Design and analysis of drone propeller by using aluminium and nylon materials

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Abstract: It is undeniable fact that the importance of drones has increased in every aspect of the daily life such as Defence, agriculture, film shooting, disaster management, transportation etc. In the view to increasing the efficiency of a drone, Using Solid works it is proposed to design the Drone Propellers and analyse the output parameters such as thrust produced, pressure and velocity of the propeller. The objective of this research work is to design thrust optimized blade of length 134mm and 167mm with a density of air 1.204 kg/m3 and perform thrust, velocity and pressure analysis with respect to change in material, RPM, angle, and length of the blade. The property of aluminium 1060 H12 and Nylon 101 being lightweight is chosen for designing and analysing of blades. The modal analysis shows the first natural frequency occurs at around 5000 RPM which is safe for operating the blade. So, it had been considered as 2500rpm and 3500rpm to calculate thrust and other parameters as mentioned. The CFD analysis of the model was performed in solid works and required parameters has been obtained.

1. Introduction:

Drones have become an age that no longer like toys or playing flies for those interested and enthusiasts. A drone can be considered an unmanned aerial vehicle (UAV). Quadro copter is short for a quadrotor helicopter, which is also commonly known as a quadrotor and drone. This mechanism uses a multi-rotor for lifting and propulsion against gravity with four rotors widely used for many purposes these days. A pair of diagonal propellers will rotate clockwise and another pair counter clockwise. This motor rotation speed is used to control the direction and achieve the movement of the drone. Propellers are one of the fundamental elements of aircraft propulsion and construction, they function as a rotating wing that creates lift in the same direction as the axis of rotation.

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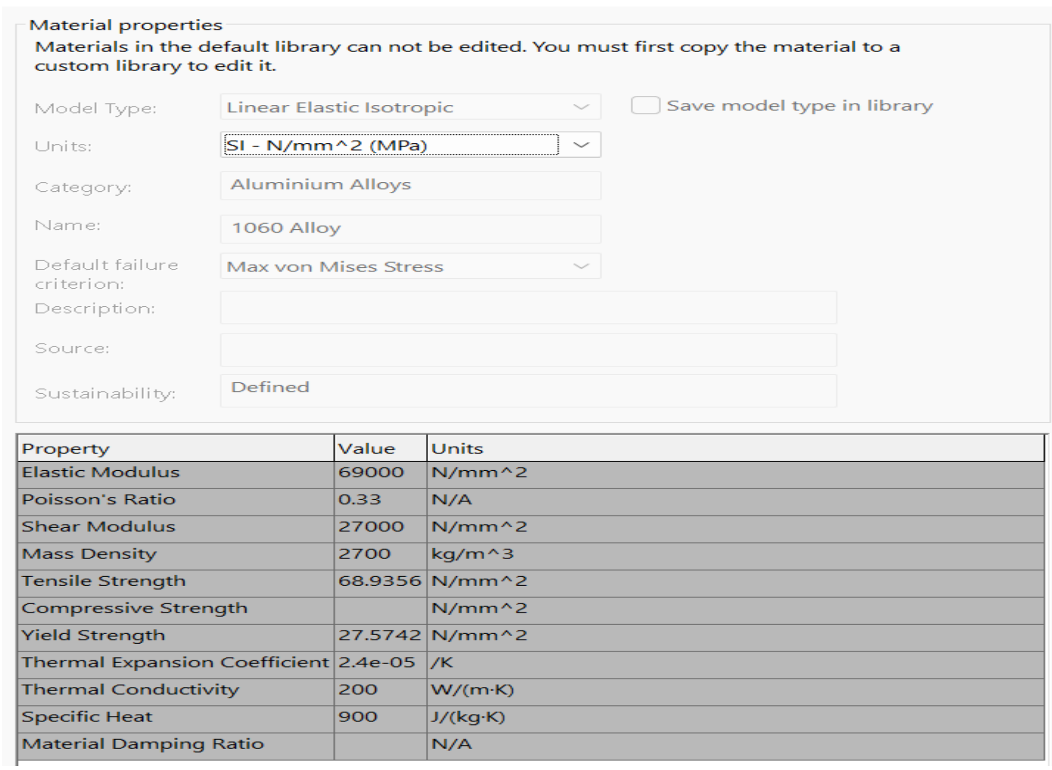
A propeller is a rotating air foil that is mounted on the motor crankshaft and has at least two sharp edges attached to it. A propeller can convert mechanical energy into useful thrust. The cutting edges of a propeller have a leading edge, the following edge, a tip, a shank, a face, and a back. Propellers convert rotating motion from electric motors, turboprop engines, or cylinder motors into propulsion power. They could have a fixed pitch or fluctuate. A cylinder motor's crankshaft typically has a propeller attached to it, either directly or indirectly through a reducing unit. Although large motors and turboprop airliners typically do not require multifaceted quality of adapting, light airship motors frequently don't require this quality of adapting.

