ME 4501 - Vibrations and Control Laboratory

Lab 2: SDOF Vibrations

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Due: 1/30 for Section 3 and 2/1 for Section 4, I will be checking everyone's report in the beginning of the class.

<u>Show all the calculations in your report.</u>

<u>Objectives:</u>

- To measure the natural frequency of several one-degree-of-freedom (DOF) vibration systems using simple experiments and comparing with theory.
- Understand how changing mass or spring constant/stiffness affects the natural frequency.
- To calculate the spring constants from theory using Machine Design equations and compare with given values.
- To obtain the key properties of a single-degree-of-freedom (SOF or 1DOF) freely vibrating system using experiments and theory
- To experimentally determine the <u>damping coefficient and damping ratio</u> of a SDOF system.

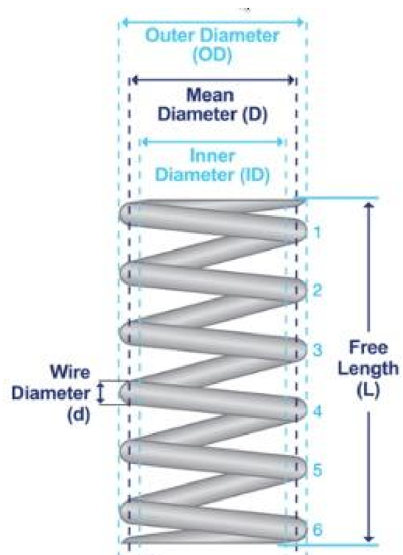
<u>Equipment:</u>

The equipment required to successfully complete your lab is listed below:

1. ECP Model 210
2. Scale
3. Accelerometer
4. NI Signal Express
5. Data Acquisition Card
6. Cable
7. Loads
8. Springs

The image below is only used for illustration, the masses might be different.

A. Spring Constant Calculation:



Theory:

The main dimensions of a helical spring subjected to compressive force are shown in Figure 2. They are as follows:

k= Spring constant of spring (N/m)

d = wire diameter of spring (m)

Di = inside diameter of spring coil (m)

Do =outside diameter of spring coil (m)

D = mean coil diameter (m)

G= shear modulus (stainless steel), 75 GPa

Nt= number of coils (Based on the numebr of turns, Nt can be also a decimal such as 9.5)

Na= efficient number of coils (N-2)

Therefore,

$$D_i = D_0 - 2 \times d$$

$$D = \frac{D_0 + D_i}{2}$$

$$k = \frac{d^4 G}{8 D^3 N_a}$$

<u>Do the following:</u>

1.Measure the outside diameter of the coils for each spring (Do).

2.Measure the coil diameter of each spring (i.e. the spring diameter, d).

3.Measure the free length of each spring type.

4.Count the total number of coils, Nt, in each spring, including the “squished” coils at the ends.

5.The nominal values of the spring constants are 200 N/m (soft), 400 N/m (medium) and 700 N/m (stiff).

6.Calculate the stiffness of each spring using the equations and then create a table such that the one below by writing a script using the similar commands in [*]. You can alo create table from Insert and Task tabs, please refer to either [1,2] (After creating your table, please delete the Table image since you don't need it in your lab report). **Show all your calculations below.**

Spring Type	N_t	N_a	d	D_o	D	L	K_{th}	$K_{nominal}$	% Diff
Soft									
Medium									
Stiff									

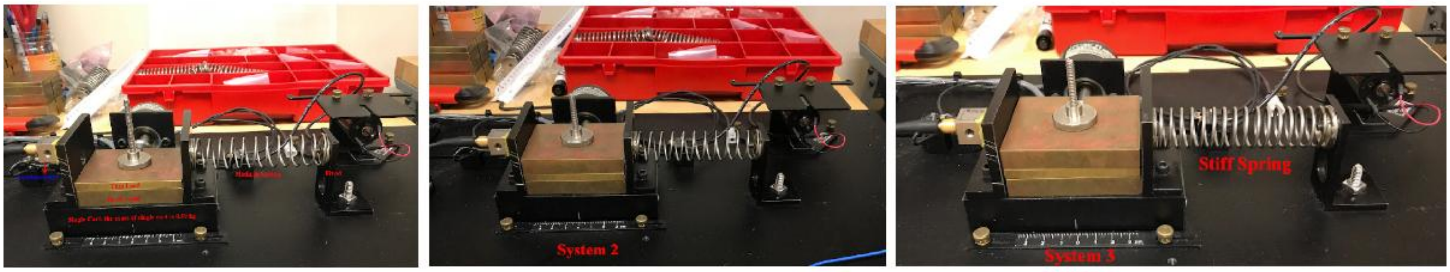
Percent Different Equation= $\%\text{Difference} = \frac{(K_{\text{nominal}} - K_{\text{theoretical}})}{(K_{\text{nominal}} + K_{\text{theoretical}})/2} * 100$

