EXPERIMENTAL INVESTIGATION OF MICRO-ROTOR BLADE TIP VORTICES

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INTRODUCTION

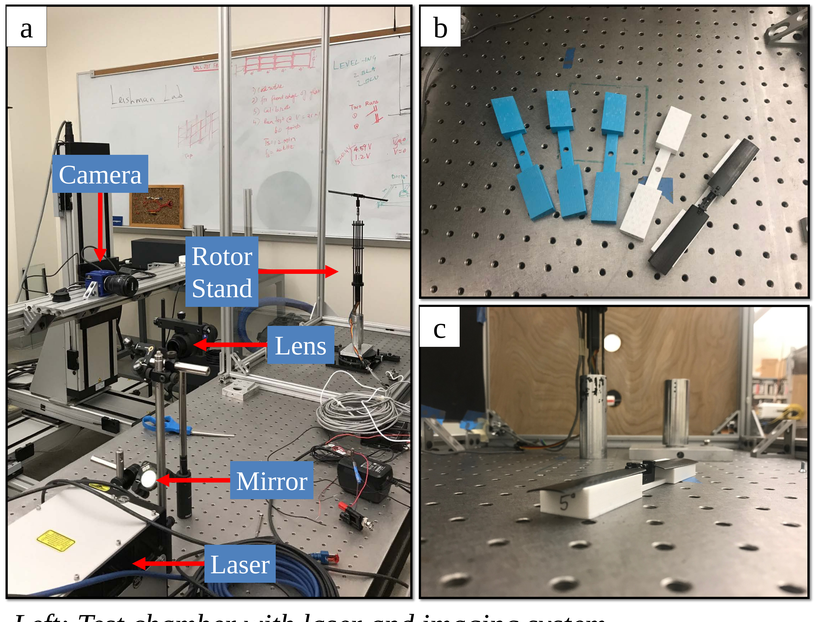
The rotor wing project was initiated to investigate the root causes of brownouts and the wobbling effect observed on helicopter's flight which occurs during takeoff and landing phases. Micro-rotors also have are highly impacted by the separation bubble at low Reynolds number conditions. The long-term goal of the research is to help to minimize these problems seen in the field.

Approach

- Flow visualization of micro-rotor at varying RPMs and blade angle-of-attack.
- Particle image velocimetry (PIV) to measure flow field surrounding a micro-rotor.
- Quantify thrust and torque using force balance sensors.

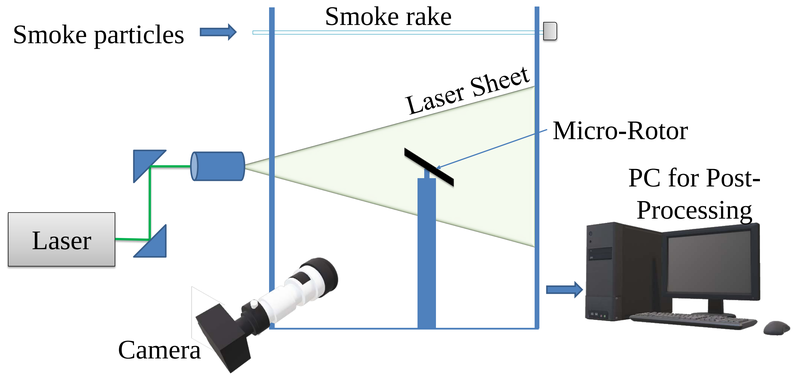
TEST CHAMBER AND TEST MODEL

- A closed test chamber allows for measuring forces and imaging without interruption of ambient flow.
- Test chamber was built on a heavy-duty optical bread board for isolating vibration and mounting optical parts (laser, lens, mirror, etc.)
- Pitching angle of the blade can be adjustable from 5° to 15 °.

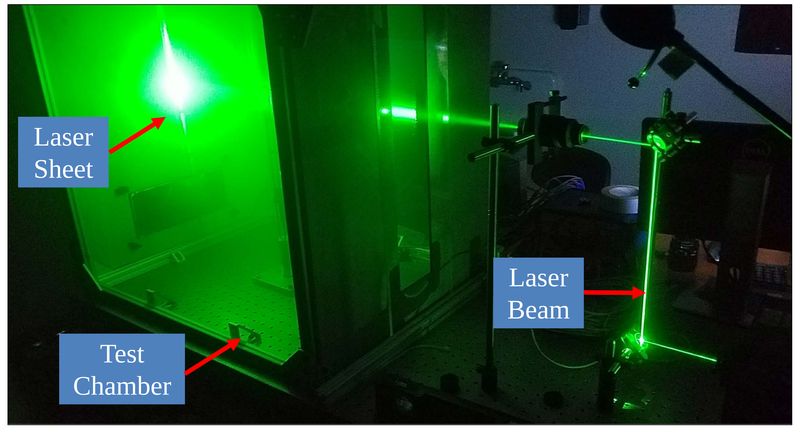


Left: Test chamber with laser and imaging system
Right up: 3D-printing blocks for blade pitching angle adjustment
Right down: Pitching angle set at 5°

