Date: Feb 14, 2023
To: Richard Auhl, Instructor of AERSP 305
From: Brandon Fischer, Ankit Gupta, Andrew Laudenslager, Jack Tyndall - Section A6
Subject: Experiment to determine the lift force, rotor RPM, and input power of a remote-controlled helicopter

Introduction

The purpose of this experiment is to investigate the relationship between lift force, rotor's RPM, and power for a small remote-controlled helicopter. It is assumed that varying the throttle of the helicopter will increase the lift force, but it is unclear whether that relationship is linear. Past experiments have been conducted, collecting data independently for lift force and RPM. The independent data allows for more discrepancies in the relationship between the three variables. This experiment will simultaneously acquire voltage readings in a load cell, RPM sensor, and input power. We use Ohm's Law equation to determine the current going through the circuit

$$I=V/R \tag{1}$$

where V is voltage, R is the resistor used in the circuit and I is the current going through the circuit. Then using equation 2, power, P, is found:

$$P=V*I \tag{2}$$

where V is voltage and I is current.

Procedure

To quantify the lift of the small remote-controlled helicopter, the helicopter is attached to a load cell to measure the lift produced by it. The rotation speed of the helicopter blades is recorded using an RPM sensor which uses a reflective sticker mounted on the helicopter's blade to measure RPM. Voltage values from the load cell and the RPM sensor are recorded in a LabView Data acquisition code, along with the input power provided to the helicopter. A standard remote control is used to operate the helicopter.

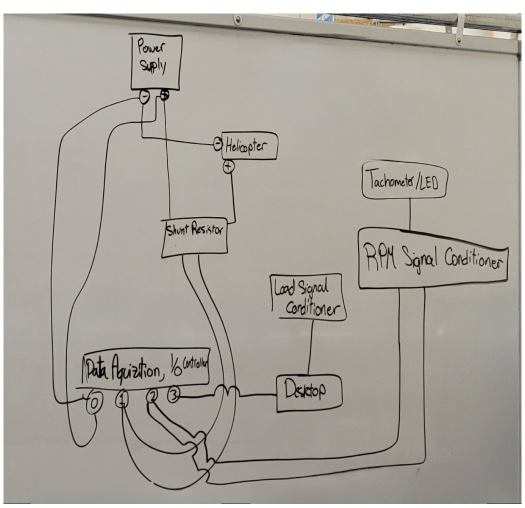

Figure 1: Wiring diagram of helicopter test setup

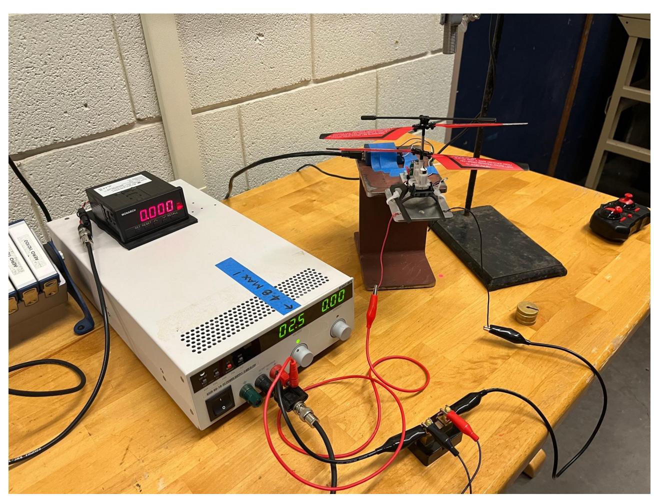

Figure 2: Experimental setup for helicopter testing

The voltage readings from the load cell first must be calibrated using small known masses before using it for the experiment. The relationship between the applied load and associated voltage is shown in Figure 3.

