

# Aerodynamics of Insect Hovering Flight Methods

## Abstract

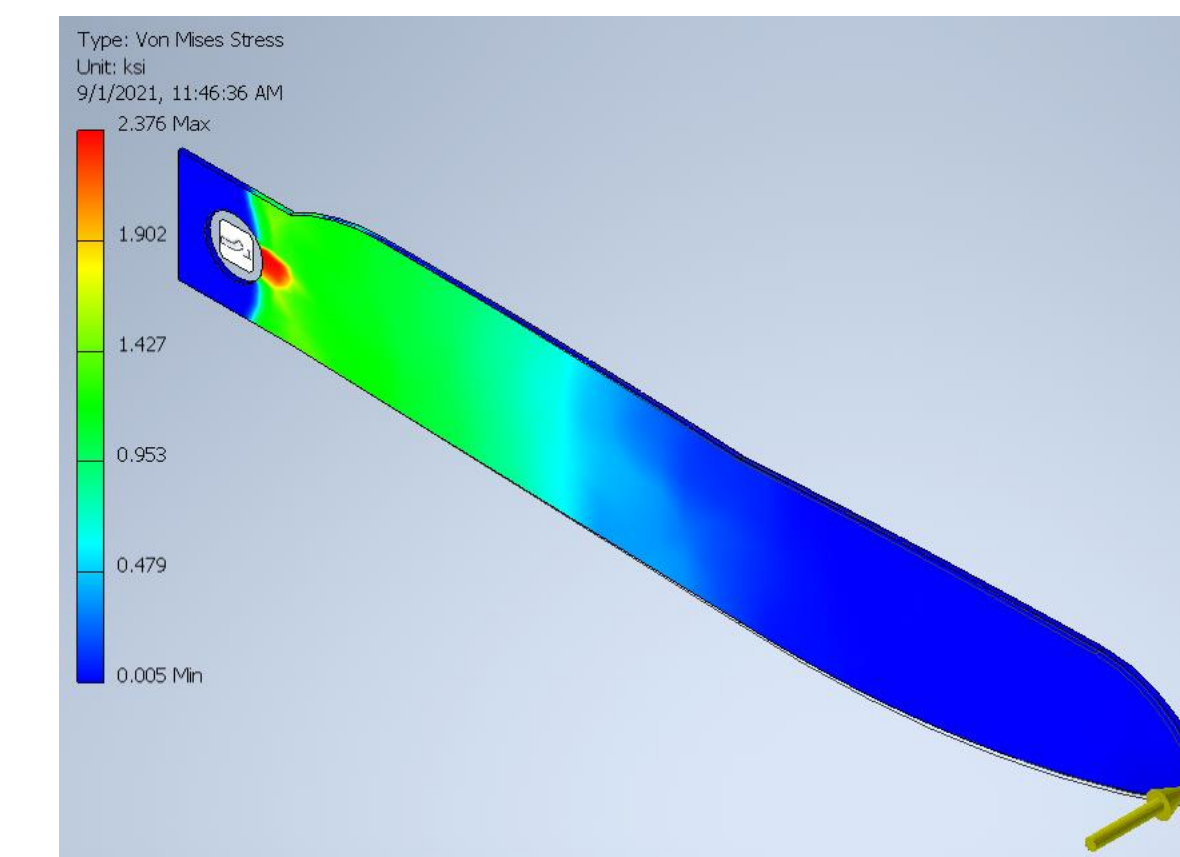
- Flapping hovering flight challenges traditional aerodynamics for small scale production of lift.
- Two main styles of insect flight; hovering flight and clap-and-fling hovering flight.
- The main source of lift generation is wing-vortex interaction
- Unsteady aerodynamics are necessary for calculating lift forces due to wing size

