

System Analysis & Mathematical Modelling Of Bus Suspension System Using Matlab

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Abstract— Suspension system is the most significant part which heavily affects the vehicle handling performance and ride quality. The design of the control strategy is the core of suspension system technology. So the research of the application of system modelling in automobile suspension spreads out in this thesis. According to the automobile suspension system dynamic characteristic, this thesis use modern control theory in the active suspension system. The author puts forward new control strategies and combined with PID control, which make suspension system control performance further improve. The author uses the vehicle kinematics theory to set up active suspension system dynamic model. The author also established form of input mathematics and simulation model. Through the MATLAB software, simulation model was constructed. It achieved the control simulation with different input of the suspension system. Through the analysis of simulation results, we know that feedback control strategies are more reasonable and feasible. The combination of PID control is more competitive, it has shown best stability and reliability. This combination also greatly improves the stability characteristics, and the curve is more smoothly, which achieved great effect. This new type of intelligent control strategy provides a new thinking way for the automotive suspension control theory.

Keywords— Suspension system, Matlab, System Analysis, Bus suspension system, dynamic modelling, P controller, PI controller, PID controller, State space model.

I. INTRODUCTION

At the present time, there is a great problem providing the bus suspension system with high speed & smooth drive from olden days, large control method has been proposed to overcome these suspension problem. 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 PID controller is used to control the bus suspension system. The values of K_p , K_d and K_i are calculated using Ziegler-Nicholas method. State space theory will be used in order to create the mathematical modelling of the system. The simulation is using the Matlab/Simulink software.

II. BUS SUSPENSION 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. There are three system 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 into the Matlab to get the transfer function using the built in function. In this paper 1/4th model of the bus is used to design a simple bus suspension system. The model of bus suspension system is shown below - proposed methodology.

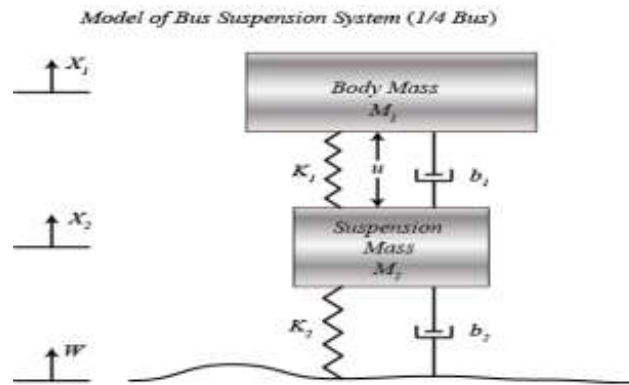


Fig. 1 Bus suspension system model of 1/4th bus

Where the constraints and variables are

System Parameters

- $M_1 = 250$ kg, 1/4 bus body mass
- $M_2 = 320$ kg, Suspension mass
- $K_1 = 80,000$ N/m, spring constant of suspension system
- $K_2 = 500,000$ N/m, spring constant of wheel and tire
- $b_1 = 350$ Ns/m, Damping constant of suspension system
- $b_2 = 15,020$ Ns/damping constant of wheel and tire
- U = Control force

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 can use Matlab Simulink software

