ASEN 2803 Dynamics & Controls Lab
Spring 2025

Lab 2: Locomotive Crank

Assigned Monday, February 17, 2025
Due Friday, March 14, 2025, at 11:59pm

OBJECTIVES

1. Analyze general planar motion
2. Practice using kinematical descriptions of a physical system
3. Investigate discrepancies between a model and a physical system
4. Assess experimental results
5. Continue to improve MATLAB skills

PROBLEM STATEMENT

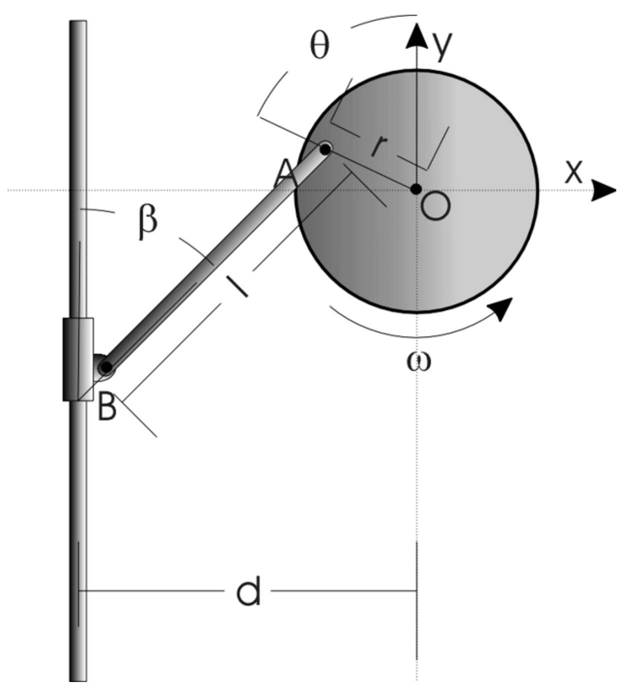
The locomotive crank shaft apparatus is designed to demonstrate kinematic relationships for linked mechanisms. Students will develop a model for the ideal relationship between the rotational motion of the wheel and the translation of the collar. In this lab, we will use sensors to measure these motions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

MODEL DERIVATION

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, $\boldsymbol{\theta}$**, measured counterclockwise, $+k$, from the y-axis, $+j$, and the **angular velocity of the disk, $\boldsymbol{\omega}$**, also measured about the positive z-axis, $+k$.

1. Derive an expression for the angle β in terms of the geometric constants and θ.

2. Derive an expression for the velocity vector of the collar in terms of the geometric constants, β, θ, and ω; make sure the direction is included.

3. Write a MATLAB function (`LCSMODEL.m`) to implement your model that takes input values of the geometric constants, the angular position, and the 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 (`LCSMAIN.m`) that assigns reasonable values for r, d, l, and ω, 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.

PROCEDURE AND EXPERIMENTAL SETUP

Refer to the full experimental procedure in Appendix A and the interactive presentations on Canvas to understand how the provided data was collected.

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 geometric constants - r, d, and l, to the best precision you can. Note the uncertainty in your measurements. **Use <u>metric</u> units.**

7. Record the motion you observe for the different voltages using the provided videos, reference these observations in the Results & Analysis Section.

RESULTS AND ANALYSIS

8. 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 (θ), measured disk angular velocities (ω), and your derivation from the first section.

9. 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° and increases continuously, and
    c. outputs the experimental (measured) angle, angular rate, vertical velocity, and time for the first six revolutions of the disk.

    The call to the function should look like this:

    ```
    [theta_exp,w_exp,v_exp,time] = LCSDATA(filename)
    ```

10. Plot the results (`v_exp` versus `theta_exp`) for all of the experiments on separate graphs. Ensure that the scale of your plots is the same for all the examples so that they can be easily compared. In other words, select a consistent set of x-axis and y-axis limits for all of your plots. Make sure to include plot titles, axes labels, and units.

11. Compute your model velocity for the experimentally measured angles and angular rates. Plot these using a different line type on the same graph as the experimental results. Use a legend to identify the different lines.

12. On a new graph, plot the residuals vs. time (also called the misfit, or the difference between the experimental results and the model). Make a table of the mean and standard deviation of the error for each experiment, using 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.

