Measuring Bicopter Motor Thrust and Power

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Measuring Bicopter Motor Thrust and Power Overview

1. Procedure
2. Error Characterization
3. Acquired Airspeed
4. Motor Power
5. Motor Thrust
6. Conclusion

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1. Procedure

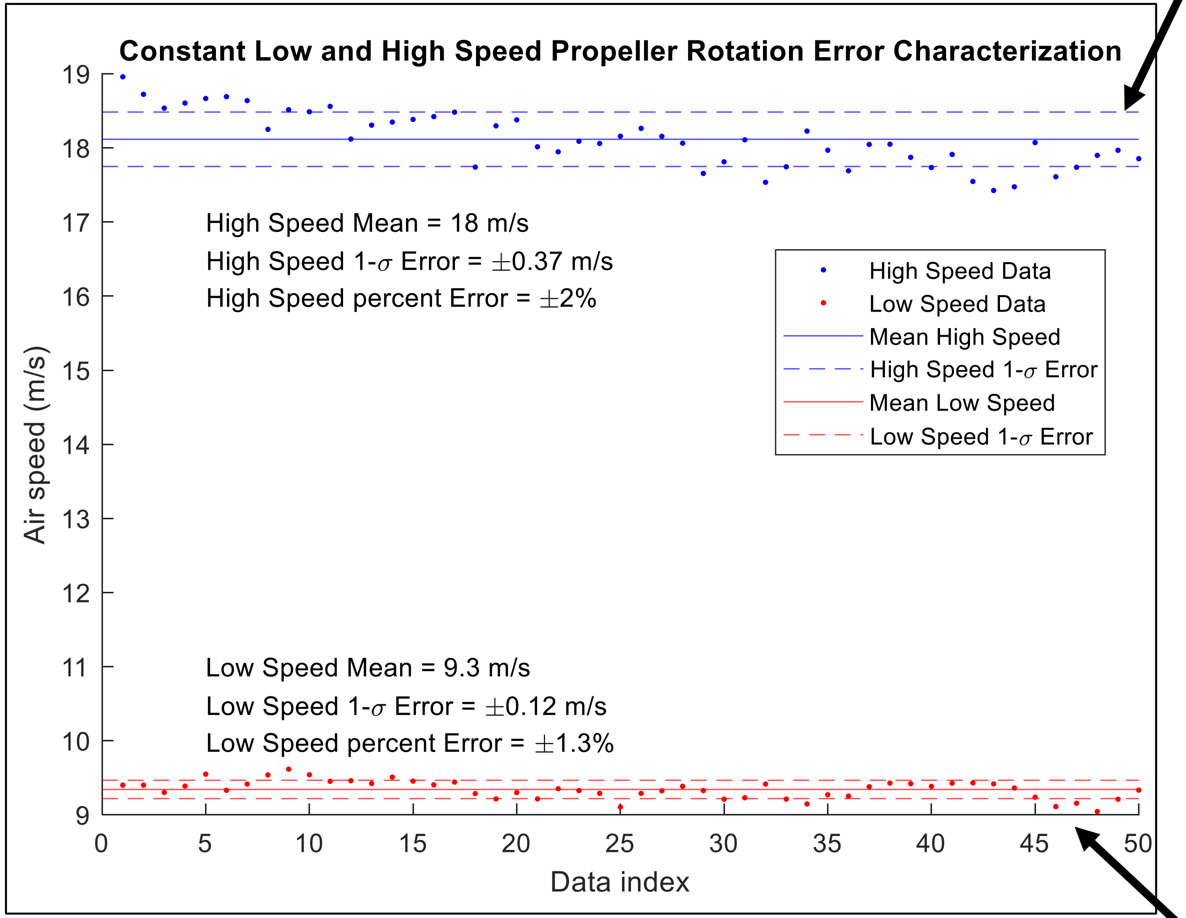
1. Airflow Sensor Characterization

1. Airflow sensor setup
2. LabVIEW opened to acquire data
3. Motor ran at 6600 RPM constant for 20 seconds
4. Motor ran at 3800 RPM constant for 20 seconds

2. Radial Airflow Measurements

1. All data acquired and saved in LabVIEW
2. Airflow sensor set 4 in. axially from motor
3. Motor ran at constant 6600 RPM (“high speed”)
4. Motor swept from 0 mm to 270 mm radially in 8 mm increments
5. Above two steps repeated for 3800 RPM (“low speed”)
6. Above repeated for 7.325 inch and 10.5 inch axial positions.

