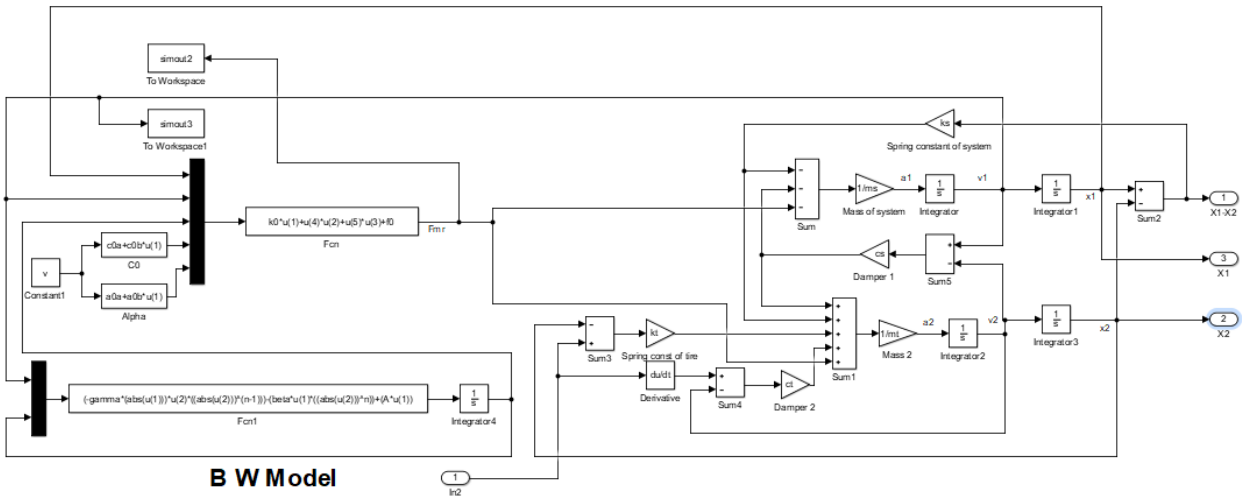


Figure 4. Simulink model of passive landing gear system with MR damper

 

C. *PID Controller*

PID means proportional integral derivative controller. It is an advance control technique which is widely used in automobile but in aviation it is still in development phase.

The controller design can be defined by equation (9)

$$G_c = K_p * e(t) + K_i * \int_0^t e(t) + K_d * \frac{de(t)}{dx} \tag{9}$$

Where $G_c$ is the input from controller. $K_p$, $K_i$, $K_d$ are proportional gain, integral gain and derivative gain of PID controller

The PID controller SIMULINK model is shown in the Figure 4.

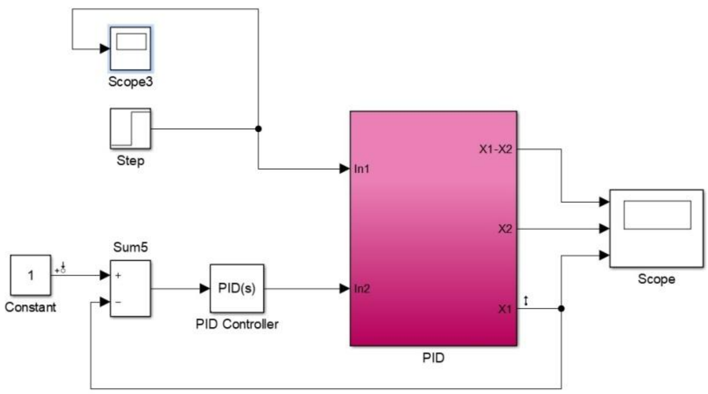


Figure 5. Simulink model of PID controller with MR damper

## IV. NUMERICAL SIMULATION

The aircraft parameters used for simulation in simulink are: [11]

TABLE I

Aircraft parameters

| S No | Parameter Name | Notation | Value | Units |
|---|---|---|---|---|
| 1 | Aircraft mass | ms | 250000 | kg |
| 2 | Wheel mass | mt | 800 | Kg |
| 4 | Landing gear stiffness | ks | 600000 | N/m |
| 5 | Wheel stiffness | kt | 3200000 | N/m |
| 6 | Landing gear damping coefficient | cs | 50000 | N s/m |