2. Propeller material:

Aluminium 1060 Alloy:

Fig.2.1 Aluminium 1060 Alloy



Material properties
Materials in the default library can not be edited. You must first copy the material to a custom library to edit it.

Model Type: Linear Elastic Isotropic
Save model type in library
Units: SI - N/mm^2 (MPa)
Category: Aluminium Alloys
Name: 1060 Alloy
Default failure criterion: Max von Mises Stress
Description:
Source:
Sustainability: Defined

Property	Value	Units
Elastic Modulus	69000	N/mm^2
Poisson's Ratio	0.33	N/A
Shear Modulus	27000	N/mm^2
Mass Density	2700	kg/m^3
Tensile Strength	68.9356	N/mm^2
Compressive Strength		N/mm^2
Yield Strength	27.5742	N/mm^2
Thermal Expansion Coefficient	2.4e-05	/K
Thermal Conductivity	200	W/(m·K)
Specific Heat	900	J/(kg·K)
Material Damping Ratio		N/A

Propeller Design:

Pitch angle, flow angle, chord distribution at the blade span, and twist distribution are only a few of the numerous factors that have an impact on the building of propellers. The propeller will be built using the theory of blade elements. If vibration could be tolerated, a single-blade propeller would be the most effective. Therefore, a two-bladed propeller is the best in terms of practicality for achieving a reasonable level of balance with far less vibration.

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Fig.2.2 Propeller design

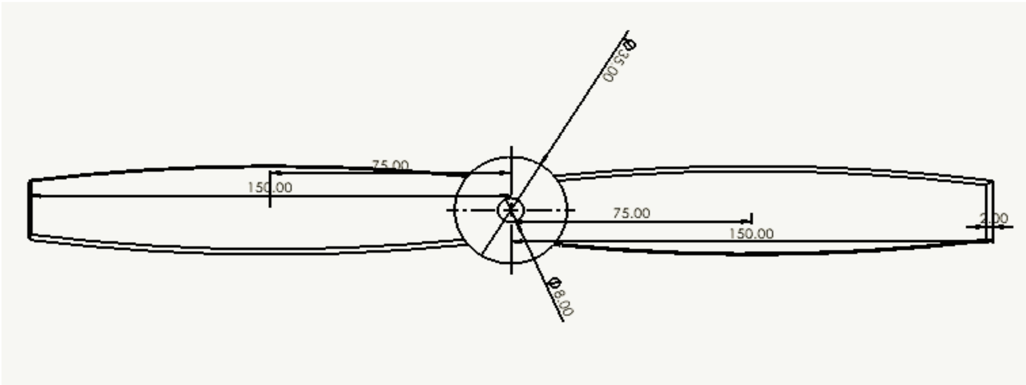

Table 2.1 Propeller dimensions:

S.No.	Specifications	Dimensions
1.	Length of blade	150mm.
2.	Angle of cut	15deg.
3.	Thickness of blade	2mm.
4.	Mid blade length	75mm.

Table 2.2 Simulation results of standard data:

LENGTH OF PROPELLER (mm)	RPM OF PROPELLER	THRUST OBTAINED(N)
150 mm	2500	1.57
150 mm	3500	2.61

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3. Analysis data:

Table 3.1 Simulation results of propeller at 2500rpm

Name	**Unit**	**Value**	**Criteria**	**Delta**
Total Pressure	Pa	100806.42	1227.91829	626.370411
Velocity	m/s	-11.465	4.8665587	3.29658106
Force (thrust)	N	0.343	5.64076708	1.14475515

