DARcorporation
Design • Analysis • Research
1440 Wakarusa Drive, Suite 500, Lawrence, Kansas 66049, USA
(785) 832-0434

Memo

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Title:	**Sterna Ground Adjustable Propeller Testing**
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Prepared By:

Joel Eppler – Aerospace Engineer

Document Approvals:

Willem Anemaat, PhD – President

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List of Symbols

Symbol	Description	Unit
D	Diameter	in
P	Power	W
Q	Torque	ft-lb_f
T	Thrust	lb_f

Greek	Description	Unit
ρ	Density	$slug/ft^3$

Acronym	Description
FOM	Figure of Merit
LabVIEW	Laboratory Virtual Instrument Engineering Workbench
RPM	Revolutions per Minute

1. Introduction

The purpose of this document is to present the data from the testing of the 50” Sterna ground adjustable propeller. The performance of the propeller is tested at pitch values ranging from -3° to 12°. The propeller is tested using the MGM-COMPRO REG 60 electric motor (Reference 1).

2. Test Setup

Testing is conducted in the University of Kansas Propulsion Lab at the Lawrence Municipal Airport. It is a natural air test chamber: 12’ wide, 13’ tall and open at both ends. There is a control room adjacent to the test chamber with a control panel, where tests are monitored and data is recorded.

2.1 Propulsion System

The propeller tested is the Sterna 50” ground adjustable propeller. It has composite blades and an aluminum hub. The propeller is shown in Figure 2.1 with the blades configured at several different pitches.

Figure 2.1 Sterna Propeller

The propeller is powered using the MGM-COMPRO REG 60 motor. The REG 60 is a 28 pole BLDC motor with a weight of 7.75 lb. and diameter of 4.5”. Under the conditions of this test, the motor supplied up to 6.5 kW. The propeller is bolted to the motor using an adapter. The REG 60 motor is shown in Figure 2.2.

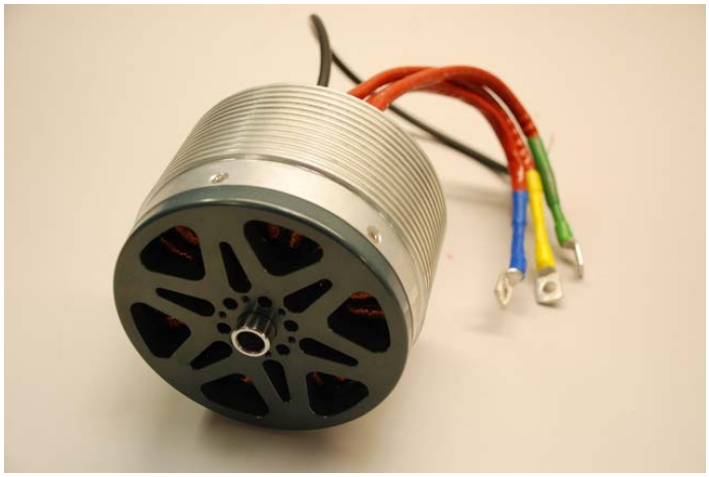

Figure 2.2 MGM-COMPRO REG 60

2.2 Thrust Stand

The motor is mounted with four bolts to the central shaft about which torque is measured. Torque is measured by a load cell mounted 3 inches from the centerline of the shaft. A spring is used to hold the torque load cell in position and prevent shifting when small loads are applied. The shaft is mounted to a stand which is supported by two rails. The rails react all forces except for the horizontal force which is in line with the engine. This is reacted and measured by the thrust load cell. The test stand is shown in Figure 2.3. A diagram of the thrust stand with load cell locations is shown in Figure 2.4 and Figure 2.5.

