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Controlling the Vibration of Bus Suspension System using different Controller

[1] Ms. Sonam Rani, [2] Ms. Swati Gaur

[1] Research Scholar Department of Electronics & Comm. Engg. in Delhi College of Technology & Management

[2] Assistant Prof. in Delhi College of Technology & Management

ss.sec.10@gmail.com

Abstract:
This paper presents the application of PI and PID controller to control the vibration occurred in the bus suspension system. When the suspension system is designed, a ¼ model of bus is used to simplify the problem to a one dimensional mass spring-damper system. Its open-loop performance on the basis of time response is observed which depicts that the bus suspension has oscillations with large settling time. To overcome this problem, closed-loop system is used. Despite continuous advancement in control theory, Proportional –Integral (PI) and Proportional-Integral-Derivative (PID) Controllers are the popular technique to control any process. In this paper, Proportional-Integral (PI) and Proportional-Integral-Derivative (PID) controllers are used to control the vibrations to give smooth response of the bus suspension system and carry-out their comparison on the basis of time and frequency using Matlab environment. The simulation and implementation of the controller is done using MATLAB/SIMULINK.

Keywords: Bus suspension system, dynamic modeling, P controller, PI controller, PID controller, State space model, Matlab/Simulink.

I.INTRODUCTION

Increasing progress in automobile industry demands for better riding capabilities and passenger comfort, to produce highly developed model. The aim of the advanced bus suspension system is to provide smooth ride and maintain the control of the vehicle over cracks, uneven pavement of the road. Many active suspension control approaches such as linear Quadratic Gaussian (LQG) control, adaptive control & nonlinear control are developed and proposed so as to manage the problem. In this paper P, PI, & PID controller are used to control the bus suspension system. The values of Kp, Kd and Kiare calculated using Ziegler-Nichol as method. State space theory will be used in order to create the mathematical modeling of the system. The simulation is using the Matlab /Simulink software.

II.BUSSUSPENSION SYSTEM

The bus suspension system is one of the impressive challenging problems in terms of controlling the system. The control objective of this system is to give the smoothest riding for who is on the bus. The rear three systems for suspension system which are active, semi active and passive suspension system. From the bus suspension system model, the dynamic equation is obtained by using the Newton's law. Then, this dynamic equation will be transfer in to the Matlab to get the transfer function using the built in function.

Inthispaper1/4th model of the bus is used to design a simple bus suspension system .The model of bus suspension system is shown below

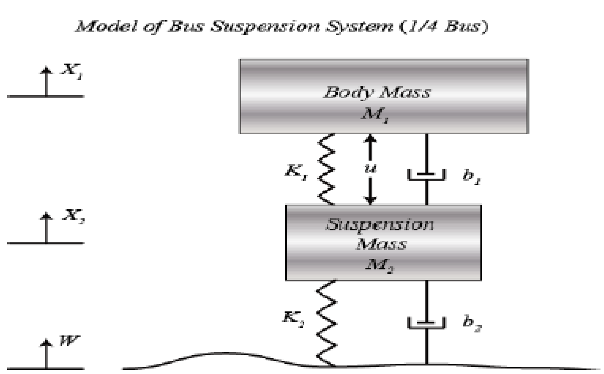

Figure 1: Bus suspension system model of 1/4th bus

Corresponding author: Ms. Sonam Rani

Where the constraints and variables are

System Parameters
M1=250kg,1/4busbodymass
M2=320kg,Suspensionmass
K1=80,000N/m,springconstantofsuspensionsystem
K2=500,000N/m,springconstantofwheelandtire
b1=350Ns/m,Dampingconstantofsuspensionsystem
b2=15,020Ns/dampingconstantofwheelandtire
U = = Controlforce

The dynamic equation can be obtained as the following-

$$M_1 \ddot{X}_1 = -b_1 (\dot{X}_1 - \dot{X}_2) - K_1 (X_1 - X_2) + U$$

$$M_2 \ddot{X}_2 = b_1 (\dot{X}_1 - \dot{X}_2) + K_1 (X_1 - X_2) + b_2 (\dot{W} - \dot{X}_2) + K_2 (W - X_2) - U$$

