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Comparative Analysis of P, PI, PD, PID Controller for Mass Spring Damper System using Matlab Simulink.

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Abstract: The objective of this paper is to design and comparatively analyze the P, PI, PD, and PID Logic controller for Mass Spring Damper system. Simulink model for Mass Spring Damper system is designed within MATLAB/Simulink. Tuning of parameters for PID controller is done using signal constraint block in MATLAB/simulink. Simulated results were compared to verify the performance of the control system in terms of rise time, steady state error, settling time and overshoot.

IndexTerms - **Mass Spring Damper, MATLAB/Simulink, PID Controller.**

I. INTRODUCTION

A Simulink library block diagram is used to characterize time-based relationships between signals and state variables. The solution of a block diagram is obtained by evaluating these relationships over time, where time starts at a user specified "start time" and ends at a user specified "stop time." Each evaluation of these relationships is referred to as a time step.

Signals represent quantities that change over time and are defined for all points in time between the block diagram's start and stop time.

The relationships between signals and state variables are defined by a set of equations represented by blocks. Each block consists of a set of equations (block methods). These equations define a relationship between the input signals, output signals and the state variables.

Mostly PID controller is used in commercial industries for control process due to its simple structure and simple for implementation purpose. Conventional P controller is used to reduce the rise time and it can eliminate the present error proportionally but cannot eliminate steady state error. Conventional 'I' controller is used to eliminate the steady state error. Conventional 'D' controller effects in increasing the stability of system because it starts working before error start increasing in the system. PID controller use mathematical model of the system as it is difficult to find proper gain so it is not good for highly non linear system. In this work second order mass spring damper system is used which is a linear system. Where PI controller is suitable for low order process where accuracy does not the prime factor but for higher accuracy it is not suitable. It is also difficult to get desired result by using conventional PI controller as it gives poor performance for higher order process.

Model-Based Design is a process that enables faster, more cost-effective development of dynamic systems, including control systems, signal processing, and communications systems. Model-Based Design is changing the way architects and researchers work by moving outline undertakings from the lab and field to the work area. Whenever programming and equipment execution necessities are incorporated, for example, settled point and timing conduct, you can consequently produce code for implanted organization and make test seats for framework confirmation, sparing time and maintaining a strategic distance from the presentation of physically coded mistakes.

In Model-Based Design, a system model is at the center of the development process, from requirements development, through design, implementation, and testing. The model is an executable specification that you continually refine throughout the development process. After model development, simulation shows whether the model works correctly.

II. MATHEMATICAL MODELLING OF MASS SPRING DAMPER SYSTEM

Let us consider simple Mass Spring Damper linear system which is generally used to reduce vibrations in a mechanical system shown in figure 1. Mathematical equation of the system is shown as equation 1.

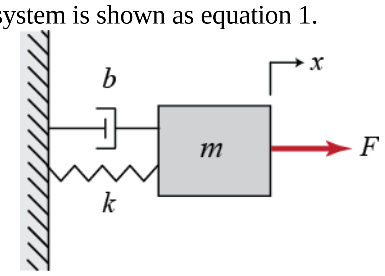

Fig 2.1. Schematic diagram of Mass Spring Damper System**.**

Let us consider m as mass of the system in kg, k as spring stiffness in N/m, and b as damping coefficient in kg/sec.

The transfer function between Output X(s) and Input F(s) of the system is given by,

$$\frac{X(s)}{F(s)} = \frac{1}{ms^2+bs+k} \quad (1)$$

III. METHODOLOGY

Follow the steps to evaluate the model:

1. Defining the System
2. Identifying System Components
3. Modeling the System with Equations
4. Building the Simulink Block Diagram
5. Running the Simulation
6. Validating the Simulation Results

Perform the first three steps of this process outside of the Simulink software environment before you begin building your model.

