Concordia University

Department of Mechanical, Industrial and Aerospace Engineering

Mech 6021 - Final Project, Summer 2023
Pendulum Control System

Description

An overhead crane is used in industry to lift and displace heavy items inside large buildings (where a regular crane cannot reach). It moves on two parallel rails near the ceiling and the sides walls of the building to locate where a load is. After it lifts the load it must move to another location to lay the load down.
When the moving crane stops, the load hanging from it oscillates, and it can take a while before it finally comes to a stop. It is desirable that the load stops oscillating and comes to a halt much faster than it naturally takes.

To control the oscillation of the load a force F can be applied on the carrier (or cart), as shown in figure 1. This force is different from the force to bring the crane to this position. By adjusting the force, the motion of the load can be controlled.

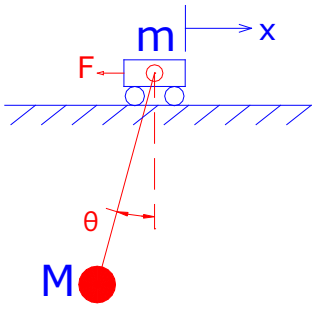

Fig. 1 Part of an Overhead Crane

For simplicity, it is assumed that the oscillations take place in one plane (2D). Figure 1 shows the notations for various parameters: M: mass of the load, m: mass of the cart to which the load is hanging and to which the force F applies, x: the linear displacement of the cart, θ: the angular displacement of the load cord with a vertical line in the plane of motion The equations of motion corresponding to this system, after simplification, are:

$$\ddot{\vartheta} = -\frac{(M+m)g}{ml}\vartheta + \frac{F}{ml} \qquad (1)$$

$$\ddot{x} = \frac{Mg}{m}\vartheta + \frac{F}{m} \qquad (2)$$

The parameter l is the length of the pendulum chord. You need to work on equation (1) but use the results in equation (2) to see the displacement of the cart.

M = (100 + your group number) Kg
m = 20 Kg
l = 12 m
g = 10 m/sec^2 (for simplicity, instead of g =9.81)

What you need to do

Using Matlab, Simulink or any other appropriate tool/software:

a- Form the Transfer function of the system
b- Design a controller of your choice for the system and demonstrate the behavior of the controlled system in response to a step and an impulse input
c- Discuss what you have done and why you have done that way

Note that your design must be based on

1 The maximum overshoot, rise time and settling time for the step input (you choose these values),
2 The steady-state error (If it exists),
3 The total motion of the cart (Obviously the cart must eventually stop where you need the load to be)
4 The amount of the required force

Show all your results with figures indicating the variation of a variable versus time.

Your mark will be based on your understanding of the theory, your analysis of the problem, your effort to tackle the problem, your reasoning for choosing the acceptable values for variables, and the quality of your presentation (report).