Vibration Using Matlab and Simulink

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Single Degree of Freedom Vibration Using Matlab and Simulink

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Abstract:

This work in progress paper presents an active learning approach to teach vibrations effectively to students without any labs/hands on experiments. Computer simulation is a vital part of any course involving moving systems. Vibrations is mathematically very intensive course and often students find it very difficult and boring. To make this class interesting and engaging, the instructor integrated Simulink and Matlab in the course to help students understand the dynamics of moving parts and vibrating systems. In this paper our focus is on Single Degree of Freedom Vibration, both free and Forced Vibration problem is discussed. This paper also presents results from a survey regarding how the software affected students' learning and understanding of vibrating systems.

Introduction:

Mechanical Vibration[8] is a mandatory class for Mechanical Engineering major in Wentworth Institute of technology. In this 3 credit course Senior students learn about basic of Vibration. The major student outcomes of the course are that the student must be able to a) derive the system differential equations for single (one) and multiple degree-of-freedom vibrating systems {sdf and mdf systems}; b) solve for the analytical solutions for single degree-of-freedom systems for free and forced responses; c) solve analytically for the natural frequencies and mode shapes for multiple degree-of-freedom systems, with primary emphasis on two degree-of-freedom systems; d) design a simple vibration absorber system. The prerequisite for the course is Engineering Dynamics course. When I taught this course for 1st time in Spring 2022 the majority of class time went on deriving the equations and solving lots of differential equations by hand, in a nutshell this course was more of an extension of many differential course that student take. To make the lecture more engaging I introduced MATLAB modules for all the kind of problems that we cover in this class. Once our model is established, we use that to solve different application problems and spend more time of the class in analysis then derivation and calculation. In this paper I will discuss 3 problems that I did as part of this class.

Students are introduced Matlab in their 1st year Engineering course. To review the matlab and have familiarity with basics students are asked to complete Matlab OnRamp and Simulink OnRamp course offered by Mathworks[9]. These are self paced free online course offered by Mathworks. In my interaction with Industry which recruits Wentworth graduates a frequent advice is that students of all majors should be comfortable with Programming and Simulation. Many papers discuss how Simulink can be used effectively in areas such as dynamic systems, [1],[3],[6] and mechanical systems,[2],[9] and [7].

Model Description:

In this section we have developed the Matlab and Simulink models for 3 problems

1) Spring Mass Damper System under free Response
2) Spring Mass Damper System under forced Response
3) Simulink Model for Damped system with Forced Response

Spring Mass Damper System under free Response
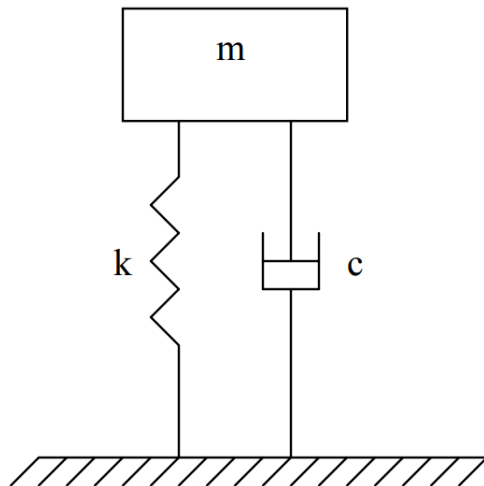
m = mass of system (Kg)

k = stiffness of the system (N/m)

c = damping constant of the system (N-s/m)

The response for the free Vibration system is given as

$$m\ddot{x} + c\dot{x} + kx = 0 \qquad\qquad (1)$$

The above equation is a second order constant-coefficient differential equation. To solve this equation we have to reduce it into two first order differential equations. This step is taken because MATLAB uses a Runge-Kutta method to solve differential equations, which is valid only for first order equations.

