

Experimental Study on Relation of Small UAV Propeller Thrust Generation and The Mouth-Ring

**M N K Othman¹, Z M Razlan¹, M S Muhamad Azmi¹, I Zunaidi¹, W K Wan¹,
Shahriman A B¹, M S M Hashim¹, M K Faizi¹, I Ibrahim¹ and N S Kamarrudin¹**

¹ School of Mechatronic Engineering, Universiti Malaysia Perlis, Pauh Putra Campus,
02600 Arau, Perlis, Malaysia.

Corresponding author: zuradzman@unimap.edu.my

Abstract. In this study, the main focus is to study the thrust generation of various propeller blade width-spans with the mouth-ring application. By using the parameter, the thrust were calculated based on the value of velocity, voltage and RPM. The testing was performing in three different width-span that are; 10mm, 8mm and 5mm. There are also variable that be tested that cover the reducing the diameter of mouth-ring from 36 mm to 32mm. In addition, if compared the gaps and different position proved that centre position gives better thrust. Furthermore, the application of mouth-ring is evaluated to be good base on this study

1. Introduction

Quadcopters are typically class of Vertical Take-Off and Landing (VTOL) vehicles, that means it will take off and landing vertically by the ground. This idea was driven by Leonardo da Vinci attempts to design a vehicle that can moved up and forward. Quadcopters are categorizing by the six degree of freedom vehicle and the translational position (x, y, and z) is measured by internal coordinate of the system [1]. As the comprehension of inflexible body flight elements enhanced over time, researchers and architects could in the end outline a rotorcraft plane equipped for producing and keeping up lift over developed timeframes by mid twentieth century. These airships were kept an eye on and with the section of time alongside advances in innovation, the classification of kept an eye on air ship developed into unmanned air ship [2].

Quadcopters by and large utilize two sets of indistinguishable altered pitched propellers; two clockwise (CW) and two counter-clockwise (CCW). By changing the speed of each rotor it is possible to specifically generate a desired total thrust; to locate for the centre of thrust both laterally and longitudinally; and to create a desired total torque, or turning force. For best execution and most straightforward control calculations, the engines and propellers ought to be put equidistant.

An arrangement of propellers that being closed by shroud is called ducted fan or mouth-ring, this mouth-ring suitable to use for small type quadcopters. A typical mouth-ring that been used at the quadcopters propeller as the protection guard to protect the propeller when impact, the other function is to enhanced recovery the guard helps deflect the drone after a collision. It also gives better landing protection; the quadrotor will eventually land on its side. But with the guards, the props are protected [2].



2. Ducted fan (mouth-ring)

Ducted fan of unmanned ethereal vehicles (UAVs) give vehicles with the propeller encompassed by a duct and are fit for drifting flight for Vertical Take Off and Landing (VTOL). For a ducted-fan UAV, the duct expands the thrust by around 25% - 30%, and the surrounded propeller guarantees the security of the vehicle [3]. Ducted propellers consist of a combination of two principal components. The first is an annular wing which can be either symmetric with respect to the rotation axis or asymmetric to accommodate for the wake flow field variations [4].



Figure 1. Ducted propeller (mouth-ring) [5]

For the unique geometric structure, the duct produces an extra lift on the vehicle contrasted and a helicopter in drifting flight. In journey flight, the duct act as part of a ring air foil which delivers the dominant part aerodynamic lifts, but it additionally confronts a solid pitching moment that produce by an important aerodynamic drag on the vehicle [6].

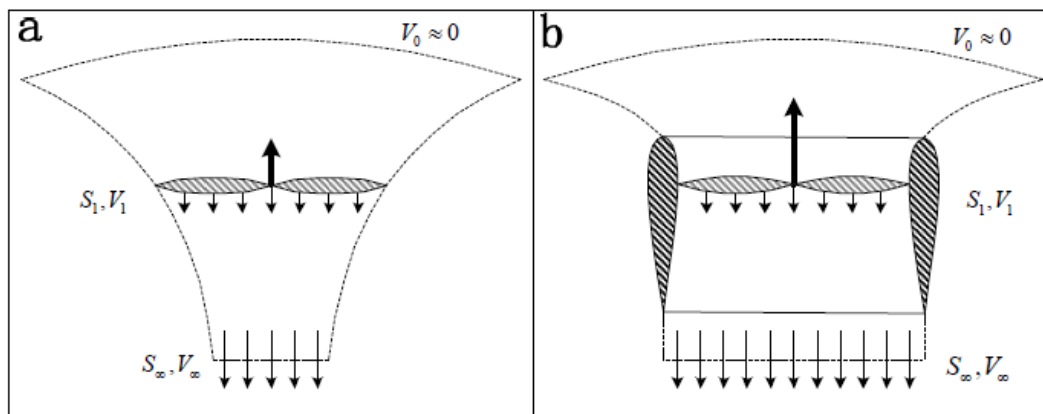


Figure 2. Contraction of air stream from propellers; (a) free fan (b) ducted fan

2.1. Measure the thrust generation

Thrust generation basically base on Newton's second law and third law, the generation of thrust that make the quadcopters to hovers and able to take off and landing. To measure the thrust generated by the quadcopters, first the will condition and the air flow shall be ignored. In mathematical terms;

$$T = v \frac{dm}{dt} \quad (1)$$

where T is thrust generated, v is the air velocity and $\frac{dm}{dt}$ is mass flow rate of the air, m.

