The University of Texas at Austin
Aerospace Engineering and Engineering Mechanics
Cockrell School of Engineering

ASE 375 Electromechanical Systems
Section 14115

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Final Report: Propeller Twist Effect on Efficiency

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1 Introduction

The purpose of this lab is to investigate the effect of propeller twist on propulsive efficiency. We will be using a brushless DC motor to spin a propeller at different speeds and measure the thrust produced by the propeller using strain gages. We will measure the electrical power consumption using a wattmeter. The wattmeter also outputs the current and voltage readings while the motor is spinning. Thus efficiency of the propeller will be calculated by taking the ratio of the thrust to the electrical power consumption measured. We will compare the efficiency of two propellers with the same diameter but different twist angles spinning at a chosen PWM signal, which is sent to the motor to rotate at a certain angular rate.

2 Equipment

Measurement devices and hardware used in this lab include:

1. Carbon Fiber Beam with motor mounting holes:

   A cantilevered carbon fiber beam will be used to mount the motor, strain gages, and electronic speed controller. Below is the setup of the experiment:

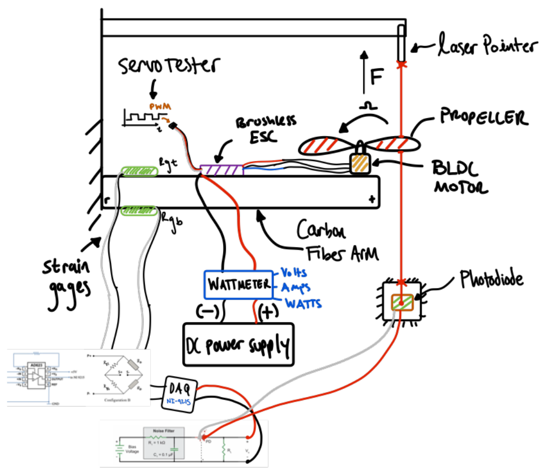

Figure 1: Experiment Setup

2. Dummy resistors. Specifically, a 10kΩ resistor, a 1kΩ resistor, and two 350Ω resistors will be used in the circuit. The two 350 Ω resistors will be used as dummy resistors for the wheatstone half-bridge configuration (Configuration B used as shown in Lab 5), and the 10kΩ and 1kΩ resistors will be used for the photodiode circuit.

3. Two strain gages, one placed on the top of the carbon-fiber beam and one placed on the bottom. The strain gages will be connected to a DAQ to measure the strain on the beam.

4. NI-9215 DAQ [7] to measure the strain gage and photodiode electrical output.

5. Instrumentation Amplifier (AD623) [8], to amplify the output of the strain gages and reduce the impact of bias error.

6. 650nm Laser Pointer (Red). The laser pointer is placed above the propeller offset by 2-3 centimeters from the center and shines through it to hit the photodiode.

7. Si Photodiode [6], which converts optical power to electrical current. This in concert with the laser pointer will measure the RPM of the propeller, as the propeller will break the beam twice per rotation.

8. BLDC Motor [1] with 20A Brushless Electronic Speed Controller [2]
9. Power Supply supplying operational voltage, with Voltmeter, Ammeter, and Watt-meter
10. PWM Wave Generator or PWM/Servo Tester
11. 2 Two-Blade Propellers of same diameter and different twist (6x6 in and 6x5.5in)
12. Thrust Stand/Arm with mounting for BLDC Motor, this uses aluminum 40/40 extrusions to mount the motor and propeller.
13. Breadboard and wires to connect the circuit.

To prepare the carbon fiber beam for the strain gages, we sanded down the beam with 80, 120, and 220 grit sandpaper. We then cleaned the beam with isopropyl alcohol and applied the strain gages to the beam with superglue as performed in lab 4. The strain gages were connected to a DAQ and dummy resistors to calibrate the strain gages.

After some initial testing, the strain gage output was not considered distinguishable from the bias error. To reduce the impact of bias error, we used an amplifier (AD623) to amplify the output of the strain gages as requested by Dr. Sirohi. This greatly improved the accuracy of our results.

3 Procedure

3.1 Strain Gage Calibration

For calibration, as in lab 3, variable weights were placed on the far end of the cantilevered beam. The strain gage output was recorded at each weight increment, loading from 0 to 250 grams and then unloading back to 0 grams. The strain gage output was tared before the loading and unloading process.

