# Analysis of Propeller Efficiency and Current Consumption in Brushless DC Motor-Driven Drones

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## 1 Abstract

This paper presents a detailed analysis of the impact of propeller design and size on the performance and current consumption in drones powered by Brushless DC (BLDC) motors. As the propeller is a critical component influencing the thrust, flight stability, and energy efficiency of the drone, this study explores the relationship between propeller size, blade pitch, motor speed, and current drawn. Empirical data from experimental tests conducted on a 5kg drone platform with various propeller configurations are discussed. The results are expected to contribute to optimizing drone designs for specific flight requirements, reducing energy consumption, and enhancing flight time.

## 2 Keywords

BLDC motors, Propeller efficiency, Current consumption, Drones, Thrust, Energy optimization.

## 3 Introduction

With the rise of unmanned aerial vehicles (UAVs) in applications ranging from delivery services to surveillance, there is a growing need for optimizing the performance of these drones. A critical component that governs the flight characteristics of UAVs is the propeller, which directly interacts with the motor to produce thrust. However, the relationship between propeller design and current drawn by the motor is often overlooked.

In this paper, we focus on the efficiency of propellers in terms of thrust-to-power ratio and their effect on the overall current consumption in BLDC motors. We aim to provide a comprehensive analysis of different propeller configurations and their performance characteristics when applied to a 5kg UAV platform.

# 4 Background and Related Work

## 4.1 Propeller Characteristics

Propellers are designed to convert rotational motion from the motor into thrust, enabling the UAV to lift off and maneuver. Two main factors influence the performance of a propeller:

- **Diameter**: Larger propellers generally produce more thrust but may require more power.
- **Blade Pitch**: The pitch denotes the angle of the blades. Higher pitch values result in faster acceleration but can increase the current draw due to the added resistance on the motor.

## 4.2 BLDC Motor Overview

BLDC motors are widely used in UAVs due to their high efficiency, low maintenance, and better speed-torque characteristics. However, the current consumed by the motor is highly dependent on the load, which in this case is influenced by the propeller configuration.

Several studies have explored the efficiency of BLDC motors with respect to speed and torque; however, fewer studies have focused on propeller selection and the corresponding current consumption.

# 5 Methodology

## 5.1 Experimental Setup

The experiments were conducted using a quadcopter drone with a total weight of 5kg. The main elements of the setup include:

- **Motors**: Four BLDC motors with a KV rating of 500.
- **Propellers**: A range of propeller sizes (12 inches, 14 inches, and 15 inches) and pitches (4.5, 5, and 6) were tested.
- **Battery**: 6S (22.2V) 6000mAh LiPo battery.
- **Electronic Speed Controllers (ESC)**: 30A ESCs for controlling motor speed.
- **Flight Controller**: Ardupilot for data collection and control.

### 5.2 Measurement Techniques

- **Thrust**: Measured using a thrust stand connected to the motor-propeller assembly.
- **Current Draw**: Measured using a current sensor attached to each ESC.
- **Flight Time**: Calculated based on the energy consumption during hover and maneuvering.

## 6 Results and Discussion

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### 7.1 Propeller Diameter vs. Current Consumption

As expected, larger propellers produced higher thrust but also resulted in increased current consumption. The 15-inch propeller, while efficient in generating the required thrust, consistently drew 10-20 percent more current compared to the 12-inch propeller, as shown in Table 1.

| Propeller Size | Thrust (N) | Current (A) | Efficiency (N/W) |
|---|---|---|---|
| 12x4.5 | 20 | 15 | 0.90 |
| 14x5 | 25 | 18 | 1.00 |
| 15x6 | 28 | 20 | 0.95 |

Table 1: Comparison of thrust, current, and efficiency for different propeller sizes.

## 8 Blade Pitch and its Impact on Efficiency

Higher blade pitch values improved thrust output but significantly increased the load on the BLDC motors, which resulted in higher current consumption. For instance, a 6-inch pitch propeller on a 15-inch diameter required nearly 25A of current under full load conditions.