<u>B. Free Response Data Collection for System 1, System 2 and System 3</u>

In this section, you are given an example system. When it’s your turn to setup and conduct the experiments, please design your own system and change the system parameters based on your team’s decision.

Watch the video to record acceleration data using NI DAQ, tri-axial or uni-axial accelerometer, and NI Signal Express. Please also watch the video of data collection and obtaining power spectrum.

EXAMPLE SYSTEMS



System 1 System 2 System 3

1.System 1 Design: Create a SDOF system (*System 1*) arranged with a single cart, # of thin load, # of thick load and a medium spring. Attach the triaxial accelerometer to the cart as shown in the Figure. Connect the accelerometer to the channel 1 on data acquisition card (DAQ). Connect the DAQ to the computer.

The nominal values of the thick and think loads are 0.5 kg and 0.25 kg respectively. The mass of a single cart is 0.59 kg. The nominal value of the medium spring constant is 400 N/m.

Indicate System Specifications for the number of thin loads, thick loads using and spring type using an Edit Field from Control Menu under Insert Tab. Please refer this link for help. An example is shown below only for thin number of thin loads.

```
Number_Of_Thin_Loads= 0
```

```
Number_Of_Thin_Masses = 0
```

2.Experimental Data Collection: Open NI Signal Express and add acceleration using Channel 1. Set the correct parameters for the accelerometer. Collect free response data by replacing the cart by 2 cm to the left. Record the data in NI Signal Express while releasing the cart. Once the data is collected, add a power spectrum by watching the ME 4501-Lab 2- Spectrum Analysis System 3 Video. Export the acceleration and power spectrum data to an excel file.

3.System 2 Design and Experimental Data Collection: Create *System 2* by changing the total mass of system 1 as shown in Figure above and record free response data by replacing the cart by 2 cm to the left and releasing through NI Signal Express. Plot the power spectrum and acceleration data, export both the acceleration and power spectrum data to an excel file.

4.System 3 Design and Experimental Data Collection: Create *System 3* by changing the stiffness of system 2 as shown in the Figure above and record free response data by replacing the cart by 2 cm to the left and releasing through NI Signal Express. Plot the power spectrum and acceleration data, export both the acceleration and power spectrum data to an excel file.

5.Save the exported excel files to your flash disk or email to your team members and import data in Matlab for further analysis.

C. Finding the Natural Frequency of SDOF

1.Download "Lab 2 Notes- Natural Frequency" document from D2L.

2.Watch "Lab 2 Finding Natural Frequency of SDOF" Video from D2L.

3.Watch "Lab 2 Finding Natural Frequency of SDOF from Experimental Data" from D2L.

4.Using the recorded acceleration data,

- Calculate the natural frequencies (ω_n, f_n) and show your calculations below.
- Create a similar table as shown below following the same instructions given in Section A, Step 6 and delete the image of the below table after since you don't need it in your lab report.
- Compare the natural frequency obtained from the theoretical, experimental, and power spectrum for all systems and comment on the possible reasons for the differences.

System	Total mass, M	Stiffness K	$\omega_{n_{theoretical}}$	$f_{n_{theoretical}}$	$f_{n_{experimental}}$	$\omega_{n_{experimental}}$	% Diff
System 1							
System 2							
System 3							

D. Finding the Damping Constant of Underdamped System

1.Download "Lab 2 Notes-Calculating the Damping Constant" document from D2L.

2.Watch "Lab 2 Calculating the Damping Constant" video form D2L.

3.Plot time vs acceleration for each system by writing your script below.

4.Calculate the damping constant of each system. Please show all your calculations below.

Enter your equation.

E. Critical Thinking Questions

Please answer the following questions briefly.

1.In vibration analysis, can damping always be disregarded? Does damping have an effect on natural frequency.

2.How do you connect several springs to increase the equivalent stiffness? What is one example from industry or other real-life situations where this occurs?

3.What causes decay in the amplitudes of vibration?

4.What parameter(s) inversely effect the natural frequency?