The parameters used for MR damper using Bouc Wen technique are: [12]

TABLE II

MR damper parameters

| S No | Parameter Name | Notation | Value | Units |
|---|---|---|---|---|
| 1 | Parameters of the Hysteresis Shape | gamma, beta, A, n | 136320, 2059020, 58, 2 | - |
| 2 | Stiffness of the spring element | ko | 3610 | N/m |
| 3 | Input Voltage | v | 5 | V |
| 4 | Other parameters | C0a, C0b, a0a, a0b | 784, 1803, 12441, 384300 | - |
| 5 | Pre- yield Stress | fo | 0 | N |

 

## V. GENETIC ALGORITHM

It is a search method that copies the process of natural evolution. It is one of the methods used for optimization

The code for GA is shown in the Figure 6.

```
function z=optimmr(p)
global kp ki kd base
kp=p(1)
ki=p(2)
kd=p(3)
assignin('base','kp',kp);
assignin('base','ki',ki);
assignin('base','kd',kd);
sim('comparison_between_passive_mr_pid');
z=sum(xyz)   %objective fcn
```

Figure 6. MATLAB Genetic Algorithm Code

The obtained value of gains of PID using GA is shown in the Table 3.

TABLE III

Parameters of PID controller Obtained through Genetic Algorithm:

| Gains | Values |
|---|---|
| Kp | 99.801 |
| Ki | 67.911 |
| Kd | 8.901 |

## VI. RESULTS

*Comparison Between Passive, Passive with MR and PID*

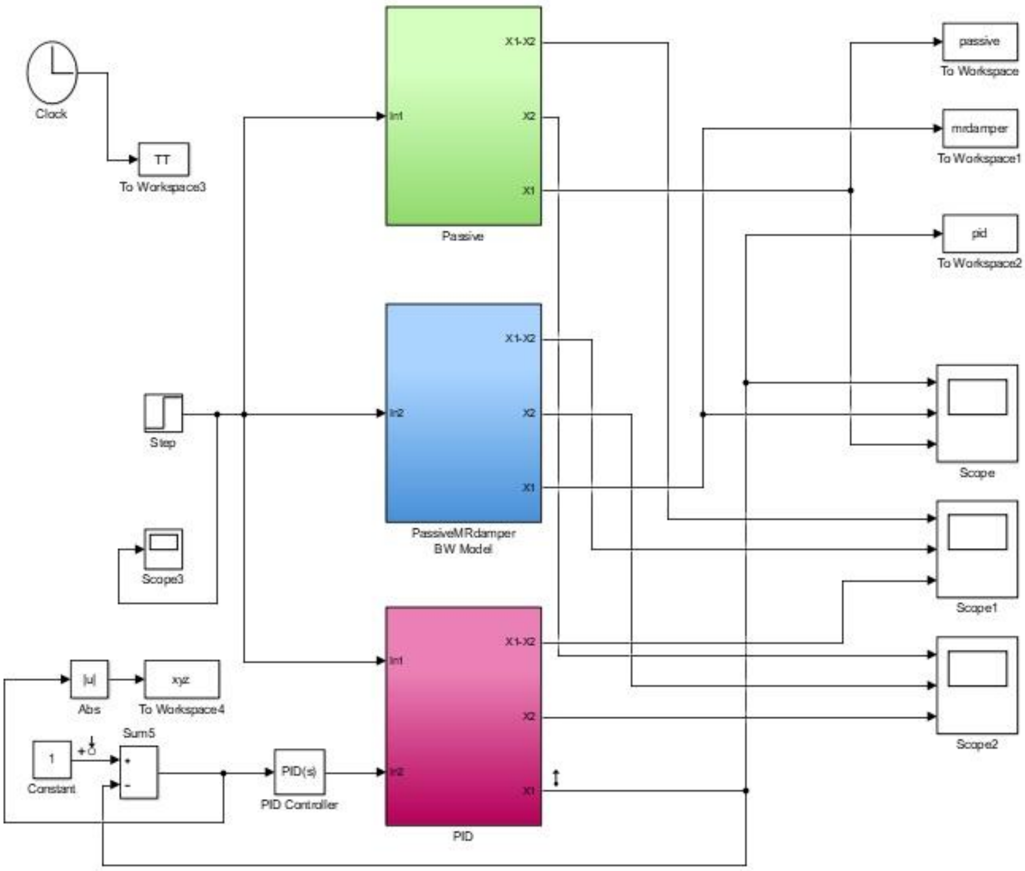


Figure 7. Simulink model of comparison between all three models

During comparison between passive, passive with MR, PID with step input it was shown that the PID reduces the maximum amplitude significantly and has minimum settling time