2. Airspeed Measurement Error Characterization



6600 RPM (1.75 ms pulse width)

3800 RPM (1.36 ms pulse width)

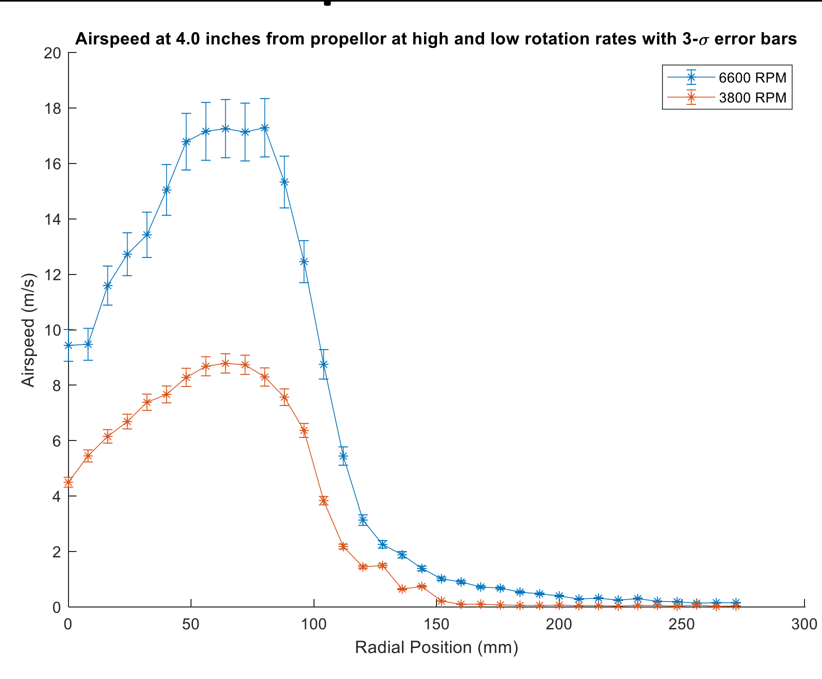
Summary

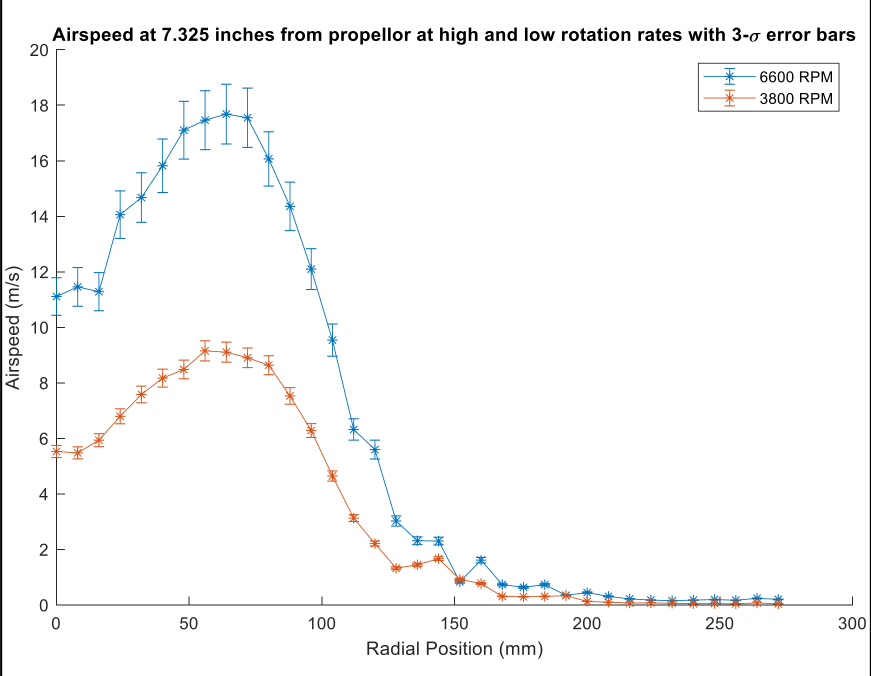
Before taking any real measurements of the bicopter motor performance, the motors were made to spin at a constant speed to characterize the error of the measurements.

