MATLAB application in quality-spring-damper system

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Abstract

Quality - spring - damper system is a kind of simple mechanical systems, Matlab has powerful functions of numerical analysis, matrix calculation and drawing, we can solve the differential equations, the transfer function and time domain response of the system, and then use Matlab to draw block diagram , build mathematical modeling and physical modeling of the system,. and to analyze the frequency domain and the stability of the system, thus get profound understanding of the system. In another way, we laid the foundation of other subsequent mechanical systems research.

Keywords

Quality - spring - damper system, the matlab simulation language, system modeling.

1. Introduction

With the development of computer technology, a series of simulation software has been developed and applied, which has brought new development direction for mechanical design. Matlab, as a powerful mathematical calculation software, is widely used in mechanical, electronic and other design experiments due to its strong reliability, function and convenient operation. Matlab can be used to model the mechanical system, so as to predict the reliability and stability of the system, reduce the actual consumption, and provide direction for subsequent optimization [1]. The mathematical model and physical model are used more in Matlab. The mathematical model is to describe the dynamic characteristics of the system quantitatively, and to reveal the mathematical expression of the relationship among the structure, parameters and dynamic characteristics of the system [2]. The physical model is based on the analysis of phenomena and mechanism, which describes the physical processes of the object system "how to do" and "how to implement" the system. In the control engineering, the second order system is widely used, and other higher-order systems can be converted into second order systems under certain conditions. Matlab is widely used in mechanical design system research, not only because of its powerful function, but also because it has a fairly high reliability, and it has quite a number of subroutines [3]. We can use Matlab to do in-depth analysis of the mechanical system and to create more advanced mechanical design system. The emergence of Simulink greatly improves the development efficiency of simulation application. In this paper, a simple quality - spring - damping system is studied, and Matlab is used for simulation analysis, which provides a direction for subsequent research of other mechanical systems.

2. Mass - Spring - Damping System Dynamics Modeling

The schematic diagram of a mass - spring - damping system is shown in Fig.1

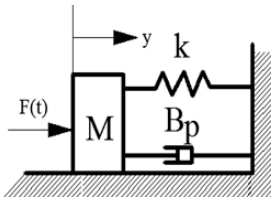

Fig.1Schematic diagram

Fig. 2 is the isolation figure, Bp is the viscous damping coefficient, k is the spring stiffness, and M is the mass of the moving object.

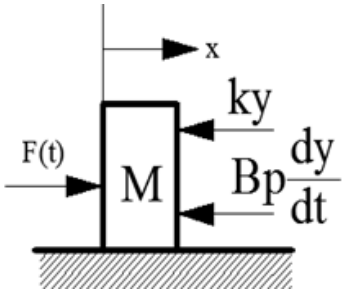

Fig.2 Isolated body figure

The input of the system is F, and the output is y. According to Newton's second law, the motion equation of the system is:

$$M\ddot{y}+B_p\dot{y}+ky=F \tag{1}$$

M, Bp and k are constants, and the equation is linear constant coefficient second order differential equation, which is a linear time-invariant system. According to the differential equation of the system, the transfer function of the system can be obtained:

$$G(s)=\frac{Y(s)}{x(s)}=\frac{F}{ms^2+B_{ps}+k} \tag{2}$$

In order to facilitate the simulation analysis in Matlab, the state space modeling of the system is made.

$$X=[X_1 \quad X_2]^T \tag{3}$$

$$X_1=y, X_2=\frac{dy}{dt} \tag{4}$$

The matrix expression of the system can be obtained:

$$\begin{bmatrix}\dot{X_1}\\ \dot{X_2}\end{bmatrix}=\begin{bmatrix}0 & 1\\ -\frac{k}{m} & -\frac{B_p}{m}\end{bmatrix}\begin{bmatrix}X_1\\ X_2\end{bmatrix}+\begin{bmatrix}0\\ \frac{F}{m}\end{bmatrix} \tag{5}$$

The output equation is:

$$y=x_1=[1 \quad 0]\begin{bmatrix}X_1\\ X_2\end{bmatrix} \tag{6}$$

3. Mathematical Model Simulation and Analysis of Mass - Spring - Damping System.

3.1 The Time Domain Response and Stability of the System.

According to the transfer function of the system, the programming language of Matlab is as follows:

```
m=77.23; Bp=181.6;k=296.7;
F=8.9;
sys=F*tf(1,[m Bp k])
subplot(121)
step(sys,'k-');grid
subplot(122)
impulse(sys,'r--');grid
```

Run the program to get the time domain response curve as shown in figure 3. The graph shows that the curve is convergent, so the system is stable.

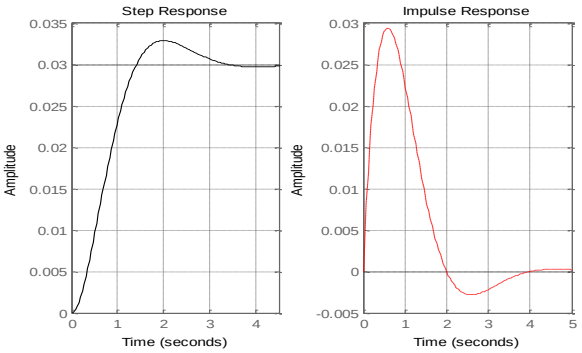

Fig.3 time response curve of the system

3.2 Use the Simulink to Draw the System Block Diagram, as Shown in Figure4

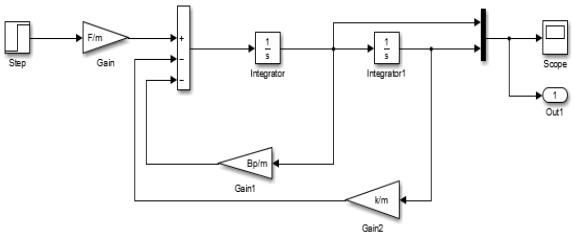

Fig.4 block diagram of the system

Simulink is a special dynamic simulation toolbox in Matlab, which further expands the function of Matlab [4-5]. Using the simulink to establish the system model is more intuitive and obtain the model response curve, which can be seen that the steady-state value of the system is 0.03.

