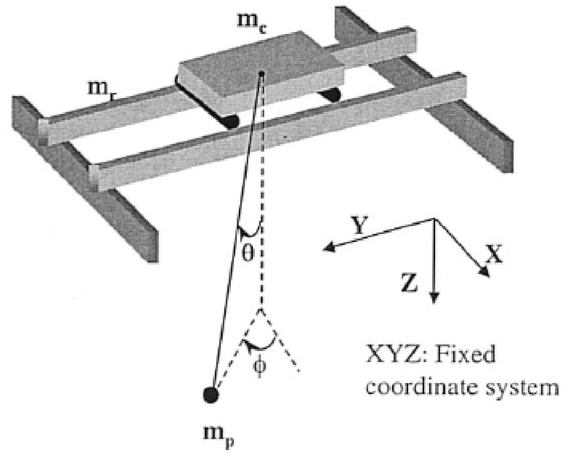
Rose-**H**ulman **I**nstitute of **T**echnology
Department of Mechanical Engineering

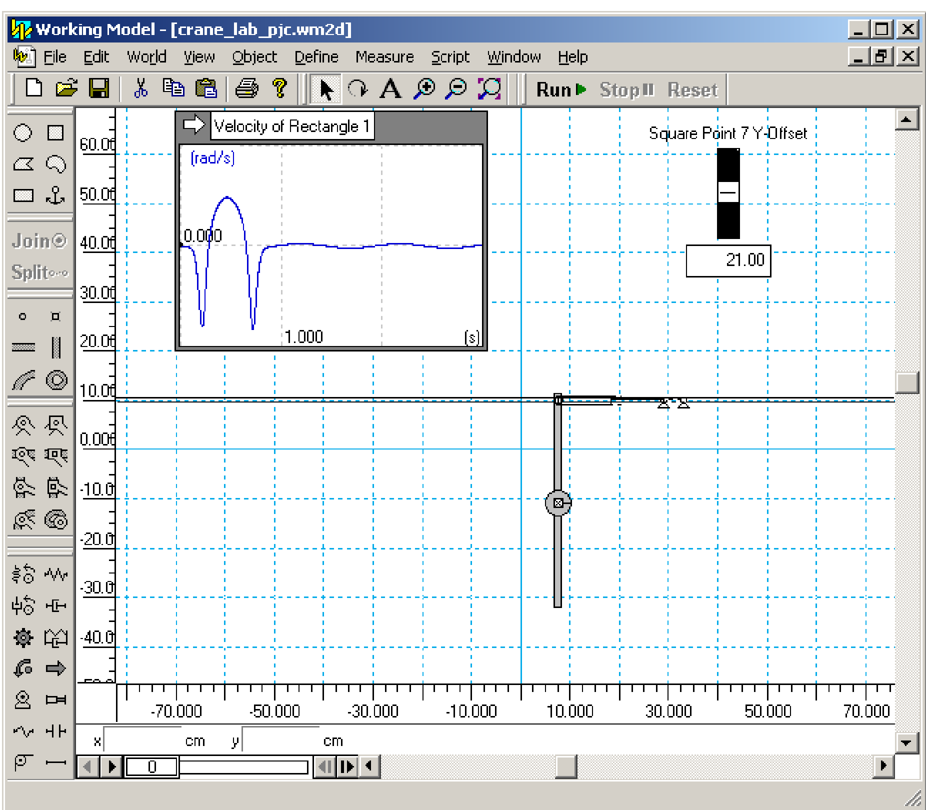
ES204 -Mechanical Systems
Working Model Lab 03



Precise payload positioning by an overhead crane (especially when performed by an operator using only visual feedback to position the payload) is difficult due to the fact that the payload can exhibit a pendulum-like swinging motion. In this lab, we experimentally investigate the overhead crane model (pendulum) and simulate its motion using Working Model.

In this portion of the lab you will compare, in a simulation, the final angular velocity of rods with weights attached that demonstrate general plane motion. Try to predict the best location of the moveable mass, such that residual oscillations are zero, after the 'trolley' moves. You will be able to understand the overhead crane problem a bit better and you will use the model to help predict the behavior of the hardware experiment. At the same time, you will increase your ability to use Working Model.