3.2 Trial Procedure

4 Data Processing

5 Results and Analysis

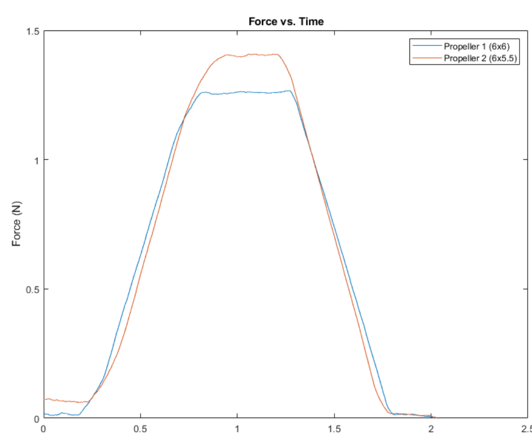

Figure 2: Force vs Time for Trial 1

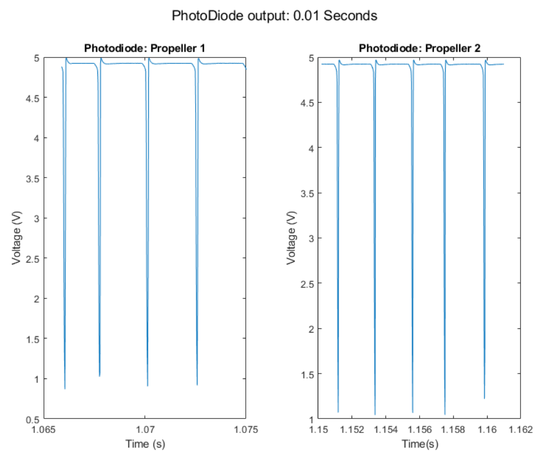

Figure 3: Photodiode Output for Trial 1

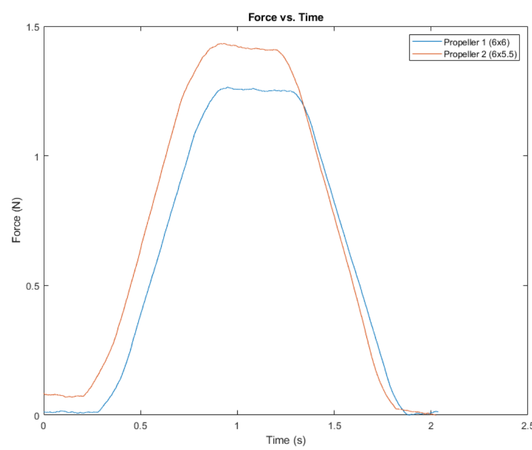

Figure 4: Force vs Time for Trial 2

Parameter	**Propeller 1 (6 x 6)**	**Propeller 2 (6 x 5.5)**
Name	6 x 6	6 x 5.5
RPM (measured)	26453.2969	27705.3444
RPM (Theoretical)	26197	26990
RPM (% error)	0.97834	2.6504
Force (g)	129.1952	143.6091
Wattage (W)	45.55	46.7
Thrust-to-Power (g/W)	2.8363	3.0751
Uncertainty (%)	0.017541	0.016756

Table 1: Comparison of Propeller Performance - Trial 1

For Uncertainty in the Thrust to Power ratio, the Wattage, Strain Gage, and DAQ were all sources of error. It was calculated using

$$\epsilon = \sqrt{\frac{\delta x_1}{x_1}^2 + \cdots + \frac{\delta x_n}{x_n}^2} = \sqrt{\frac{\delta W}{W}^2 + \frac{\delta \epsilon_{SG}}{\epsilon_{SG}}^2 + (\epsilon_{DAQ})^2} \tag{1}$$

Parameter	**Propeller 1 (6 x 6)**	**Propeller 2 (6 x 5.5)**
Name	6 x 6	6 x 5.5
RPM (measured)	25883.3191	26272.3077
RPM (Theoretical)	26197	26990
RPM (% error)	1.1974	2.6591
Force (g)	128.9811	146.1474
Wattage (W)	44.25	47.3
Thrust-to-Power (g/W)	2.9148	3.3028
Uncertainty (%)	0.017554	0.01674

Table 2: Comparison of Propeller Performance - Trial 2

6 Conclusion

Appendix

A Datasheets

[1] Multistar Elite 2204-2300KV Multi-Rotor Motor

[2] Afro 20A Race Spec Mini ESC with BEC

[3] APC 6x6E Propeller

[4] APC 6x5.5E Propeller

[5] HFP-25 Digital Servo Programmer & Tester

[6] Silicon Photodiode, FDS1010

[7] NI-9215 Datasheet

[8] AD623 Instrumentation Amplifier Datasheet