

Increasing the Thrust Developed by Modifying the Design of Propeller

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ABSTRACT: The aim of the project is to increase the thrust developed by the propeller in the Quadcopter by modifying the dimensions of the propeller so that the payload of the Quadcopter is also increased. Here SOLIDWORKS 2015 sp0 is used to analyze the propeller model and to figure out the maximum thrust. Analysis is carried out with parameters like increasing number of blades, increasing length of blade and bending the tip from mean axis, on considering the number of blades as two we realized that the thrust developed by two blades propeller with tip bent is maximum, so tip bending is the best way to increase the thrust as per our analysis. The bent tip propeller is developed by Fused Deposition Modelling (FDM). The thrust produced by propeller is experimentally validated using Torque measurement trainer.

KEYWORDS: Payload, Thrust, Propeller design.

I. INTRODUCTION

The aerial robotics is the developing field. Among drones the Quadcopter gain its popularity due to easy maneuverability and low cost. A Quadcopter/ Quad rotor helicopter is lifted and propelled by four rotors. Quadcopter use two pair of propellers, two rotates in clockwise and other two in counter clockwise. So the net torque is equal to zero, when the Quadcopter is hovering. The weight carried by the Quadcopter other than the weight required for flying is called payload. The Quadcopter will carry weight, which is equal to half of the lift i.e. thrust produced by the propeller. Quadcopter has many applications like surveillance, aerial photography etc. some of the applications are security patrols, agricultural surveying, Aerial photography, search and rescue and filming etc.

II. RELATED WORK

Pan et.al. 2015 [1] presented, the frame of the Quadcopter must have the sufficient strength and rigidity, because it is under enormous pressure, instant impact and partially reversed torque during the flight. In addition, the electronic control system, the motor system are mounted on the frame. There are two kinds of frames they are profiled frame and X frame. Profiled frame has a larger space and the centre of gravity is simple and quick to position. X frame's design is simple, good symmetry, more flexible and suitable for stunt flying. But it's aside space is limited and inconvenient for post-upgrade. A.V.Javir et al. 2015 [2] in his findings, the propeller is converting the rotational force into thrust. Propellers are classified on the basis of their diameter and pitch. The three important dynamic parameters in Quadcopter is pitch, yaw and roll. The thrust produced by the propeller should be twice the weight of the Quadcopter for flight. Irfan et al. 2013[3] in his study the material for fabricating Quadcopter is studied. In that study he found out that the aluminum is an appropriate material due to its easy availability and low cost. The Electronic component required for Quadcopter is briefly studied. Anudeep et.al. 2014 [4] found out that, in the Quadcopter the lift force is produced by the four motors which is used to rotate the propellers. In the Quadcopter two propellers rotate in clockwise direction two rotates in anti-clockwise direction. By Changing the shape of the base plate in the frame has no influence in the performance of the Quadcopter but reducing the weight of base plate reduces the power consumption. Aditya 2015[5] conducted the computation

analysis of Vertical Take-Off and landing Vehicle (VTOL) with ANSYS considering the forces like thrust force and the motor weight. The deformation and the stress distribution produced by the load on the VTOL is calculated and he verified by the analytical results and the best design among the variants is selected. Mohd2014 [6] presented the dynamics of Quadcopter flight and the ways to adjust the thrust by varying the voltage supply of the individual rotors is explained. The empirical formula of the thrust developed by the propeller during the take-off, landing and hovering and the motion of the Quadcopter is mathematically described and the relation between the thrust produced and motor voltage is. Monk et al. 2002 [7] found out that, the small modification done in the geometry of propeller or by varying the parameters the propeller will move towards the optimum design. The modification is done in chord length and twist to obtain the optimal performance, but the optimum remains unknown. Chao et al. 2014 [8] concluded that, ducted propeller increases the efficiency of the propeller and it will also give protection to the propeller.

Paper is organized as follows. Section II describes computational analysis of the propeller in SOLIDWORKS 2015 sp0. Results of the computational analysis is given in Section III. Section IV presents experimental setup and the experimental results obtained during testing of propeller. Finally, Section V presents conclusion.

III. COMPUTATIONAL ANALYSIS

The propeller model which is used for analysis is 8045 propeller, it means the diameter of the propeller is 8 inch and the pitch of the propeller is 4.5 inch. The analysis is carried out in SOLIDWORKS sp0 software.

