3D CAD DESIGN OF PROPELLER WINGS

A MAJOR PROJECT REPORT

Submitted by

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in partial fulfillment of the award of the degree

Of

BACHELOR OF TECHNOLOGY

IN

INTRODUCTION TO DRONES

श्रद्धावान् लभते ज्ञानम्

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BONAFIDE CERTIFICATE

This is to certify that the major project report entitled "**3D CAD DESIGN OF PROPELLER WINGS"** submitted by

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in partial fulfillment of the requirements for the award of the **bachelor of Master of Technology** in **COMPUTER SCIENCE AND ENGINEERING** is a bonafide record of the work carried out under my guidance and supervision at Amrita School of Engineering, Chennai.

Signature

Dr. Abhishek jha, Dr. G Rajkumar, KB Badri Narayanan, G Deenadayalan

Mech professsor

This project report was evaluated by us on ……………...

INTERNAL EXAMINER   EXTERNAL EXAMINER

DECLARATION

We the undersigned solemnly declare that the thesis “3D CAD design of propeller wings” is based on our own work carried out during the course of our study under the supervision of Dr. Abhishek Jha - MEE - Assistant Professor, Dr. G Rajkumar - MEE - Assistant Professor, KB Badri Narayanan - MEE, Assistant Professor, G Deenadayalan - MEE - Faculty Associate, Assistant professor of Computer Science & Engineering, and has not for the basis for the award of any other degree or diploma,in this or any other Institution or University. In keeping with the ethical practice of reporting scientific information, due acknowledgment has been made wherever the findings of others have been cited.

Anbazhagan, Smithin, Ramya, Trinaya, Abhiram

ABSTRACT

Understanding the fundamental concept of propellers largely depends on the various types of propeller. 2-blade propellers are typically a little more effective. However, thrust, not efficiency, is what moves an aircraft forward. To counteract drag and weight, thrust is required, which aids in the aircraft's ascent.

The number of propeller blades to use relies on a variety of factors, including the engine power of the particular aircraft, the propeller's operating RPM, diameter restrictions, and performance needs. The efficiency of a propeller would decline if more blades were added, if these variables remained constant. However, in order to effectively utilise the increased engine power and produce thrust, more blades are typically needed as engine power increases. As a result, the combination of these factors—which, of course, will vary depending on the aircraft, determines the optimal number of propeller blades for an aircraft. This work presents a comparative study of three-winged propeller design with a tangent ogive propeller nose in fusion 360 and analysing of static stress and thermal stress components in fusion 360

ACKNOWLEDGEMENT

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Anbazhagan, Smithin, Ramya, Trinaya, Abhiram

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CHAPTER 1

INTRODUCTION

A drone is an aircraft which is unpiloted and flies autonomously or through remote control. These drones are called unmanned aerial vehicles (UAVs) and are used for a wide variety of tasks starting from courier services to military operations. Depending on the purpose, they come in different shapes and sizes. For a drone to successfully take off, fly, and land, a combination of hardware and software components are required. Drones are often controlled by ground control stations, have rotors or fixed wings, sensors, navigation systems, and gyroscopes (for stability).

1.1 COMPONENTS OF A DRONE

Every part of the drone is important for smooth and safe flight. The main components to build a drone are described below.

1.1.1 Drone frame

This is the skeleton of the drone where all the other parts are fixed to. The components that are fixed to the frame are fixed in such a way that the centre of gravity is evenly distributed on the drone.

1.1.2 Motors

The rotation of the propeller requires motors and it increases the thrust needed to move the drone. The number of motors and propellers need to match. Their rotation improves the drone's ability to control direction. For the drone to operate effectively, selecting the correct motor is crucial.

1.1.3 Electric speed controllers

The speed of the motor is adjusted by this electrical control board. It serves as a dynamic brake as well. The part helps the ground pilot in estimating the drone's height while it is in flight. This is achieved by calculating how much power each motor uses individually. Power loss from the power reservoirs is related to elevation.