## Mechanism Design

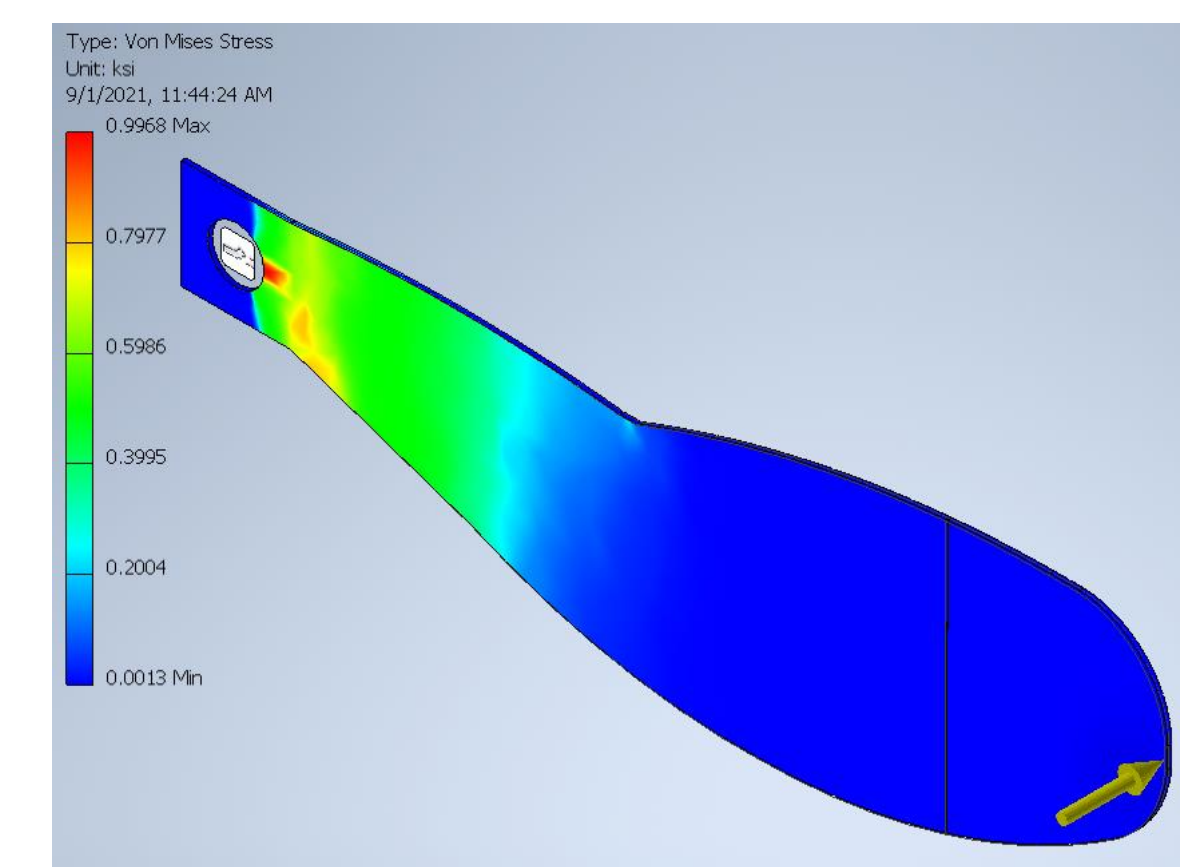
- Mechanism was built to simulate flapping flight in an experimental environment
- Sized to fit within the wind tunnel and be of comparable scale to the insects being studied
- Simplification of flapping dynamics to allow effective modeling for experimentation
- Motor runs under velocity PI control with live adjustable gains

## Wing Analysis

- Wing material and thickness calculations were performed in Matlab based on aerodynamic stresses
- Distributed loads simulated as point loads on the wingtip to determine maximum bending moment and wing factor of safety
- Wings needed to both be thin and strong enough to have comparable properties to insect wings, as well as be able to withstand multiple tests



