ME4020: Machine Dynamics Lab

Balancing Rotating Masses

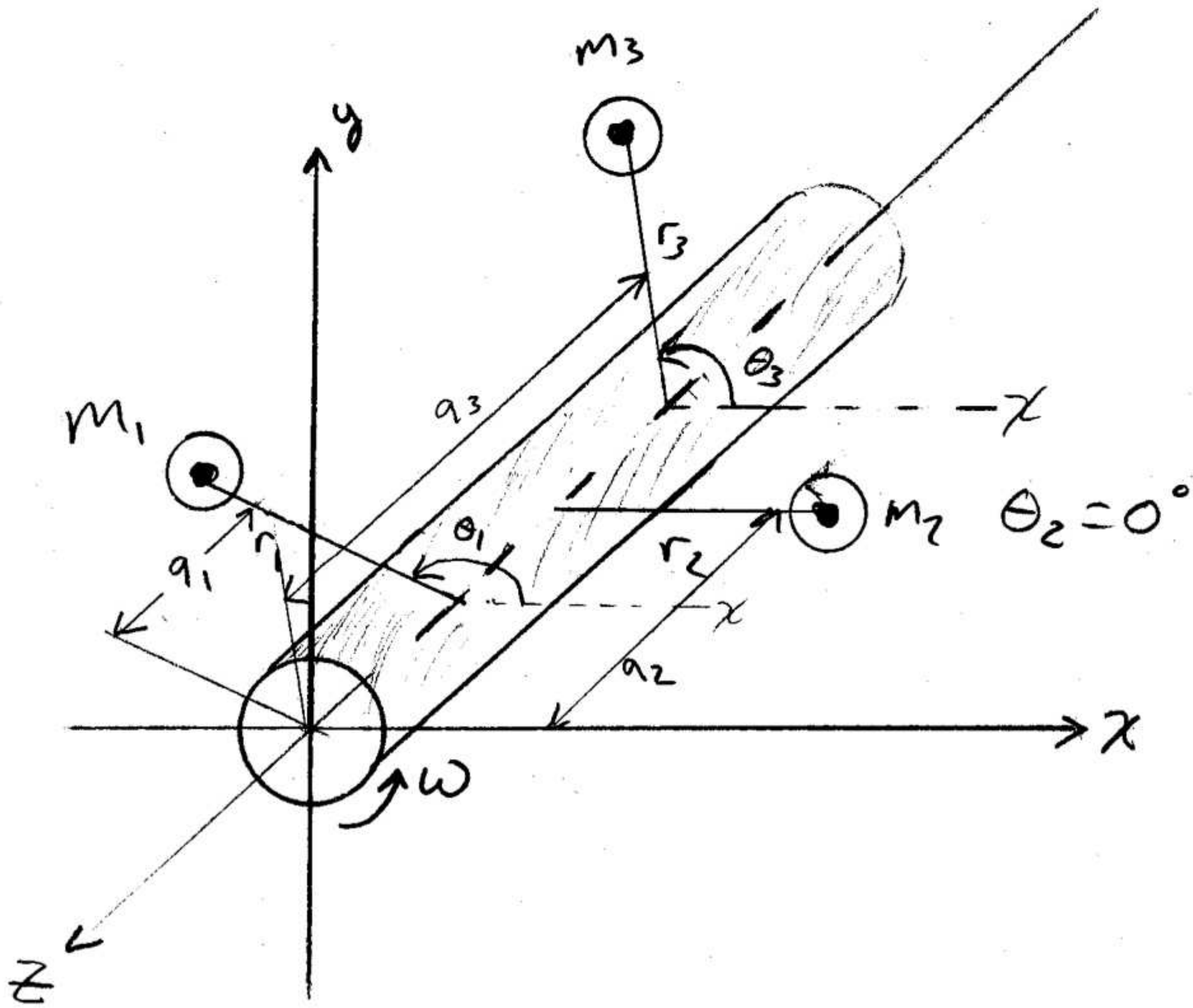
Spring 2018

1 Objective

The purpose of this lab is to balance a rotating shaft. The level of vibration caused by an unbalance will be monitored by an accelerometer connected with LabVIEW.