3.3 The Matlab Language of the State Space Model

```
m=77.23;Bp=181,6;k=296.7; F=8.9;
a=[0 1;-k/m -Bp/m];b=(F/m)*[0 1]';c=[1 0];d=0;
sys=ss(a,b,c,d);
subplot(121)
step(sys,'k-');grid
subplot(122)
impulse(sys,'k-');grid
```

Run the above program and get the curve shown in figure 5.

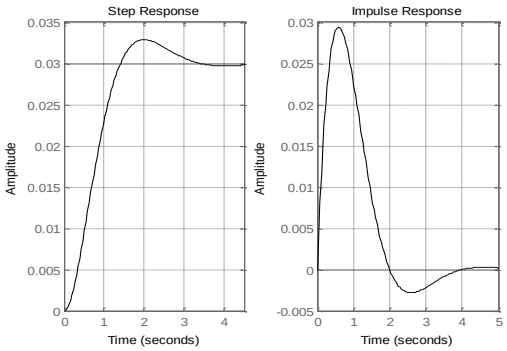

Fig.5 Pulse step response curve of the system

3.4 System Frequency Domain Analysis

Frequency domain analysis is an indirect method for studying the performance of the control system, and the stability of the system is studied by studying the frequency characteristics of the system [14-15]. Enter the following language in Matlab:

```
m=77.23;Bp=181.6;k=296.7; F=8.9;
sysk= tf(F,[m Bp k -F])
figure(1)
subplot(121)
pzmap(sysk) ;grid
subplot(122)
nyquist(sysk);grid
figure(2)
margin(sysk);grid
```

The above program is run, and the system frequency domain analysis curve is obtained. Figure 6 is the system Nyquist plot, and figure 7 is the Bode diagram of the system. It can be seen that the system is stable.

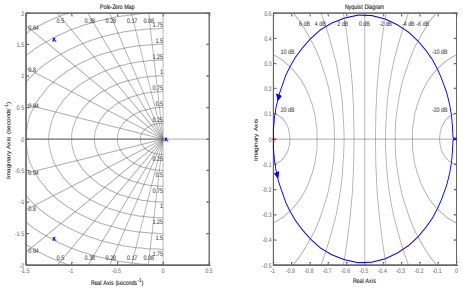

Fig.6 Nyquist diagram of the system

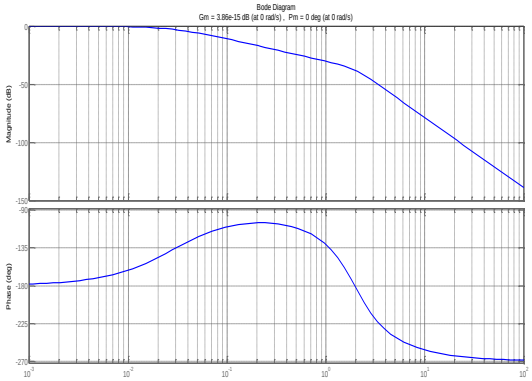

Fig.7 Bode diagram of the system

4. Physical Model Simulation and Analysis of Mass - Spring - Damping System.

According to the quality block used in the hardware system, the translational spring and the dynamic damper, the input force is regarded as the amplitude of the unit step function. The output translational velocity and displacement of the stationary sensor are selected, and the oscilloscope is used for real-time display. Draw the physical model diagram as shown in figure 8.

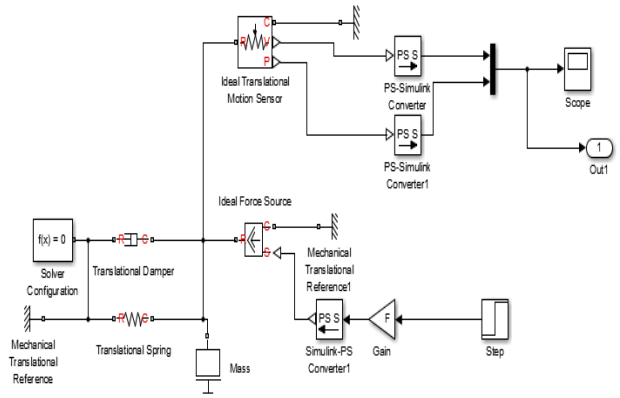

Fig.8 physical model of the system

Simulink software is very interactive [6], and the physical model image drawn is intuitive, which can be adjusted easily and quickly for physical components.

5. Conclusion

Simple quality - spring - damper system combined with Matlab simulation, based on quality - spring damping system for mathematical modeling and physical modeling, written in the matlab programming language, according to the different model for the simulation curve, the result is the same. Through simulation, it can be seen that the system is a stable system. Matlab has the powerful analysis and simulation function, through the quality - spring - damping system simulation analysis, to the subsequent other mechanical system research provides the reference.

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