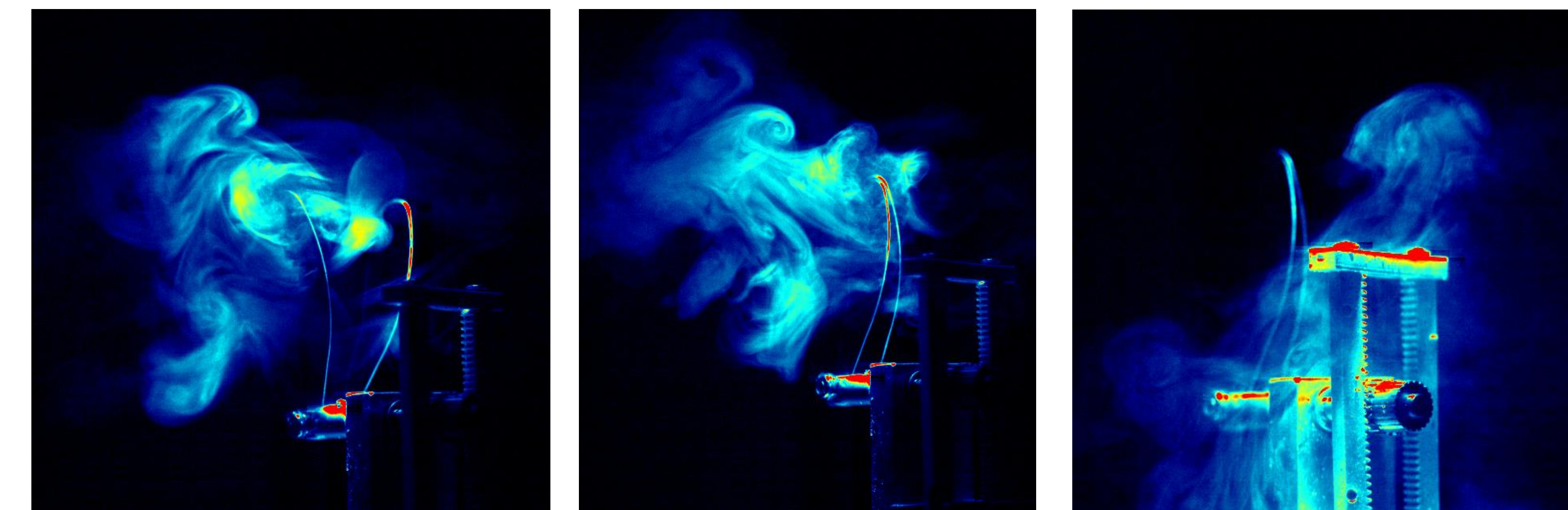
Dragonfly wing deflection analysis



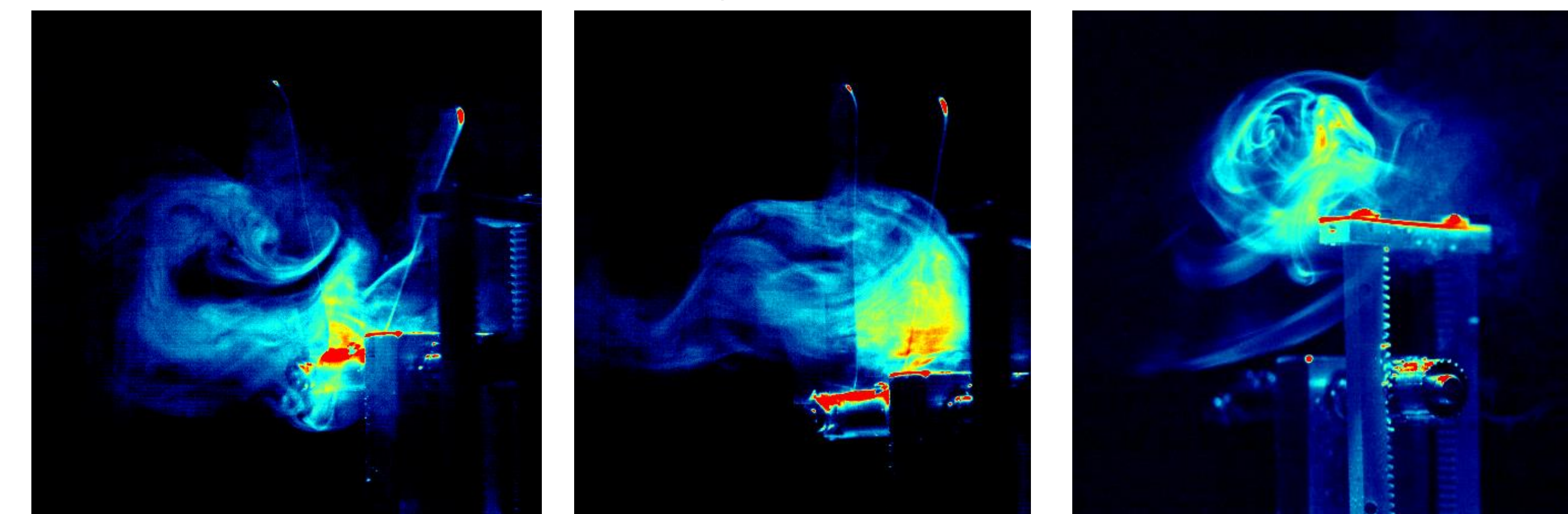
Damselfly wing deflection analysis

## Flow Visualization

- To gather data describing the wing-shed vortex interactions high speed imaging was performed at a rate of 5kHz (5000 images/second), and shutter speed of 1/10000 in order to limit the light allowed into the camera to not damage the lens



Damselfly wing flow visualization



Dragonfly wing flow visualization

## Flow Analysis

- The major differences between non-interference (dragonfly) flight and clap-and-fling (damselfly) flight is the presence of the wing impact vortices
- The mushrooming present in the third damselfly flow visualization figure is the result of vortex-vortex interaction, when created wing vortices collide in the flight wake