1. The first step is to create the rotating region by extruding a circle which envelopes the propeller as in Fig 1.a.
2. The Flow simulation is selected in “add in features” and the units are initialized in S.I units. The surrounded fluid is initialised as air. In the analysis type “external analysis” is chosen. The reference axis for rotation is set as Y-axis as shown in Fig 1.b.
3. The computational domain that surrounds the propeller is introduced. It conveys that the computational analysis is taken place inside this region. The limits are $x = [0.5, -0.5]$ m, $y = [0.5, -0.5]$ m, $z = [0.6, -0.6]$ m. This will form a cuboid around the propeller, which is the computational domain Fig 1.c.
4. The rotating region is picked and the speed at which propeller rotates is initialized. The speed of propeller is initialised in angular velocity as 1214 rad/s Fig 1.d.
5. After initialization the analysis is started by pressing “run” command, after the completion of computation the results are viewed in the “solution” column.

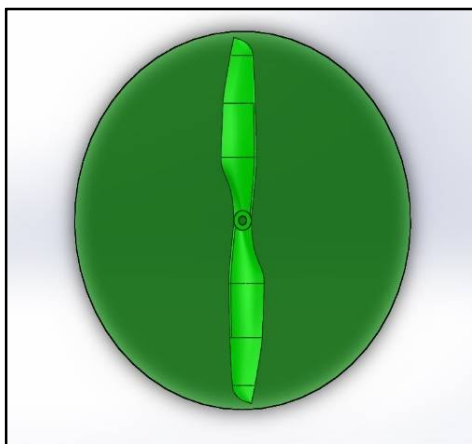


Fig 1.a Creating rotating region extruding a circle which envelopes the propeller

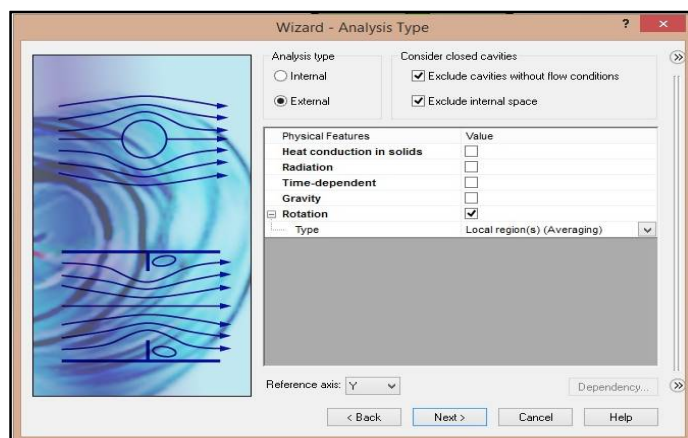


Fig 1.b Analysis type “external analysis” wizard where the physical features are available. Only rotation is enabled.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 5, Issue 12, December 2016

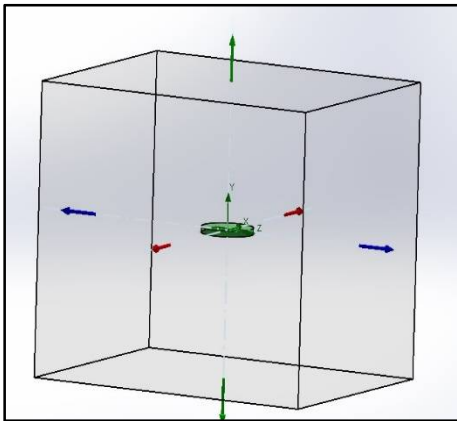


Fig 1.c Computational domain with limits are $x = [0.5, -0.5]$ m, $y = [0.5, -0.5]$ m, $z = [0.6, -0.6]$ m. the computational analysis is taken place inside this cuboid region

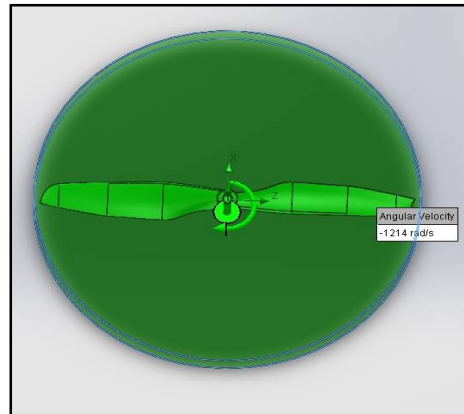


Fig 1.d Initializing Rotating region the speed of propeller is initialised in angular velocity as 1214 rad/s

The analysis is repeated for various design variants such as varying number of blades, varying length of blade and bending of tip from mean axis and the simulation models are in Fig 2, Fig 3 and Fig 4.