IV. PID CONTROLLER DESIGN FOR THE SYSTEM

A simulated model for PID control system is as shown fig.2 the difference of set point and measured variable goes to the controller. PID controller combines the control action of Proportional, Integral and derivative controller where Proportional controller reduces the rise time, integral controller eliminates steady state error and derivative controller reduces overshoots of the system. PID controller involves three tuning parameters Kp, Ki and Kd. In this paper parameters are tuned within MATLAB/Simulink block signal constraint. This tool helps in optimization of parameters very fast. In this tool we used 0 to infinity tolerance for finding optimal solution or feasible solution.

Let us consider Proportional constant (Kp) = 10
Derivative constant (Kd) = 2
Integral constant (Ki) = 5
Mass of the system (m) = 1 kg
Damping Coefficient (b) =2 kg/sec
Spring Stiffness (k) = 1 N/m

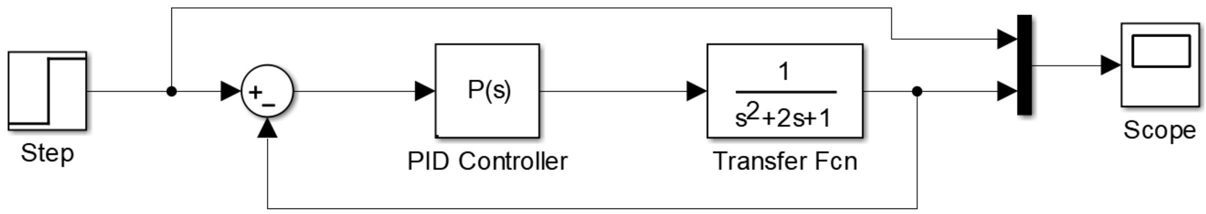

Fig 4.1 Simulated Model for PID control system.

V. SIMULATION RESULTS AND COMPARISONS:

The simulink model for Mass Spring Damper system , PID controller and their simulated response to find rise time, setting time overshoot and peak value of the controllers are shown below.

Proportional Controller results:

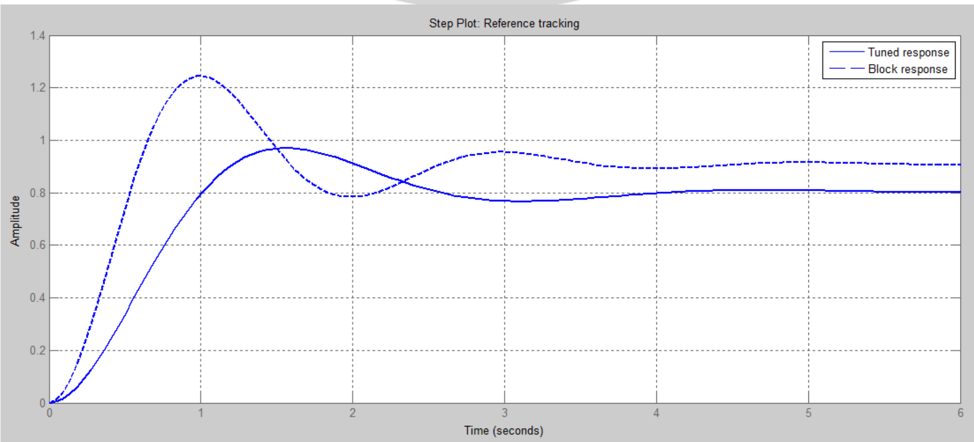

Fig 4.2. Tuned response of Proportional Controller.

