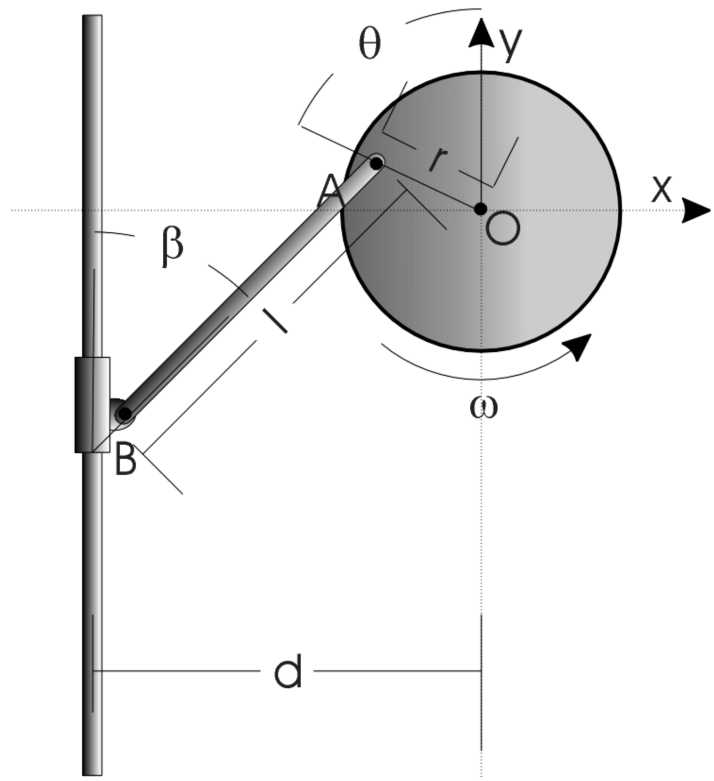
ASEN 2003 LAB 3: LOCØMOTIVE CRANK SHAFT

- Assigned: Wednesday, February 13, 2019 / Thursday, February 14, 2019
- Group Report Due: End of lab Monday, February 25, 2019/ End of lab Tuesday, February 26, 2019



OBJECTIVES

- Analyze general planar motion.
- Practice using kinematic 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) 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.

4) To check your model code, write a script (`LSCMAIN.m`) that assigns reasonable values for r, d, l, and w, and sets up an angle input from 0 to 6 revolutions. Call the model function from your script and plot the returned model speed (magnitude of the velocity) (in cm/s) as a function of θ (in degrees). Explain how you checked that it is working correctly.

EXPERIMENT

5) Sketch the experimental set up. Identify the key components - make sure to note the sensors used to measure the angle of the disk (motor encoder) and the position of the collar (linear potentiometer). The LABVIEW vi assumes that the collar is initially positioned at its lowest point and offsets the angular position for this location. The angular speed of the disk and vertical speed of the collar are computed in the vi by differencing the measured positions. The speed of the disk rotation is controlled by the input voltage to the motor.
6) Measure the geometrical constants r, d, and l to the best precision you can. Note the uncertainty in your measurements. Use metric units!
7) Use the LABVIEW vi to run the apparatus and record results at three different voltages between 6 - 11 Volts. Set the voltage to an integer value (it does not need to be exact, just close). 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

9) 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.
10) Write a MATLAB function (LCSDATA.m) that: a) loads in a specified data file, b) subtracts 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) outputs the experimental (measured) angle, angular rate, and vertical velocity for the first 6 revolutions of the disk.

    The call to the function should look like this:

    ```
    [theta_exp,w_exp,v_exp]=LCSDATA(filename)
    ```
11) Plot the results (v_exp versus theta_exp) for each of your experiments on separate graphs. 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.
12) 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.
13) 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.
14) How well did the model match the experimental results? What is the nature of the error (bias, misalignment, noise, time delay?) 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.

(15 pts) **MODEL** - Answer questions 1-4 in the model section. The derivations do not need to be typeset - neatly handwritten expressions with clear drawings are preferred. Include a printout of your MATLAB code and any graphs you used to check the correct operation.

(10 pts) **EXPERIMENT** - Answer questions 5-7.

(25 pts) **RESULTS & ANALYSIS** - Answer questions 8-13. Include a printout of your MATLAB code and the requested plots and tables.

(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).

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