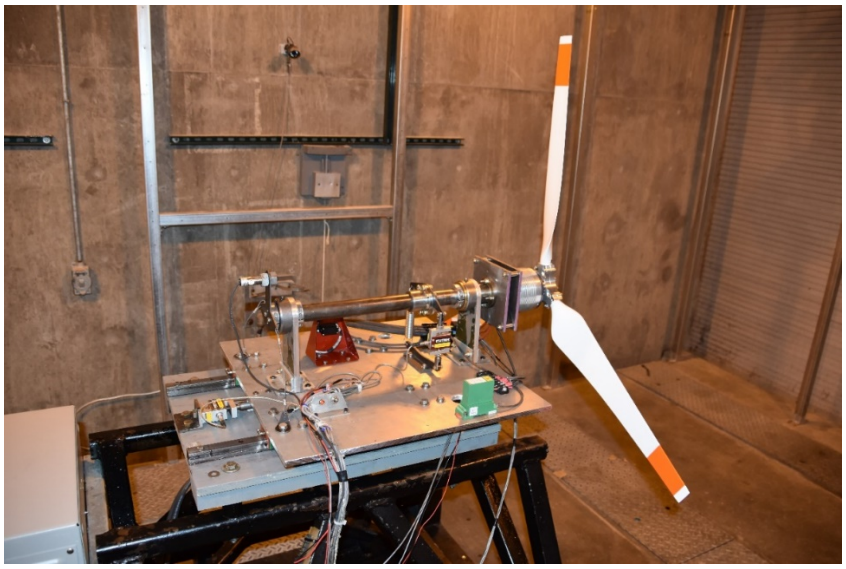

Figure 2.3 Small Engine Test Stand

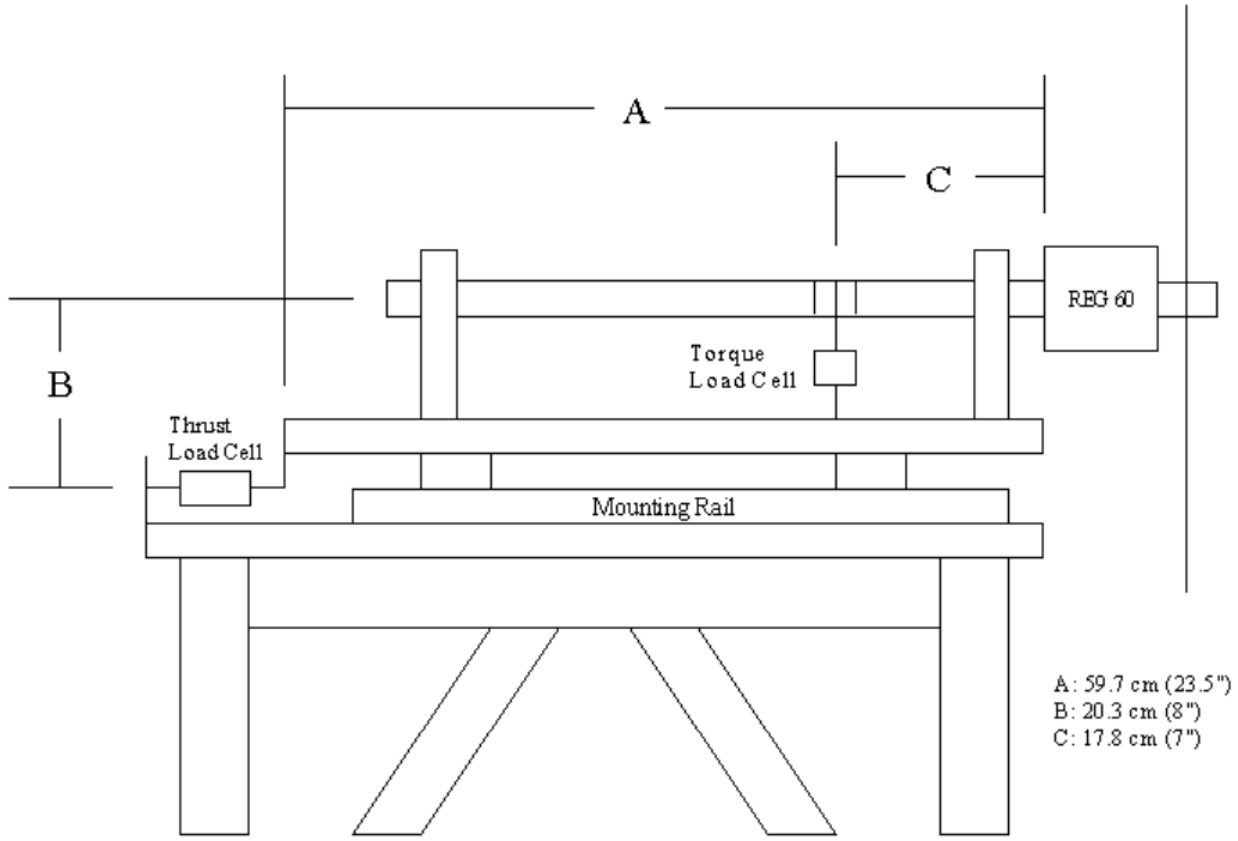

Figure 2.4 Thrust Stand Diagram (Side View)

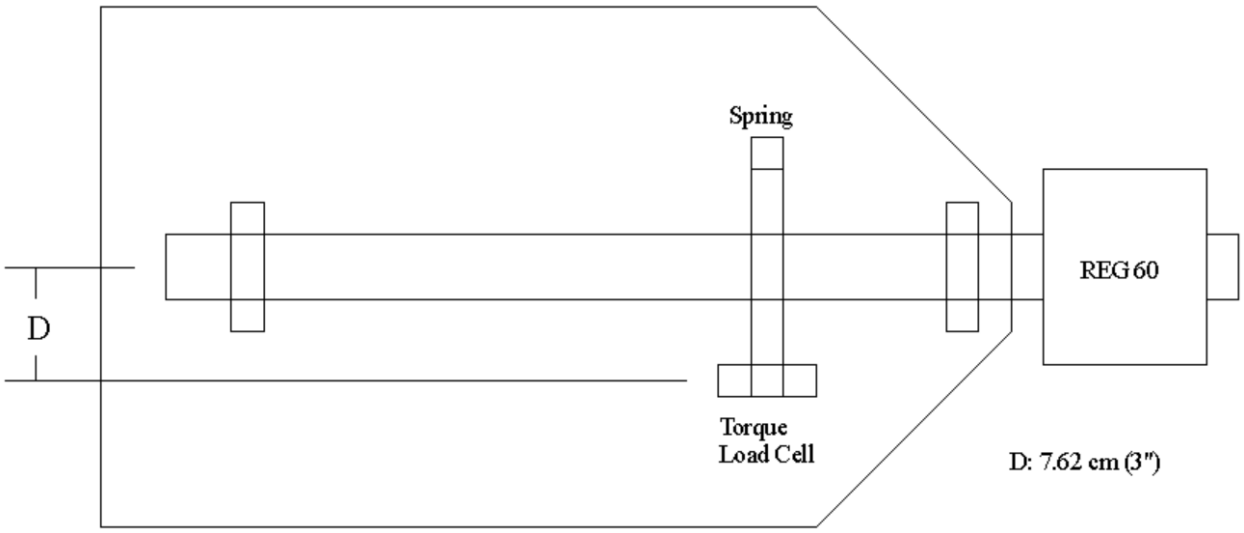

Figure 2.5 Thrust Stand Diagram (Top View)

2.3 Data Collection

The data collected to test the performance of the propeller consists of thrust, torque and RPM. The data from the sensors is processed using LabVIEW (Reference 2). The sensors used are shown in Table 2.1 and the arrangement of the sensors is given in Figure 2.6.