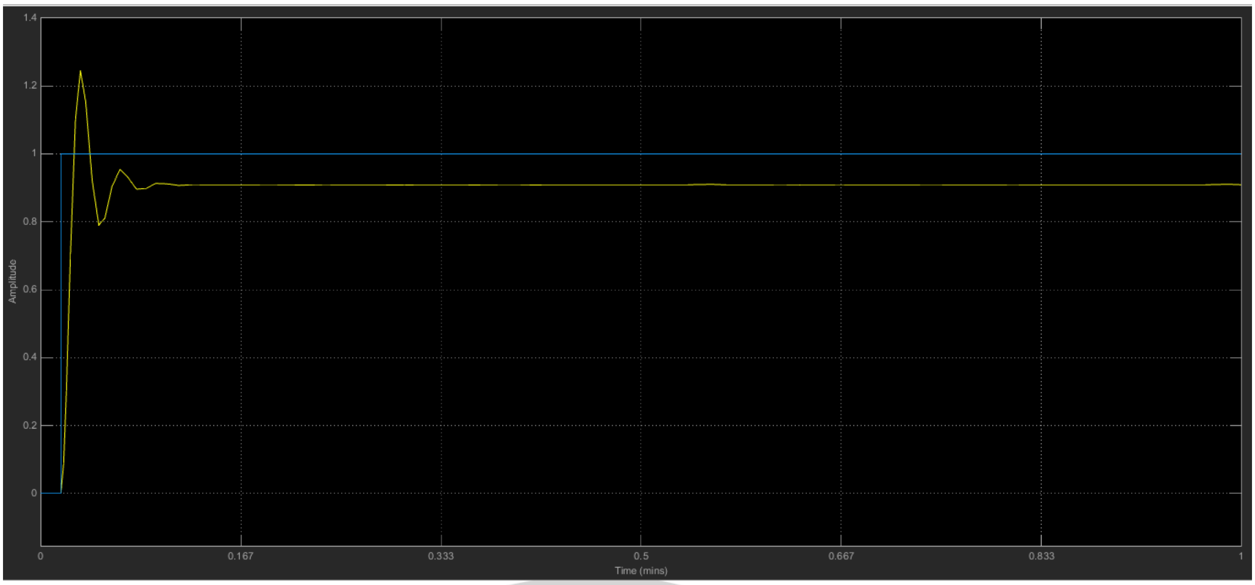

Fig 2.3 Time Scope response of Proportional Controller.

Proportional Derivative Controller Results:

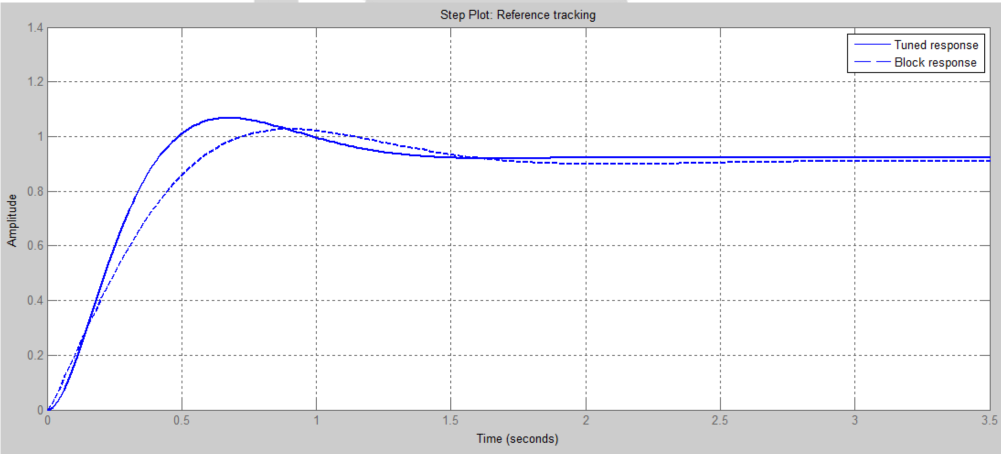

Fig 4.4 Tuned response of Proportional Derivative Controller**.**

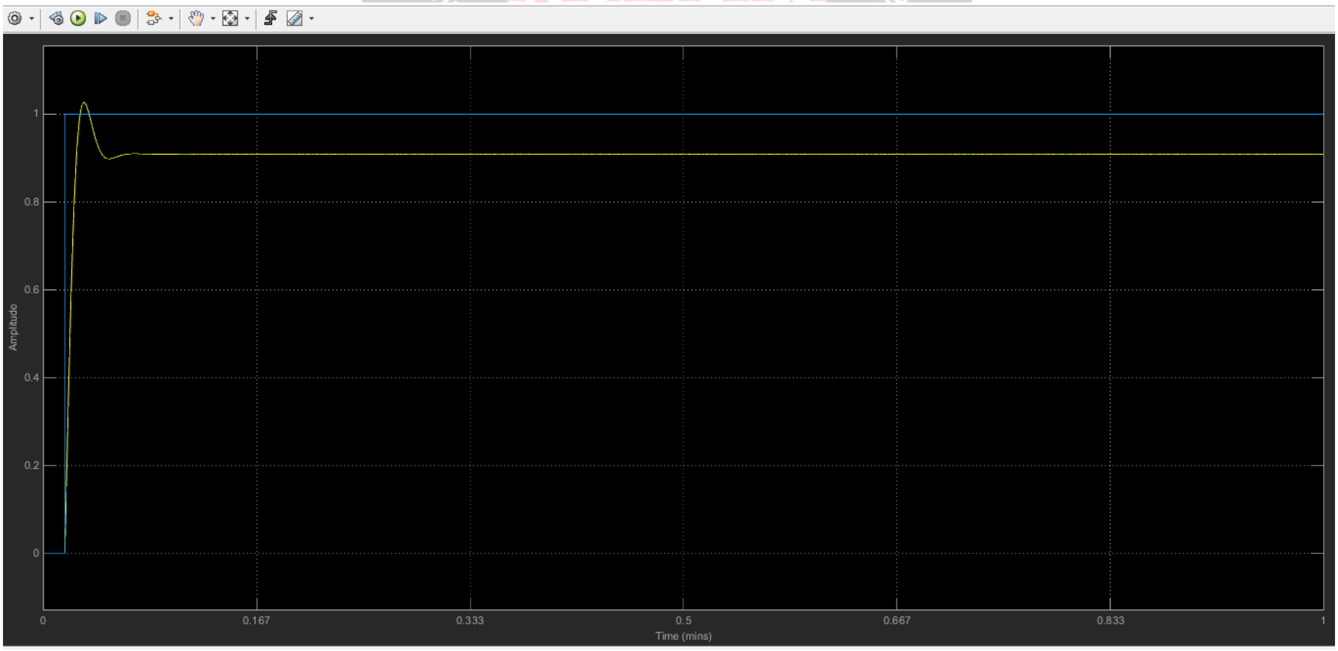

Fig 4.5 Time Scope Response of Proportional Derivative Response.

Proportional Integral Controller Results:

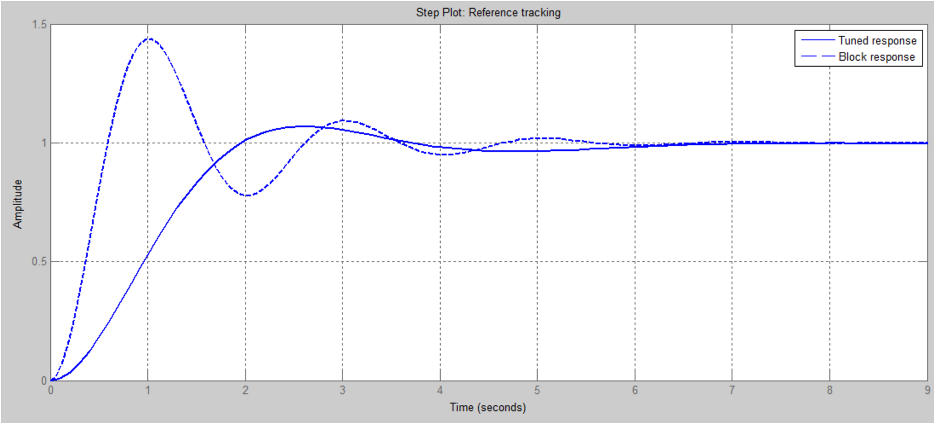

Fig 4.6 Tuned Response of Proportional Integral Controller.