2 Theory

Consider the following schematic of a rotor with three unbalanced masses attached.



The dynamic forces and moments are balanced when the following conditions are met:

$$\sum F_{x,i} = 0$$

$$\sum F_{y,i} = 0$$

$$\sum M_i = 0$$

where the forces due to inertial effects, $|F_i| = m_i r_i \omega^2$. Since gravity and angular velocity are the same for each component on the shaft, they cancel and the following two equations must be satisfied to balance the forces:

$$\sum (wr)_i \cos\theta_i = 0$$

$$\sum (wr)_i \sin\theta_i = 0$$

If these equations are not satisfied, then an unbalance exists. The quantity of wr have units of a moment. A systematic approach to solving this problem is to build a table to set up the system of equations.

Number	Weight, w	Radius, r	Angle, θ	$F_x = wr\cos\theta$	$F_y = wr\sin\theta$
1					
2					
$\vdots$					
N					
Total				0	0

To sum the moments, the dimensions along the shaft must be considered. If the orientation of the shaft is such that the force balance was done in the x-y plane, then the moment balance is done along the z-axis.

$$\sum (wr)_i a_i \cos\theta_i = 0$$

$$\sum (wr)_i a_i \sin\theta_i = 0$$

To assist in formulating the solutions, construct another table.

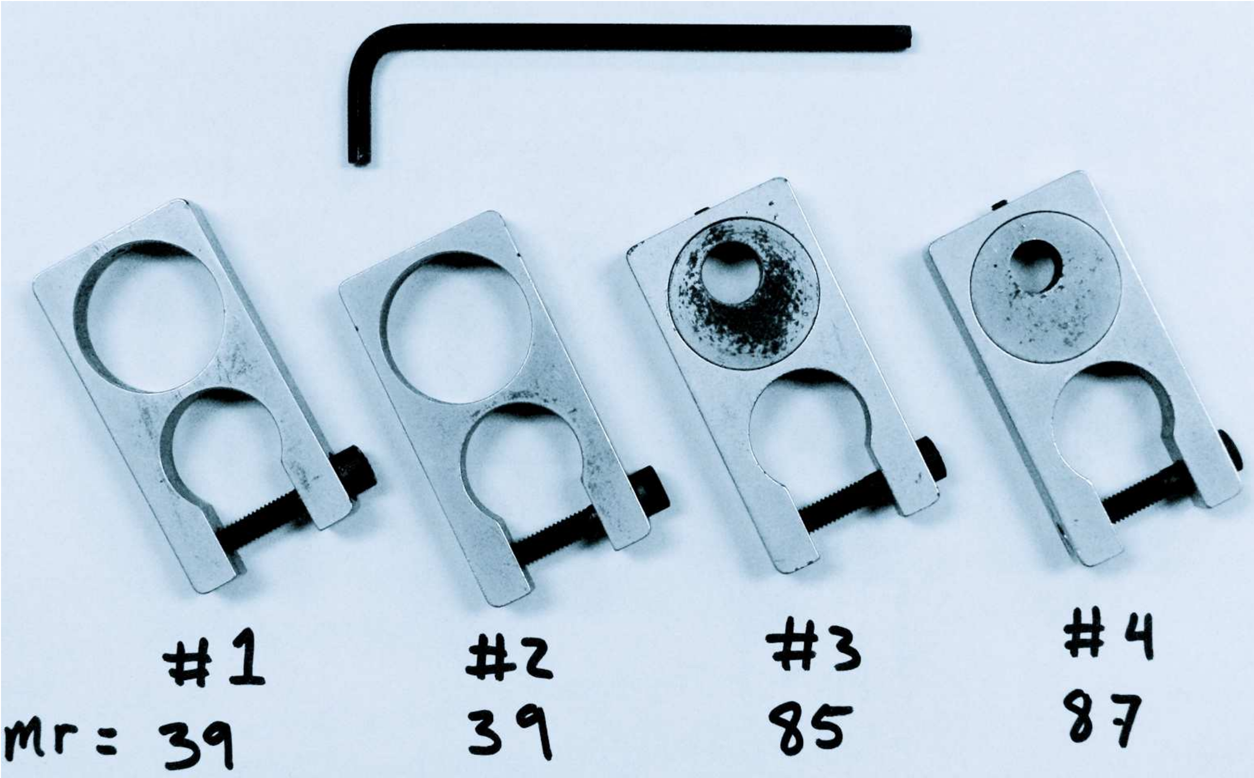
Number	Weight, w	Radius, r	Lever Arm, a	Angle, θ	$M_x = wra\cos\theta$	$M_y = wra\sin\theta$
1						
2						
$\vdots$						
N						
Total					0	0

