A Simple Brushless Motor and Propeller Test Stand for Experiment from Home

Erwan Eko Prasetyo
Sekolah Tinggi Teknologi Kedirgantaraan, Jl. Parangtritis Km 4,5 Sewon, Bantul, D.I. Yogyakarta
Email: erwan.eko@sttkd.ac.id

Abstract. A brushless motor and propeller test stand is used to test brushless motors and propellers. This testing instrument is still only available in research laboratories. Students and researchers are unable to use laboratory facilities because of the Covid-19 epidemic, thus students must be able to do tests independently from home. Purchasing this testing instrument would be too expensive for students. It is essential to construct a brushless motor and propeller testing instrument at home using simple components that are easy to get on the marketplace. The design concept reads force data using a loadcell sensor and an HX711 driver, and current and voltage data with an INA 219 sensor. The brushless motor's rotational speed is controlled by a potentiometer. Force, current, voltage, and power are all examples of test results data. A 16x2 LCD is used to show data immediately. Data is also transmitted via a USB connection to a computer device for storage or additional analysis. This study proposes a simple brushless motor and propeller test stand that can measure forces from 0 gf to 1000 gf with an error rate of 0.72 %. The power that can be read ranges from 0 mW to 18960 mW, with a 0.59 % error rate.

1. Introduction
An unmanned vehicle requires a propeller driven by a motor. A Brushless motor is an electric technology that has a very high rotation, low energy consumption, and is not easy to heat. Unmanned vehicles use a brushless motor to rotate the propeller to produce thrust. Unmanned vehicles are designed by choosing an energy-efficient brushless motor [1]. Motor efficiency is related to the flying durability of an aircraft, considering that the battery resources used are limited. In unmanned vehicles with energy sources from batteries, the efficiency of using battery energy is very important to consider. Therefore, it is necessary to choose the right brushless motor and propeller.

The power from the battery is one of the factors that influence how well an unmanned aircraft performs in flight [2]. To extend the flight length of an unmanned aircraft, one of the attempts is to select a brushless motor with the lowest power consumption. This allows the aircraft to fly longer. Experiments and testing must be carried out to determine the brushless motor's power output. When the power consumption of a brushless motor is known, it may be used to determine an unmanned aircraft's flying performance.

Brushless motor and propeller testing can be done using a brushless motor and propeller test stand. The existence of this testing tool is still limited to research laboratories. The existence of the Covid-19 pandemic condition provides limitations for students and researchers in using laboratory facilities so that students must be able to do testing independently from home. However, this testing tool is still
quite expensive for students if they have to buy it. Therefore, it is necessary to make a brushless motor and propeller testing tool independently.

Research and development on brushless motor and propeller testing tools have been carried out [3], [4]. A test bench for comparison of given motors and propellers is introduced [5]. A propeller-motor test bench is designed to design an efficient quadrotor. The Thrust Benchmarking System (TBS) is a low-cost, easy-to-manufacture sensor for measuring the performance of electric UAV propulsion systems [6]. Its applications include calculating a propeller’s static thrust using basic empirical characterization modeling. The development of a laboratory tester for evaluating the effectiveness of propeller-engine groups (PEG) of electric unmanned aerial vehicles (UAV) [7]. A system has been developed that enables the measurement of motor amperage, the generated thrust of PEG, battery voltage, and motor temperature. Research to test the performance of the propeller is carried out by comparing the calculated data with experimental data [8]. The theoretical performance estimations for the motors and propellers are calculated and compared to experimental findings from static thrust testing [9]. The goal is to check the models’ accuracy and make choosing the right brushless DC motor and propeller for flight applications easier.

This paper proposes a simple brushless motor and propeller test stand which can be used for experimental testing of brushless motors and propellers on a small scale, especially during home experiments. The design concept uses a load cell sensor and HX711 driver to read force data and an INA 219 sensor to read current and voltage data. The rotational speed of the brushless motor is regulated using a potentiometer. The test results data are in the form of force, current, voltage, and power. Data is displayed directly using a 16x2 LCD. Data can also be sent to a computer via a USB port for storage or further analysis.

2. Design A Simple Brushless Motor and Propeller Test Stand
A simple brushless motor and propeller test stand consists of 4 main parts, namely the input unit, the controller, the output unit, and the brushless motor mounting. The block diagram is shown in figure 1.

![Figure 1. Block diagram of general system architecture.](image)

2.1. The Input Unit
In the input unit, there are two sensors. Loadcell sensor to read force data with a capacity of 1Kg and INA219 sensor to read voltage and current data. The loadcell sensor is connected to the HX711 type module via pins A+, A-, E-, and E+. The HX711 module is connected to the Arduino controller via the I2C pin.

2.2. The Controller
The controller uses an Arduino Uno with an ATmega 328 processor. The controller is used to process data from the sensor, then sends data to a 16x2 LCD (Liquid Crystal Display) and sends data serially to a computer via a USB port.
2.3. The Output Unit
The output unit there is a display using a 16x2 LCD to display force, current, voltage, and power data. The reading data is also sent to the computer serially via the USB port so that the data can be displayed on the serial monitor and can also be stored for further analysis purposes.

2.4. The Brushless Motor Mounting
The brushless motor mounting serves to put the brushless motor to be tested. In addition, this brushless motor mounting also functions to transmit the force generated by the brushless motor to the loadcell sensor. Brushless motor mounting made of an acrylic board with a thickness of 3mm. All electronic components are placed on a wooden board measuring 26cm x 15cm x 1 cm. In addition to electronic components, this board is also a brushless motor mounting mount that unites all components into one integrated testing system. The overall configuration of the wiring diagram is shown in figure 2.

