DRONE PROPELLER THRUST TESTING RIG

Saravana Kumar V [1], Surya K [2], Karthikeyan P N [3], Abdul Asif A [4], Ajay E [5], Mayil Raj B [6]
1 Assistant Professor, Department of Aeronautical Engineering, Hindusthan College of Engineering and Technology, Coimbatore
2 Assistant Professor, Department of Science and Humanities, Karpagam Academy of Higher Education, Coimbatore
3 Professor, Department of Aeronautical Engineering, Hindusthan College of Engineering and Technology, Coimbatore
4, 5, 6 UG Student, Department of Aeronautical Engineering, Hindusthan College of Engineering and Technology, Coimbatore

ABSTRACT:

The performance and efficiency of unmanned aerial vehicles (UAVs) are greatly affected by the effectiveness of their propulsion systems. To enhance drone functionality, it is essential to evaluate the thrust output of different motor-propeller combinations under varying conditions. This project focuses on the design, construction, and operation of a specialized thrust testing rig tailored for drone propellers.

The setup incorporates a load cell, an ESP32 microcontroller, an Electronic Speed Controller (ESC), an LED display, and an adjustable RPM control unit. It is engineered to accurately assess parameters such as thrust-to-weight ratio, power usage, and rotational speed for a variety of propulsion configurations. Offering a compact and cost-effective testing platform, the rig enables detailed analysis and optimization of drone propulsion systems.

Designed as a stable and rigid frame, the test rig houses precision sensors, including a load cell to measure thrust, a torque sensor to evaluate rotational force, and voltage/current sensors for monitoring electrical power consumption. The motor and propeller unit are firmly mounted on the testing bench, allowing consistent and repeatable testing at different RPMs and load settings. A high-speed data acquisition system captures and processes real-time data, delivering insights into the performance and efficiency of various propeller designs and configurations.

Keywords: drone propulsion system, testing rig, thrust performance, real time data

1. INDRODUCTION

Unmanned Aerial Vehicles (UAVs), commonly known as drones, have gained significant attention across various industries due to their versatility, efficiency, and ability to perform complex tasks. One of the most critical aspects influencing drone performance is the propulsion system, particularly the thrust generated by the propeller-motor combination. Accurate measurement and analysis of thrust are essential for optimizing flight performance, ensuring stability, and selecting suitable components for drone design.

A Drone Propeller Thrust Testing Rig is a specialized setup designed to measure the thrust produced by a drone's motor and propeller under static conditions. It allows engineers and hobbyists to assess different combinations of motors, propellers, and power sources to determine the most efficient setup for specific applications. This rig typically includes a load cell or force sensor to measure thrust, a microcontroller or data acquisition system to process the data, and a mounting mechanism to secure the motor and propeller during testing.

The primary objective of this testing rig is to provide a controlled and repeatable environment for evaluating propeller performance. By understanding the thrust characteristics, power consumption, and efficiency of various setups, users can make informed decisions in drone design and development. This rig also plays a crucial role in academic and research settings, where empirical data is required to validate theoretical calculations and aerodynamic simulations

2. FABRICATION AND EVALUATION OF THRUST TESTING RIG

The fabrication of the thrust testing rig involves designing and assembling a robust and precise setup capable of accurately measuring the static thrust generated by a drone motor-propeller system. The following steps outline the fabrication process:

2.1 Frame Construction:

A rigid frame is fabricated using lightweight yet strong materials such as aluminum or acrylic sheets. The frame must minimize vibration and deformation during motor operation to ensure accurate readings.

2.2 Motor Mount:

A secure and adjustable mount is designed to hold different types of brushless DC motors. The mount allows easy interchangeability for testing various motor-propeller combinations.

2.3 Load Cell Integration:

A calibrated load cell or force sensor is installed beneath the motor mount to measure the thrust force. It converts the mechanical thrust into electrical signals, which are then processed.

2.4 Electronics and Data Acquisition:

The load cell is connected to an amplifier and a microcontroller (ESP 32) for signal processing and data acquisition. The setup may include a digital display or data logging system.

2.5 Power Supply System:

A suitable ESC (Electronic Speed Controller) and battery or power supply unit are included to run the motor. Throttle input is provided either via a remote or programmatically using the microcontroller.

2.6 Safety Enclosure:

A transparent acrylic shield or mesh cover is added to protect the operator from the spinning propeller during testing.