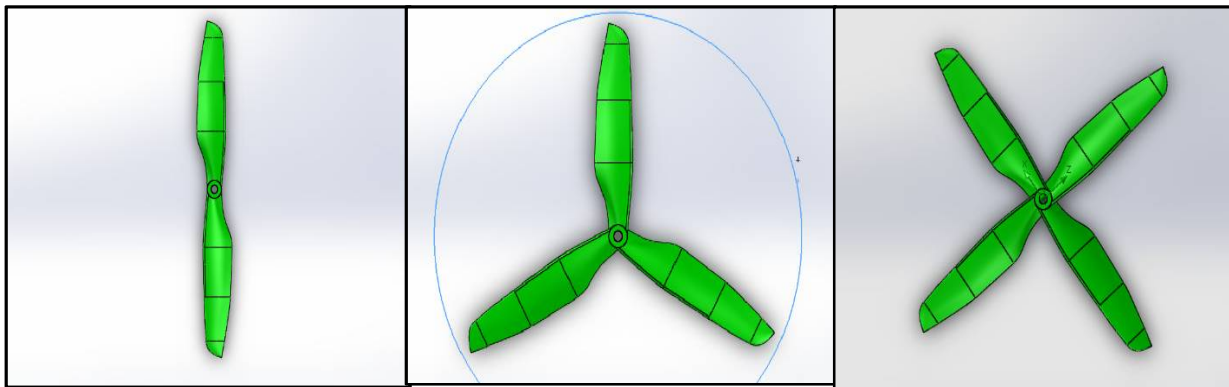


Fig 2. Two blade, three blade and four blade propeller with the standard length is created in SOLIDWORKS

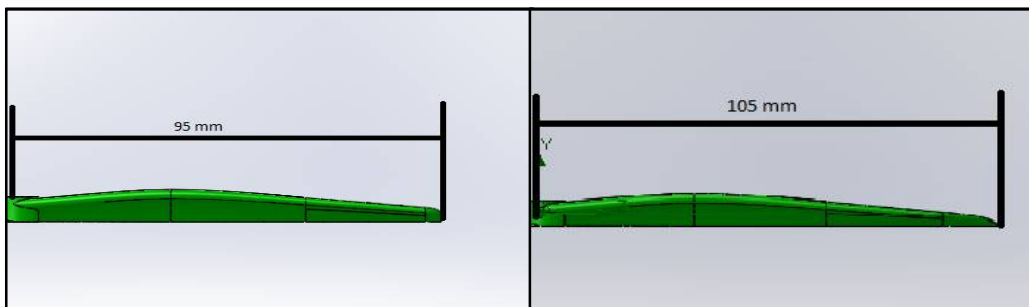


Fig 3. Blade length 95 mm and 105 mm propeller in addition to standard length is modelled in SOLIDWORKS

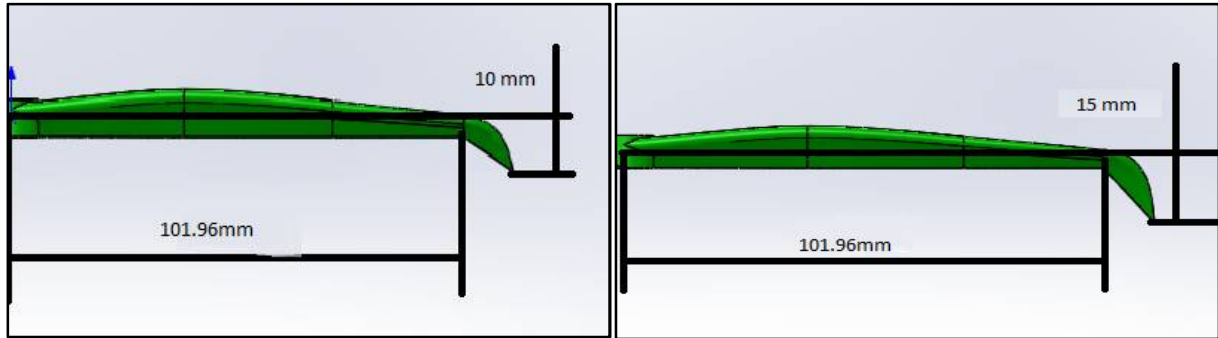


Fig 4. 10 mm bent and 15 mm bent propeller from the mean axis is taken into account for analysis

IV. COMPUTATIONAL RESULTS

The computational results are plotted in graph. The variation of thrust in each condition is found out. Both the Number of blades and the Length of blade leads to increase in thrust but however due to the increase in material on the propeller it will need high power to rotate it. So Tip bending is chosen as a reasonable one to improve the thrust. The justification is in Fig 5.

