Simulation of Two-Degree-of-Freedom Damped Dynamic Vibration Absorber Based on Simulink

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Abstract

Matlab is an internet application with high performance offered by Math Works, which provides powerful function in matrix disposing and plotting. The numerical method for solving differential equation by Matlab has great advantages in the simulation analysis of mechanical vibration system. In this paper, the physical model of two degree of freedom damped dynamic vibration absorber is introduced at first, and the corresponding mathematical model is established. Then, the vibration absorber is simulated by using the Simulink module in Matlab. The displacement of the system which the vibration absorber is acted on is plotted, and the working principle of the vibration absorber is analyzed.

Keywords

mechanical vibration; differential equations; Matlab.

1. Introduction

From the view of mathematics, the analysis of mult-degree-of-freedom system needs the solution of second-order simultaneous differential equations, the phenomenon named "coupling" exists between those variables, namely, the interaction forces exist between mass, spring and damping in mechanical model, and the relation of variable exists between the mathematical equations. As for the vibration of two-degree-of-freedom system, as the simplest example of mult-degree-of-freedom system, is widely used in various fields, in which a two-degree-of-freedom damped dynamic vibration absorber is applied to this principle. This kind of vibration absorber is suitable for a wi frequency range, and is mostly used in diesel engines or reciprocating engines to absorb torsional vibration.

For the common mechanical vibration system, by using computer simulation to observe the response of the system and analyze its characteristics, we can foresee the approximate result in the stage of design, so as to verify the theory of design, or make scientific estimates and improvement scheme of the new system. Therefore, the dynamic analysis and dynamic design of mechanical system in the mechanical industry has become an important means to improve the quality of the mechanical products and ensure the reliability of the work. Simulink is a kind of current simulation software based on Matlab, which provides a new solution for the system simulation technology. It can improve not only the efficiency of programming, but also the quality and reliability. Therefore, it has becoming the first choice of computer simulation software.

2. Brief introduction of matlab/simulink

Matlab is a kind of engineering application which combines multiple functions of scientific calculation, data visualization, image processing and engineering design into a whole. It consists of Matlab main package, different toolbox and Simulink—— the structure-oriented analysis system. As a comprehensive analysis software, Simulink has been used for modeling, simulation, analysis and so on. The system is very extensive, and can support linear or nonlinear systems which may be continuous, discontinuous or a combination of the two. It can also support a multirate system with variety of sampling rates. The interactive interface that Simulink use to interact with the users is the

Windows programming method based on graphics, when a user intend to establish the block diagram of the control system, what should he or she do is just open the model library, simply click or drag the mouse, and a complex simulation model can be constructed. Its appearance is shown in block diagram, and adopts layered structure.

The model library of Simulink includes: Sources, Sinks, Discrete, Linear, Nonlinear, Connections, Blocksets and toolboxes, and Demos. At the same time, a variety of numerical algorithms for simulation are provided by Simulink, which allows users to select the appropriate algorithm according to the actual situation, define the accuracy of simulation, specify the simulation step size and the simulation range. The simulation results can be output to the receiving module, such as displayed directly on the oscilloscope, or to the Workspace for further processing by subsequent programming, and then we can get the simulation results of graphics.

3. Simulation example of two-degree-of-freedom damped dynamic vibration absorber

3.1 Establish mathematical model

For a multiple-degree-of-freedom linear vibration system, the dynamic equation is expressed in the form of matrix equation. The dynamic equation of n degrees of freedom vibration system is:

$$M\ddot{X} + C\dot{X} + KX = f(t)$$

Where M is the mass matrix of the system, C is the damping matrix, and K is the stiffness matrix, all of them are square matrix of order n. $f(t)$ is the external excitation force acting on the system , which is a n dimensional column vector; X is the displacement variable of n degree of freedom, that is, the dynamics equation consists of n second-order differential equations.

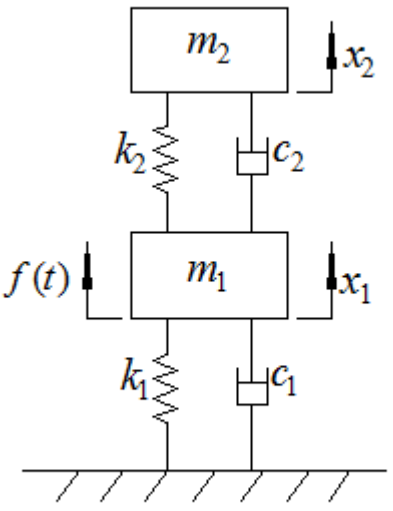

Fig.1 Physical model of the Two-Degree-of-Freedom damped dynamic vibration absorber