The mass flow rate of an air flow is denoted by;

$$\dot{m} = \rho Av \quad (2)$$

where ρ is air density and A is the flow area.

Substitute equation 2 into equation 1;

$$\begin{aligned} T &= (\rho Av)v \\ T &= \rho Av^2 \end{aligned} \quad (3)$$

2.2. Assembly of experimental rigs

The type of propeller that will be used should be constant, thus the effect of thrust generation will be studied, and quadcopters that will be used also should be the same throughout this experiment to prevent any error or data that will affect the experiment later. The suitable length and diameter of mouth-ring will propose and the experiment will be conduct to study the relationship between thrust generation and the mouth-ring. Three propellers with different diameter were used in this research.

2.3. Method used

The position of apparatus must be as stated to prevent any disturbance during experiment. The propeller must be attach strongly to the motor to make sure that it will not break or will collide with the mouth-ring. For the positioning of mouth-ring, used the water balancer to make sure that mouth-ring is stable both ends. That makes the experiment more accurate. Mouth-ring also needed to be place first at the centre from its diameter and the propeller.



Figure 3. Apparatus setup for experiment

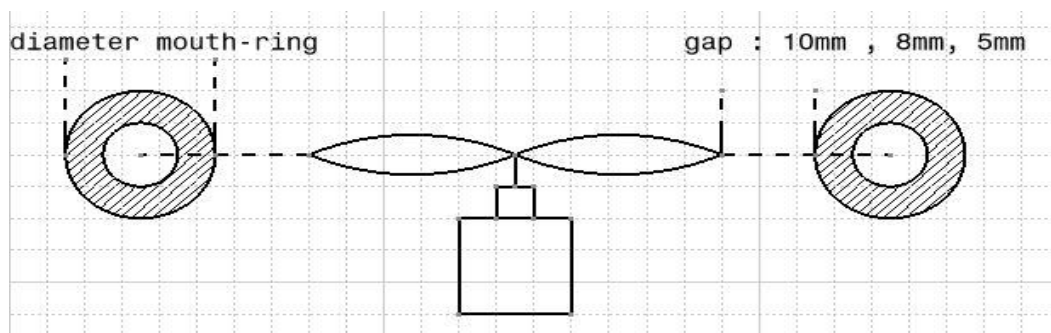


Figure 4. Schematic diagram of propeller

3. Results and Discussion

Figure 5 (a), (b) and (c) shows the comparison between 36mm diameter and 32mm diameter for position at centre, which is at 10, 8 and 5 mm gap from propeller, respectively. From Fig. 5(a), the 36mm diameter gives more thrust reading compare to the 32mm diameter. This is because the wider diameter conducts more air to the propeller thus gives higher thrust. In Fig. 5(c), thrust generated at the 36mm diameter gives higher reading compare to 32mm diameter but there is slightly increase value of thrust at 1.4635 N. compare to the 32mm diameter the thrust increase smoothly as the RPM increase. Figure 5(c) shows graph trends of 36mm diameter increase steadily as the RPM increase. Although for the 32mm diameter show that there are rapidly increase value of thrust at 1.0485 N, this rapidly increase value of thrust may be obtain by the ducted air is being disturbed or at certain RPM the Thrust value is high due to the air flow being conducted highly.

