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ME370 KDOM LAB: Experiment No. 9

Forced Vibration and Vibration Absorber

The objective of this lab is to study the forced vibration response of systems. The basic system to be considered here is a single degree of freedom spring-mass system. During the free response, system vibrates at its natural frequency. However, when external forcing is applied on the system, response may contain other frequency components depending on nature of forcing. Apart from this, system's vibration amplitude depends only on initial condition during free vibration; whereas in forced response, amplitude depends on forcing amplitude and frequency as well. When the forcing frequency matches with any of the natural frequency of the system, the amplitude of vibration is maximum and system vibrates violently. This phenomenon is termed as 'resonance'. It is necessary to avoid this situation in many applications. In this lab you will

- Study the frequency response of single DoF system when it is subjected to periodic external forcing.
- Design an absorber to minimize the vibration of system during resonance by changing the natural frequencies.

Hardware Provided:

- Springs
- Motor with eccentric mass
- Accelerometer

Part I:

In this experiment, the external forcing is provided by using an eccentric mass mounted on the rotating motor. Due to rotation, eccentric mass will experience a centripetal force in the radial direction. This force when resolved in horizontal and vertical direction, can be written as '$fcos(\omega t)$' and '$fsin(\omega t)$' respectively. The motion of the mass on which motor is mounted, is restricted only in the vertical direction.

Thus, the equation of motion of single DoF spring-mass system with periodic forcing is written as

$$M\ddot{x} + Kx = me\omega^2 sin(\omega t)$$

where, M, K, m, e, and ω are mass of the system, equivalent stiffness, eccentric mass, eccentricity and rotational frequency respectively. The solution of this equation normally contains both homogeneous and particular components. However, in the presence of even small damping, the homogeneous part dies down after some time and system's response only contains forcing characteristic.

Procedure:

- You will be given setup for this experiment, in which two springs are connected parallel with eccentric rotating mass (forced vibration).
- Now with the help of TAs mount the accelerometer on vibrating mass and connect it to the computer.
- Increase the supplied voltage of motor from 0V to 12V in the step of 0.5V.
- Capture the acceleration response of the mass for around 10 seconds in each step using an accelerometer.
- Now, perform FFT analysis to find the amplitude and frequency of the oscillation of mass in each case. You may use the provided code to speed up the calculations. Frequency in this case corresponds to the RPM of motor (i.e. excitation forced frequency). Note down the peak amplitude and frequency in each of the case in tabular form.
- Now plot the frequency response curve i.e. peak amplitude vs frequency obtained from the table in the previous step. Note that while plotting this curve, you should normalise the amplitude obtained through each of the FFT (by dividing it by the square of the corresponding frequency) since forcing amplitude depends on ω^2.
- Attach the frequency response curve and write down the observations.

Part II:

The excitation frequency may be constant in many cases as in case of a machine with rotor-unbalance running at constant speed. By attaching a separate smaller spring-mass system, an auxiliary system, to the main system the vibration of the main system can be reduced, drastically, if the auxiliary system is tuned to the natural frequency of the main system and the excitation frequency. Under this condition, the vibration of the main system is reduced almost to zero. So, it is termed as vibration absorber.

In this lab, you will try to design a tuned vibration absorber. When the frequency of the excitation force and natural frequency of main system are matched with each other, the main system will run at resonance having large response, which will be reduced by attaching a properly tuned vibration absorber.