Table 2.1 Sensors Used for Data Collection

Type	Description
RPM	Monarch Instrument Rols-W Optical RPM Sensor
Thrust	Futek LSB350 500 lb S-Type Load Cell
Torque	Futek LSB300 200 lb S-Type Load Cell

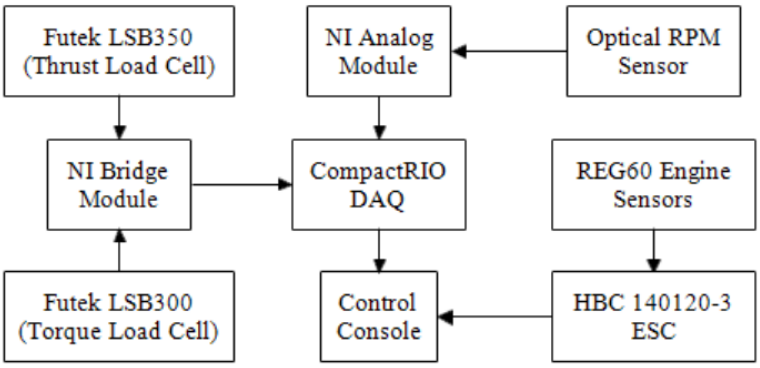

Figure 2.6 Instrumentation Block Diagram

2.4 Instrument Calibration

The load cells are calibrated prior to testing using a series of known weights. The weights are cantilevered off the side of the stand to calibrate the torque load cell. To calibrate the thrust load cell, the weights are hung with a pulley system off of the front of the stand to provide a horizontal force.

After collection, the data is normalized to account for varying atmospheric conditions. To normalize the data the density ratio is calculated using ambient temperature and pressure data and used to normalize to standard sea level conditions (59 °F, 29.92 inHg).

3. Propeller Testing

The Sterna propeller is tested at blade pitch settings ranging from -6°to 12°. The blade pitch is measured at the tip of the propeller with a digital throw incidence meter. The propeller is tested throughout the operating envelope of the REG 60 motor. As the results show, the motor is limited to a maximum torque of 16 ft-lb and a maximum RPM of 3000.

During the test, the throttle is slowly increased from 0% to 100% and then decreased to 0%. Throttle holds at particular RPM levels are not used for this test because the electric motor does not produce vibrations like an internal combustion engine can at certain RPM's. Also, the energy available to provide electrical power to the motor is limited by the batteries limiting time available for testing. Data is recorded from 500 RPM to up to the limit of the motor. A picture of the Sterna propeller during testing is shown in Figure 3.1.

Figure 3.1 Sterna Propeller Test

4. Propeller Testing Results

The results of the propeller test are displayed in Figure 4.1 to Figure 4.4.