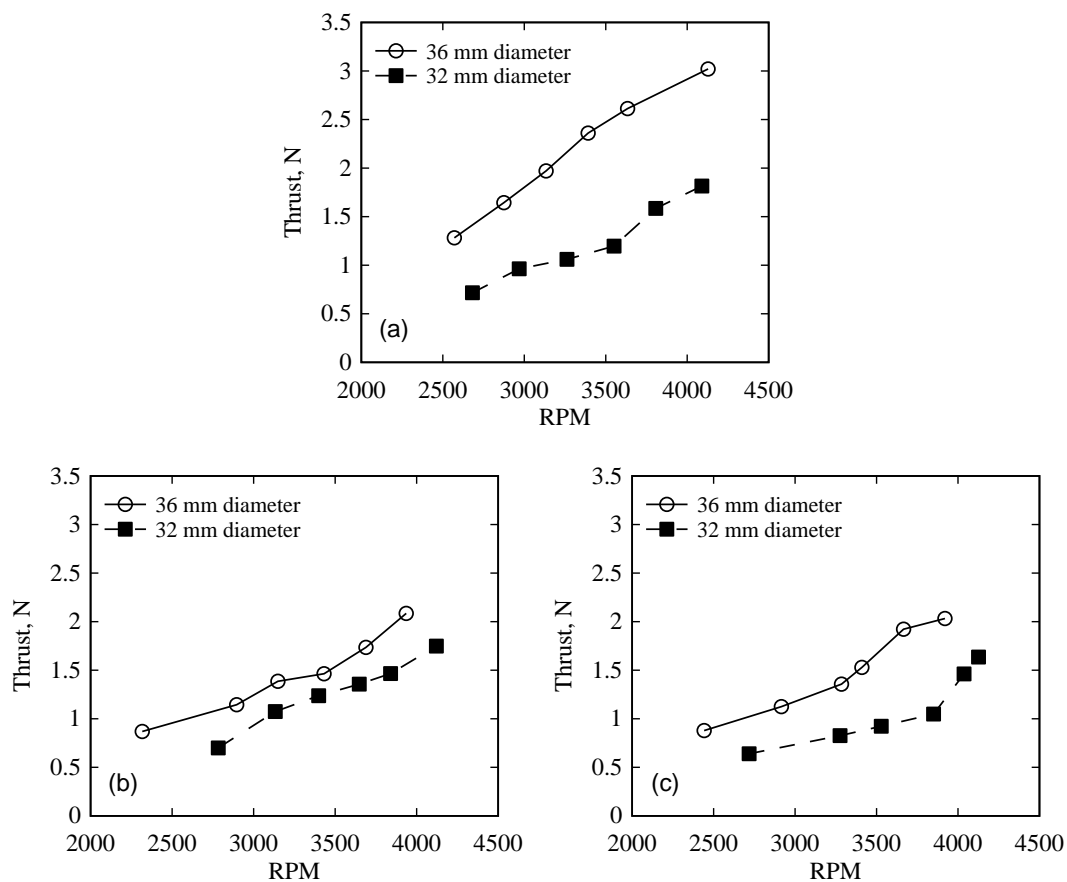


Figure 5. Graph of different diameters at centre for (a) 10 mm gap, (b) 8 mm gap and (c) 5 mm gap

Based on data above, thrust generated of 36 mm diameter mouth-ring are higher than the 32mm diameter mouth-ring for all gaps different. Furthermore, the longest gap (10 mm) between mouth-ring and propellers gives the highest reading that is 3.0206 N gives the highest reading of thrust 62.46% higher than 32 mm diameter mouth-ring.

From Figure 5, higher diameter of mouth-ring increase the thrust generated that's means the thrust can be optimize using much more wide mouth-ring. Although it increase the thrust, this experiment does not include the mass of mouth-ring its selves this results might be differs when the different mases is used.

The increase velocity in 10 mm gap is because of the broke down of tip vortex at the end of the blade tip. It happened that 10mm has the biggest gap that cross the tip vortex and make the air flow much more stable. Thus the air flow along the propeller stable and velocity increase.

The higher thrust by wider diameter mouth-ring is because the air flow from above the propeller can be utilized by much more wide diameter. This is because 36 mm diameter can assure that air flow

from upper blade can optimize be across the centre much more efficient than 32 mm diameter. This wider diameter stabilizes air flow towards propeller's vortex that produces higher velocity.

From this study, this is the data form testing shows that in particular clearance, the air flow rate differ from each other. This is maybe because of the placing of mouth-ring have made turbulence at blade tips did not happened so that air flow would come straight downwards.

The wider diameter assures that air flow inside the propeller towards laminar flow, which makes that wider diameter mouth-ring gives higher reading. This also may because of wider diameter can ducted more air towards the blade tips compare to others. This ducted air flow much more stable and will produce thrust.

This research is typically based on experimental parts only; all data that get from experiment may be different from the theoretically. But, based on data that have been observe the experiment may be have some errors due to the position of the anemometer might be not at the best point to get the higher velocity. Furthermore the errors may be because of the air humidity might be different from time to time and also wind condition might be slightly effected the reading

4. Conclusion

Thrust generation of various propeller blade-span and additional condition of mouth-ring application was examined through this research. Both of tests with 36 mm mouth-ring and 32 mm of mouth-ring were tested also with different position and blade-span. The conclusions which can be getting from this research are;

- a) The size of blade tip clearance also affect the thrust generation by reducing the turbulence air flow at the vortex. If the gap is too large, it rejects all the advantages of using the duct. If the gap is too close, it will reduce the flow of air because the air will be collides with the walls thus reducing the velocity.
- b) The diameter of mouth-ring can be change by reducing it to study the effect towards thrust generation. By reducing the diameter of mouth-ring, it also reduce the thrust because of the air might be not enough be ducted into the blades. The wider diameter ensures that air is ducted through the blades thus produce higher thrust.
- c) Application of mouth-ring might be importance with the suitable design and size. The uses of mouth-ring (ducted) helps in velocity increase with the good streamline of air flow through the duct.

5. References

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