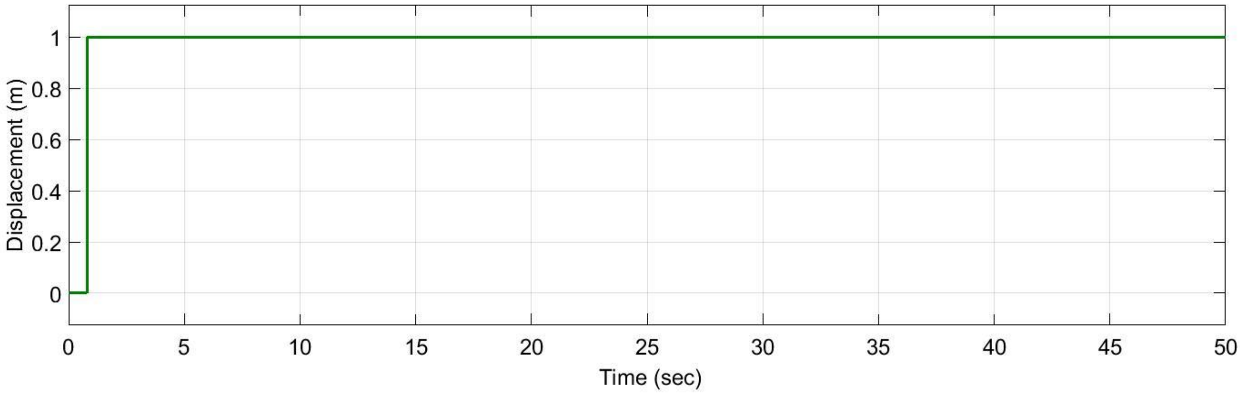


Figure 8. Step Input Disturbances to Suspension System

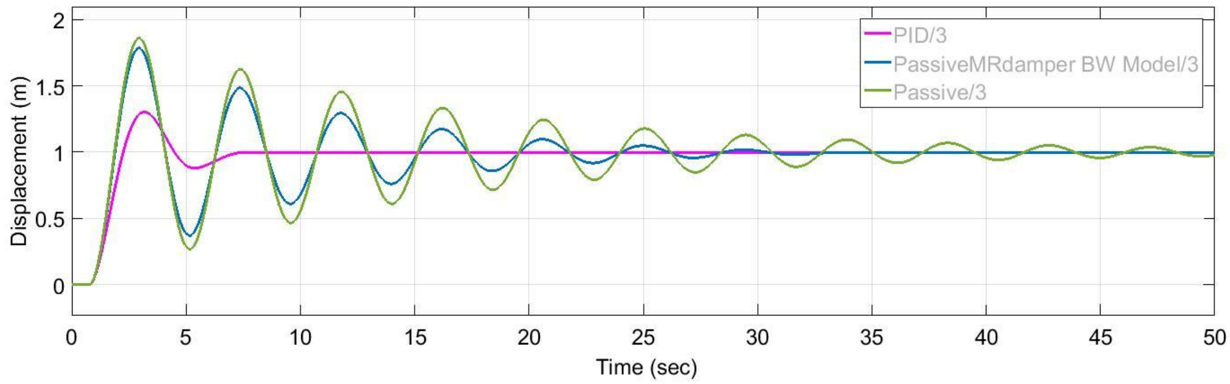


Figure 9. Fuselage displacement during step input

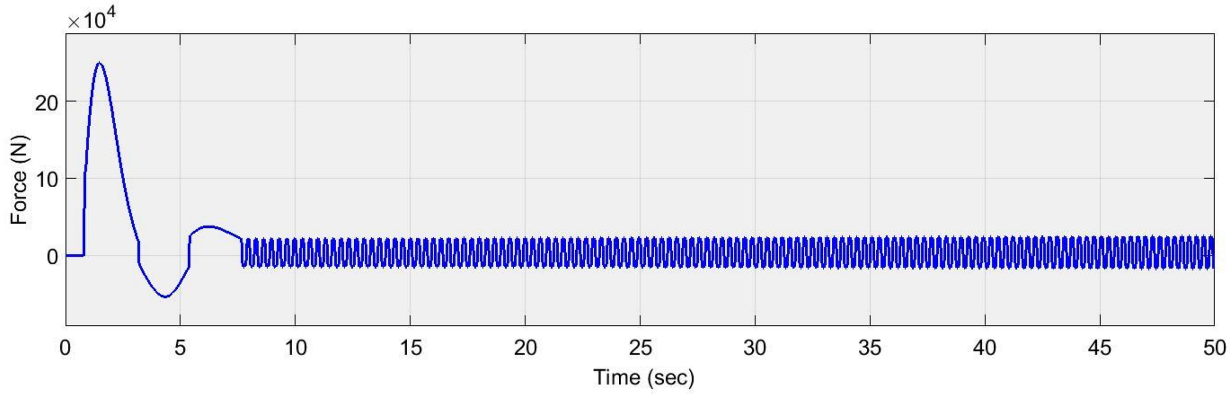


Figure 10. Active force during impact

When random input was provided the PID shows minimum amplitude which greatly reduces the vibration levels when the aircraft taxies on an uneven surface.

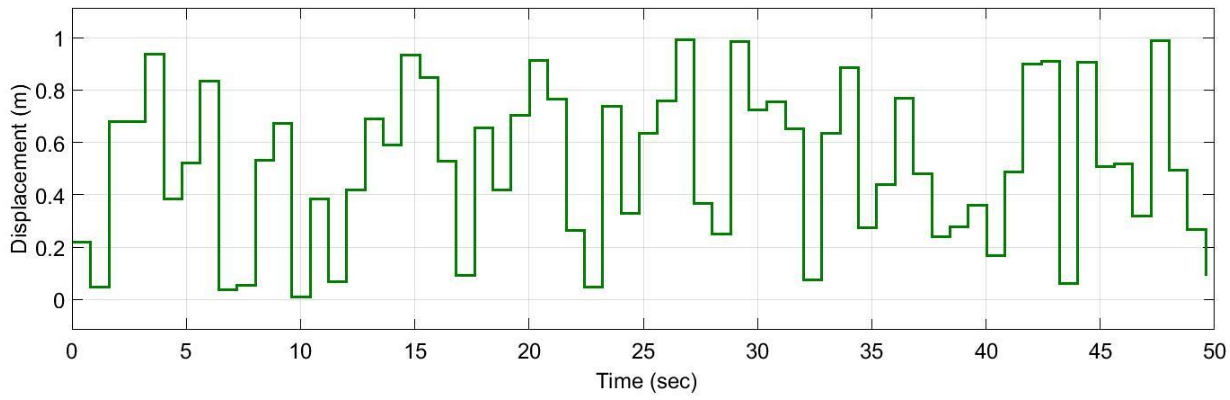


Figure 11. Random disturbance to Suspension System

 