Let

x = v   (2)

The above expression can be simplified as

$$m\dot{v} + cv + kx = 0$$

We can write as

$$\dot{v} = \left[-\frac{c}{m} v - \frac{k}{m} x \right] \qquad\qquad (3)$$

We can see that the second order differential equation (1) has been reduced to two first order differential equations (2) and (3).

For simplicity let's put

x = y(1) and v = y(2)

Equation 2 and 3 can be written in variable y as

$$\dot{y}(1) = y(2) \tag{4}$$

$$\dot{y}(2) = \left[-\frac{c}{m} y(2) - \frac{k}{m} y(1) \right] \tag{5}$$

4 and 5 are the 2 differential equation that we can solve using the function ode45 in Matlab to get value for position(x) and velocity ($\dot{x}$). The response for x is shown in Fig 1
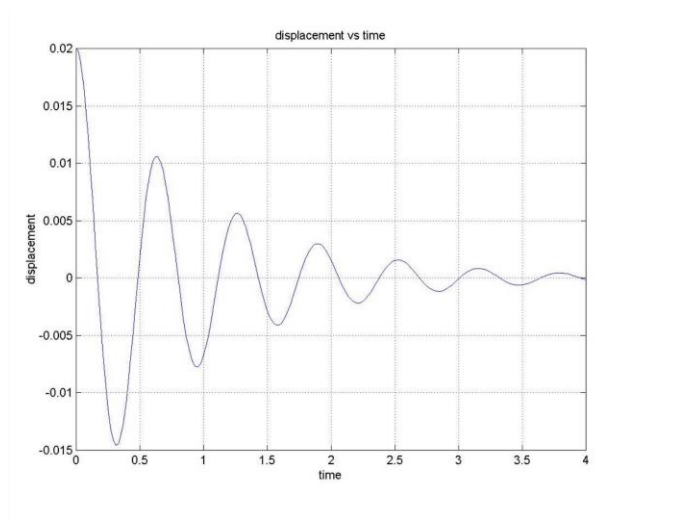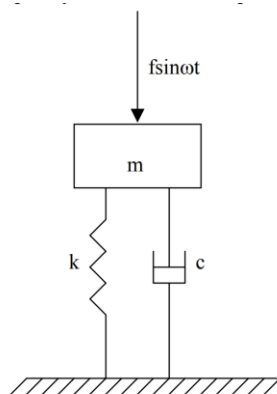

Fig-1 Response of Position for Free Vibration Single Degree of Freedom

Spring Mass Damper System under forced Response

m = mass of system (Kg)

k = stiffness of the system (N/m)

c = damping constant of the system (N-s/m)

f = Magnitude of applied force

w = Frequency of Force applied

For the forced vibration problem the governing equation is given as

$$m\ddot{x} + c\dot{x} + kx = f\sin(wt) \tag{6}$$

Similar to previous problem in this case also the ode can be

$$\dot{y}(1) = y(2) \qquad\qquad (7)$$

$$\dot{y}(2) = \left[\frac{f}{m} sin(wt) - \frac{c}{m} y(2) - \frac{k}{m} y(1) \right] \qquad (8)$$