![Figure 2. Wiring diagram.](image)

The components needed to make a simple brushless motor and propeller test stand consist of two parts, namely electronic components and mechanical components. The electronic components are loadcell sensor, INA 219 sensor, Arduino Uno, 16x2 LCD, ESC, and battery. The mechanical components are the board and the brushless motor mounting. The list of components and estimated costs are presented in table 1.

| No | Name of Component                  | Quantity | Price per Item (IDR) | Total Price (IDR) |
|----|-----------------------------------|----------|----------------------|-------------------|
| 1  | Loadcell 1 Kg and Modul HX711     | 1        | 45.000               | 45.000            |
| 2  | INA219 sensor                     | 1        | 35.000               | 35.000            |
| 3  | Arduino Uno R3                    | 1        | 55.000               | 55.000            |
| 4  | LCD 16x2 Green Background         | 1        | 17.000               | 17.000            |
| 5  | I2C LCD Converter                 | 1        | 10.000               | 10.000            |
| 6  | Hobbywing Skywalker 30A ESC       | 1        | 145.000              | 145.000           |
| 7  | Potentiometer 50K                 | 1        | 3.500                | 3.500             |
| 8  | Battery Lipo Turnigy 1300mAh 3S 30C | 1   | 265.000              | 320.000           |
| 9  | Brushless Motor Mounting          | 1        | 20.000               | 265.000           |
| 10 | Board 26cm x 15cm x 1 cm          | 1        | 50.000               | 50.000            |

|    | Total                             | 10       | 945.500              |
3. Implementation and Testing
The implementation phase is divided into 2 (two) stages, namely hardware and software implementation. Hardware implementation starts from assembling the brushless motor mounting with the loadcell sensor and then installing it on the circuit board. The next stage is to install all the components on the circuit board according to the layout then connect the cables from one part to another according to the wiring diagram. If the wiring stage is complete, then proceed with checking to avoid installation errors, especially in the power supply section. After the hardware implementation is complete, then proceed with programming using the Arduino IDE. Programming is done in stages to ensure each part can function properly. The results of the implementation of A Simple Brushless Motor and Propeller Test Stand are shown in figure 3.

![Figure 3. The implementation.](image)

The performance testing of the Brushless Motor and Propeller Test Stand was carried out using 3 types of brushless motors and 1 type of propeller. The type of brushless motor used is type A2212(6T)-2200 KV, MR2205-2300 KV, and MT2204-2300 KV. The type of propeller used is type 5055 with 3 blades.

3.1. Sensor Function Testing
This test is to determine the accuracy and precision of reading data. The test is done by comparing the data from the sensor readings with the readings of the measuring instrument. The results of reading the current, voltage, and power data on the sensor are compared to the data readings on the measuring instrument. Each test was carried out 3 times and then the average value was taken. The results of the sensor function test are shown in table 2.

| Sensor | Instrument | %Error |
|--------|------------|--------|
| V (V)  | I (mA)     | P (mW) | T (gf) |
| V (V)  | I (mA)     | P (mW) | T (gf) |
| V (V)  | I (mA)     | P (mW) | T (gf) |
| V (V)  | I (mA)     | P (mW) | T (gf) |
| V (V)  | I (mA)     | P (mW) | T (gf) |

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According to the test results, the INA219 sensor can read voltage values with an error percentage of 0.55 %, current values with an error percentage of 0.23 %, and power values with an error percentage of 0.59 %. The loadcell sensor can function properly to read the force value with an error percentage of 0.72 %. The results in this study are different when compared to the results of the INA219 sensor testing in previous studies. Sensor testing in the previous study was carried out at a voltage of 3V-5V with an error percentage of 0.2% and testing at a current of 2V-3V with an error percentage of 0.17% [10].

### 3.2. Power and Force Reading Performance Testing

Tests were carried out on three types of brushless motors with one type of propeller. The test is done by adjusting the speed of the brushless motor from minimum rotation to maximum rotation. The power supply voltage used is from a power supply with a capacity of 15VDC 50A. The observed data are power data and force. The test is carried out by adjusting the force from 0-200 gf in multiples of 10 gf and then observing the amount of power consumed by the brushless motor. The 0 – 200 gf interval was chosen because it refers to the maximum capability produced when tested with a propeller at a power supply voltage of 15VDC 50A.

Each test was taken three times, then the data that had been obtained was taken the average value. This is done to reduce the risk of errors during data collection. Data from the test results of power and force readings are presented in a graph as shown in figure 4.
Figure 4. The reading test results in force and power with 0–200 gf interval of force.

Based on the test data, it can be seen that the Brushless Motor and Propeller Test Stand can test the three types of brushless motors with 3 blades propeller type 5055. The graph in figure 4 shows that the performance of the Brushless Motor and Propeller Test Stand can read data stably. When testing using a brushless motor, the A2212(6T)-2200 KV type and the MR2205-2300 KV type were able to read forces from 20 gf to 200 gf, while the MT2204-2300 KV type was able to read forces from 15 gf to 200 gf. The power that is read on the brushless motor on the type A2212(6T)-2200 KV is between 5.29 W and 50.06 W, on the type MR2205-2300 KV between 4.16 W and 46.76 W while on the MT2204-2300 KV type it is between 3.62 W and 51.74 W. This is enough to test a small capacity brushless motor.

4. Conclusion
The simple brushless motor and propeller test stand makes it simple to test a variety of brushless motors and propellers. The power and force generated by brushless motors and propellers may be tested using this instrument. This equipment may be used to perform experiments and test different types of brushless motors and propellers at home. This study proposes a simple brushless motor and propeller test stand that can measure forces from 0 gf to 1000 gf with an error rate of 0.72 %. The power that can be read ranges from 0 mW to 18960 mW, with a 0.59 % error rate.

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