MUP100 / MUP300 – PROJECT

Dragonfly-Inspired Flapping Wings: Elliptical vs. Rectangular Wing Geometry

Department: Aeronautical Engineering
Project Team: 6 Students
Project Type: Experimental Design, Mechanical Prototyping and Aerodynamics Demonstration

1. Project Overview

Flapping-wing flight is one of the most interesting flight mechanisms observed in nature. Dragonflies are particularly fascinating because of their ability to generate aerodynamic forces through the coordinated motion of four wings.

In this project, students will design, build, and demonstrate a simple mechanical flapping-wing system inspired by dragonfly flight.

The main purpose is to investigate how wing geometry influences airflow patterns and aerodynamic behavior during flapping motion.

Students will construct a vertically mounted mechanical rig attached to a laboratory table. The wings will be driven by one or two small electric motors, such as brushless DC (BLDC) motors or other suitable low-cost miniature motors.

Two different wing planform geometries will be investigated:

- **Elliptical wing:** Inspired by the wing shape of a dragonfly.
- **Rectangular wing:** A conventional rectangular wing geometry used for comparison.

The mechanical system and operating conditions should remain as similar as possible. The wing geometry will be the only intentionally changed experimental parameter.

2. Project Objectives

By completing this project, students are expected to:

1. Understand the basic principles of flapping-wing aerodynamics.
2. Explore the relationship between wing geometry and airflow generation.
3. Design and construct a simple mechanical flapping mechanism.
4. Compare elliptical and rectangular wing configurations.
5. Visualize airflow using the smoke generator available in the laboratory.
6. Observe and document the airflow patterns generated by the moving wings.
7. Develop basic experimental observation, technical reporting, and presentation skills.

3. Experimental Setup and Design

Students will construct a simple mechanical flapping-wing demonstration rig.

The system will consist of:

- A vertical support structure mounted securely to a laboratory table.
- One or two small electric motors to generate the flapping motion.
- A simple mechanical transmission mechanism connecting the motor(s) to the wings.
- A pair of interchangeable wings.
- An electrical power supply and suitable motor control system.

The overall arrangement should be inspired by the dragonfly wing mechanism shown in the reference image provided by the instructor.

Important: The objective is to build a simple, functional, and observable demonstration system rather than a sophisticated robotic or biomimetic flying vehicle.

4. Experimental Configurations

Only the wing planform geometry will be changed during the experiment.

Configuration A – Elliptical Wings

Students will design and manufacture elliptical wings inspired by dragonfly wings.

Configuration B – Rectangular Wings

Students will manufacture rectangular wings with comparable dimensions and, as far as practical, comparable wing area.

Both configurations will be tested using the same mechanical setup and comparable operating conditions.

The motor arrangement, mounting system, flapping mechanism, and test environment should remain unchanged between experiments.

5. Laboratory Demonstration: Smoke Visualization

An important part of this project will be the experimental visualization of airflow.

During the laboratory demonstration, students will use the smoke generator available in the laboratory to visualize the airflow produced by the flapping wings.

Students should:

- Operate the flapping mechanism under controlled laboratory conditions.
- Introduce smoke into the airflow around the moving wings.

- Observe the resulting airflow patterns and wake structures.
- Take photographs and, if possible, short videos of both wing configurations.
- Compare the observed airflow behavior of elliptical and rectangular wings.

The smoke visualization should be documented and included in the final presentation and individual reports.

Students should pay particular attention to the differences in airflow direction, wake development, flow disturbance, and the qualitative effects of wing geometry.

6. Group Organization

The project will be conducted by a team of **six students**.

All six students will work together to design, construct, assemble, and demonstrate the experimental setup.

However, each student must submit an **individual technical report**.

The team will also prepare and deliver one common PowerPoint presentation.

7. Deliverables

A. Individual Technical Report

Each student must submit an individual report covering the project.

The report should include:

1. Introduction and background
2. Basic principles of flapping-wing aerodynamics
3. Description of the mechanical design
4. Motor and flapping mechanism
5. Elliptical and rectangular wing designs
6. Experimental procedure
7. Smoke visualization photographs
8. Comparison and discussion of observations
9. Conclusions
10. References

Although the experimental work is conducted as a group, each student must write and submit their own report using their own explanations and analysis.

B. Group PowerPoint Presentation

The team will prepare one common PowerPoint presentation.

Total presentation time: 30 minutes

Each student will present for approximately **5 minutes**.

All six students must actively participate in the presentation.

The presentation should cover:

- Project motivation and objectives
- Dragonfly-inspired flapping mechanism
- Mechanical design and construction
- Elliptical wing configuration
- Rectangular wing configuration
- Experimental demonstration and smoke visualization
- Comparison of observations and conclusions

C. Working Prototype and Laboratory Demonstration

The group must present a fully assembled and operational flapping-wing mechanism.

