INVESTIGATION OF A TOROIDAL PROPELLER FOR DRONES

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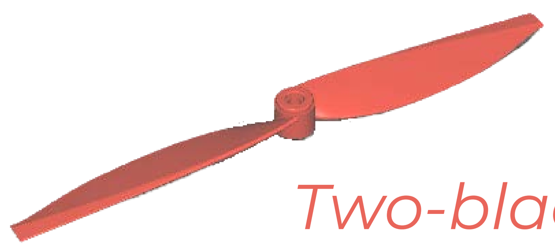
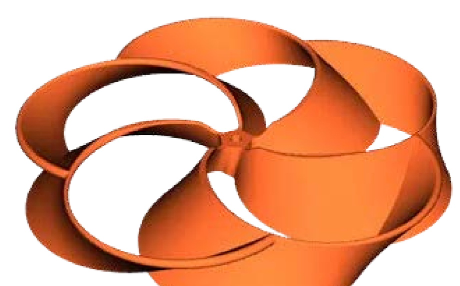
INTRODUCTION

The aerodynamics of drones heavily rely on their propellers. This study examined two different types: **traditional two-blade propellers** and **toroidal fans**. The research aimed to investigate the airflow around moving propeller blades, utilizing a laser-based *Particle Image Velocimetry (PIV)* system. The focus was on observing the formation of vortices near the blades.

Propellers are crucial components in both aviation and marine propulsion systems, driving aircraft and vessels through their respective mediums. The traditional design of classic propellers has been prevalent for many years, while toroidal propellers represent a more innovative and promising approach.



Two-blade propeller



Toroidal fan

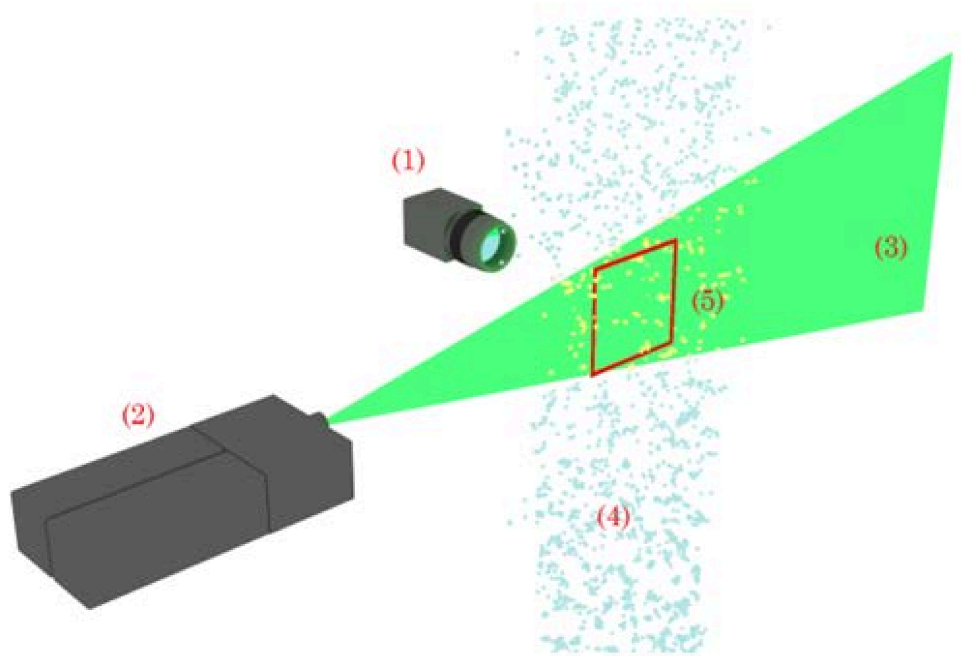


Figure 1 : PIV Setup

METHODOLOGY

Firstly, the necessary equipment was procured to operate drone propellers. This included small motors capable of running with a simple `ARDUINO` program, allowing adjustement of the rotational speed of the propellers using PWM signals for the experiments.

Additionally, different types of propellers were obtained for comparative studies. Two categories were **3D-printed** : simple propellers and toroidal fans.