You will analyze this problem in homework for day 25 (problem 4.48) using principles that you have learned in ES204. You will be required to use this information to predict the behavior of the swinging rod device and to compare your analytical solution to your Working Model solution. Your final Working Model should look like the following:



Working Model Instructions

Be sure the units you are using are SI and radians (View/Numbers and Units). It is often convenient to turn on a rulers, grid and axes (View/Workspace)

1. Set the mass unit to grams and the length unit to centimeters. (View/Numbers and Units/more choices)
2. Set view size window width to 230 cm. (View/View Size)
3. Create a rectangle that is 43.2 cm tall by 1.5 cm wide (height = 43.2, width = 1.5) and has mass equal to 68.5g.
4. Create a horizontal slot element that will serve as the crane track.
5. Place a round point element at the top of the rectangle. Select both the round point element and the slot element (shift-click) and then click Join.
6. Modify the equation for the pin to move it down half the radius of the sensor for the rod. Double-click on the pin and modify the formula for the y-location to be:

    body[?].height/2.0-1.25, where ? simply is the object number of the rod.

7. Create a circular object of radius 2.5 cm to act as an adjustable weight. Place a square point element in the center of the circle.
8. Place a square point element in the middle of the rod and, while the point element is highlighted, create a slider control by choosing, Define - New Control - Offset. Delete the x-offset control. Double-click on the word “yoffset” and set the min and max values to 0 and 40.
9. Select the square point element and change the y equation from “Input[?]” to “43.2/2-1.25 – Input[?]”. When the offset is set to zero the disk should be at the pin location of the pendulum.
10. Highlight the two square point elements using shift-click and then click on JOIN.
11. Set the adjustable mass weight to 88g.
12. Create a meter to measure the angular velocity of the bar. Highlight the rod choose Measure-Velocity-Rotational Graph. Click twice on the white arrow in the upper left of the meter and you will have a digital meter rather than a graph. Set the y1 minimum to -1 and the maximum to 1 and the x minimum to 0 and the maximum to 2.5. Be sure to deselect the “auto” checkboxes .
13. Add two actuators, anchored to the background, and the round pin element at the top of the rod. You may need to zoom in to be sure you select the pin in the slot as one end of the actuator. Open the actuator properties window and change the type to Acceleration, then type in the equation:

100.000*(-0.018952*43.5668^2*exp(-43.5668*(time-0.2153))*(exp(-43.5668*(time-0.2153))-1)/(1+exp(-43.5668*(time-0.2153)))^3)

Change the ‘Active When’ to ‘time<0.5’.

For the second actuator, the equation is:

100.000*(-0.018952*43.5668^2*exp(-43.5668*(time-0.7153))*(exp(-43.5668*(time-0.7153))-1)/(1+exp(-43.5668*(time-0.7153)))^3)

Change the ‘Active When’ to ‘time>0.5’.

Your should have a simulation that now works with a double move. For convenience, we are going to have two different working model files – one for a single move and one for a double move. **Be sure to save the work you have done so far with a filename such as “crane_double_move.wm2d”. For a single move strategy, let’s save this file with a different name, such as “crane_single_move”.**

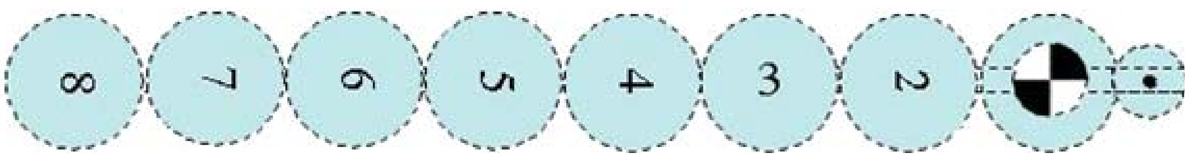
Once you have a file for the single move, delete the second actuator and double the magnitude of the first prescribed acceleration:

200.000*(-0.018952*43.5668^2*exp(-43.5668*(time-0.2153))*(exp(-43.5668*(time-0.2153))-1)/(1+exp(-43.5668*(time-0.2153)))^3)

Change the ‘Active When’ to Always.

Test the eight configurations represented by:

$$L_{wcg} = d_s/2 + (n - 1/2)d_w, \quad n = 1, 2, \ldots, 8$$



Where:

Sensor diameter................ d_s = 2.5 cm
moveable weight diameter.. d_w = 5 cm

Try both the single and double move strategies for each configuration. Use the Excel spreadsheet sent to you to record your numbers. To find the angular velocity scroll the time to a peak (after the actuators stop) and then turn the graph into a meter.

Finally use trial and error to find the ideal mass location to reduce the angular velocity of the rod.

Figure 1 taken from: Y. Fang, W. E. Dixon, D. M. Dawson, and E. Zergeroglu, ‘Nonlinear Coupling Control Laws for an Underactuated Overhead Crane System’, *IEEE/ASME Transactions on Mechatronics*, Vol. 8, No. 3, September 2003