Equation 7 and 8 can be solved to get the response of position and velocity for the mass.
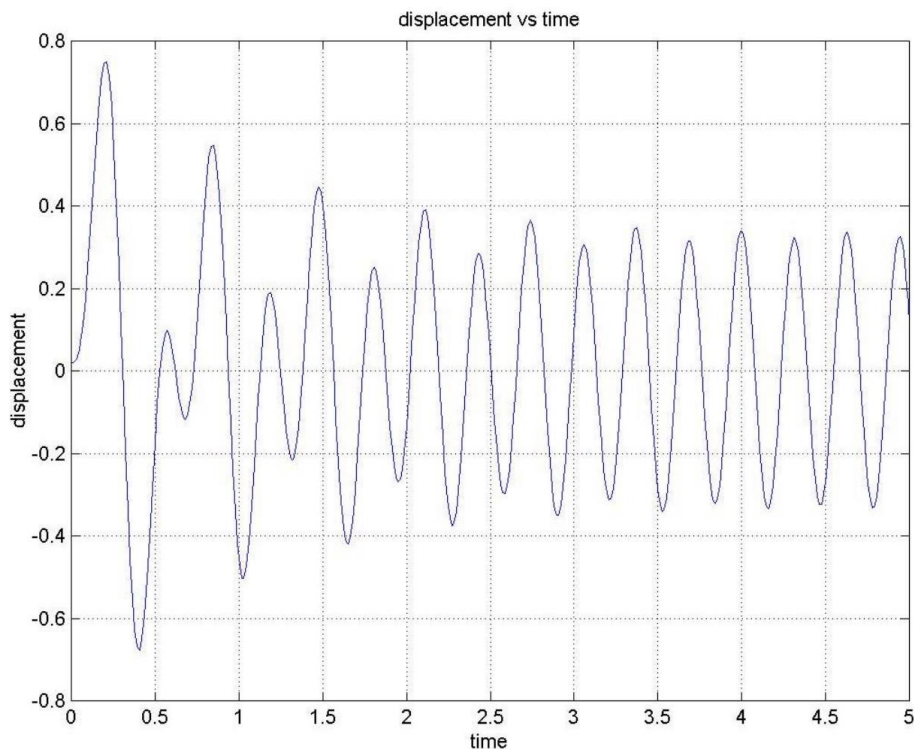

Fig-2 Response of Position for Forced Vibration Single Degree of Freedom

Simulink Model for Single Degree of Freedom

The Simulink model developed for single degree of freedom system is shown below, k is for stiffness, b is for damping constant and m is for mass of the system. Input is source function and output is value for position(x). Basic operators of Simulink such as Integrator and Sum is used to make this model.
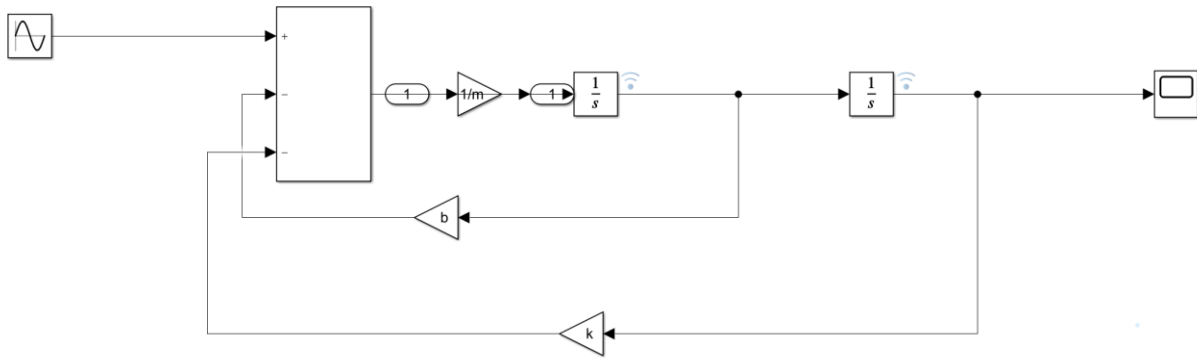
Figure 3   Simulink Model for Forced Single Degree of Freedom system

Student Survey:

Sample size: 25

The following questions were asked in the survey to assess the interest of students in using ADAMS in future offerings.

Question 1. Simulations provide an effective source of learning response analysis. The options were Strongly agree, Agree, No Opinion, Disagree and Strongly Disagree

23/25 students have Opinion better than Agree and Strongly Agree.

Question 2. Did Matlab Module helped learn the concept of Vibration better ?

Only 3 students out of 25 have opinion either neutral or less than that.

Conclusion:

In this paper I have discussed the use of Matlab to ease learning in Vibration course, hypothesis for learning is validated by student survey. This helps students to learn about the concept without getting overwhelmed by all the mathematical function behind that. In the future work I will add more degree of freedom and complex problems using Simulink.

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