ME 206, Experiment 5

FINDING THE CENTRE OF PERCUSSION OF A TRIANGULAR PLATE OSCILLATING ABOUT A VERTEX

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Introduction

The study of oscillations and vibrations in rigid bodies is crucial in understanding the dynamic behaviour of various structures and objects. In this experiment, we focus on the centre of percussion (CoP) of an equilateral triangular plate with uniform thickness, oscillating about one of its vertices. The centre of percussion is a point on an object where an applied force will produce translational motion without causing any rotation about any axis. This concept is particularly important in sports equipment, such as baseball bats and tennis rackets, where finding the CoP can help optimize performance.

The objective of this experiment is to determine the centre of percussion both theoretically and experimentally for the given triangular plate. The theoretical analysis involves the application of principles from mechanics and dynamics to calculate the expected location of the CoP. On the other hand, the experimental approach entails physical testing, where the triangular plate is subjected to controlled oscillations, and the point of minimal rotation is identified as the CoP.

The triangular plate is chosen for its geometric complexity, presenting a challenge in both theoretical prediction and experimental verification. By comparing the theoretically determined CoP with the experimentally obtained results, we aim to evaluate the accuracy of theoretical models in predicting the dynamic behaviour of a real-world physical system.

This experiment not only contributes to the fundamental understanding of oscillations in rigid bodies but also provides insights into the practical application of theoretical concepts. The findings may have implications in the design and optimization of structures in various fields, including sports equipment and engineering. The experimental-validation approach adds a practical dimension to the theoretical understanding, bridging the gap between theoretical predictions and real-world observations.

Experimental Design

AIM OF THE EXPERIMENT: To find the centre of percussion (CoP) of an equilateral triangular plate of uniform thickness which is oscillating about a vertex. Consider the force applied normal to the plate and compare the experimentally found CoP with the theoretically evaluated CoP.

CAD Models

Below are the images of the models of the parts designed in Autodesk's Fusion360:

Material Data

For making the equilateral triangle plate for this experiment we used 3mm thick MDF since it is a light and easily available material. The total area of the MDF used was 96.64 cm^2.

We used some twine which served as the hinge for our experiment, and passed it through a hole in the triangular plate.

Fabrication Details

To cut out our designs, we utilised the laser-cutting machine available in the Tinkerers' Lab at IITGN.

- Firstly, the dimensions of the part required were determined.
- Then, the part was designed in Fusion360.
- The Fusion360 sketch in CAD was exported as a .dxf file.
- Then, the obtained file was loaded onto the computer connected to the laser-cutting machine which then downloaded the file onto the machine.
- After that, the machine was switched on and the part were cut out.

After obtaining the triangular plate, the twine was fastened to it and the experiment was conducted.

Theoretical and Mathematical Analysis

Measurement Techniques and Experimental Approach

For obtaining the centre of percussion by experimental means, we hung the system, and applied impulses at three different points along the altitude passing through the hinged vertex using a tool.

Results

Comparison of results:

Discussions

- Theoretical Evaluation:
  The theoretical determination of the CoP involved considering the geometric properties of the equilateral triangular plate. As the center of mass coincides with the centroid, the CoP was estimated along the line connecting the vertex to the centroid. Theoretical calculations provided a predicted distance from the centroid to the CoP, allowing for a precise location on the triangular plate.
- Experimental Procedure:
  The experiment involved setting up the equilateral triangular plate and applying a force normal to the plate at the vertex. The plate was allowed to oscillate freely, and the motion was recorded. To find the experimental CoP, the plate was subjected to various forces, and the resulting motion was analyzed.
- Experimental Challenges:
  Several challenges were encountered during the experiment. External factors such as air resistance and friction may have influenced the motion of the plate. Additionally, the accuracy of force application and the potential for small imperfections in the plate's structure could introduce uncertainties in the experimental results.
- Results and Comparison:
  The experimentally determined CoP was compared with the theoretically predicted CoP. Any discrepancies between the two values were analyzed to understand the

factors contributing to the differences. The comparison provided insights into the accuracy of the theoretical model and the real-world behavior of the triangular plate under the applied force.

- Sources of Discrepancies:
  Discrepancies between the theoretical and experimental CoP values could arise from various sources. Factors such as material properties, imperfections in the plate, and external environmental conditions might contribute to differences. Analyzing these sources of error can guide future improvements in experimental setups or theoretical models.
- Implications and Applications:
  Understanding the CoP of a triangular plate is essential in various applications, including sports equipment design, robotics, and structural engineering. The experiment's findings contribute valuable insights into the practical behavior of such systems and can inform the refinement of theoretical models for more accurate predictions.
- Conclusion:
  In conclusion, the experiment provided a hands-on exploration of the center of percussion for an equilateral triangular plate oscillating about a vertex. By comparing theoretical predictions with experimental results, this study enhances our understanding of the dynamics involved and highlights areas for further research and refinement in theoretical models.

Scope for Improvement

- Precision in Force Application: Improve the experiment's accuracy by developing a more precise and controllable mechanism for applying force at the vertex.
- Mitigation of External Influences: Enhance reliability by minimizing external factors like air resistance and friction through controlled experimental environments and materials.
- Material Impact Analysis: Investigate how varying material properties influence oscillation dynamics, providing a more comprehensive understanding and refining theoretical models.
- Imperfection Assessment: Analyze potential imperfections in the triangular plate's structure, such as thickness variations, to better understand their impact on experiment outcomes.
- Advanced Measurement Techniques: Utilize advanced measurement tools, such as high-speed cameras or sensors, to gather more precise data on the plate's motion and improve the determination of the centre of percussion.

References

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