Solving the systems of equation is difficult so we

Simulink model of Bus suspension system–

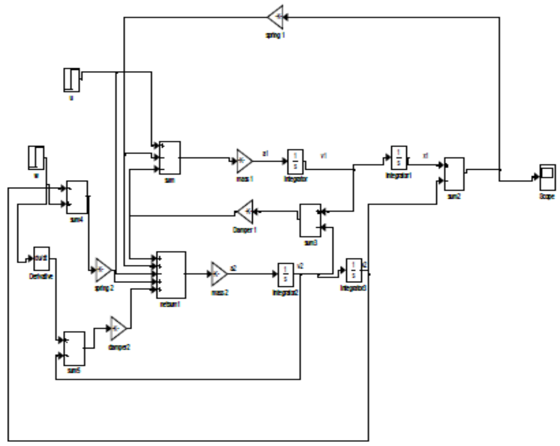

Figure 2: Simulink model of bus suspension system

Simulation output-

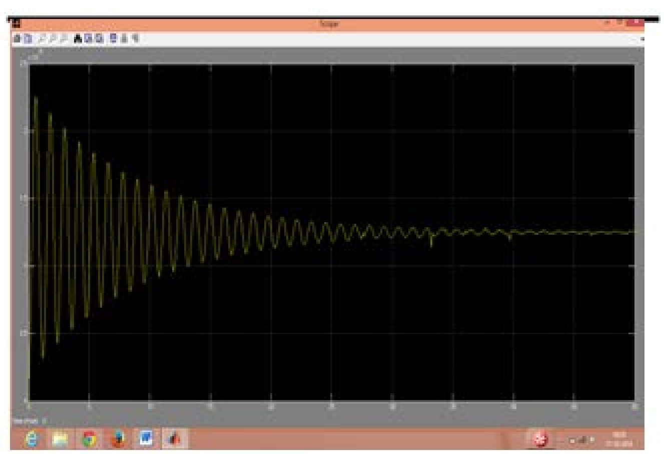

Figure3: Simulation output of bus suspension system

State space model-

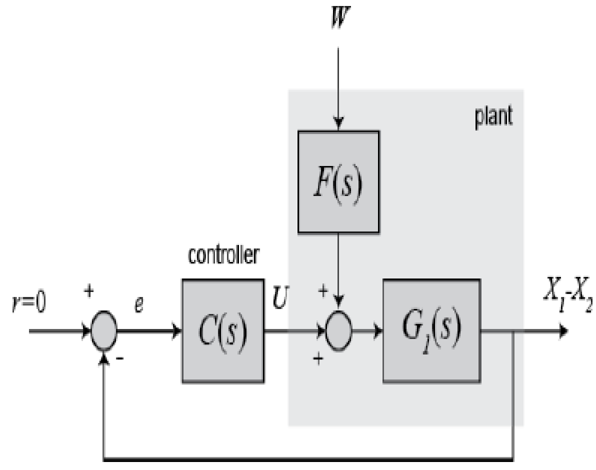

Figure 4: Open loop step response of bus suspension system

We want to design a feedback controller so that when the road disturbance (W) is simulated by a unit step input, the output (X1-X2) has a settling time less than 5 seconds and an overshoot less than 5%. For example, when the bus runs onto a 10 cm high step, the bus body will oscillate within a range of +/-5 mm and will stop oscillating within 5 seconds .

From the picture above and Newton' slaw, we can obtain the dynamic equations as the fo llowing:

$$M_1\ddot{X}_1 = K(X_2 - X_1) + b(\dot{X}_2 - \dot{X}_1) + u$$

$$M_2\ddot{X}_2 = K(X_1 - X_2) + K(W - X_2) + b(\dot{X}_1 - \dot{X}_2)$$

The equations above can be expressed in state-space formbychoosing**X1, X2, and their derivatives** as the state variables:

$$\begin{bmatrix}\dot{X}_1\\ \ddot{X}_1\\ \dot{X}_2\\ \ddot{X}_2\end{bmatrix} = \begin{bmatrix}0 & 1 & 0 & 0\\ \frac{-K}{M_1} & -\frac{b}{M_1} & \frac{K}{M_1} & \frac{b}{M_1}\\ 0 & 0 & 0 & 1\\ \frac{K}{M_2} & \frac{b}{M_2} & -\frac{2K}{M_2} & -\frac{b}{M_2}\end{bmatrix}\begin{bmatrix}X_1\\ \dot{X}_1\\ X_2\\ \dot{X}_2\end{bmatrix} + \begin{bmatrix}0 & 0\\ 1 & 0\\ 0 & 0\\ 0 & \frac{K}{M_2}\end{bmatrix}\begin{bmatrix}u\\ W\end{bmatrix}$$

$$Y = \begin{bmatrix}1 & 0 & -1 & 0\end{bmatrix}\begin{bmatrix}X_1\\ \dot{X}_1\\ X_2\\ \dot{X}_2\end{bmatrix} + \begin{bmatrix}0 & 0\end{bmatrix}\begin{bmatrix}u\\ W\end{bmatrix}$$