1.1.4 Flight controller boards

If the drone needs to return to its takeoff site unguided, the flight board keeps a record of the location. It also calculates the drone's height in relation to how much power it uses.

1.1.5 Propellers

Propellers are blades that are designed to adjust air pressure. They cut through the air as they move, producing a variation in pressure at the top and bottom of the rotors. The top side has lower pressure than the bottom, which causes the drone to rise into the air.

1.1.6 Radio transmitter

It serves as the drone's channelled transmitter and communicator. Each channel has a unique frequency that can direct the drone in a certain direction. Drones need at least 4 channels to operate efficiently.

1.1.7 Battery, electronics and power distribution cable wires

The drone gets its power from the battery. Through the power distribution connections, it provides electricity to all of the gadgets in the structure. An ideal battery has a 3000mAh and 4V rating. An essential component for drone control and operation is the electrical and electronic component.

These are just the basic necessary components, more components such as GPS, camera, landing gear, LiDAR sensor, etc can be added to the drone based on the requirements

1.2 PROPELLER IMPORTANCE FOR A FIXED WING DRONE

A fixed-wing drone's lift is provided by a single propeller. Lift is produced by a single forward thrusting propeller. Long flights are best served by fixed-wing drones because they are more efficient than multirotor aircraft. Propeller efficiency is required for better (smooth and quick) movement of the drone. The propellers effect the lift force, drag force and pitching movement.

CHAPTER 2

LITERATURE REVIEW

Two aircrafts Two Cassna 172 and CessnaFR172F Reims Rocket with two and three blades of propellers respectively were taken for conducting an experiment. There are relatively slight variations in interior noise levels despite the variety in propeller blade counts. 50% more blade passes per second are produced by a three-blade propeller. [1]

It makes sense that the pilot and passengers would prefer higher tones (at low frequency range). The two blade propeller and four cylinder engine combination was chosen by listeners in hearing noise preference tests over the three blade propeller and six cylinder engine combination. This might be because lower frequencies are discounted by the human hearing curve. Three blades provide a somewhat better climb and are more smoother. Two-blade propellers are a little bit noisier because they have a slightly wider diameter and can attain faster tip speeds at the same rotational speed. [1]

It is suggested to use a variable pitch system to deliver the best propulsive efficiency. But, due to the addition of actuators and pitch linkages, its adoption comes with added weight and complexity. Therefore, it is challenging to implement the variable pitch system because to the requirement for reliability and being ultra-lightweight, which are top-level restrictions of UAVs. [2]

The combination of airfoils and radial distribution from NACA 4309, NACA 4410, NACA 4510, NACA 4512, NACA 5513, and NACA 5521 is produced for a three-bladed propeller with a diameter of 254mm. The model was examined using Ansys CFD in accordance with the procedures and it has been discovered that the created carbon fibre propeller can provide 5.7 N of thrust force at 3000 rpm. Therefore, the created propeller can be used in any micro UAV powered by a 1200 KV motor and an 11.1 v Lipo battery. [2]

CHAPTER 3

PROPELLER DESIGN

Choosing a proper propeller for your drone is important as it has an influence over power and can affect how smoothly a drone flies. When selecting a drone propeller, two factors should be taken into consideration. The first one is about how well the drone and propeller's parameters mesh together. The latter refers to the precise manner in which you want to fly your drone. You may make a wise choice by considering things like the propeller pitch.

Main factors to be considered are type, size, blade configuration, pitch and diameter.

3.1 PROPELLER WINGS

3.1.1 Size

Thrust and responsiveness are directly influenced by propeller size. Each size of propeller has a different function.

- Smaller propellers are lightweight and require less air resistance to spin. These are ideal for when the drone has the purpose of taking sharp turns. They become more sensitive as a result and are simple to slow down and accelerate. The majority of pilots choose these.
- Larger propellers provide a greater pressure difference and use more power. Simply put, they produce more propulsion. So they are used when the drone has to carry heavy payloads.