2.7 Design of Testing Rig Components:

With the increasing use of drones in various industries, accurate performance testing of propulsion systems has become critical. A key element in such testing setups is the motor mount, which must be designed for strength, vibration isolation, and ease of integration with sensors. In this study, a motor mount and other structural components were designed using **CATIA V5** software and fabricated using PLA material on an FDM type Ender 3 Pro 3D printer**.**

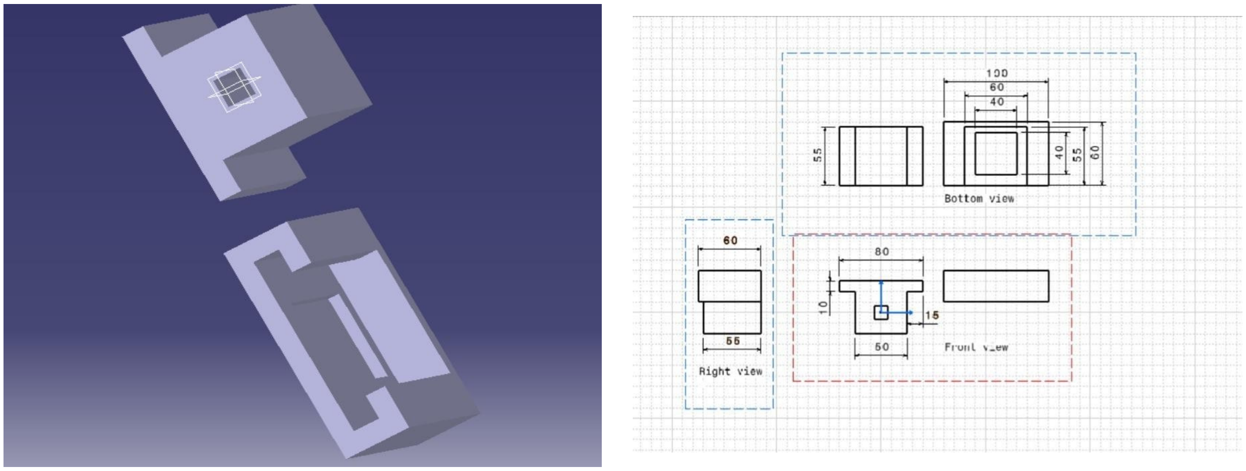


Figure: 2.1 CATIA Part module & Drafted View

The entire mechanical structure of the test rig, including the motor mount, sensor housing, and frame supports, are modeled in **CATIA**. The motor mount design focused on:

- **Precise alignment** for vertical thrust measurement
- **Ventilation slots** for motor cooling
- **Modular mounting holes** for compatibility with different BLDC motors
- **Vibration damping features** to reduce noise in sensor readings

A finite element analysis (FEA) was conducted in CATIA to ensure the structure could withstand forces from high-RPM propeller rotations.

2.8 Material and Manufacturing

The designed components were exported as STL files and 3D printed using PLA (Polylactic Acid) due to its lightweight, rigidity, and good dimensional accuracy. FDM printing parameters included:

- **Layer height:** 0.2 mm
- **Infill:** 50% for optimal strength
- **Nozzle temperature:** 200°C
- **Bed temperature:** 60°C
- **Print speed:** 50 mm/s

2.9 Components used:

- **Load Cell:** Measures the upward thrust produced by the rotating propeller. It converts mechanical force into electrical signals.
- **ESP32:** A powerful and versatile microcontroller used for data acquisition and processing. It reads load cell data via HX711 amplifier and controls ESC signals.
- **Electronic Speed Controller (ESC):** Regulates the speed of the BLDC motor connected to the propeller.
- **LCD Display:** Displays real-time thrust, RPM, and power consumption values.
- **RPM Regulator:** Allows manual variation of motor speed during testing.

- **Power Measurement Module:** Measures voltage and current supplied to the motor for power calculation.

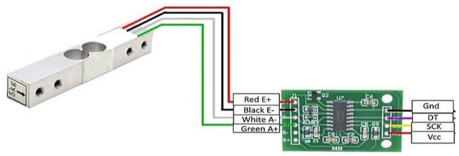


Figure 2.2 Load Cell

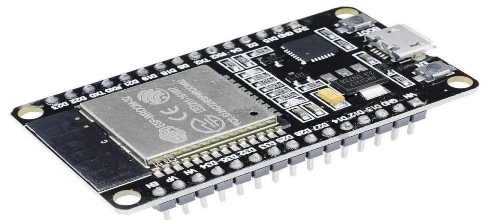


Figure 2.3 ESP

32

Figure 2.4 LCD Display

Figure 2.5 RPM Regulator

3. WORKING PRINCIPLE & EVALUATION

The propeller, driven by a BLDC motor via the ESC, produces vertical thrust. The load cell senses this thrust, transmitting data to the ESP32. Simultaneously, voltage and current are logged to compute power consumption. The results are processed and displayed, enabling evaluation of thrust-to-weight ratio and power efficiency.