For the physical model shown in Fig.1, the differential equation of motion can be set up as follows:

$$m_1\ddot{x}_1 - c_2(\dot{x}_2 - \dot{x}_1) - k_2(x_2 - x_1) + c_1\dot{x}_1 + k_1x_1 = f(t)$$

$$m_2\ddot{x}_2 + k_2(x_2 - x_1) + c_2(\dot{x}_2 - \dot{x}_1) = 0$$

By using the method of Influence coefficient, the matrix form of the equation is established:

$$\begin{bmatrix} m_1 & 0 \\ 0 & m_2 \end{bmatrix}\begin{bmatrix} \ddot{x}_1 \\ \ddot{x}_2 \end{bmatrix} + \begin{bmatrix} c_1 + c_2 & -c_2 \\ -c_2 & c_2 \end{bmatrix}\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} + \begin{bmatrix} k_1 + k_2 & -k_2 \\ -k_2 & k_2 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} f(t) \\ 0 \end{bmatrix}$$

4. Establish simulation model

According to the mathematical model, the Simulink model of the mechanical vibration system can be established by using Matlab software. Usually, Matlab modeling includes integral module modeling, state space module modeling, S-Function module modeling and so on. In this paper, the modeling method of integral module with faster modeling speed is adopted.

4.1 Build the modules and set the simulation parameters

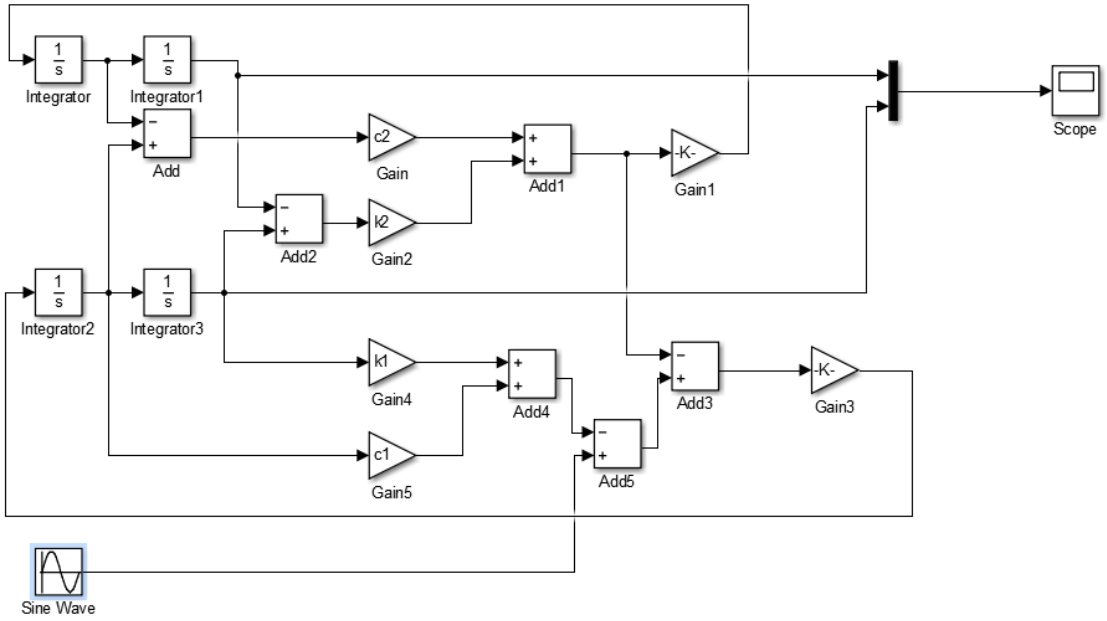

Fig.2 Simulation model established by integral module in Simulink

As the model shown in Fig.2, the variables should be assigned before run the simulation. The method of assignment is relatively simple, the values of each variable are entered directly in the Matlab command window. parameters are set as below:

$$m_1 = 2\,, k_1 = 2\,, c_1 = 0.5$$

$$m_2 = 0.1\,, k_2 = 0.4\,, c_2 = 0.05$$

4.2 Operation of the simulation model and analysis of the simulation results

The start time of the simulation system is set as 0, while the stop time is set as 2000. The excitation frequency is set to the same as the resonance frequency of the main vibration system (1Hz), and the amplitude is observed as shown in figure 3:

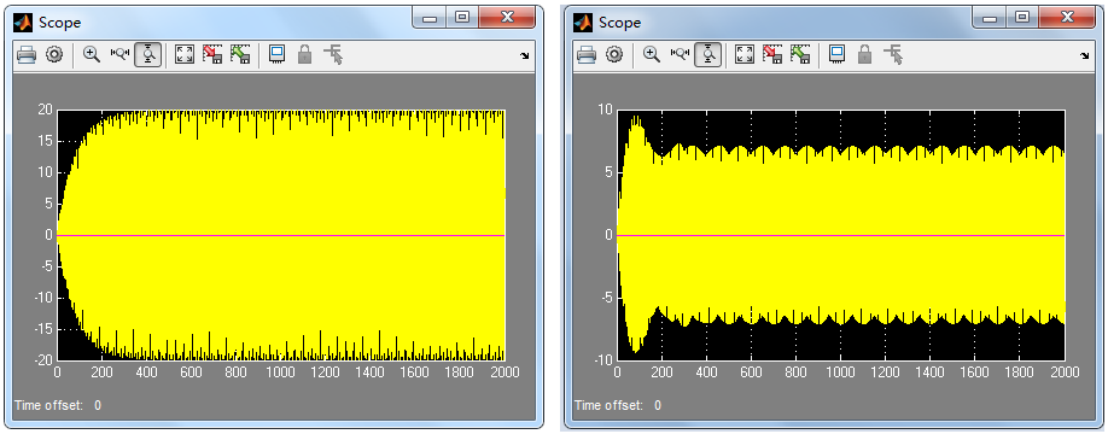

Fig.3 Before and after install the vibration absorber when the excitation frequency is 1Hz.

The excitation frequency is set to the same as the natural frequency of vibration absorber (2Hz), and the amplitude is observed as shown in figure 4:

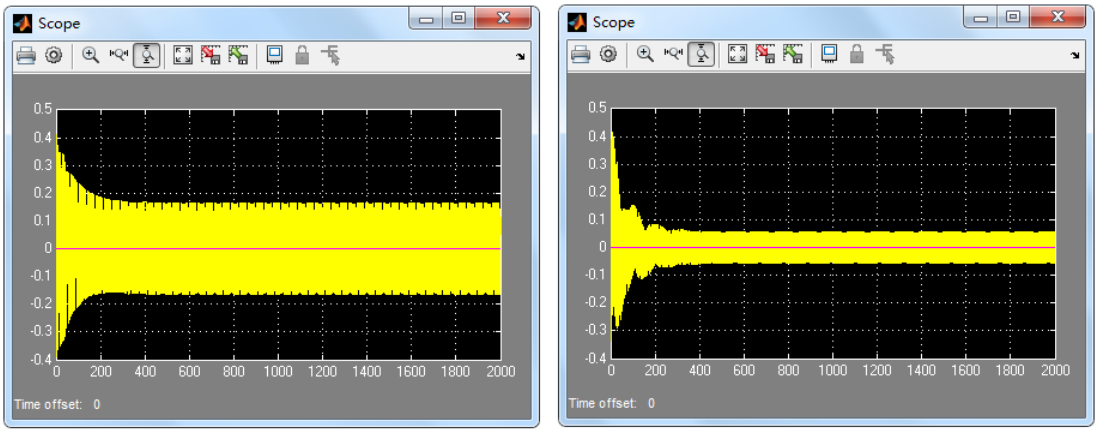

Fig.4 Before and after install the vibration absorber when the excitation frequency is 2Hz.

The amplitudes are recorded as follows:

Table.1 The compare of amplitudes with and without the vibration absorber

	Without the vibration absorber	When install the vibration absorber	Decrease of the amplitude
Resonance frequency (p=1Hz)	19.500	6.760	65.64%
Natural frequency (p=2Hz)	0.160	0.056	65.63%

It can be found from the table that the amplitude of the main system is obviously reduced after the dynamic vibration absorber is added, so that the dynamic vibration absorber can effectively reduce the vibration of the main system.

5. Conclusion

From the simulation process of the two-degrees-of-freedom damping dynamic vibration absorber above we can see that simulation based on Simulink programming software is very simple, with a friendly interface and high reliability, especially suitable for engineering and technical personne. The different simulation modules are suit for different system models, with their different characteristics. This paper use the method of integral module modeling, which is simple, fast, and can express differential equations intuitively, but the model is complex and has poor readability, By using the method of state space modeling, the model looks simple, but each time when they need to enter the corresponding value of the program code or the name of the M-file, is not convenient; As for using S-function module, the S-function is constructed by Matlab language or C language, and is called directly in the Simulink mode, which is easy and flexible, but its complex programming process need some skills of programming, which may not easy to learn. In summary, only by choosing the right modules appropriately can the simulation process be simpler and more reliable.

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