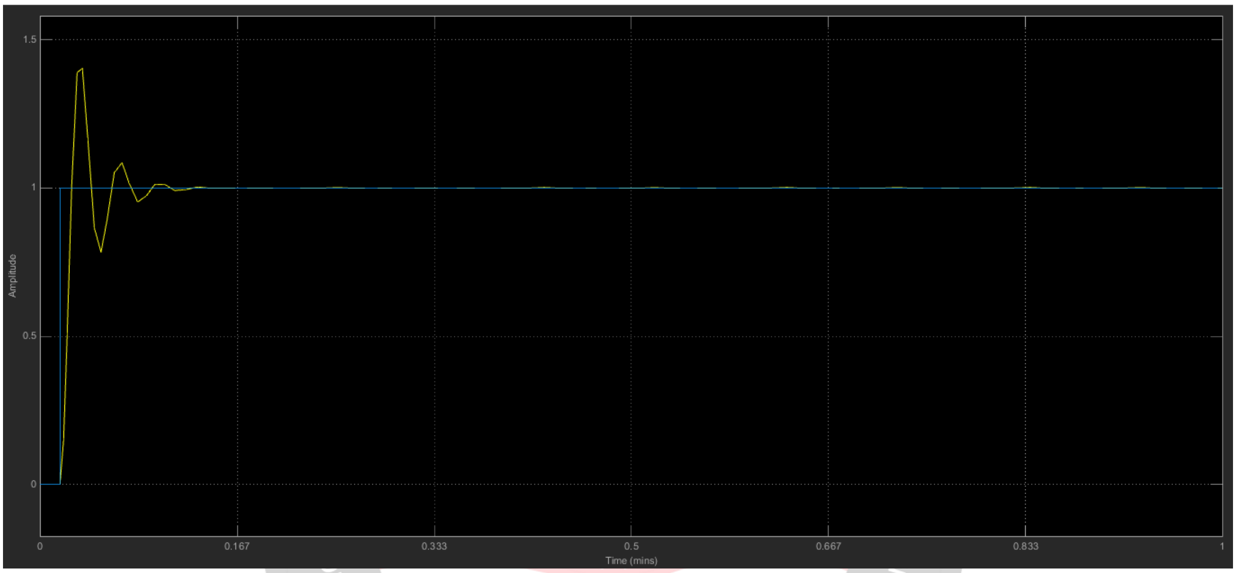

Fig 4.7 Time Scope Response of Proportional Integral Controller.

Proportional Integral Derivative Controller:

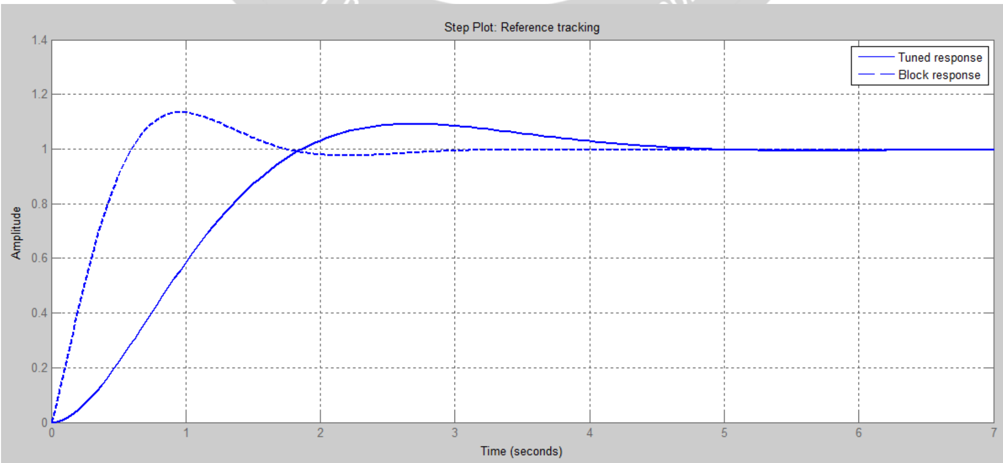

Fig 4.8 Tuned Response of P-I-D Controller.