However, the propellers' increased weight also means that they react to changes in RPM more slowly.

3.1.2 Number of Blades

The blade configuration comes next. Similar to how they are classified based on size, propellers are frequently categorised depending on how many blades they have.

The flying of drones is impacted similarly by this attribute. Increasing the number of blades on a propeller does increase thrust, but it won't produce as smooth of a flight as increasing the size would. In fact, changing the blade layout is sometimes used as a substitute for changing the size, though it is not a perfect solution. Increased thrust also reduces efficiency since more blades draw more power from the batteries. The most popular propellers are dual-bladed ones since they are a balanced option, though ardent racers also employ three-bladed ones. The key point is that a propeller with more blades is thought to corner better and provide more overall control. The total speed suffers as a result.

3.1.3 Pitch

Due to its significance in propeller specifications, the pitch is an essential component to take into account. It is usually measured in inches and is defined as the propeller's travel distance per revolution.

- Lower pitch propellers spin more quickly, enabling more acceleration. The amount of current drawn is also decreased.
- Higher pitch will result in more thrust being produced. Although the top-end speed is increased, this has the disadvantage of consuming more power.

3.1.4 Type

The type of propeller describes the substance that was utilised to make it. The two kinds of materials usually are carbon fibre and plastic. The former is by far the material that is utilised the most frequently in modern propellers. In addition to carbon fibre composites, the structures are also made up of aluminium and titanium.

- Plastic propellers are less expensive and rigid. They are more durable thanks to their flexibility, which is a crucial quality for beginning pilots.
- Propellers made of carbon fibre perform better and are quieter. Although expensive, they are perfect for seasoned drone pilots who have a lower crash rate.
- Motors of fixed wing drones can generate high amount of heat so materials like aluminium which have high thermal conductivity can help cool the motor down.

When it comes to smoother flights and producing more lift, 3-blade propellers for drones are superior to 2-blade propellers. However, 2-blade propellers outperform other propeller types in terms of speed and effectiveness. The flying times are also longer since they use less current.

The efficiency of a drone's flying can be altered by altering the propeller's diameter. This also holds true for minor adjustments. At the same speed, a propeller with a bigger diameter produces more thrust. Conversely, a smaller diameter implies the propeller will react more quickly.

3.2 PROPELLER NOSE DESIGN

For the least amount of drag, the nose cone's shape must be chosen. There is no break in the line where the ogive enters the cylindrical body since the arc of the ogive nose cone meets the body contour smoothly. In other words, the arc's rotational centre is located in the plane of the nose's base.

There’s the ogival shape as well as the conical, but the ovigal has a few advantages over the latter. It features somewhat more volume for the same base and length, improved structural quality, and significantly less drag thanks to a blunter nose. Amongst the ogival shaped, there are two types of noses – the tangent ogive and the secant ogive.

- The arc's centre of rotation in a tangent ogive is located in the plane of the nose cone's base.
- In a secant ogive, the arc's centre of rotation is located behind the plane of the nose cone's base.

3.3 CALCULATION OF RESULTANT ANGLE OF ATTACK OF PROPELLER

A propeller blade is nothing more than a wing with a bent portion of an airfoil that rotates along an axis perpendicular to the plane's motion. A propeller blade, like a traditional wing, will generate lift and drag forces proportional to the square of the velocity flowing over the blade (relative airflow). While an aircraft's forward speed determines the aerodynamic forces on its wings, the propeller's resulting velocity depends on both the forward flying speed and the blade's rotating speed (propeller rpm).

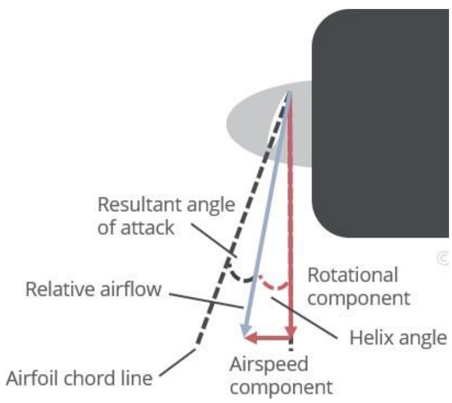


Fig 1 Angle of attack of a propeller blade [3]

Higher airspeeds cause the relative airflow's airspeed component to rise, which lowers the angle of attack at a given blade angle. In contrast, the angle of attack rises with lower airspeeds.