3.1 Circuit Diagram

The complete hardware interconnection is illustrated in Figure 3.1.

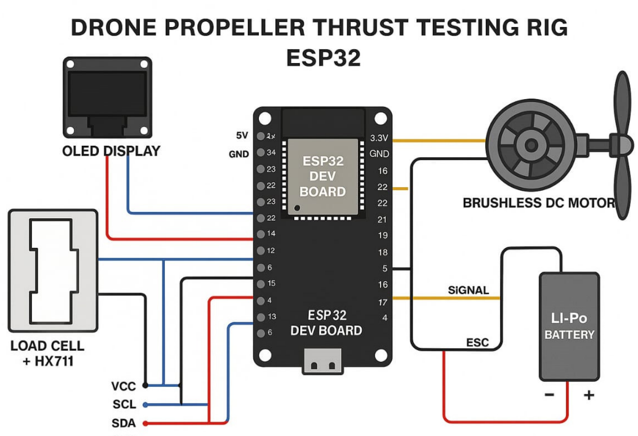


Figure 3.1 Hardware Interconnection

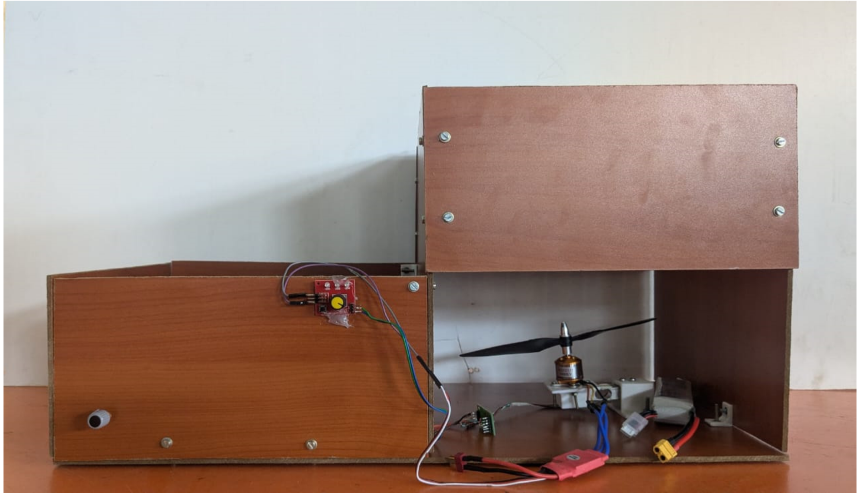


Figure 3.2 Fabricated Testing Rig

3.2 Experimental Evaluation

Initial experiments with 1045 and 6045 propellers were conducted. The rig recorded varying thrust values and corresponding power consumption at different RPM levels. The results assist in selecting the optimal motor-propeller configurations for various drone types.

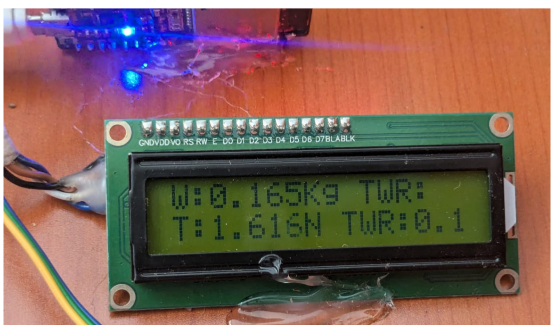


Figure 3.3. T/W/TWR values through LCD display

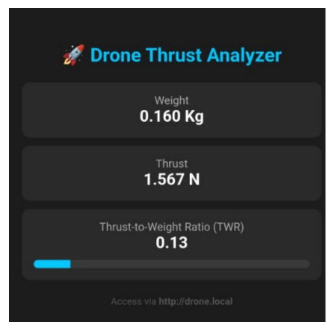


Figure 3.4. Thrust Analyzer Application

Below table shows the RPM, Thrust Developed, Thrust-to-Weight Ratio, and Power Consumed for a 1045 propeller (10-inch diameter, 4.5-inch pitch) commonly used in drones. These are typical experimental values using a standard 1000KV brushless motor with a 3S LiPo battery (11.1V).

