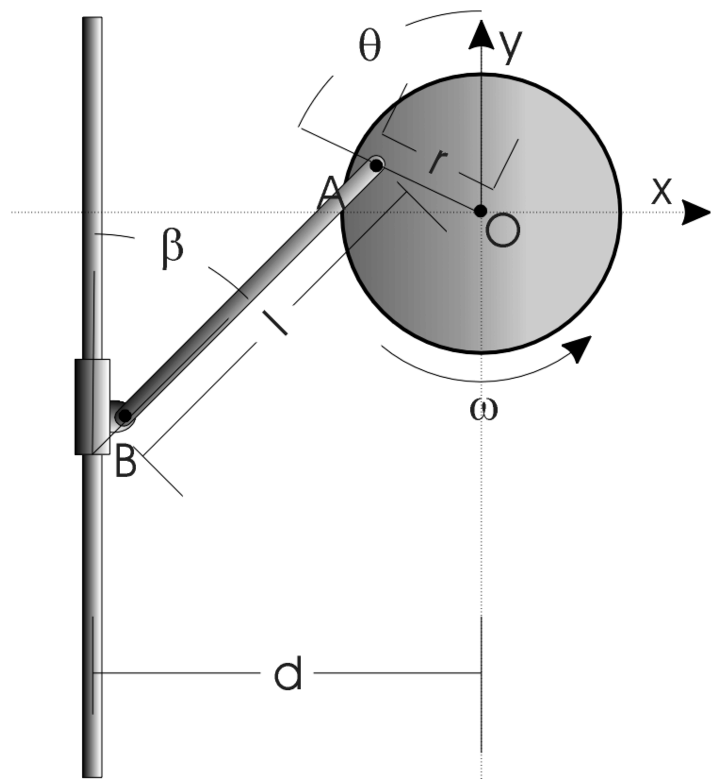
ASEN 2003 LAB 3: LOCOMOTIVE CRANK SHAFT

- Assigned: Wed, 15 Feb 2017
- Group Report Due: End of class, Mon, 27 Feb 2017



OBJECTIVES

- Analyze general planar motion.
- Practice using kinematical descriptions of a physical system.
- Investigate discrepancies between a model and a physical system.
- Continue to improve MATLAB skills.

PROBLEM STATEMENT

The locomotive crank shaft apparatus is designed to demonstrate kinematic relationships for linked mechanisms. Students develop a model for the ideal relationship between the rotational motion of the wheel and the translation of the collar. In the lab we will use sensors to measure these motions and then compare the experimental results to the predictions.

MODEL

The first step is to develop a model for the motion of the collar as a function of the geometry of the apparatus. Point A is pinned to the disk that rotates about O. Point B is pinned to the collar that slides vertically on the shaft.

Use the following as geometrical constants in your model:

r - distance between the origin (rotation axis) and the attachment point A.

d = horizontal distance between the vertical shaft and the center of the disk.

l = length of the connecting bar from A to B

The input to your model is the angular position of the disk (θ) measured counterclockwise (+k) from the y-axis (+j), and the angular velocity of the disk (ω) also measured about the positive z-axis (+k).

1) Derive an expression for the angle β in terms of the geometrical constants and θ.
2) Derive an expression for the velocity vector of the collar in terms of the geometrical constants, β, θ, and ω. Make sure the direction is included.
3) Use MATLAB to implement your model as described below in the analysis section.

EXPERIMENT

4) Pay attention to our lab instructors when they describe the locomotive crankshaft apparatus. A motor drives the rotation of the disk with speed controlled by the input voltage to the motor. It measures the angle of the disk with the motor encoder and the position of the collar with a linear potentiometer. Sketch the setup and identify the key components used.
5) Measure the geometrical constants - r, d, and l to the best precision you can. Note the uncertainty in your measurements. Use metric units!
6) Use the LABVIEW vi to run the apparatus and record results at three different voltages between 6 - 11 Volts. The LABVIEW vi assumes that the collar is initially positioned at its lowest point and offsets the angular position for this location, carefully follow the instructions for starting the run. Set the voltage to an integer value (it does not need to be exact, just close).
7) Describe qualitatively the motion you observe for the different speeds. Download the data you collected from the ITLL machines into files with names that include the voltage you set.
8) Open one of the data files in a text editor. Figure out what data types are in each column and what units are used.

RESULTS & ANALYSIS

The goal of this section is to write concise/efficient MATLAB code using structured programming concepts to compare the **observed** collar velocities and the **modeled** collar velocities. The former is simply one of the observed quantities. The latter is based on the measured rotation angles (theta), measured disk angular velocities (omega), and your derivation from the first section.