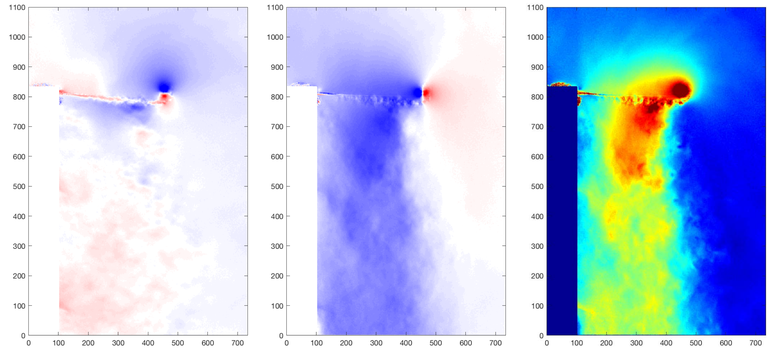
PARTICLE IMAGE VELOCIMETRY



Schematic of PIV and flow visualization setup



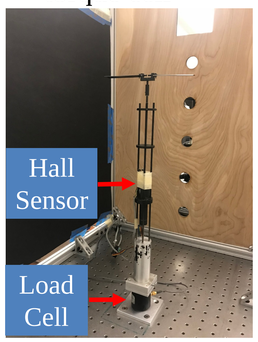
Laser with 532 nm wavelength (green) shining into the test chamber



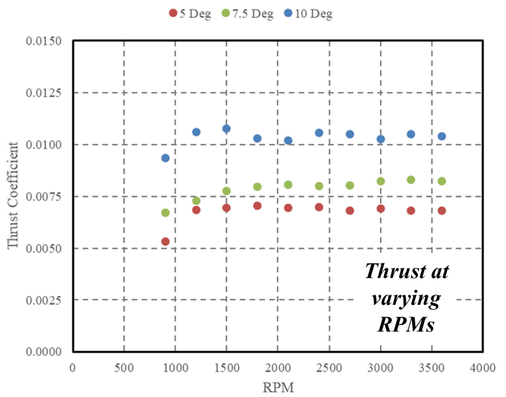
Left: Mean velocity distribution in the rotor blade spanwise direction (blue: towards blade root, red: towards blade tip)
Center: Mean velocity distribution in streamwise direction (blue: downwards, red: upwards)
Right: Turbulence intensity distribution (blue: low, red: high)

FORCE MEASUREMENTS

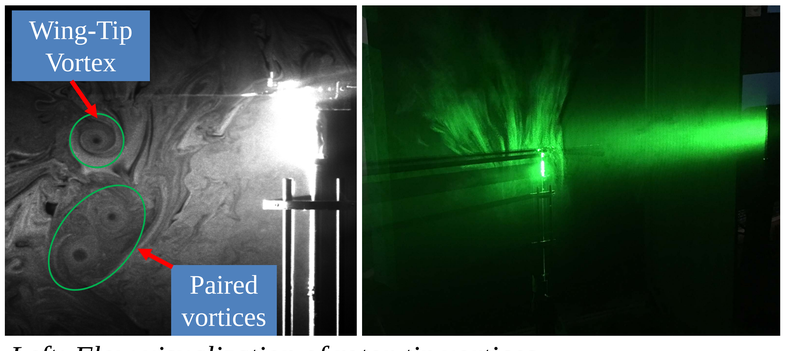
- Thrust and torque were measured to evaluate rotor blade performance at different pitching angles.
- Two load cell sensors were used, the tensile load cell and torque cell



Force Measurement Setup



SMOKE VISUALIZATION



Left: Flow visualization of rotor-tip vortices.
Right: Illumination of upstream flow.

CONCLUSIONS

An increase in the rotor's rpm caused an increase in strength of wingtip vortices. The flow near the eye are seen to be laminar, however it induces a greater vorticity at farther distance which causes larger instability in the flow. These vortices are seen pairing up with the ones formed before as they move down to the ground. This pairing phenomena causes the vortices to be bigger in dust. The pairing is seen as a contribution to the movement of dust particles.

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