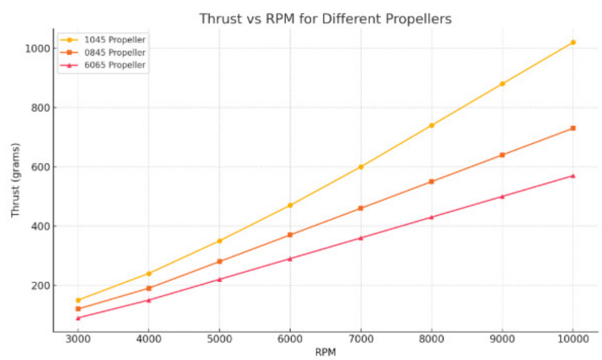
S. No	RPM	Thrust Developed (g)	Power Consumed (W)	Thrust-to-Weight Ratio*
1	3000	150	12	0.15
2	4000	240	22	0.24
3	5000	350	35	0.35
4	6000	470	52	0.47

Table 1. Data acquired from Propeller Testing rig for 1045 propeller

S.No	Propeller Type	RPM	Thrust Developed (g)
1.	1045	3000	150
2.		4000	240
3.		5000	350
4.		6000	470
5.	0845	3000	120
6.		4000	190
7.		5000	280
8.		6000	370
9.	6065	3000	90
10.		4000	150
11.		5000	220
12.		6000	290

Table 2. Thrust vs RPM values for 1045, 0845, and 6065 propellers

The below graph showing Thrust vs RPM for the 1045, 0845, and 6065 propellers. As you can see, the 1045 propeller produces the highest thrust across all RPM levels, followed by the 0845 and then the 6065, which is expected due to their relative sizes and pitch.



Thrust vs RPM Graph

CONCLUSION

The thrust testing rig designed and fabricated in this project provides a reliable and efficient solution for analyzing drone propulsion systems. By integrating high-precision sensors and a microcontroller-based data acquisition system, the rig offers accurate measurement of key performance parameters such as thrust, power consumption, and RPM. Its modular and compact design makes it both cost-effective and accessible for educational, research, and development purposes.

Through systematic testing of various motor-propeller configurations, the rig enables better understanding of aerodynamic behavior and assists in optimizing propulsion setups for enhanced UAV performance. Overall, this rig serves as a valuable tool for improving the design, efficiency, and stability of drone systems. In future developing a PC or mobile application to visualize thrust curves, generate reports, and store data for long-term comparison, Adding thermal and vibration sensors to study the effect of heat buildup and mechanical stress during long-duration tests and implementing machine learning algorithms to automatically suggest the best motor-propeller combinations based on test results.

REFERENCES

1. S. Ganesan, C. Shanthi, Sravanth, and Chandaka, *Integration and Testing of Multi Rotor Unmanned Aerial Vehicle*, Madras Institute of Technology, Anna University, 2024.
2. P. Daponte, L. De Vito, G. Cornacchia, and M. Pompetti, "An innovative procedure and indexes for UAS testing," *Measurement*, vol. 165, pp. 108–121, 2020.
3. M. Wojtas, P. Wyszkowski, M. Mądro, M. Osiewicz, and P. Kmita, "Test stand for propellers and rotors in VTOL drone systems," *Sensors*, vol. 23, no. 3, pp. 1–18, 2023.
4. S. Afshaan, Priyanka, Manoj, Venu, A. Hussain, and Rajashekharareddy, "Design and analysis of UAV test bench for engine/motor characterization," *International Journal of Engineering Research & Technology (IJERT)*, vol. 12, no. 3, pp. 45–52, 2023.
5. H. Jansen, "Impact of toroidal propeller design on unmanned aerial vehicle acoustic signature and aerodynamic performance," *AIAA Journal of Aircraft*, 2024.
6. B. Panjwani, C. Quinsard, D. Gacia Przemysław, and J. Furseth, "Virtual modelling and testing of the single and contra-rotating co-axial propeller," *Journal of Aerospace Engineering*, vol. 34, no. 9, pp. 1012–1023, 2020.
7. C. Russell, J. Jung, G. Willink, and B. Glasner, "Wind tunnel and hover performance test results for multicopter UAS vehicles," *NASA Technical Reports*, NASA/TM-2020-220497, 2020.
8. P. Cwiakala, "Testing procedure of unmanned aerial vehicles (UAVs) trajectory in automatic missions," *Journal of Automation and Control*, vol. 7, no. 2, pp. 44–51, 2019.
9. F. Panayotov, V. Serbezov, and M. Todorov, "Aerodynamic testing of rotors and propellers for small unmanned aerial vehicles," *Aerospace Science and Technology*, vol. 98, pp. 105661, 2020.