Simulink model using states pace model –

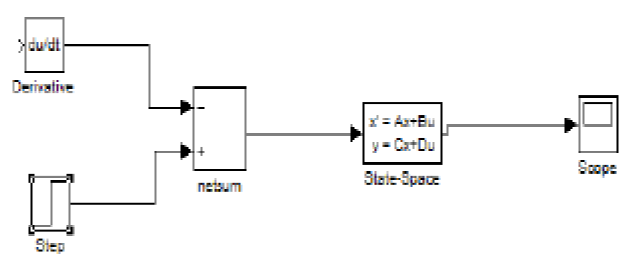

Figure5: States pace model of bus suspension system

Simulinkoutput-

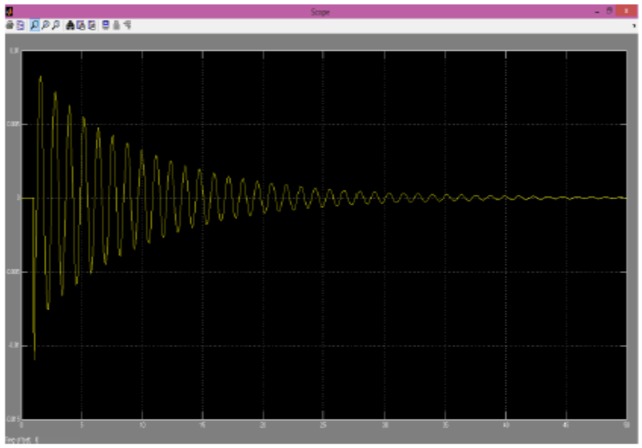

Figure6: Simulink output of state space model of bus suspension system

III. CONTROLLER

A controller is a device, may be in the form of analogue circuit, chip or computer that monitors and physically alters the operating conditions of a given dynamical system. From the past decades, the importance of the control system has been increased due to the increment in complexity of the system under control and to achieve optimum performance of the system.

Table: 1Response of proportional, integral and derivative controller [1]

Closed loop Response	Rise Time	Overshoot	Settling Time	Steady state Error
K_P	Decrease	Increase	No change	Decrease
K_I	Decrease	Increase	Increase	Eliminate
K_D	No change	Decrease	Decrease	No change

A. P controller-

P controller is mostly used in first order processes with single energy storage to stabilize the unstable process. The main usage of the P controller is to decrease the steady state error of the system. As the proportional gain factor K increases, the steady state error of the system decreases.

Simulink model of P controller with bus suspension system–

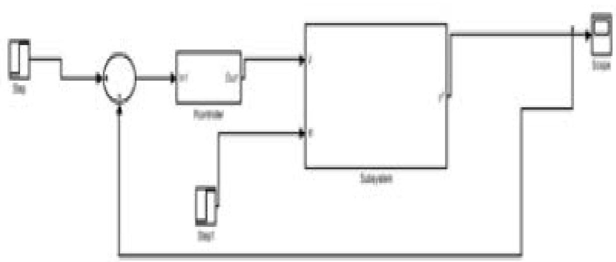

Figure 7: Simulink model of bus suspension system using P controller

Simulink output–

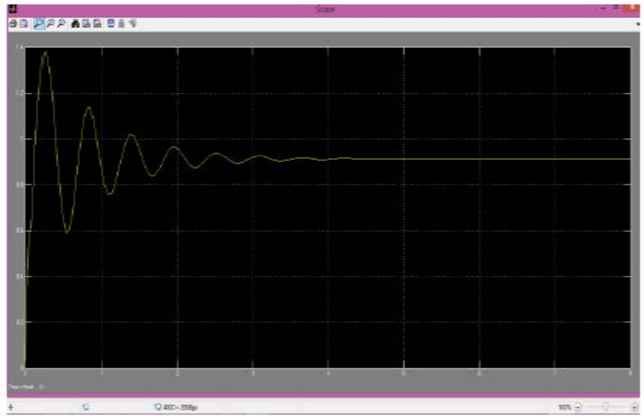

Figure 8: Simulink output of bus suspension system using P controller

B. PIcontroller-

P-I controller is mainly used to eliminate the steady state error resulting from P controller. However, in terms of the speed of the response and over all stability of the system, it has a negative impact. This controller is mostly used in areas where speed of the system is not an issue.