13. 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

Reports should be written using the AIAA paper format. Word and LaTeX templates may be found at the following website: https://www.aiaa.org/publications/Meeting-Papers/Meeting-Paper-Author.

The report should follow the structure outlined below:

1. **Abstract**
   a. This should be a brief summary of your work, and should cover the ***motivation***, ***problem statement***, ***approach***, ***results***, and ***conclusion***.
   b. The abstract should be less than 200 words.
2. **Model Derivation**
   a. Address Items 1-4 in the Model section.
   b. The derivations may be typeset or handwritten – however, if handwritten, the derivations and expressions should be legible, neatly presented, and any diagrams should be clear.
   c. Include a printout of your MATLAB code function calls and any graphs used to check the correct operation (Do not include your full MATLAB code in the main body of your lab report. Include the full code in the Appendix.).
   d. For this section, these are the plots you should include in your group's lab report:
      i. Plot of ***Collar Velocity from Model*** (in cm/s) vs ***theta θ*** (in degrees). When validating the model, you can use reasonable values of r, d, l, and *omega* ω.
3. **Procedure and Experimental Setup**
   a. Address Items 5-7 in the Procedure and Experimental Setup section.
   b. The Lab 2 Assignment Appendix and Introduction Videos on Canvas might be useful when writing up this section.
4. **Results and Analysis**
   a. Address Items 8-13 in the Results and Analysis Section.
   b. Include the requested MATLAB function calls and any plots or tables (Again, do not include your full MATLAB code here, just the function call. Include the full code in the Appendix.).
   c. For this section, these are the plots you should include in your group's lab report:
      - ***Model vs Experimental Data***
         i. Plot of ***Collar Velocity from Model*** and ***Collar Velocity from Experiment*** (in cm/s) vs ***theta θ*** (in degrees), for all voltages.

            Please plot these as six plots on a 2x3 subplot. For the "Collar Velocity from Model", remember to compute the model velocity using the experimentally measured angles and angular rates in the data files.

- ***Residuals***

  i. Plot of ***Signed Residuals*** vs ***Time***, for all voltages

     (six plots on a 2x3 subplot, include the mean line)

  ii. Plot of ***Absolute Residuals*** vs ***Time***, for all voltages

     (six plots on a 2x3 subplot, include the mean line)

  iii. Comparison Plot of ***Signed and Absolute Residuals*** vs ***Time***, for one voltage

     (your team's choice of voltage)

  iv. Comparison Plot of ***Signed Residuals*** vs ***Time***, for all voltages

     (one plot)

  v. Comparison Plot of ***Signed Residuals*** vs ***Theta***, for all voltages

     (one plot)

  For these residual plots, refer to the sample plots shown in lab.

d. Please additionally take note of the following:

   - Each figure/plot in the report should have a figure number.
   - Remember to describe and explain your plots. Brief explanations should accompany each plot.
   - Limit your plots to showing only 6 revolutions of data, whether plotting vs time or vs *theta* θ.
   - Each set of subplots should have the same scales on the x- and y- axes.
   - All plots should include plot titles, axes labels with units, and a legend (where appropriate).

5. Conclusions and Recommendations

a. This should include a ***brief summary of your work***, ***what was learned from the work***, ***comments on the experiment that performed best/worst***, and ***recommendations to improve the model*** in the context of future work.

b. Remember that the conclusion should not be a direct re-statement of your abstract.

6. Member Contributions

List the contributions of each team member (one to two sentences for each person).

7. Acknowledgements

Acknowledge any resources or help you might have received from sources outside your team.

8. Appendix

Include the full MATLAB code used to compute values or generate plots. Ensure that the code is reasonably well-commented and can be understood by the reader.

9. Style and Clarity

Points are awarded for style and clarity (ie. Assigning pages to your submission in Gradescope, submission organization, grammar, spelling, clarity of diagrams & figures, etc.).

REPORT GRADING

1. Group Submission

10 Abstract
20 Model Derivation
15 Procedure and Experimental Setup
15 Results and Analysis
10 Conclusions and Recommendations
5 Member Contributions and Acknowledgements
15 Appendix
10 Style and Clarity

____
100 points total

2. Individual Submission

10 Self-Assessment and Peer Evaluations

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10 points total