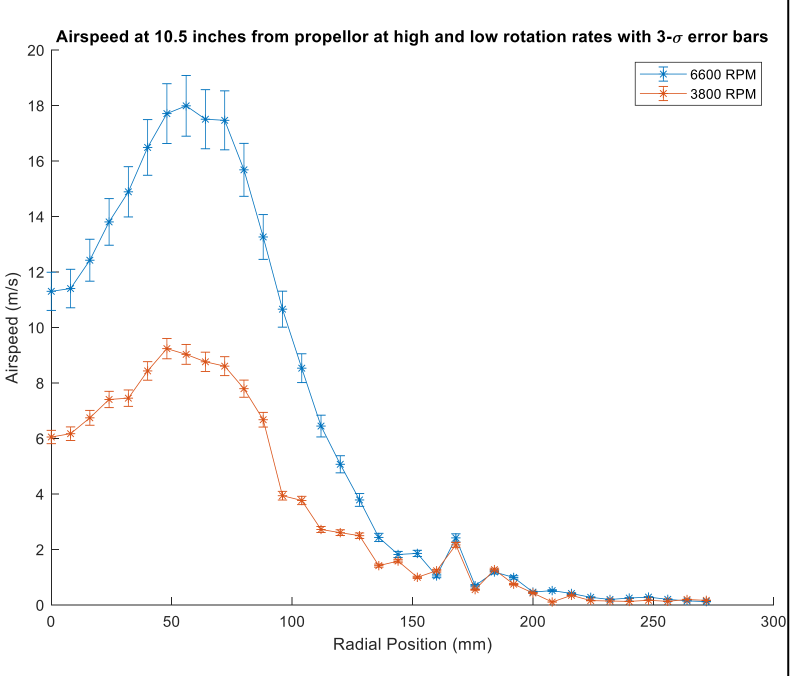
Two speeds were tested, a low speed and high speed. These speeds were used for previous testing efforts and so they were reused for this test to keep the data consistent between tests.

The higher speed has about 2x higher percent error than the lower speed, with 2% error compared to 1.3% at the low speed. This error was calculated with the standard deviation which if the data is assumed to be normally distributed, which most sensor data can be assumed to, then approximately 66% of the data will fall within these bounds.

3. Airspeed At Different Radial And Axial Positions







Summary

The airspeed was measured at three different axial distances from the propeller: 4.0 inches, 7.325 inches, and 10.5 inches. At each axial position, the air speed probe was swept from the center of the propeller to 270 mm from the central axis at two different rotational speeds, 6600 RPM and 3800 RPM as shown above. The three graphs above show this data at each axial position with 3-sigma error bars. 3-sigma was chosen as it should encompass 99.7% of the data the sensor could read. Between each axial position, the air speed does not change a lot and stays within the error bars between each axial position. This means that the airspeed can be considered to remain mostly constant from 4 to 10.5 inches from the propeller axially.