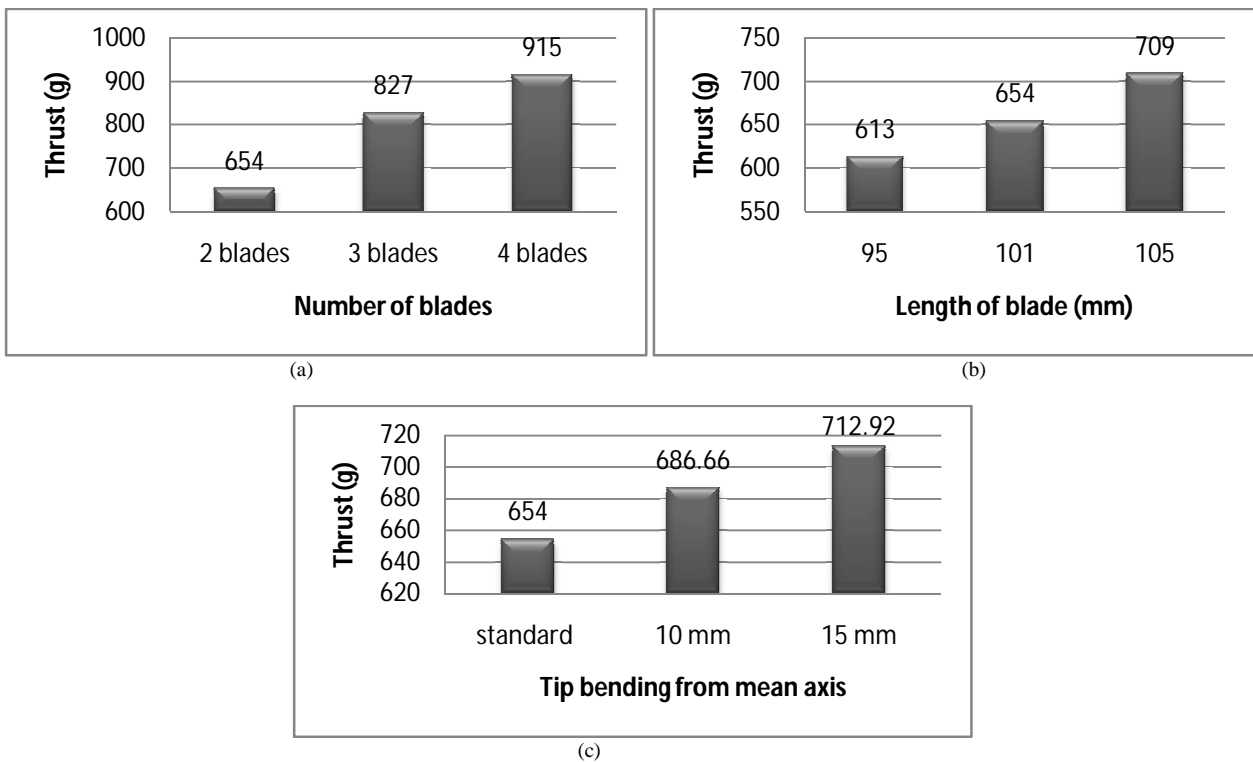


Fig. 5 Computational results (a) Thrust vs. Number of blades (b) Thrust vs. Length of blade (c) Thrust vs. Tip bending from mean axis

V. EXPERIMENTAL RESULTS

The model of propeller is developed using Fused Deposition Modelling (FDM). This method uses Acrylonitrile Butadiene Styrene (ABS) as material. First the CAD model of the design is converted into STL (Stereo Lithography) file format (.stl). The file is then transferred to the computer which is connected to the FDM machine and the file is opened by the 3d slicer tool. The process ran up to 1.30 hrs and the model is prepared. Prepared models are given in Fig 6, Fig 7 and Fig 8 respectively.



Fig 6. Fabricated 8045 standard propeller



Fig 7. Fabricated 10 mm bent propeller



Fig 8. Fabricated 15 mm bent propeller

The prepared propeller prototypes are tested in a Torque measurement trainer to measure the thrust. In torque measurement trainer, multiplication of weights (W) and length of the arm (d) results the torque reading ($T=W \times d$). In our experimental setup instead of weight the propeller attached motor is used. $W = \text{Motor weight force} + \text{thrust produced by the propeller}$. During each experiment as the initial torque set zero the force due to motor weight has no effect on the results. Experimental setup and concept diagram are shown in Fig 9 and Fig 10 respectively. During tabulation the weight of the motor is subtracted and the results are tabulated. The motor with the propeller is fitted in the 1m length arm at a distance of 1m and 0.75m. The initial torque set zero. The propeller is powered and the thrust force generated is displayed in the display panel. The displayed torque divided by the distance of rotor is the thrust force. The experiment is repeated for 20 times and the averages of obtained results are tabulated.