### 8.1 Energy Consumption and Flight Time

Based on the current measurements and energy consumption, the drone with smaller propellers exhibited a longer flight time by approximately 10 percent. However, for higher payload capacities, larger propellers were necessary despite the increase in current consumption.

## 8.2 Effects of Excessive Current on BLDC Motors and Propellers

Passing more current than the usual operating range of BLDC motors can have significant effects on both the motors and the overall performance of the drone. Some of the key impacts are as follows:

### 8.2.1 Overheating of BLDC Motors

BLDC motors are designed to operate efficiently within a specific current range. When more current is passed than the motor's rated capacity, the motor coils experience increased resistance, which leads to excessive heat generation. Overheating can cause:

Degradation of Insulation: Excessive heat can break down the insulation around the motor windings, leading to short circuits or even complete motor failure. Reduced Motor Efficiency: The increased temperature reduces the motor's efficiency, causing it to consume more power to produce the same level of thrust, further exacerbating the overheating issue. Permanent Damage: Continuous overheating can cause permanent damage to the motor, leading to premature failure.

### 8.2.2 Escalated Wear on ESCs (Electronic Speed Controllers)

Electronic Speed Controllers (ESCs) regulate the amount of current delivered to the BLDC motors. If more current is drawn than the ESC's rated capacity, it can:

Overload the ESC: Most ESCs are equipped with thermal protection circuits, but prolonged exposure to high current can damage the MOSFETs (transistors within the ESC), reducing their lifespan or causing immediate failure. ESC Shutdown: In some cases, ESCs may temporarily shut down or throttle the current to prevent overheating, which could lead to a sudden loss of power mid-flight, resulting in drone instability or crashes.

### 8.2.3 Increased Propeller Stress

Passing more current results in higher RPMs for the propeller. While this can lead to higher thrust, it also has adverse effects:

Increased Vibration: Higher RPMs lead to increased vibration, which can negatively affect flight stability and the onboard sensors. Propeller Fatigue: High rotational speeds put additional mechanical stress on the propeller, especially if the material is not designed to handle such loads. This can lead to: Blade Warping: The centrifugal force at high RPMs may cause the propeller blades to warp, reducing their aerodynamic efficiency.

Structural Failure: In extreme cases, the propeller may crack or shatter during flight, potentially leading to catastrophic failure.

#### 8.2.4 Reduced Battery Life

The battery's discharge rate is directly proportional to the current drawn by the motors. Excessive current draw can:

Increase Battery Drain: The drone's flight time is drastically reduced as higher current demands deplete the battery more quickly. Heat the Battery: Overdrawing current from the battery can lead to excessive heating, which may cause: Swelling: In LiPo batteries, overcurrent can cause swelling due to internal pressure buildup. Permanent Damage: Continuous high-current draw can lead to the internal degradation of battery cells, shortening the overall battery lifespan.

#### 8.2.5 Motor Torque Saturation

Exceeding the current beyond the recommended operating range can result in torque saturation. While initially, more current increases motor torque, once the motor reaches its saturation point, further increases in current will no longer produce additional torque. Instead, the motor will simply overheat and draw more power inefficiently, without contributing to improved performance.

#### 8.2.6 Impact on Overall Drone Performance

While more current may temporarily increase thrust and speed, the negative consequences on system reliability, motor health, and overall energy efficiency outweigh the short-term benefits. Additionally, higher power consumption reduces the drone's effective flight time, which is critical for most applications.

# 9 Conclusion

This study demonstrated that the choice of propeller has a significant effect on both the thrust generated and the current consumed by the BLDC motors. Larger and higher-pitched propellers produce more thrust but at the cost of increased current consumption, which directly affects flight time and energy efficiency. For drones with a 5kg payload, selecting a propeller that balances thrust and current draw is essential for maximizing performance.

Future work will focus on further refining these models with advanced propeller materials and variable-pitch mechanisms to enhance UAV flight time and performance in various operating conditions.

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