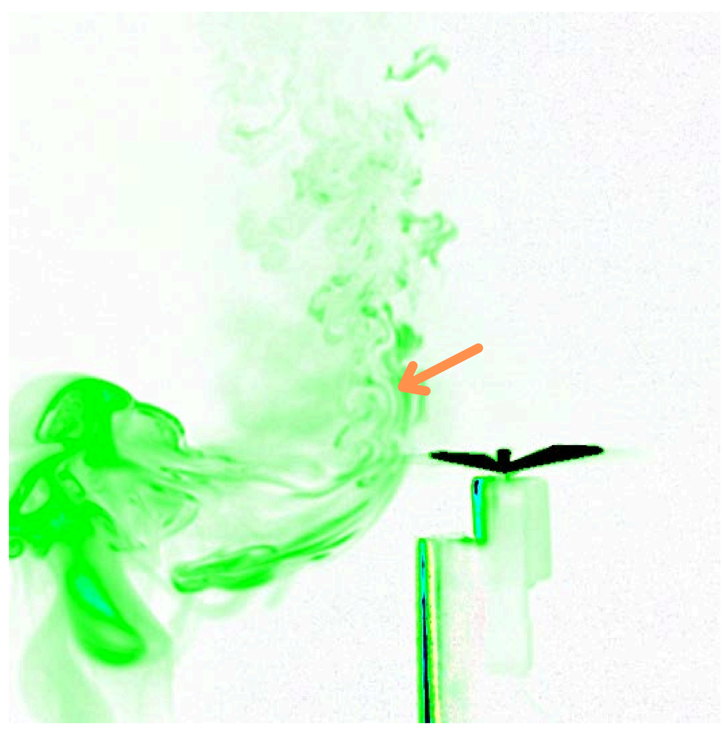
The most crucial step was the experimental phase conducted using ***Particle Image Velocimetry (PIV)***. A precise experimental setup *(Figure 1)* was established, wherein a camera imaged particles suspended in the flow, illuminated by a laser sheet. This setup allowed capture of fluid motion and analysis of velocity gradients. Adjustments were made to software parameters such as focus, brightness, and pattern noise reduction for obtaining usable results. Given that the experiments were conducted in darkness, appropriate equipment was employed.

RESULTS & DISCUSSIONS

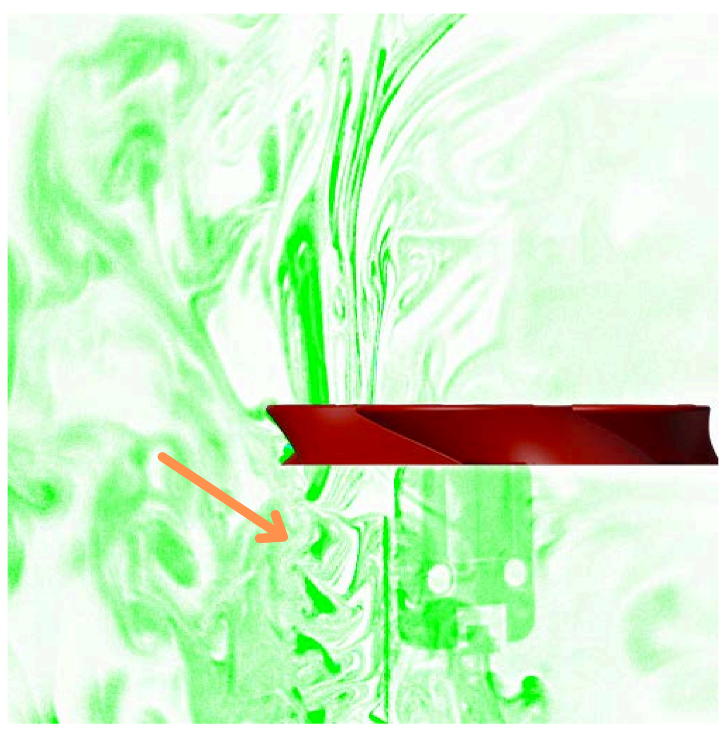
Both types of propellers rotated in a *clockwise direction*. Care was taken to ensure that the laser's built-in fan did not interfere with the results.
Multiple recordings were conducted with variations in motor position, camera angle, and Powell Lens orientation to the beam.

Particularly, a transition from **laminar flow** to **periodic chopping** were noticed, indicating a shift from continuous to intermittent behavior. This wake chopping is expected to contribute to noise characteristics, resulting in acoustic noise.
Comparing the two types of propellers proved challenging due to variations in vortex behavior and the influence of viscous drag. In attempting to eliminate tip vortices on classic propellers, toroidal fans introduce another type of vortex, known as *Kelvin-Helmholtz (KH)*. The presence of KH instability around the circumference of the fan is attributed to shear between the fan wall and the surrounding air, leading to reduced fan performance.
The airflow passing through the toroidal fan resembled that of a ventilation system. In contrast, classic propellers exhibited distinct impulse waves with each blade passage.