Fig 9. Experiment setup with contains torque trainer setup, motor and fabricated propeller

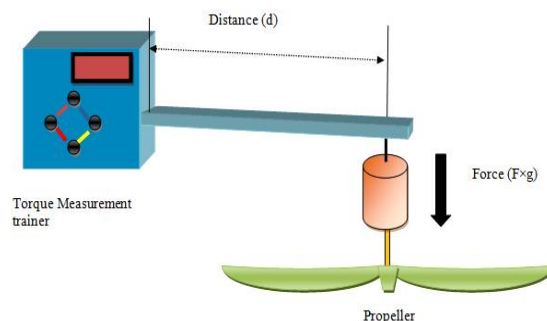


Fig 10. Experiment setup concept diagram in which the torque values are displayed for the weights provided ($T=d \times W$). In the modified torque meter, instead of Weight force, Thrust force is used.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 5, Issue 12, December 2016

Sl.No	Torque (kg.m)	Distance (m)	Force (g)
8045 propeller			
1	0.03	1	30
2	0.02	0.75	20
Average			25
10 mm bent propeller			
3	0.05	1	50
4	0.03	0.75	40
Average			45
15 mm bent propeller			
5	0.07	1	70
6	0.05	0.75	66
Average			68

Table 1. Experimental results of thrust by various fabricated propellers in Torque measurement

The experimental analysis is carried Out at 120 rad/s but computational analysis is carried out at 12000 rad/s, so the computational analysis results are scaled down to 120 rad/s. The comparison bar chart is shown in Fig 11.

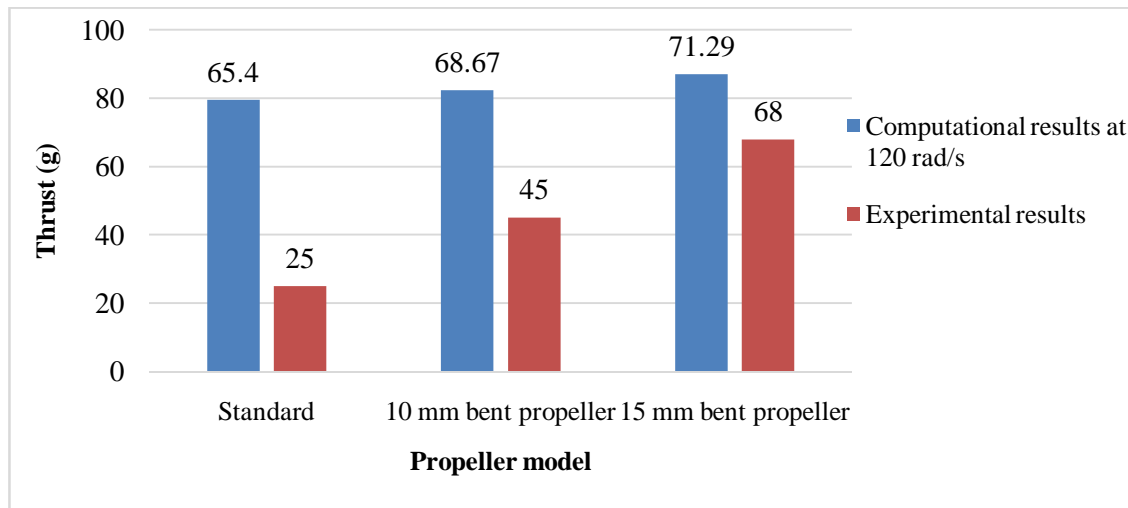


Fig. 11 Analysis results obtained by SOLIDWORKS and experimental results obtained are compared. Though deviations are present in the results, due to bending from mean axis it is validated that thrust force increases due to the bending of the tip.

V. CONCLUSION

The steps to improve the thrust of the propeller are studied. The analysis is carried out using the following parameters, number of blades, and the length of the propeller and the bending of the blade at the tip. From the propeller analysis, while bending the tip of the blade, the thrust is increased considerably. The results are validated experimentally. For 10 mm bent the thrust is increased by 80% and for 15 mm bent the thrust is improved by 172%. On transition from 10 mm to 15 mm the thrust is increased by 92%.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

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