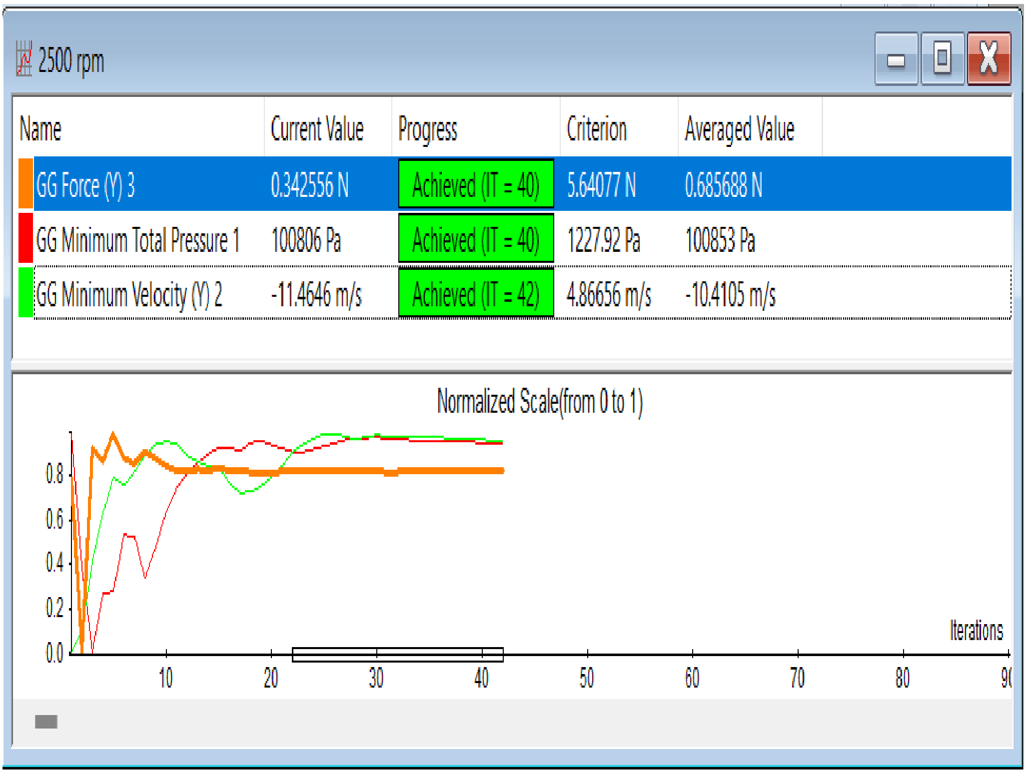

Fig 3.1 Velocity, pressure and thrust combined graph

Table 3.2 Simulation results of propeller at 3500rpm

Name	Unit	Value	Criteria	Delta
Total Pressure	Pa	100027.52	1453.38644	520.10
GG Minimum Velocity	m/s	-4.034	9.34657763	9.01
Force (thrust)	N	2.780	95.2721132	3.44

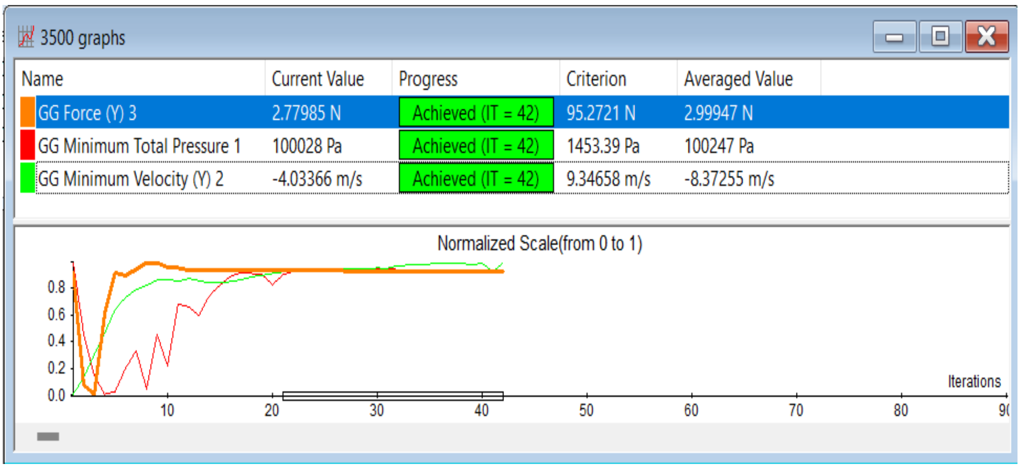

Fig 3.2 Velocity pressure and thrust a combined graph:

Table 3.3 Result comparison of standard data v/s analysis data:

RPM	Standard Thrust(N)	Analysis Thrust(N)	Difference(N)
2500	1.57	0.685688	0.884312
3500	2.61	2.99947	0.38947

At 2500 rpm the Analysis Thrust is less than standard thrust, and error parameters is obtained. And at 3500 the Analysis Thrust is higher than Standard thrust.

So, by comparing both the rpms, 3500 rpm looks more efficient compared to standard data.