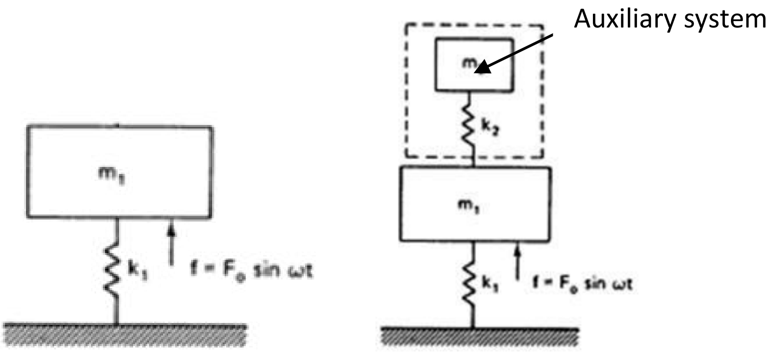

Fig 1: Vibration Absorber

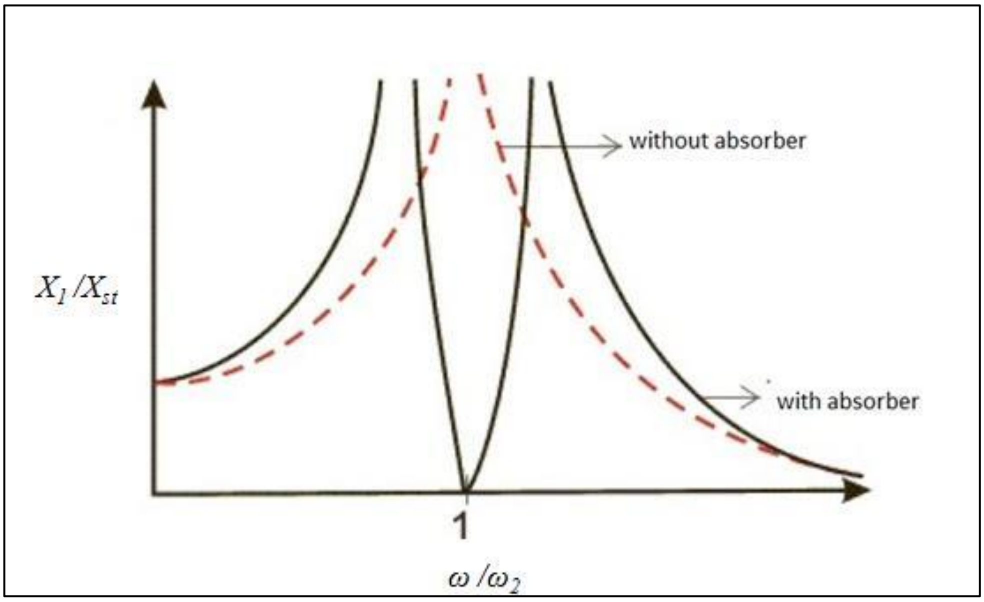

Fig 2: Frequency-band of Vibration Excitation

A sinusoidal force $F = F_0 \sin \omega t$ acts on an un-damped main mass-spring system (without the absorber mass attached). When the forcing frequency equals the natural frequency of the main mass the response is infinite. This is called resonance, and it can cause severe problems for vibrating systems. When an absorbing mass-spring system is attached to the main mass and the resonance of the absorber tuned to match that of the main mass, the motion of the main mass is reduced to zero at its resonance frequency. Thus, the energy of the main mass is apparently "absorbed" by the tuned dynamic absorber.

It is interesting to note that the motion of the absorber is finite at this resonance frequency. This is because the system has changed from a 1-DOF system to
a 2-DOF system and now has two resonance frequencies, neither of which equals the original resonance frequency of the main mass.

Procedure

- Find the natural frequency of the system from frequency response obtained in the first part i.e. where amplitude of vibration is maximum.
- Note the voltage reading for resonance condition ($\omega = \omega_n$).
- Now design the auxiliary system to reduce the vibration amplitude of main system at resonance condition forcing frequency.
- Find the spring stiffness of auxiliary system and accordingly select the required auxiliary mass.
- Attach auxiliary system to main system and observe the vibration amplitude of main system with changing the mass of auxiliary system.
- Capture acceleration data of both the masses using acceleration. Perform FFT analysis and write down the observations.
- In the report, derive the condition on the natural frequency of auxiliary system so that it acts as a tuned absorber. Also, attach relevant graphs with observations and calculations.