Note: the two moments are orthogonal and a total moment is calculated as

$$M = \sqrt{M_x^2 + M_y^2}.$$

3 Procedure

Find the following parts to use with the Techquipment rotating unbalance machine.



3.1 Establish Smooth Baseline

1. Remove all weights using an Allen key.
2. Create a LabVIEW vi to monitor the vibration levels.
3. With the apparatus completely still, zero the accelerometer signal using software.
4. Turn on the motor and observe the smooth operation of the device. Record the Peak-To-Peak and RMS value of the accelerometer signal. (Note: the acceleration signal being monitored is raw voltage and is proportional to acceleration, not the actual acceleration itself.)

3.2 Establish Unbalanced Baseline

1. Turn off the motor and add weight #1 (without a center disk) at 0 degrees and 2 cm.
2. Add weight #2 (without a center disk) at 45 degrees and 18 cm.
3. Turn on the motor and observe the vibration. Record the Peak-To-Peak and RMS value of the accelerometer signal.

4. Using the signal acquired from the accelerometer, write some LabVIEW code that will give you the angular velocity of the shaft in RPM. Use a spectrum analysis tool and transform the vibration into the frequency domain. Record this result in your laboratory notebook.

3.3 Force Balance

1. Determine the angular position for weight #3 (85 units with center disk) and weight #4 (87 units with center disk) that will balance the rotating inertial forces. To do this, you'll have to solve a simultaneous system of equations. The Solve command in Mathematica may be useful.

2. Place weight #3 at the 12 cm axial position and weight #4 at the 14 cm position.

3. Verify the shaft is in static balance by gently rotating the shaft to different positions as it is horizontal. The shaft should not rotate based on the influence of gravity.

4. Turn on the motor and observe an imbalance caused by the dynamic moment. Record the Peak-To-Peak and RMS value of the accelerometer signal.

3.4 Moment Balance

1. Determine the axial positions of weights #3 and #4 that will ensure both force and moment balance.

2. Place weights #3 and #4 at the calculated axial positions.

3. Turn on the motor and observe the system is fully balanced. Peak-To-Peak and RMS value of the accelerometer signal. The the signal from the balanced shaft should be within 10% of the baseline as calculated by

$$\frac{\mathrm{RMS}_{\mathrm{Balanced}} - \mathrm{RMS}_{\mathrm{Baseline}}}{\mathrm{RMS}_{\mathrm{Balanced}}} \times 100\%.$$

4 Reporting Requirements

In 2 pages, with your name on top of the page, submit the following:

1. a force balance table,

2. a moment balance table,
3. a results table, and
4. The LabVIEW Block Diagram and Front Panel.

The force and moment balance tables are described in the theory section of this hand out and the results table should report the RMS and Peak-To-Peak values of the total acceleration.