- The dragonfly wing flow visualization demonstrates vortex shedding and leading-edge vortex (LEV) roll off, as can be seen in the first dragonfly flow visualization
- The downward streak created by boundary layer shedding in the third dragonfly flow visualization demonstrates the trailing vortices responsible for gathering wake-shed lift forces for flight

## Future Work

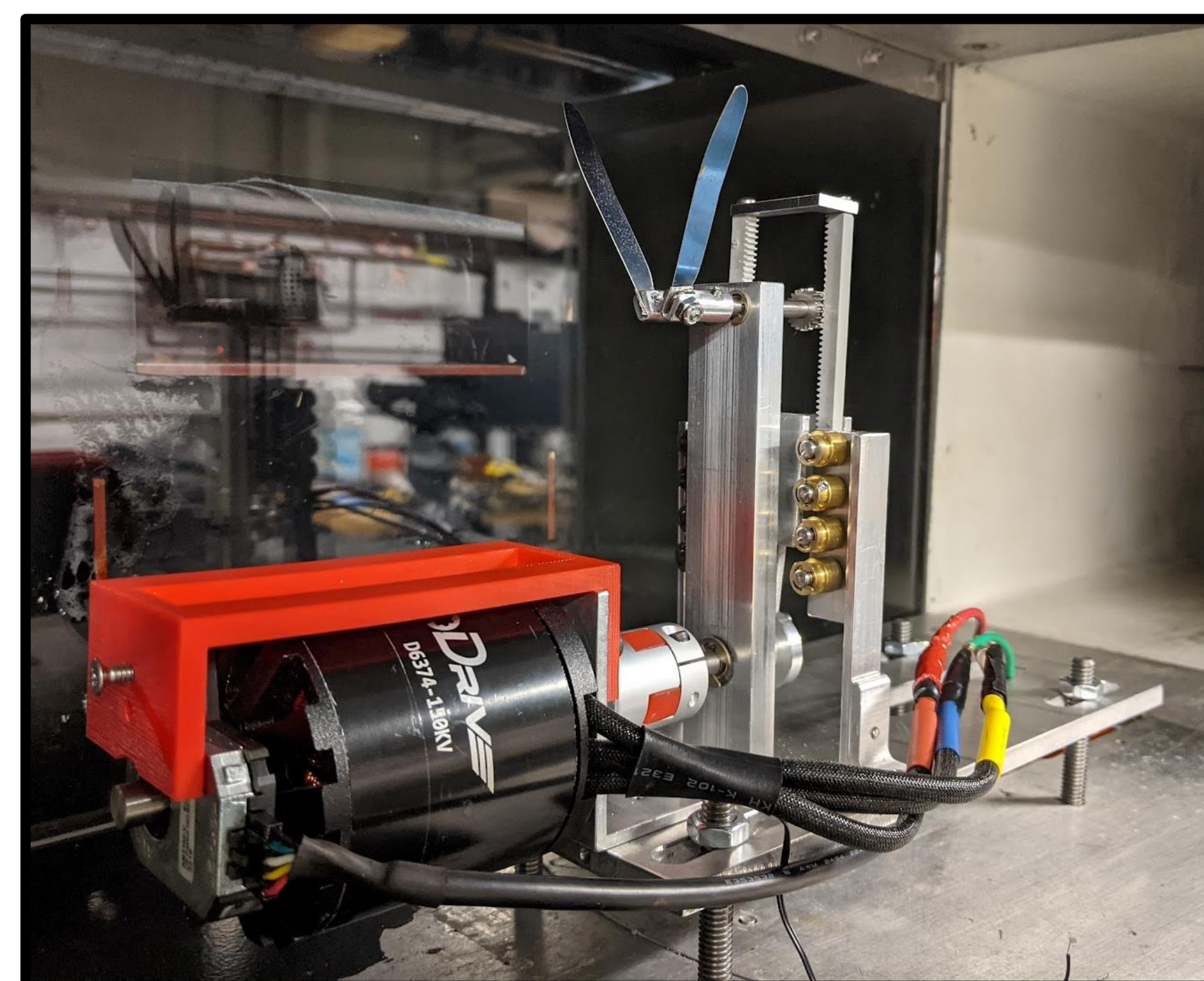
- Strain gages will be mounted at wing roots to gather wing force distributions to further quantify lift generation
- PIV (Particle Image Velocimetry) will be performed to provide mathematical data of flow behavior and development over time
- Further flow visualization data will be taken using laser illumination