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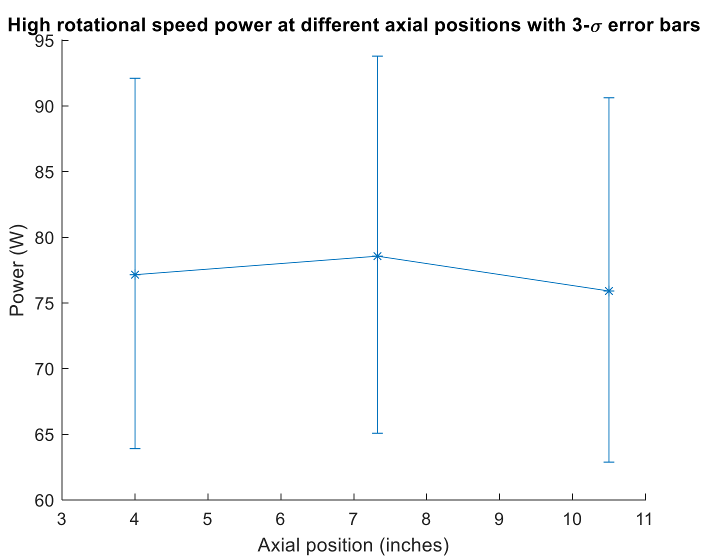
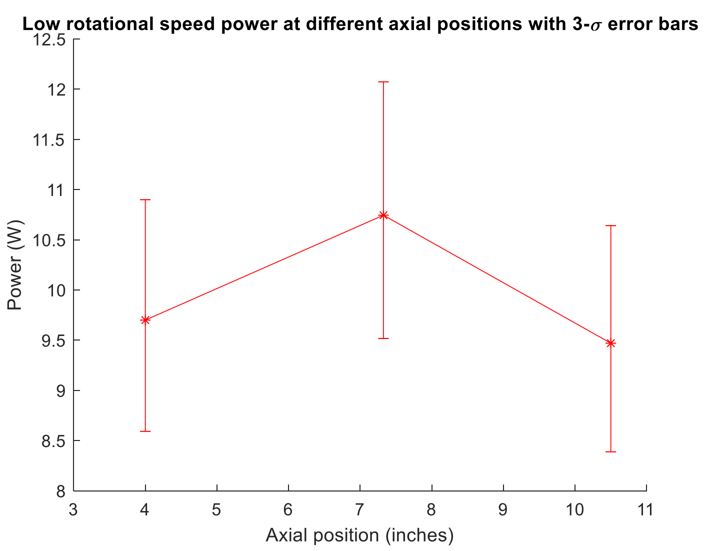
4. Calculated Motor Power





Summary

The total calculated power of the airflow from the motor was calculated via conservation of energy. By integrating the velocity over the area of the control surface, the power can be calculated after measuring several points radially. This equation is shown below and was calculated with the data in MATLAB using trapezoidal approximation of an integral.

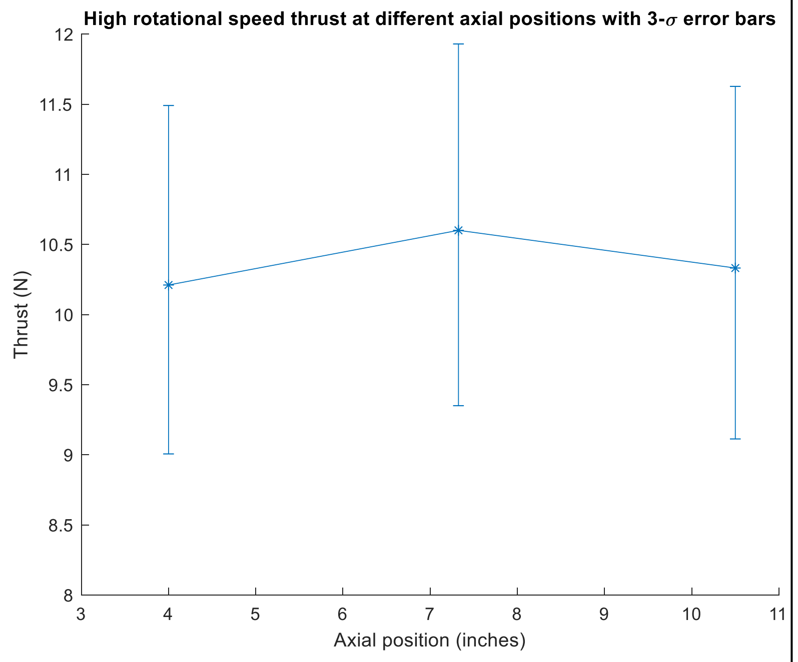
$$Power = \pi\rho \int_0^R [u(r)]^3\, r\, dr$$

Uncertainty was calculated by putting the velocity at the top and bottom of the error bars shown previously through the same equation.