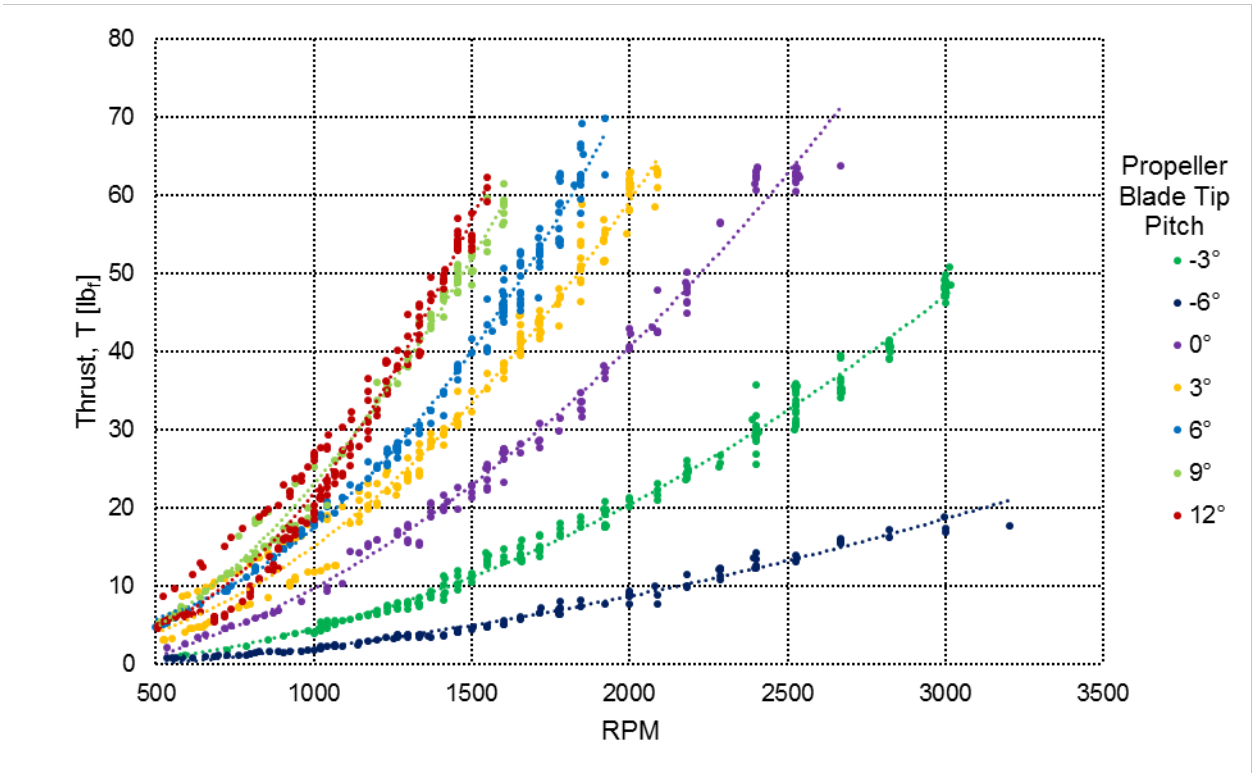

Figure 4.1 Thrust Variation with RPM

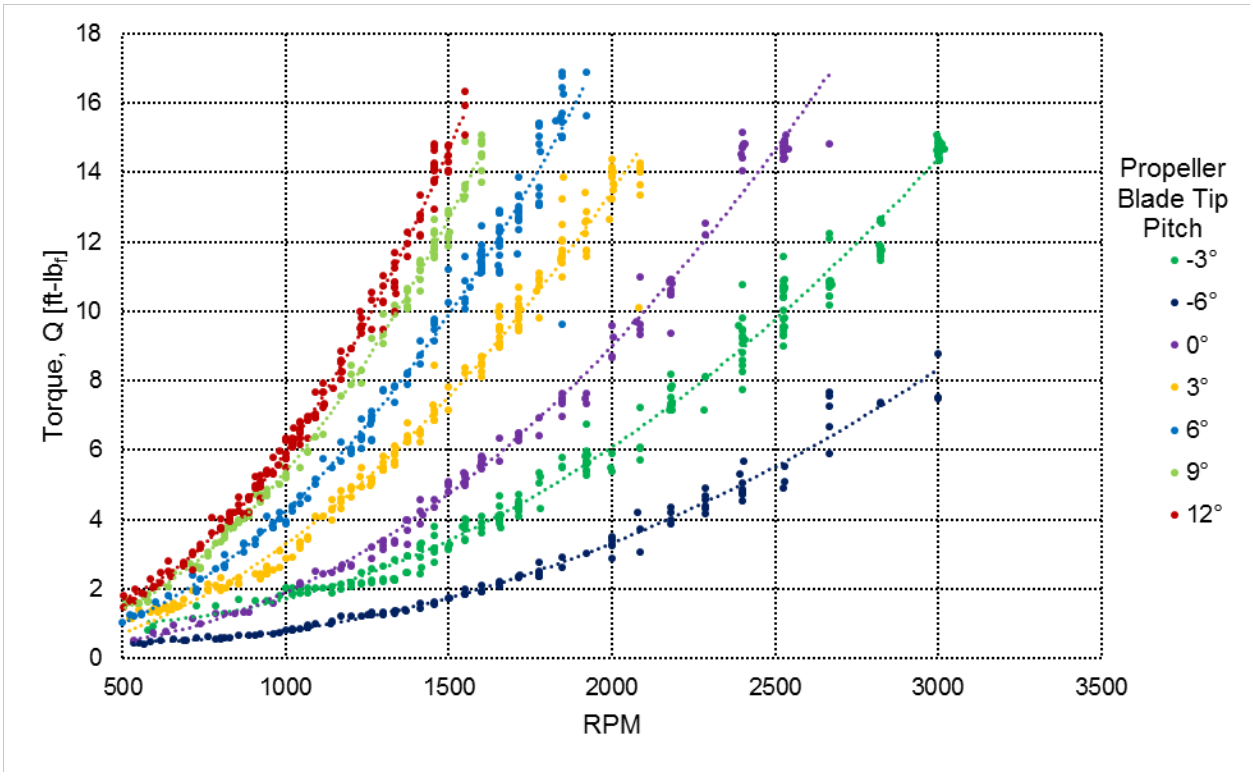

Figure 4.2 Torque Variation with RPM

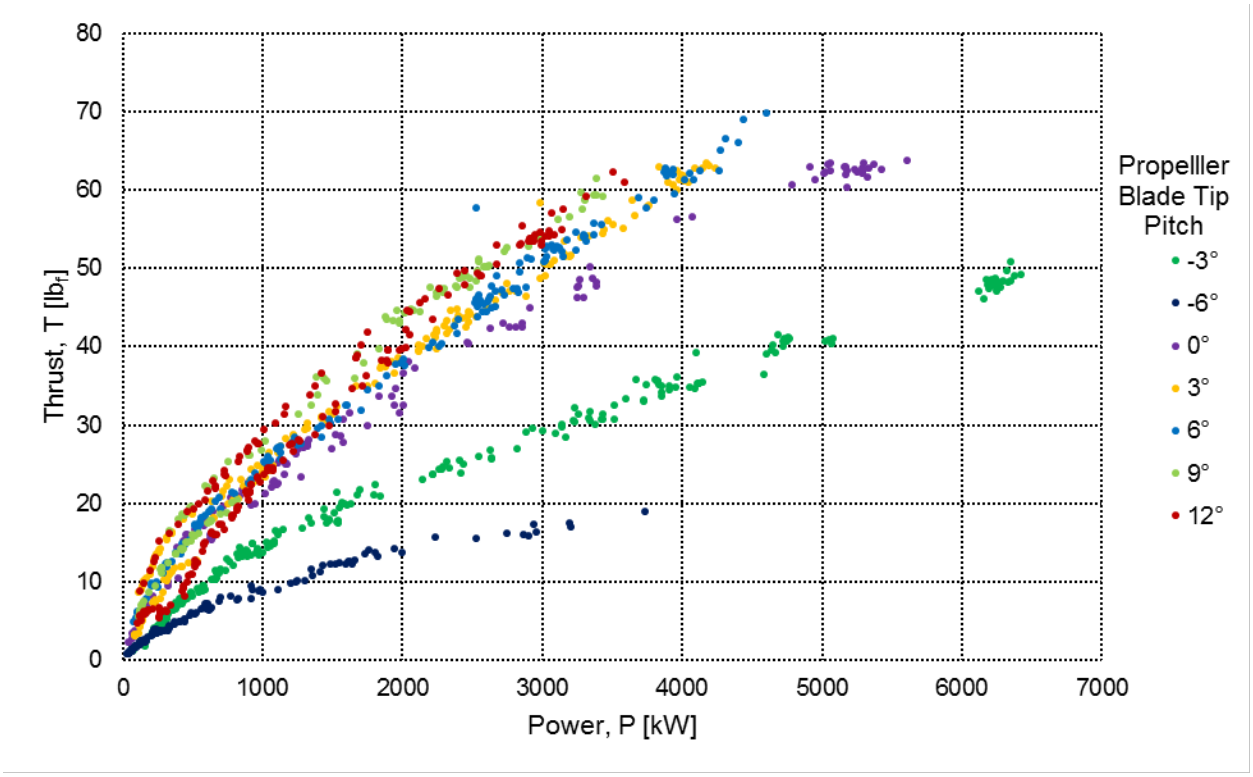

Figure 4.3 Thrust Variation with Power

The Figure of Merit (FOM) in Figure 4.4 is calculated as the ratio of measured thrust to ideal thrust. Ideal thrust is calculated using Equation 1 derived from propeller momentum theory.

