# Review of Standard Rotor Configurations for a Micro Aerial Vehicle Application

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*Abstract*—**The use of micro aerial vehicles (MAVs) is on the rise with an array of industries finding use for them in a variety of applications. This review hopes to assist potential pilots on selecting the drone best suited for their application. This paper attempts to first give a better understanding of flight theory and the basics of rotary winged vehicles. Next it builds on that knowledge and applies it to a few important selection parameters. After which it addresses the criteria and links it directly to a few standard configurations of rotorcrafts. ~~A final discussion is had where it addresses a few critical points.~~**

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In the final discussion a few key points are addressed.

## I. INTRODUCTION

With the increase in computing power making controlling rotorcraft possible, drones are becoming an ever more popular platform for a variety of applications and users. From military personnel to photographers just trying to get the best angle, drones are benefiting an array of industries. The hobbyist now can pick and choose from a warehouse full of different rotors, motors and even full drone kits.

There is a lot of documentation about rotorcraft, especially since it has recently gained a lot of attention form hobbyists. Unfortunately there are not a lot of comparisons between the different types of configurations, nor even what parameters should be looked at. This ends in the majority of people not using a drone type that is the right fit for their application. This paper will summarise a few key points of rotor dynamic theory and then use this information to address a few important parameters and finally applying it to different drone configurations. By the end of this paper the reader should be able to identify the appropriate rotor configuration for their application.

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## II. FUNDAMENTALS OF FLIGHT THEORY

### A. Basic Rotor Theory

The rotor is responsible for all the aspects of flight and generates the lift, forward propulsion and the means to control the orientation of the craft [14]. It is for this reason that an in-depth understanding of rotor characteristics and performance is needed. It is important to note that any rotating blade will cause a rotation of the craft in the opposite direction to that motion. This applied moment must be countered by a counter-torque mechanism which is visualised as the tail rotor in a traditional helicopter.

movement

The capability of any part of a rotor to produce lift is influenced by the local blade position and pressure at that

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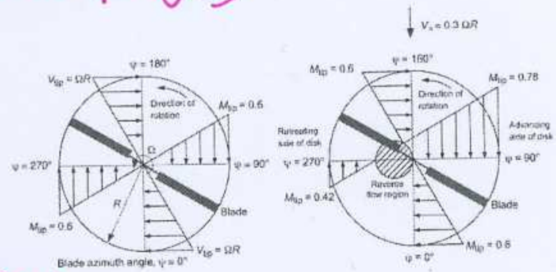


Fig. 1. Velocity components of a rotor (Taken from [14])

point [14]. As the rotor spins, the blade's angle of attack shifts. This angle is defined as an azimuth angle ($\alpha$) and is measured relative to air flow. The azimuth angle is 0°down stream and sits at 180°when it faces directly upstream. Angular velocity equations state that the speed of any part of the rotor varies along the length of the rotor. With the maximum velocity sitting at the rotor tip. space!

As the rotorcraft adds a horizontal component to it's hover or vertical flight, the relative speed of the individual rotor segments now adheres to (1). The relative velocity at the any part of the rotor is affected by the azimuth angle of the blade ($\alpha$), forward translatory speed of the craft ($V_\infty$), angular speed of the rotor ($\Omega$) and the considered distance along the rotor blade (r) [14], [1].

$$V_r = \Omega r + V_\infty \sin(\alpha) \quad (1)$$

What this relationship shows is that during forward flight the tip velocity, relative to the ground, changes even if the rotor rotates at a constant speed. This complicates the rotor dynamics at higher speeds and limits the top speed of the craft. On the retreating edge ($\alpha = 270° \therefore \sin(\alpha) = -1$) if $\Omega r <= V_\infty$ the rotor would effectively be going backwards and the helicopter is at risk of stalling out. This is known as a stall condition, while the advancing edge is reaching it's maximum speed by approaching Mach conditions and severe instability [14], [1].

Bow chika wow wow!

### B. Momentum Theory and the Basics of Thrust

As mentioned above, the rotors of a rotorcraft are responsible for generating all the forces that manoeuvre the vehicle. These forces are induced by pushing air through the rotor disk. With a fixed wing aircraft the analysis of the blades is simplified because the only air flow produced is from the translational velocity of the entire craft. Analysis of blade