Safety Hazards
Thermal Systems Laboratory Rooms 106 & 110

HAZARD: Rotating Equipment

Be aware of pinch points and possible entanglement

Personal Protective Equipment: Safety Goggles; Standing Shields, Sturdy Shoes
No: Loose clothing; Neck Ties/Scarves; Jewelry (remove); Long Hair (tie back)

HAZARD: Projectiles / Ejected Parts

Articles in motion may dislodge and become airborne

Personal Protective Equipment: Safety Goggles; Standing Shields

HAZARD: Heating - Burn

Be aware of hot surfaces

Personal Protective Equipment: Safety Goggles**;** High Temperature Gloves;

HAZARD: Electrical - Burn / Shock

Care with electrical connections, particularly with grounding and not using frayed electrical cords, can reduce hazard. Use GFCI receptacles near water.

HAZARD: High Pressure Air-Fluid / Gas Cylinders / Vacuum

Inspect system integrity before operating any pressure / vacuum equipment. Gas cylinders must be secured at all times. Use appropriate equipment guards.

Personal Protective Equipment: Safety Goggles

HAZARD: Water / Slip Hazard

Clean any spills immediately.

HAZARD: Noise

Personal Protective Equipment: Use Rated Ear Plugs

ME 406: Experiment 4

VIBRATION MONITORING

I. Objective:

To introduce a controlled vibration into a dynamic system at one point and measure and compare the resulting vibration which appears at another point. This input vibration will be varied in frequency covering a range of frequencies which encompass that associated with resonance. Comparison can then be made with the results obtained from a theoretical model which represents the actual system.

II. Background:

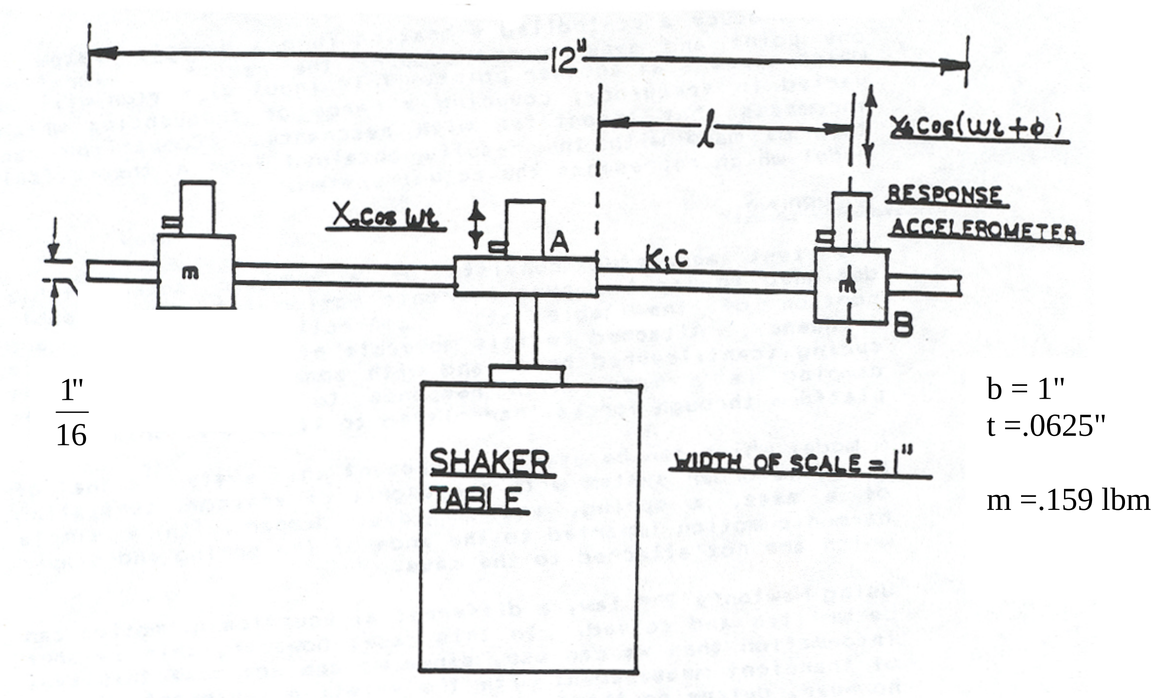
The test apparatus consists of a dynamic shaker table designed to input a pure harmonic motion into the moveable portion of the table at a controllable amplitude and frequency. Attached to this moveable platform by means of a spring (cantilevered beam) and with same amount of inherent damping is a mass which responds to the motion of the platform through forces transmitted to it by the spring.