The angle between the relative airflow and the propeller's axis of rotation is known as the helix angle.

The propeller blade has twist built into it to maintain a roughly constant angle of attack throughout the span. The radius from the hub to each spanwise point, which is a function of the rotating velocity component, determines the angle of attack along the span. The angle of attack would vary significantly along the blade if the blade was not twisted, resulting in an unpredictable force distribution. The twist angle is greatest at the hub, where rotational velocities are lowest, and lowest at the tip, when rotational velocities are highest.

3.4 FORCES ACTING ON PROPELLER

Centrifugal Force, Torque Bending, Thrust Bending, Aerodynamical Twisting, Centrifugal Twisting Force

CHAPTER 4

PROPOSED WORK

The propeller design proposed in this report is a three-winged propeller design with a tangent ogive propeller nose.

A three-bladed propeller has three blades, and their combined thrust is increased. Your drone needs thrust to rise, and a three-blade propeller can support more weight because it has more thrust. On larger drones, which have more powerful motors and require a lot of force to achieve lift, manufacturers frequently use three-blade props. Three-bladed props produce an enormous amount of thrust and are also more stable than two-bladed props, which makes three-bladed prop drones feel more secure when performing quick manoeuvres. Three-bladed propellers also have the advantage of being able to fly without being perfectly balanced. Two-blade props, on the other hand, must be perfectly balanced and in excellent condition in order to fly smoothly; if not, they will start to generate unpleasant vibrations when spinning.

A three-winged propeller is usually made up of aluminium alloy and has a manufacturing cot less than any other type. The speed of the propeller is high and gives a better acceleration than the others, but it is not as efficient when it is moving on low speed.

Fig 2 Fixed Wing Three Blade Propeller

The type of propeller is Aircraft Propellor

For the nose we have used a tangent Ogive nose cone. The body is tangent to the curve of the nose cone at its base, and the base is on the radius of the circle, forming the profile of this shape.

$$\rho = \frac{R^2 + L^2}{2R}$$

The radius y at any point x, as x varies from 0 to L is:

$$y = \sqrt{\rho^2 - (L - x)^2} + R - \rho$$

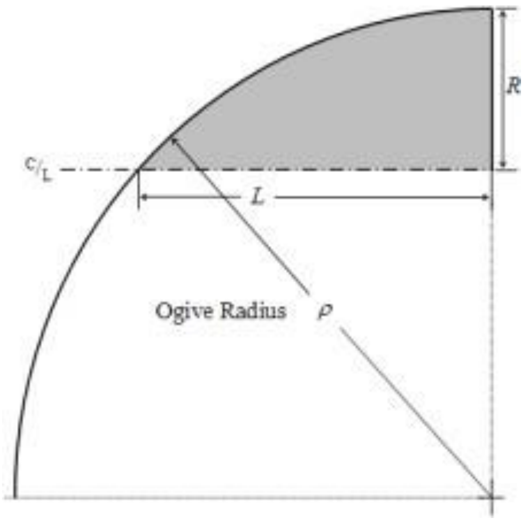


Fig 3 Tangent Ogive [4]

CHAPTER 5

SIMULATION RESULTS AND STRESS COMPONENT ANALYSIS

STATIC STRESS ANALYSIS

⊟ Simulation Model 1:1

⊟ Study 1 - Static Stress

⊟ Study Properties

Study Type	Static Stress
Last Modification Date	2022-12-17, 00:34:19

⊟ Settings

⊟ General

Contact Tolerance	0.1 mm
Remove Rigid Body Modes	No

⊟ Damping

⊟ Mesh

Average Element Size (% of model size)	
Solids	2
Scale Mesh Size Per Part	No
Average Element Size (absolute value)	-
Element Order	Parabolic
Create Curved Mesh Elements	Yes
Max. Turn Angle on Curves (Deg.)	60
Max. Adjacent Mesh Size Ratio	1.5
Max. Aspect Ratio	10
Minimum Element Size (% of average size)	20