Simulink model of Bus suspension system –

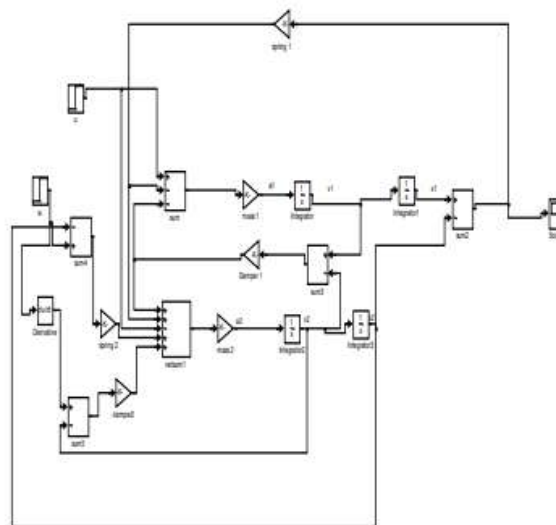


Fig. 2 Simulink model of bus suspension system

Simulation output –

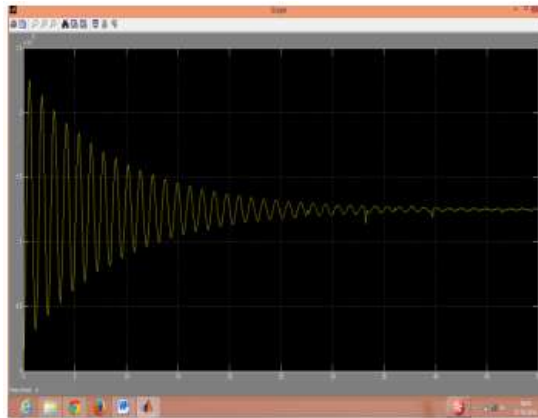


Fig. 3 Simulation output of bus suspension system

State space model –

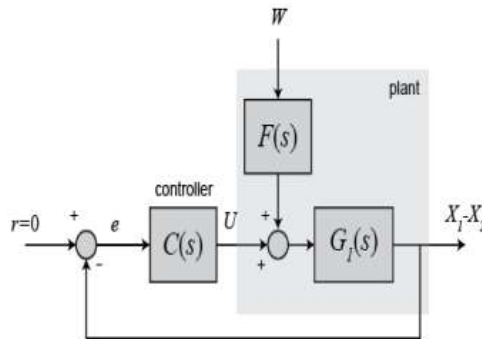


Fig. 4 Open loop step response of bus suspension system

We want to design a feedback controller so that when the road disturbance (W) is simulated by a unit step input, the output ($X_1 - X_2$) 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's law, we can obtain the dynamic equations as the following:

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

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

The equations above can be expressed in state-space form by choosing X_1 , X_2 , and their derivatives as the state variables:

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

$$y = [1 \quad 0 \quad -1 \quad 0] \begin{bmatrix} X_1 \\ \dot{X}_1 \\ X_2 \\ \dot{X}_2 \end{bmatrix} + [0 \quad 0] \begin{bmatrix} u \\ W \end{bmatrix}$$

Simulink model using state space model –

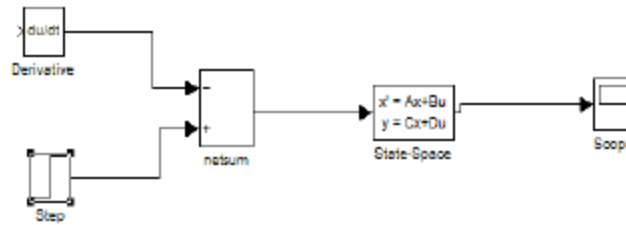


Fig. 5 State space model of bus suspension system

Simulink output-

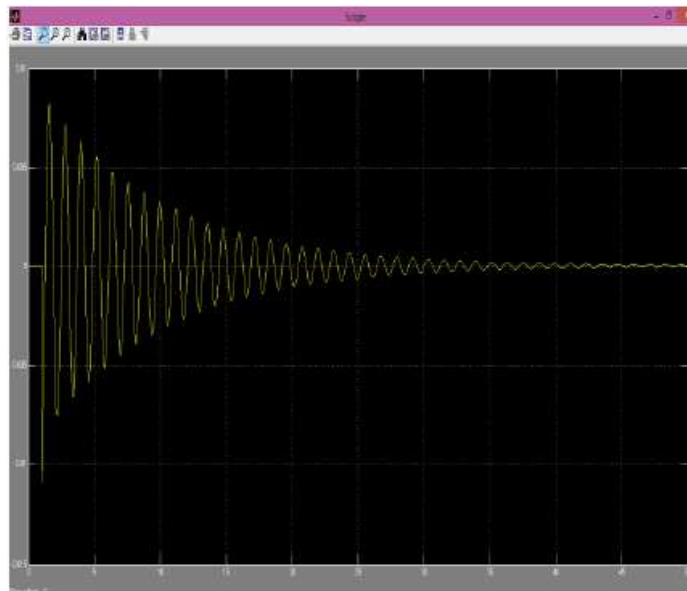


Fig. 6 Simulink output of state space model of bus suspension system

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 1
 Response 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

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 determines the reaction based on the rate at which the error has been changing.

Simulink model of PID controller with bus suspension system –

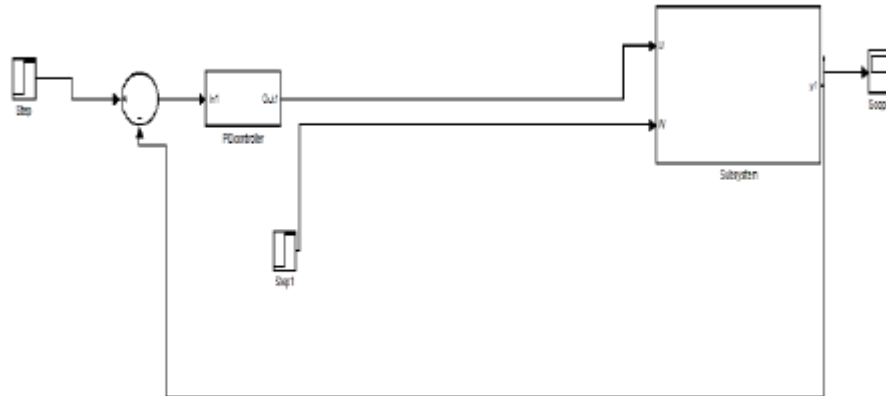


Fig. 7 Simulink model of bus suspension system using PID controller

Simulink output –



Fig.8 Simulink output of bus suspension system using PID controller

IV. CONCLUSION

This paper present using 1/4th model of bus suspension system using transfer function and state space model in Matlab/Simulink. In this paper PID controller is used to control the vibration to give the smooth response of bus suspension system.

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