Conclusion

The power of the higher rotational speed's airflow is higher as expected again, and as seen previously the power is not dependent on the position axially of the airflow sensor. This makes sense as energy is conserved, and so the airflow may diffuse further radially, the kinetic energy most likely would not dissipate in only 10 inches from the motor.

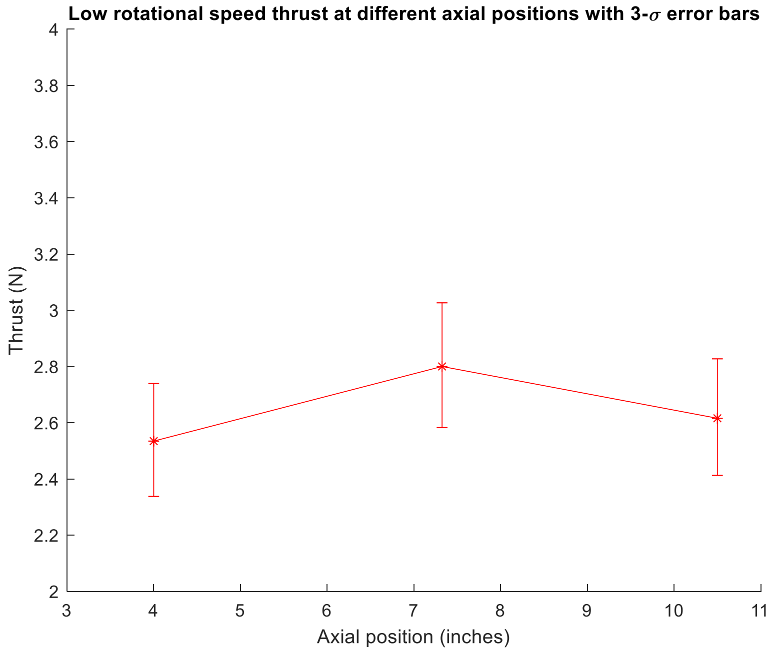
5. Calculated Motor Thrust



Summary

The airspeed from the propeller and motor was measured at different axial locations and two different speed. On the left is the high speed (6600 RPM) and below is the low speed (3800 RPM). Using the concept of conservation of momentum, the thrust was calculated with the following equation:

$$Thrust = 2\pi\rho \int_0^R [u(r)]^2 \, r \, dr$$



Conclusion

The magnitude of the thrust is much larger at the higher speed, and because the percent error is larger the magnitude of the error is also larger, with an uncertainty of close to ±1.25 N, compared to the low speed which has an uncertainty of close to ±0.2N. But one commonality between the two speeds is that axial position doesn't effect the thrust, with the nominal thrusts being within the error bars at each axial position.

6. Motor Thrust and Power Conclusion

Based upon the results discussed in the previous slides, the airspeed, motor thrust, and air power calculated in this test are not dependent upon the axial position of the air speed sensor.

These results make sense as momentum and energy, the concepts used to calculate these quantities, are conserved and in the span of 11 inches would most likely not transform due to friction or other non-conservative forces. Because of this the data acquired can be averaged obtain the best values for power and thurst at each speed setting.

The uncertainty at each speed is not the mean of the uncertainty, but instead the maximum uncertainty among the data points averaged. This is because the mean doesn’t effect the uncertainty, and so the worst-case uncertainty must be used.

Final Calculated Values

Motor Speed (RPM)	**Power (W)**	**Thrust**
3800	9.97 ±1.32	2.65 ±0.226
6600	77.2 ±15.2	10.4±1.33