Adaptive Mesh Refinement

Number of Refinement Steps	0
Results Convergence Tolerance (%)	20
Portion of Elements to Refine (%)	10
Results for Baseline Accuracy	Von Mises Stress

Materials

Component	Material	Safety Factor
Body1	Steel	Yield Strength

Steel

Density	7.85E-06 kg / mm^3
Young's Modulus	210000 MPa
Poisson's Ratio	0.3
Yield Strength	207 MPa
Ultimate Tensile Strength	345 MPa
Thermal Conductivity	0.056 W / (mm C)
Thermal Expansion Coefficient	1.2E-05 / C
Specific Heat	480 J / (kg C)

Mesh

Type	Nodes	Elements
Solids	13327	7597

Load Case1

Constraints

Fixed1

Type	Fixed
Ux	Fixed
Uy	Fixed
Uz	Fixed

Selected Entities

⊟ Loads

⊟ Gravity

Type	Gravity
Magnitude	9.807 m / s^2
X Value	0 m / s^2
Y Value	0 m / s^2
Z Value	-9.807 m / s^2

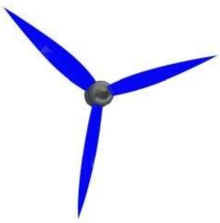
⊟ Moment1

Type	Moment
Magnitude	5000 N mm
X Value	0 N mm
Y Value	-5000 N mm
Z Value	0 N mm

⊟ Selected Entities

⊟ Hydrostatic Pressure1

Type	Hydrostatic Pressure
Offset Distance	0 mm
Fluid Type	Custom
Fluid Density	1.204 kg / mm^3



RESULTS SUMMARY:

Name	Minimum	Maximum
Safety Factor		
Safety Factor (Per Body)	0.00479	15
Stress		
Von Mises	1.395E-04 MPa	43211 MPa
1st Principal	-9326 MPa	53555 MPa
3rd Principal	-47908 MPa	13430 MPa
Normal XX	-44610 MPa	44689 MPa
Normal YY	-11066 MPa	15741 MPa
Normal ZZ	-43822 MPa	33761 MPa
Shear XY	-5885 MPa	7212 MPa
Shear YZ	-6331 MPa	5504 MPa
Shear ZX	-19955 MPa	20422 MPa
Displacement		
Total	0 mm	250.8 mm
X	-14.32 mm	181.3 mm
Y	-128 mm	132.3 mm
Z	-0.8414 mm	213.1 mm
Reaction Force		
Total	0 N	297303 N
X	-285434 N	163994 N
Y	-69913 N	44063 N
Z	-192787 N	142478 N
Strain		
Equivalent	7.775E-10	0.3119
1st Principal	-0.003793	0.3372
3rd Principal	-0.328	-8.287E-10
Normal XX	-0.1991	0.1988
Normal YY	-0.05368	0.05467
Normal ZZ	-0.175	0.1242
Shear XY	-0.07286	0.08929
Shear YZ	-0.07838	0.06814
Shear ZX	-0.2471	0.2528
Contact Force		

⊟ Safety Factor

⊟ Safety Factor (Per Body)

0 8

⊟ Stress

⊟ Von Mises

[MPa] 0 43211

⊟ 1st Principal

[MPa] -9326 53555

⊟ 3rd Principal

[MPa] -47908 13430

⊟ Displacement

⊟ Total

[mm] 0 250.8

THERMAL STRESS ANALYSIS:

⊟ Simulation Model 1:1

⊟ Study 1 - Thermal

⊟ Study Properties

Study Type	Thermal
Last Modification Date	2022-12-17, 00:53:55

⊟ Settings

⊟ General

Contact Tolerance	0.1 mm
Global Initial Temperature	20 C

⊟ Damping

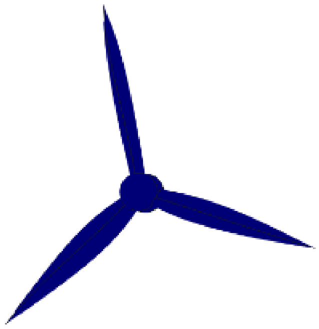
⊟ Mesh

Average Element Size (% of model size)	
Solids	5
Scale Mesh Size Per Part	No
Average Element Size (absolute value)	-
Element Order	Parabolic
Create Curved Mesh Elements	Yes
Max. Turn Angle on Curves (Deg.)	60
Max. Adjacent Mesh Size Ratio	1.5
Max. Aspect Ratio	10
Minimum Element Size (% of average size)	20

⊟ Temperature

⊟ Temperature

[C] 20 ▬ 20, Threshold: 20 - 20



⊟ Adaptive Mesh Refinement

Number of Refinement Steps	0
Results Convergence Tolerance (%)	20
Portion of Elements to Refine (%)	10
Results for Baseline Accuracy	Heat Flux

⊟ Materials

Component	Material	Safety Factor
Body4	Steel	Yield Strength

⊟ Steel

Density	7.85E-06 kg / mm^3
Young's Modulus	210000 MPa
Poisson's Ratio	0.3
Yield Strength	207 MPa
Ultimate Tensile Strength	345 MPa
Thermal Conductivity	0.056 W / (mm C)
Thermal Expansion Coefficient	1.2E-05 / C
Specific Heat	480 J / (kg C)

⊟ Contacts

⊟ Mesh

Type	Nodes	Elements
Solids	8375	4574

⊟ Load Case1

⊟ Loads

⊟ Applied Temperature1

Type	Applied Temperature
Value	20 C

⊟ Selected Entities

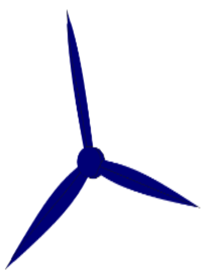
⊟ Results

⊟ Result Summary

Name	Minimum	Maximum
Temperature		
Temperature	20 C	20 C
Heat Flux		
Total	5.368E-12 W / mm^2	2.707E-07 W / mm^2
X	-2.693E-07 W / mm^2	1.672E-07 W / mm^2
Y	-6.722E-08 W / mm^2	5.739E-08 W / mm^2
Z	-4.951E-08 W / mm^2	8.995E-08 W / mm^2
Thermal Gradient		
Total	9.585E-11 C / mm	4.835E-06 C / mm
X	-2.985E-06 C / mm	4.809E-06 C / mm
Y	-1.025E-06 C / mm	1.2E-06 C / mm
Z	-1.606E-06 C / mm	8.841E-07 C / mm
Applied Heat Flow		
Applied Heat Flow	0 W / mm^2	0 W / mm^2

⊟ Temperature

[C] 20 20, Threshold: 20 - 20



CHAPTER 6

CONCLUSION

The tangent ogive nose cones offer a good balance between structural integrity and considerations for weight and drag. Additionally, tangent ogive nose cones are mathematically easier to model than secant ogive and power-series nose cones. When compared to conical and bi-conical shapes, ogive shapes have better performance characteristics for the same fineness ratio. Instead of using two blades, certain commercial aircraft have three blade propellers. Slightly improved aerodynamics, slightly better uphill, slightly better ramp appeal, and slower cruising speed. Despite the different number of propeller blades, there is relatively little variation in internal noise levels. They are very small, due to the different engines and nuances in the cabin (seats and furniture). Spectral deviations are seen because the blade passing frequencies and their harmonics are different. A 3-blade propeller provides 50% more blade transitions per second.

CHAPTER 6

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