## Acknowledgments

➤ David and Lorraine Freed Undergraduate Research Symposium, Lehigh University

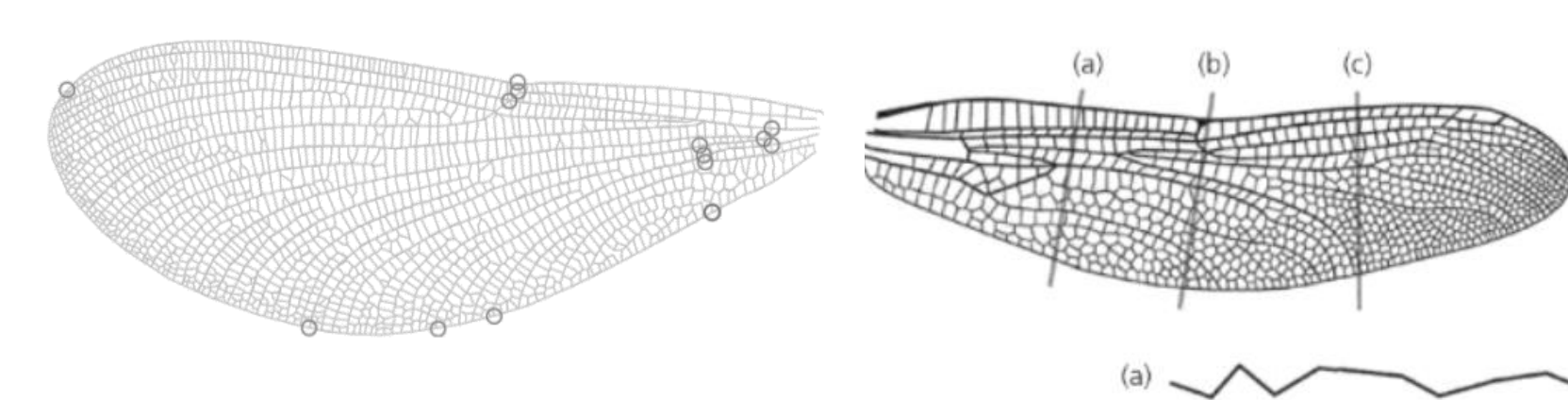
## Background

- Insect flight falls outside of steady state aerodynamics due to oscillatory wing motion
- Lift is mostly generated by shed vortices and vortex interaction
- Both non-interference and clap-and-fling generate 60% of lift through wing-vortex interactions
- Clap-and-fling uses wing-wing interactions at the top of the upstroke to generate additional shed vortices, leading to more lift generation on the downstroke



## Wing Design

- The two sets of wings used are modeled after the wings of the specific species of dragonfly and damselfly being compared
- The smaller sets of wings are modeled to scale of the biological wings
- A second set of larger wings were manufactured for use in force measurement
- These larger wings allow for clearer visualization data and a larger surface for strain gages



Damselfly wing (above)  
Dragonfly wing (right)