A model which can be used to represent this system is that of a second order system with one degree of freedom, consisting of a mass, a spring, and an ideal damper with a simple harmonic motion imparted to the ends of the spring and damper which are not attached to the mass.

Using Newton's 2nd law, a differential equation of motion can be written and solved. In this case, however this is more information than we can use since we can not make this type of transient measurement with the existing equipment. We can however, determine the frequency response of the system quite readily, something the shaker table and instrumentation are set up to do. Frequency response is defined as the steady state response of a system to a pure harmonic input and is usually examined in two separate parts; the amplitude response and the. phase responses. We will look at amplitude response only. There is an easy way to obtain the frequency response directly from the differential equation. Take the LaPlace Transform of the equation with all initial conditions set equal to zero (damping will erase the complimentary solution). Manipulate the resulting algebraic equation to obtain the transfer function, the ratio of operational output to operational input (you must first decide what you want these to be). Replace by $j\infty \left(j = \sqrt{-1}\right)$. Each phasor in Cartesian form in the resulting quotient can be put in exponential form for simplification. The coefficient of exp which results is the amplitude response, the ratio of the amplitude of the output to the amplitude of the input. The coefficient of j in the exponent of exp is the phase response, the angle by which the output phasor leads or lags the input phasor.ω

III. Equipment:

The air-cooled shaker table provides the desired input vibration to the system as shown below. The cantilever beam is clamped symmetrically to the table and masses are mounted symmetrically on the beam as shown. Accelerometers are attached to the masses and to the driven table. The table has a frequency rating up to 7500 Hz, and an armature (table) displacement ± 0.375 inches from the neutral position.



The following packages are used in the control of the table motion and as instrumentation for measurements;

1. Sweep Generator This provides a sine wave output with frequencies from 0.15 Hz to 5,000 Hz in two stages. The output feeds the shaker table at the desired forcing frequency.
2. Vibration Monitor This provides a digital measurement of the amplitude of acceleration in g's, peak velocity in inches/second, and displacement in mils DA (Double Amplitude). The accelerometers will sense the vibration

and show a digital response on the level meter of the vibration monitor. The ranges of measurement possible are:

a) Acceleration – 0 to 316g
b) Velocity – 0 to 316 inches/second
c) Displacement – 0 to 1000 mils DA

3. <u>Compressor</u> This instrument is used to control the amplitude of a vibrational control system so that it maintains a predetermined amplitude of excitation as the frequency input is varied.

Any coupling between components in the various packages could result in a frequency change affecting the amplitude. The compressor is used to guard against this happening by correcting to maintain a constant amplitude.

IV. Procedure:

1. Position the masses symmetrically about the table support at a distance suggested by the instructor or decided upon by you.

2. Set the shaker table at a low frequency by controlling the sweep generator and measure the displacement, velocity, and acceleration of the table and the mass.

3. lncrease the frequency slightly and again measure displacement velocity, and acceleration of both the table and the end mass. Repeat this process over a wide range of frequencies.

   NOTE: You are concerned with finding the condition of resonance, a condition that is marked by a peak in the frequency-response curve and very rapid changes occurring over a small frequency range. Best results will be obtained if many measurements are made at small intervals of frequency in this range and fewer measurements at wider intervals at frequency away from this range.

4. Repeat this procedure for a total of three different positions of the end masses.

V. Analysis

1. Calculate the theoretical natural frequency for a force applied to the end of a cantilever beam from stress-strain relationships, the geometry, and the beam material. You might consider refining this value by using this natural frequency in conjunction with the mass reading with the applied load as a centrifugal force.

2. Plot the ratio of amplitude of the mass to the amplitude of the table versus the ratio of input frequency to calculated natural frequency and determine

the resonant frequency from the experimental results. Although the resonant frequency is not the natural frequency at low values of damping, they are reasonably close. Compare the values of natural frequency estimated by these two methods.

3. Plot the ratios of velocities and accelerations as in Part 2. Do this for all positions of the masses, on separate graphs.

4. For a single test set which you feel is reliable, plot the theoretical response curves for several values of damping ratio and superimpose your test results on those. Try to estimate the experimental damping ratio.