$$T = \left[P\sqrt{\frac{1}{2}\rho\pi D^2} \right]^{2/3} \quad (1)$$

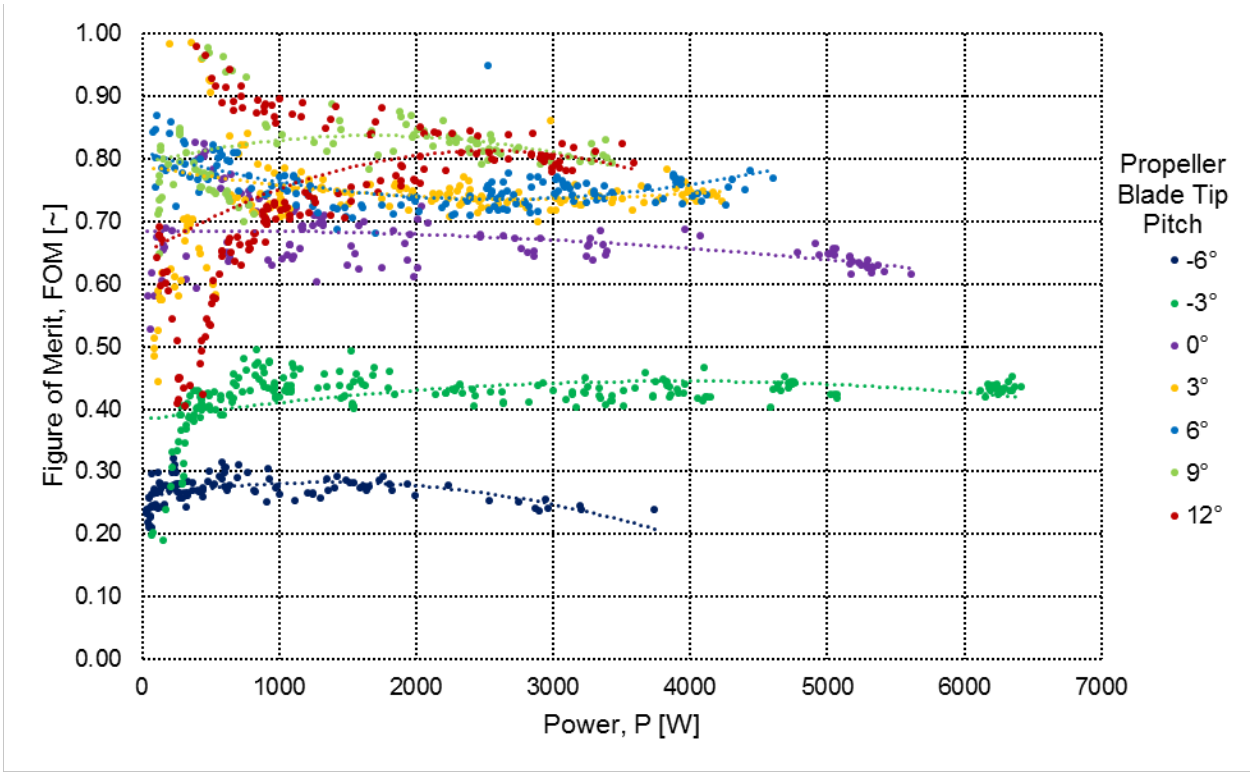

Figure 4.4 Figure of Merit

5. References

1. HBC – SERIES V7 25063-3/140120-3 Operating Manual, MGM-COMPRO, Zlin, Czech Republic, 2017.
2. National Instruments LabVIEW, Version 2014 SP1 Full Development System, Austin, Texas, 2014.