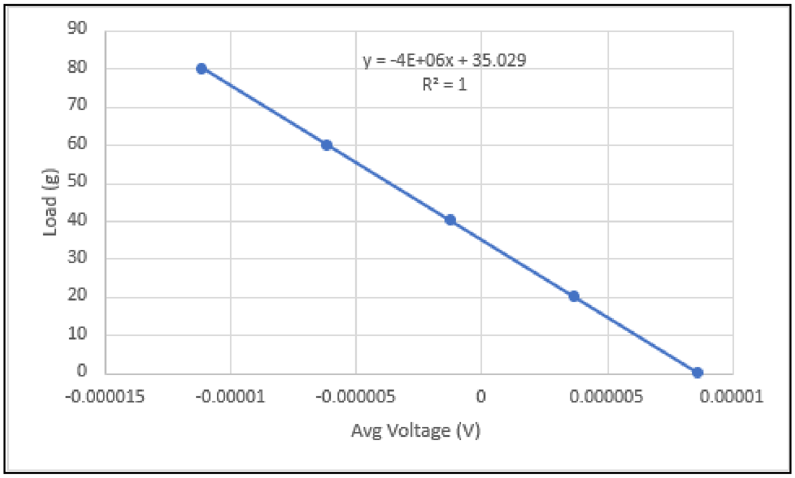

Figure 3: Graph of applied load versus voltage obtained from load cell calibration

The experiment consists of two trials: varying thrust on the remote control while holding the input power constant, and varying the input power while keeping the thrust constant. Each trial includes three sets of data acquisition, to ensure repeatability.

Results and Discussion

In the figures below, three quantities – lift, RPM, and power – are displayed against one another. The lift generated by the helicopter is shown with respect to the rotor RPM in Figure 1, lift versus power is shown in Figure 2, and RPM versus power is shown in Figure 3. A relevant interpretation of the data is provided below the figures.

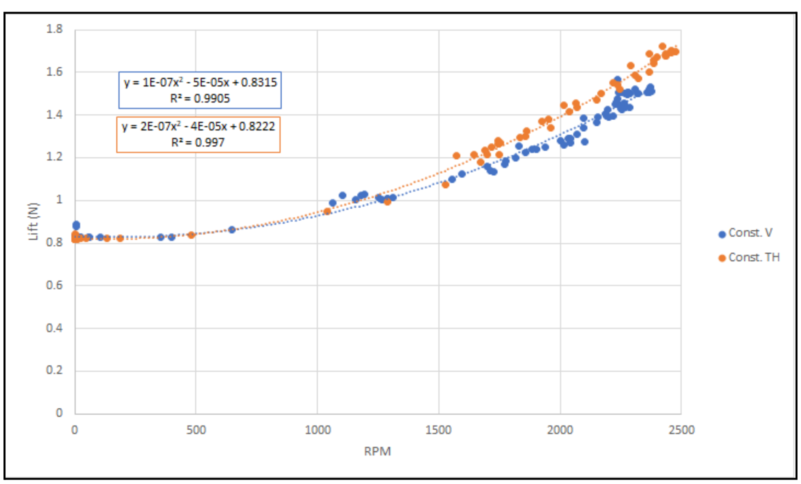

Figure 4: Graph of lift generated by the helicopter versus the RPM of its rotors

Figure 4:

- Both data subsets (constant voltage and constant. thrust) follow the trend of a second-order polynomial
  - Therefore, the lift force generated by the helicopter is proportional to the square of the rotor RPM
- Both subsets have a similar peak RPM of around 2400-2500
- The two subsets produce effectively identical thrust at lower RPM values, but the constant thrust data begins to deviate upward (with respect to const. V) as RPM increases
  - This could be due to slight sensor elasticity, in which different loading durations at high RPM may very slightly affect the deflection/resultant force observed
  - At its greatest, the difference between the two subsets is only around 0.1 N

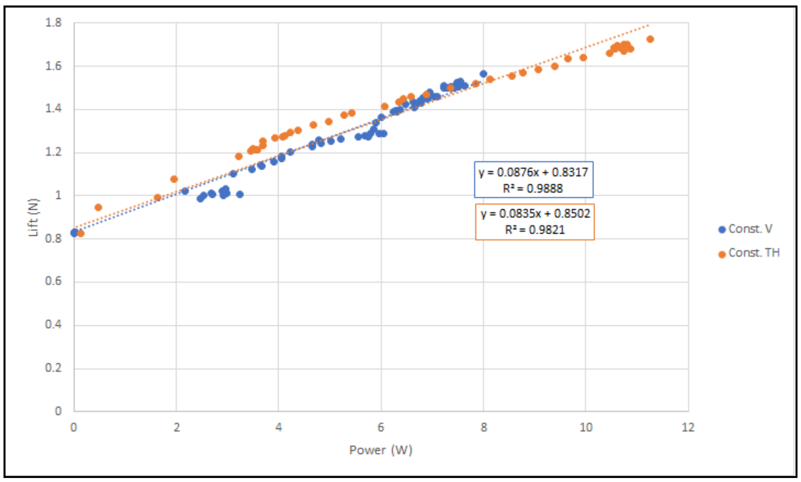

Figure 5: Graph of lift force versus the power supplied to the helicopter

Figure 5:

- Both subsets generally follow a linear trend, such that the lift force is directly proportional to the input power
  - However, the constant thrust data does not have as good a fit as the constant voltage data
- The maximum power in the constant V case is significantly lower than the maximum power in the constant thrust case
  - This could simply be due to a greater number of data points in the constant thrust subset, or because the helicopter reached a higher maximum current

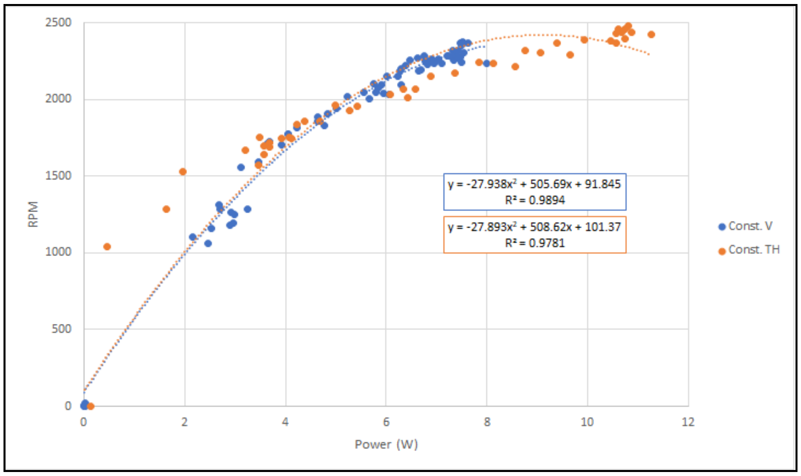

Figure 6: Graph of rotor RPM versus the input power

Figure 6:

- The constant voltage subset follows the trend of a second-order polynomial, such that RPM is proportional to the square of the input power
- The constant thrust case shows a slightly better fit when using a fourth-order polynomial, which deviates from the relationship established by the constant voltage case
  - This could be a result of inaccurate measurements or the relationship between RPM and power is, in fact, different when thrust is held constant
  - More trials would need to be run in order to verify which possibility is correct
- Similar to Figure 2, the maximum input power for the constant voltage case is lower than that of the constant thrust case

Comparisons to Simple Helicopter Data:

- In the data provided from the simple helicopter experiment, the following relationships are established (with respect to throttle percentage):
  - Power - Proportional to the square of TP
  - Lift - Directly proportional to TP, or proportional to the square of TP
  - RPM - proportional to the cube of TP
- Using this information, the correlations between the three primary quantities are:
  - Lift is directly proportional to power, or proportional to the square of power
    - The first of these relationships matches that of the more advanced experiment
    - The constant thrust case of the advanced data does somewhat resemble a second-order relationship
  - Lift is proportional to the square of RPM, or proportional to the cube of RPM
    - The square relationship aligns with the advanced data case, changing the fit to a cubic polynomial has almost no effect on the R-squared value
  - RPM is proportional to the square of power
    - This aligns with the relationship shown by the advanced experiment

Conclusion

The relationship between lift, power, and RPM for a small helicopter was experimentally determined using a Tachometer, load cell, and multimeter. From these values, we can derive our relationships. For the experiment, multiple trials were conducted. Data trials were conducted using both constant supply voltage and constant thrust. The lift vs. RPM graphs for the constant voltage and constant thrust trials are very similar, both following second-order polynomials. At maximum, their values have a percent difference of 6.89%. Likewise, the lift vs. power trends is very similar. However, there is some difference as the maximum power in the constant voltage case is much lower than in the constant thrust case. Relating the power to RPM, the constant voltage shows the expected 2nd-order polynomial fit. The constant thrust case however shows a better fit with a fourth-order polynomial. Likely due to some outliers in the data that do not exist for the constant voltage. This is likely due to the electronics reaching their shutoff voltages as we varied the voltage lower, causing the helicopter to abruptly shut off. The experiment was relatively simple in the process but additional care needed to be taken to get clean data. Our initial data was not adequate for the report and as such, we had to elect to use the provided data to analyze for our report.