The demonstration must include:

- The mechanical rig mounted vertically on the laboratory table.
- Operation of the flapping mechanism.
- Demonstration of both wing configurations.
- Smoke visualization of the generated airflow.
- Photographic documentation of the experiments.

8. Assessment Criteria

The project will be evaluated based on the following criteria:

Assessment Component	**Weight**
Mechanical design and working prototype	25%
Experimental demonstration and smoke visualization	20%
Individual technical report	25%
Group PowerPoint presentation	20%
Individual participation and contribution	10%
Total	**100%**

9. Important Notes

- The project is primarily an experimental demonstration of flapping-wing aerodynamics.
- Sophisticated aerodynamic calculations or CFD simulations are not required.
- The two wing configurations must be tested under comparable conditions.
- Students should focus on understanding and explaining the physical phenomena rather than simply building a working mechanism.
- All six students are responsible for contributing to the design, construction, testing, and demonstration.

- Each student is individually responsible for their own report and presentation contribution.
- Laboratory equipment, electrical connections, and rotating mechanical components must be used under instructor supervision.
- The prototype must be securely mounted, and moving parts must be kept clear of hands and loose objects.

10. Expected Learning Outcomes

At the end of this project, students should be able to explain how a mechanical flapping system works, identify the basic aerodynamic effects associated with flapping wings, and discuss how wing planform geometry can influence airflow generation.

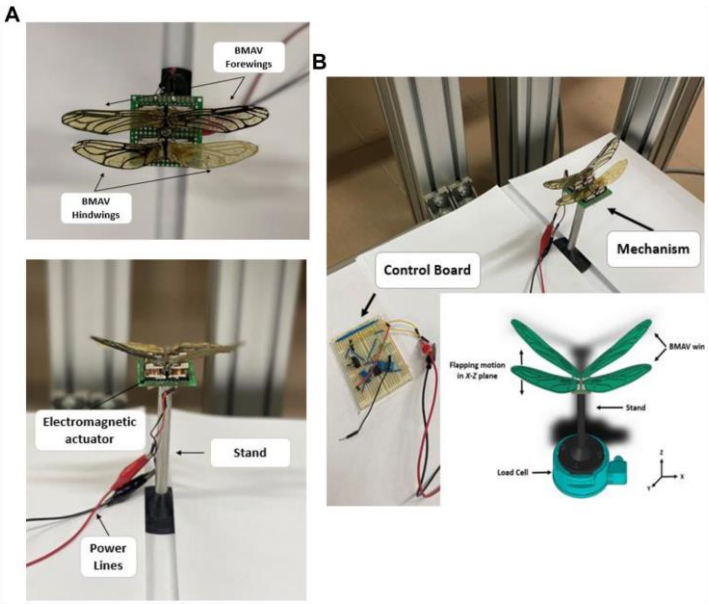
Most importantly, students will gain their first hands-on experience in translating an aerospace engineering concept into a physical experimental model.

Remember: The goal is not to build a flying dragonfly. The goal is to understand, build, test, observe, and explain how wing geometry affects airflow during flapping motion.

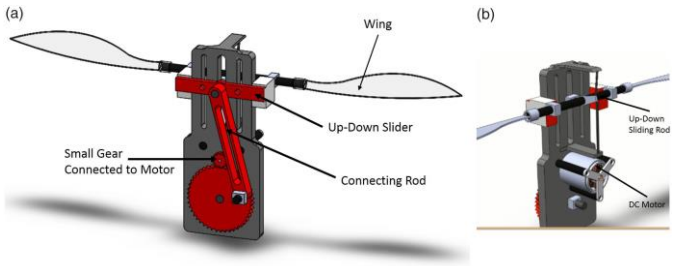
Good luck and enjoy your first aerospace engineering project!

SAMPLE Projects from online references

1) www.frontiersin.org/journals/bioengineering-and-biotechnology/articles/10.3389/fbioe.2022.787220
2) https://www.cambridge.org/core/journals/aeronautical-journal/article/role-of-flexibility-on-the-aerodynamic-performance-of-a-resonating-hummingbirdinspired-wing
3) https://www.thenakedscientists.com/articles/interviews/mechanics-insect-and-bird-flight


A
BMAV Forewings
BMAV Hindwings
Electromagnetic actuator
Stand
Power Lines
B
Control Board
Mechanism
Flapping motion in X-Z plane
BMAV win
Stand
Load Cell

2)


(a)
Wing
Up-Down Slider
Small Gear Connected to Motor
Connecting Rod
(b)
Up-Down Sliding Rod
DC Motor

3)

