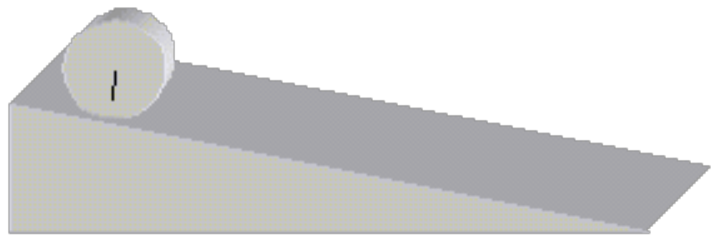
ASEN 2003 LAB 4: BALANCED and UNBALANCED WHEEL

- Assigned: Wednesday, March 1, 2017
- Report Due: Wednesday, March 15, 2017, End of Class

OBJECTIVES

- Derive dynamical models using energy methods and compare with experimental data
- Evaluate empirical models to compensate for mismatch between experiment and theory
- Improve MATLAB, data analysis, and technical writing skills.



OVERVIEW

The balanced and unbalanced wheel lab explores the impact of inertia distribution on rigid body motion. The photo on the left illustrates an apparatus consisting of a cylindrical mass, supports (sort of like training wheels), and an encoder that measures changes in the rotation angle (θ) and from that numerically calculates angular speed (ω). An extra mass can be attached to this wheel. The cylinder is rolled down a wooden ramp, as shown on the right. The ITLL staff will demonstrate how this apparatus works.

The rotation angle is measured clockwise from the perpendicular vector into the ramp, and is defined to be zero when the wheel starts to move. When the unbalanced wheel experiments are run, the extra mass should be positioned so that it is perpendicular to the ramp at $\theta=0$.

- mass of cylinder, M: 11.7 kg
- mass of trailing apparatus, Mo: 0.7 kg
- mass of extra mass m: 3.4 kg
- radius of cylinder, R: 0.235 m
- radius of gyration of wheel, k: 0.203 m
- moment of inertia I: Mk^2
- slope of ramp: 5.5 deg

- radius to extra mass, r : 0.178 m
- radius of the extra mass: 0.019 m
- g: 9.81 m/s^2

MODEL

1. For a balanced wheel with radius of gyration k, and ramp with angle β, use work-energy to derive an expression for the angular velocity (ω) as a function of angular position (θ). Assume the cylinder rolls without slipping. Further assume that the trailing apparatus translates, but does not rotate. This is model_1.
2. Modify your expression for work by assuming there is a constant (unknown) negative moment applied to the shaft of the wheel and find the new expression for ω. This is model_2.
3. Use work-energy to derive the model equation for the unbalanced wheel apparatus also including the negative moment from part 2. Model the attached mass two different ways: first assuming that it is a particle (model_3), and the second time assuming it is a rigid body (model_4).
4. Write and verify the correct operation of a well-commented MATLAB function to compute the model angular velocity as developed in steps 1-3, given a specified array of angular positions (theta). The physical parameters of the system given above should be defined within the function.
5. Plot the expected angular velocity vs theta for each model, for theta values from 0 to 15 radians. Label your axes and provide a legend that clearly indicates which model corresponds to each curve.

EXPERIMENT

6. Sketch the experimental set up and identify the key components. Use the LABVIEW vi to run the apparatus and record results for two trials of the balanced and two trials of the unbalanced wheel. Describe qualitatively the motion you observe. How does it compare with the ideal?

RESULTS and ANALYSIS

7. Write and verify the correct operation of a well-commented MATLAB function to load in a specified data file, extract the angle and angular velocity, and plot each data point on a graph of angular velocity vs angle points. Select a range of values to work with where the angle and angular rate data are reliable ($0.5 \text{ rad} < \theta < 15 \text{ rad}$ is a good starting point). Compute the angular acceleration from your data.
8. For **two** experimental trials of the balanced wheel, load the experimental data and compare with model 1. Try 5 or more values of applied moment in model 2 and identify which best matches the experimental data. The same moment should work for all of the trials.
9. Make a plot that includes data from both balanced trials, showing the observations as markers (symbols), the original model 1 as a dashed line, and model 2 with your best estimate of applied moment as a solid line. Use a legend to clearly identify the data and models shown.
10. Load the data from two of the unbalanced trials and compare models 3 and 4 with the experimental data. Plot your results.
11. Compute and plot the residuals between the experimental data and the models for each data set. (Residual = observed – predicted). Do not take the absolute value of the residual – if there is a mean offse that tells you that the model is systematically biased. <u>To do this calculation you must evaluate the model for the experimentally measured angle values.</u>
12. Use MATLAB to analyze the results and create a table of the statistics for the balanced and unbalanced wheels. The table columns should be: standard deviation of the residuals for angular velocity (rad/s), mean of the residuals for angular velocity (rad/s), the uncertainty of the mean residual (sigma divided by square root of the number of residuals), the number of observations, the number of residuals that are greater than 3 sigma.

13. Discuss- How well did the models match the experimental results? Compare results for the balanced wheel with and without the additional moment added in part 2 - is this part of the model necessary/important? Compare results for the unbalanced wheel when you modeled the additional mass as a particle versus as a rigid body - is this part of the model necessary/important? 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.

ACKNOWLEDGEMENTS

The balanced and unbalanced wheel lab was originally developed by Professor Kristine Larson, Walt Lund, and Brad Dunkin. Recent improvements are due to Prof Larson, Trudy Schwartz, and Matt Rhode.

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.

(30 pts) MODEL - Present your derivation and models for the balanced and unbalanced wheel. The derivations do not need to be typeset - neatly handwritten expressions with clear drawings are preferred. In an appendix include a printout of your MATLAB code and any graphs you used to check the correct operation.

(10 pts) EXPERIMENT - Describe the experimental set up and your observations of the tests.

(30 pts) RESULTS & ANALYSIS - Present the required plots and table comparing the models and experiments. Describe the results obtained, answer the questions posed, and explain the source of discrepancies.

(5 pts) CONCLUSIONS & RECOMMENDATIONS – Summarize the lab experience - what did you learn? How might you extrapolate the results of this experiment to determining or validating inertia properties of an object? What would you do differently if you had the chance to repeat the lab? 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 the contribution of each team member and anyone else who assisted you in the lab.

(10 pts) APPENDIX - Include your code (also contributes to the grade in the model and results sections).

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

100 Total