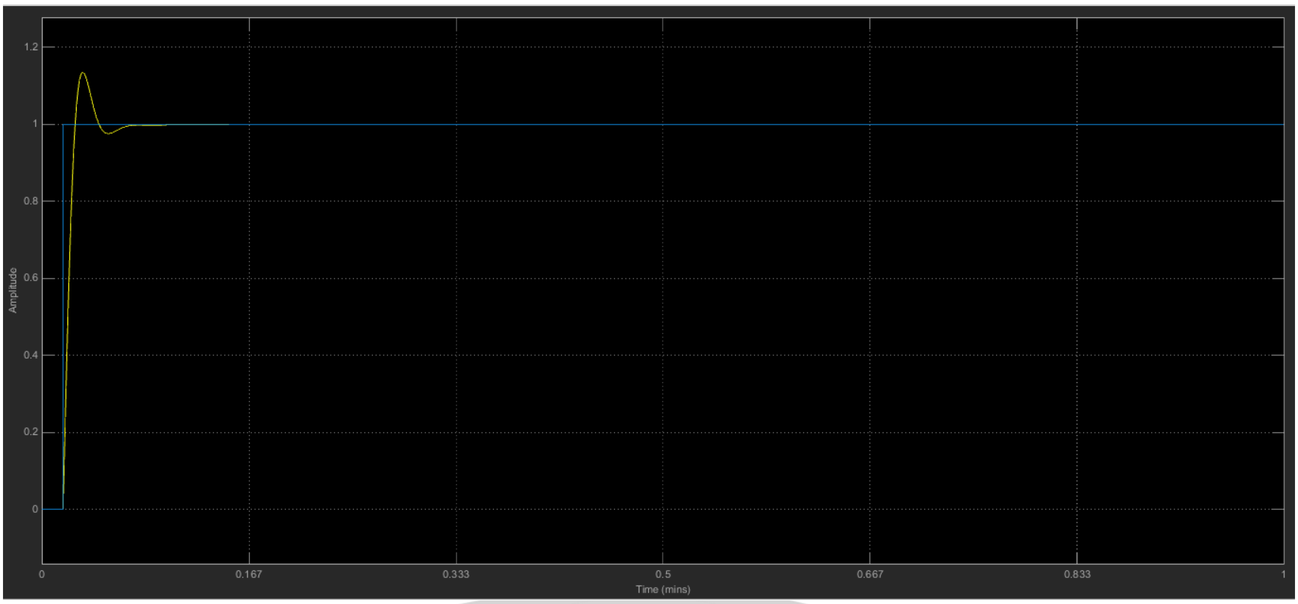

Fig 4.9. Time Scope Response of P-I-D Controller.

Process Parameters of Controllers:

Table 4.1. Comparative evaluation of Controllers in tabular form

Controller	Rise Time (Sec)		Setting Time (Sec)		Peak Overshoot (%)		Peak Value	
	Tuned	**Block**	**Tuned**	**Block**	**Tuned**	**Block**	**Tuned**	**Block**
P	0.685	0.4	3.72	3.38	21	37	0.971	1.25
PI	1.3	0.399	5.91	4.45	6.99	43.6	1.07	1.44
PD	0.287	0.41	1.24	1.56	15.3	13	1.07	1.03
PID	1.25	0.442	4.18	2.46	9.15	13.5	1.09	1.13

CONCLUSION

In this paper, we developed the mathematical model of Mass Spring Damper system and design a simulink model Mass Spring Damper system and PID controller. Designed model are simulated within MATLAB/Simulink and comparatively analyzed in terms of rise time, steady state error, peak overshoot and setting time. From the analysis we concluded that P-I-D controller gives better performance.

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