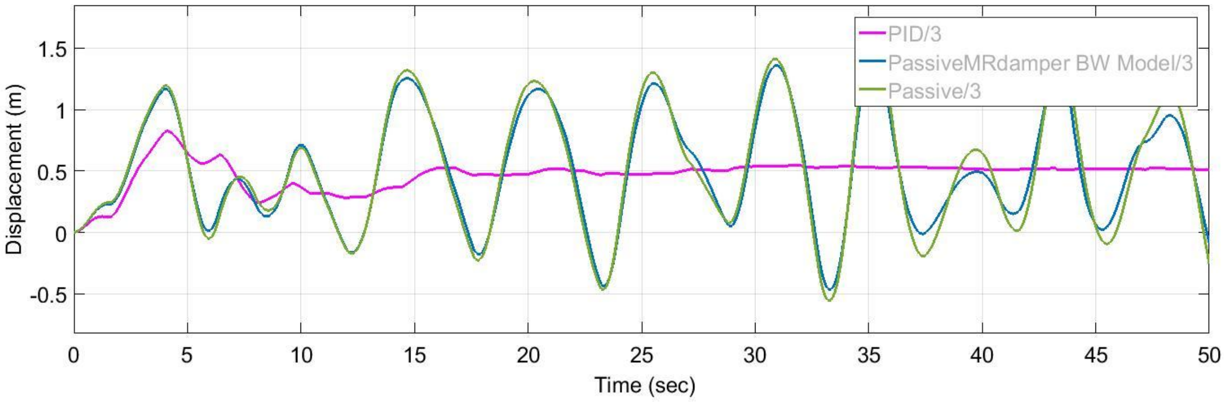


Figure 10. Fuselage displacement during random input

## VII. CONCLUSION

The formulation of non linear mathematical model of semi active suspension system has been done successfully and the model was simulated in the MATLAB SIMULINK 2016a version for a step input and random input. The graphs shows reduction in the magnitude of fuselage displacement by the semi active system than passive with MR damper and than the passive system during landing on uneven runway profile. The aircraft using PID controller takes considerably less time to stabilize after the landing impact. Thus, the airplane installed with semi active suspension system improves comfort level of passengers due to decreasing amplitudes vibrations and safety during the landing phase. The reduction of vibration level and shock strut forces improves life of airplane fuselage structure and components of the landing gear system.

## REFERENCES

[1] N.S. Currey, Aircraft landing gear design: principles and practices, AIAA Education Series, AIAA (1998).

[2] R. Freymann, Actively damped landing gear system, Landing Gear Design Loads Conference No. 20, AGARD CP-484, 1991.

[3] I.P. Jocelyn, An overview of landing gear dynamics, NASA TM-209143 (1999).

[4] B.W. Payne, A.E. Dudman, B.R. Morris, M. Hockenhull, Aircraft dynamic response to damaged and repaired runways, AGARD CP-326 (1982).

[5] Y.H. Jia, Taxiing performance analysis of active control of landing gear, Acta Aeronautica et Astronautica Sinica 20 (6) (1999) 545–548

[6] I. Ross, R. Edson, Application of active control landing gear technology to the A-10 aircraft, NASA CR-166104 (1983).

[7] W.E. Howell, J.R. Mc Gehee, R.H. Daugherty, W.A. Vogler, F-106B airplane active control landing gear drop test performance,
Landing Gear Design Loads Conference No. 21, AGARD CP-484, 1991.

[8] C.H. Lucas, Modeling and validation of a navy A6-intruder actively controlled landing gear system, NASA TP-209124 (1999).

[9] I. Ross, R. Edson, An electronic control for an electro-hydraulic active control landing gear for the F-4 aircraft, NASA CR-3552
(1982)

[10] SIMULINK—dynamic system simulation for MATLAB, —using SIMULINK, The Math Works Inc., 2016a.

[11] Disha Saxena, Vibration Control of MR Damper Landing Gear, (IJARAI) International Journal of Advanced Research in Artificial Intelligence, Vol. 2, No.3, 2013

[12] Omer Faruk Sancak, Vibration Reduction of an Aircraft using Semi Active Landing Gear with MR damper, Confrence on Advances in Mechanical Engineering Istanbul 2016 ICAME2016 11-13 May 2016, Yildiz Technical University, Istanbul, Turkey