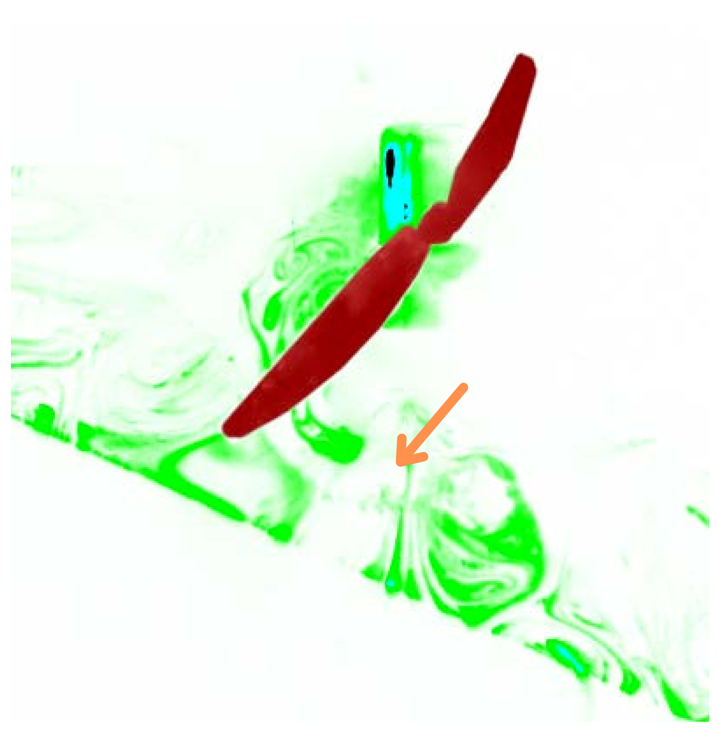
Two-blade propeller | *Toroidal fan*



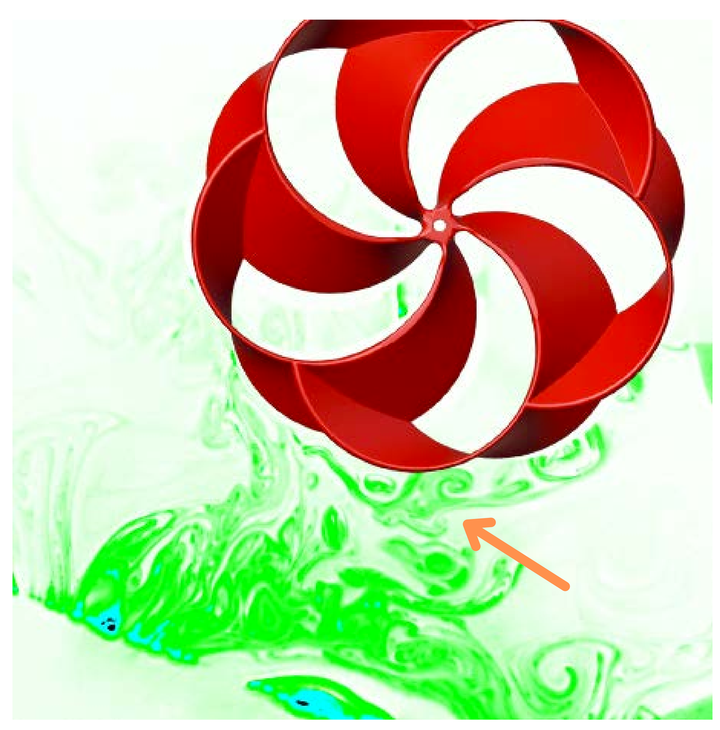
vortex formations at the tips



flow passes through



pulsation waves



vortex formations around

CONCLUSION

The experimental analysis revealed significant differences between classic and toroidal propellers. While both types exhibited distinct characteristics, the findings underscored the necessity for further comparative studies to comprehensively grasp their performance attributes and limitations.
Moreover, it's noteworthy that the traditional propeller demonstrated significant lift generation, unlike the toroidal fan model. Future endeavors should prioritize the design of toroidal fans based on scientifically documented designs. The intricate geometry of toroidal fans poses a challenge that could be effectively addressed through *Computational Fluid Mechanics*. Additionally, the weight of toroidal fans presents a considerable obstacle compared to traditional designs, warranting attention in future research and development efforts.

References

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VIDEOS

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