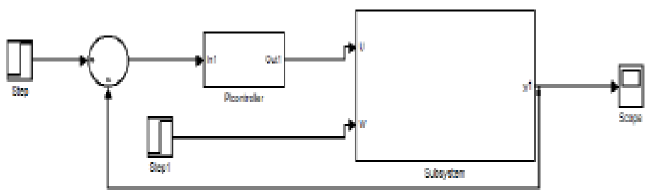

Figure 9: Simulink model of bus suspension system using PI controller

Simulink output-

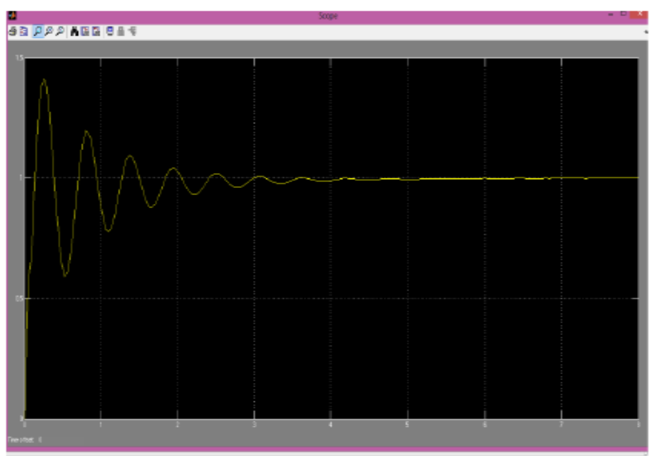

Figure 10: Simulink output of bus suspension system using PI controller

C. PID controller-

The PID controller calculation involves three separate parameters, and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted P, I, and D. The proportional value determines the reaction to the current error, the integral value determines the reaction based on the sum of recent errors, and the derivative value determine the reaction based on the rate at which the error has been changing.

Simulink model of PID controller with bus suspension system-

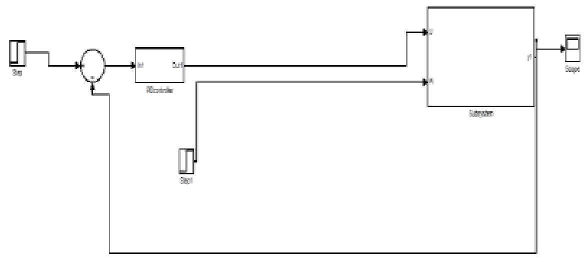

Figure 11: Simulink model of bus suspension system using PID controller

Simulinkoutput–

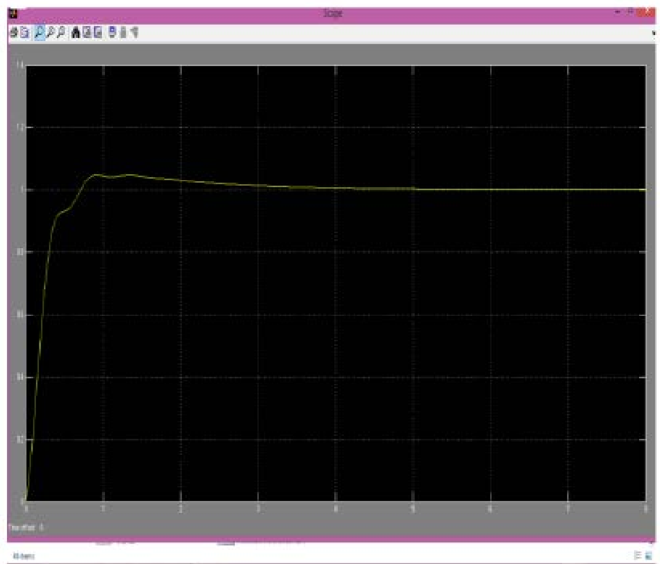

Figure 12: Simulink output of bus suspension system using PID controller

IV.C O N C L U S I O N

This paper presentusing1/4th model of bus suspension system using transfer function and state space model in Matlab / Simulink. In this paper P controller, PI controller & PID controller is used to control the vibration give the smoothresponseofbussuspensionsystem.

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