9) Write a MATLAB main script (`lab3.m`) that does the following:
   a. Gives the purpose of the script, names of all the people in the group, date
   b. Closes all figures and clears all variables
   c. Sets values for *r, d, l*, and any constants you need for conversions
   d. Chooses the data files to be analyzed
   e. In a loop, calls a function to analyze the data (`analyze.m`)

   In aw, and sets up an angle input from 0 to 6 revolutions. Call the model function from your script and plot the returned model velocity (in cm/s) as a function of θ (in degrees). Explain how you checked that it is working correctly.
10) Write a MATLAB function to load a data file. It should do the following a) load in a specified data file, b) subtract an integer number of full cycles from the angular position column so that it starts in the range of 0 to 360 deg and increases continuously; c) returns the experimental (measured) angle, angular rate, and vertical velocity for the first 6 revolutions of the disk.

    The call to the function should look something like this:

    ```
    [theta_exp,w_exp,v_exp]=load_lcs(filename)
    ```
11) Plot the results (v_exp versus theta_exp i) for each of your experiments. Select x-axis limits and y-axis limits that work for all the examples, so that someone can easily compare them. Make sure to label the axes and give the units. Include the file name in the title of your plots.
12) Write a MATLAB function (`LCSMODEL.m`) to implement your model that takes as input values of the geometrical constants, the angular position and rate of the disk and outputs the vertical speed of the collar. The call to the function should look like this:

```
[v_mod] = LCSMODEL(r, d, l, theta, w)
```

In the comments define the units used for each input and output.

13) Compute your model velocity for the experimentally measured angles and angular rates. Plot these in a different line type on the same graph as the experimental results. Use a legend to identify which curve is which.

14) On a new graph, plot the errors (also called misfit or difference) between the experimental results and the model. Make a table of the mean and standard deviation of the error for each case. (Use the correct number of significant figures.) If there are outliers in the results, remove them and report a second set of values for the mean and standard deviation on the table.

15) Consolidate your plots using 4 subplots for each voltage setting.
    a. subplot(2,2,1) Show observed angular velocity on the y-axis (rad/sec) and theta (degrees) on the x-axis.
    b. subplot(2,2,2) Show observed and modeled collar velocity using units of cm/sec. x-axis should be in theta in degrees. Use a legend.
    c. subplot(2,2,3) Show the residual collar velocity, i.e. observed collar velocity minus the modeled collar velocity (in cm/sec). x-axis should be theta in degrees.
    d. subplot(2,2,4) Make a histogram (Matlab function histfit) of the residuals using 20 bins.

16) Summarize your results in a table generated in MATLAB. Make it clear which are the class datasets and which datasets you collected.
    Include:
    a. the standard deviation of the residuals for collar velocity (which I will call sigma here)
    b. the mean of the residuals
    c. the uncertainty of the mean residual (sigma divided by square root of the number of residuals)
    d. the number of observations
    e. the number of residuals that are greater than 3 sigma

    If you wanted to print variables A, B, C, D, then you could say:

```
fprintf(1,'Speed %6.2f+-%6.2f %6.2f %5.0f \n', A,B,C,D);
fprintf(1,'You can also put column headings\n');
```

17) Discuss - How well did the model match the experimental results? What is the nature of the error (bias, misalignment, noise?) Explain the possible sources of error and which you think are most likely responsible for the majority of the error. Be quantitative in your analysis.

REPORT CONTENTS & GRADING

Title Page - Lab# and Title, Course Number, Student Names, Date Submitted

(5 pts) ABSTRACT - Briefly summarize the rest of the report including the objectives of the lab, what was actually done, the most important qualitative and quantitative results, and your conclusions. The abstract should be less than 200 words.

(10 pts) MODEL - Present the derivations including a diagram. The derivations do not need to be typeset - neatly handwritten expressions with clear drawings are preferred.

(10 pts) EXPERIMENT – Show that you did the experiment by answering the questions in this section.

(30 pts) RESULTS & ANALYSIS – Do questions 9-17. Include the requested plots and tables. Put the MATLAB code in the appendix.

(5 pts) CONCLUSIONS & RECOMMENDATIONS – Summarize the lab experience - what did you learn? What would you do differently if you had the chance to repeat it? What improvements could be made to the assignment?

REFERENCES - List reference material used in professional format. Each reference must be cited in the text.

ACKNOWLEDGMENTS - Briefly describe assistance or contributions provided by classmates or others (not including group members who authored the report).

(30 pts) APPENDIX – Provide a printout of all your MATLAB code

(10 pts - Style and Clarity - includes title page, ToC, organization, grammar, spelling, references and acknowledgements)