4. Change in parameters of propeller:

Changing the parameters of Propeller like Length, Angle of Cut, RPM, Material, and the analysis is performed to get the results.

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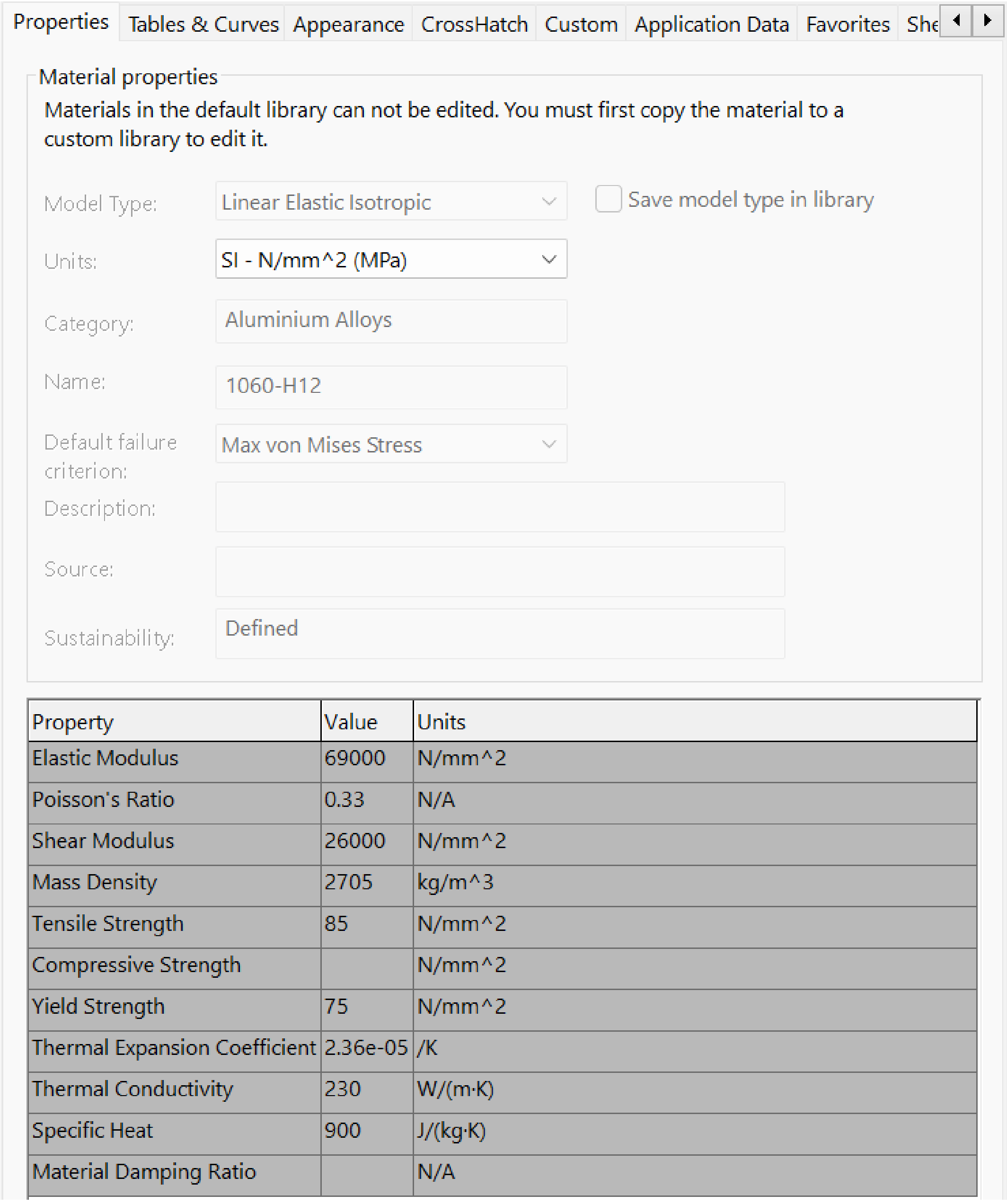
Material used and its properties:


Properties | Tables & Curves | Appearance | CrossHatch | Custom | Application Data | Favorites | She

Material properties

Materials in the default library can not be edited. You must first copy the material to a custom library to edit it.

Model Type: Linear Elastic Isotropic

Save model type in library

Units: SI - N/mm^2 (MPa)

Category: Aluminium Alloys

Name: 1060-H12

Default failure criterion: Max von Mises Stress

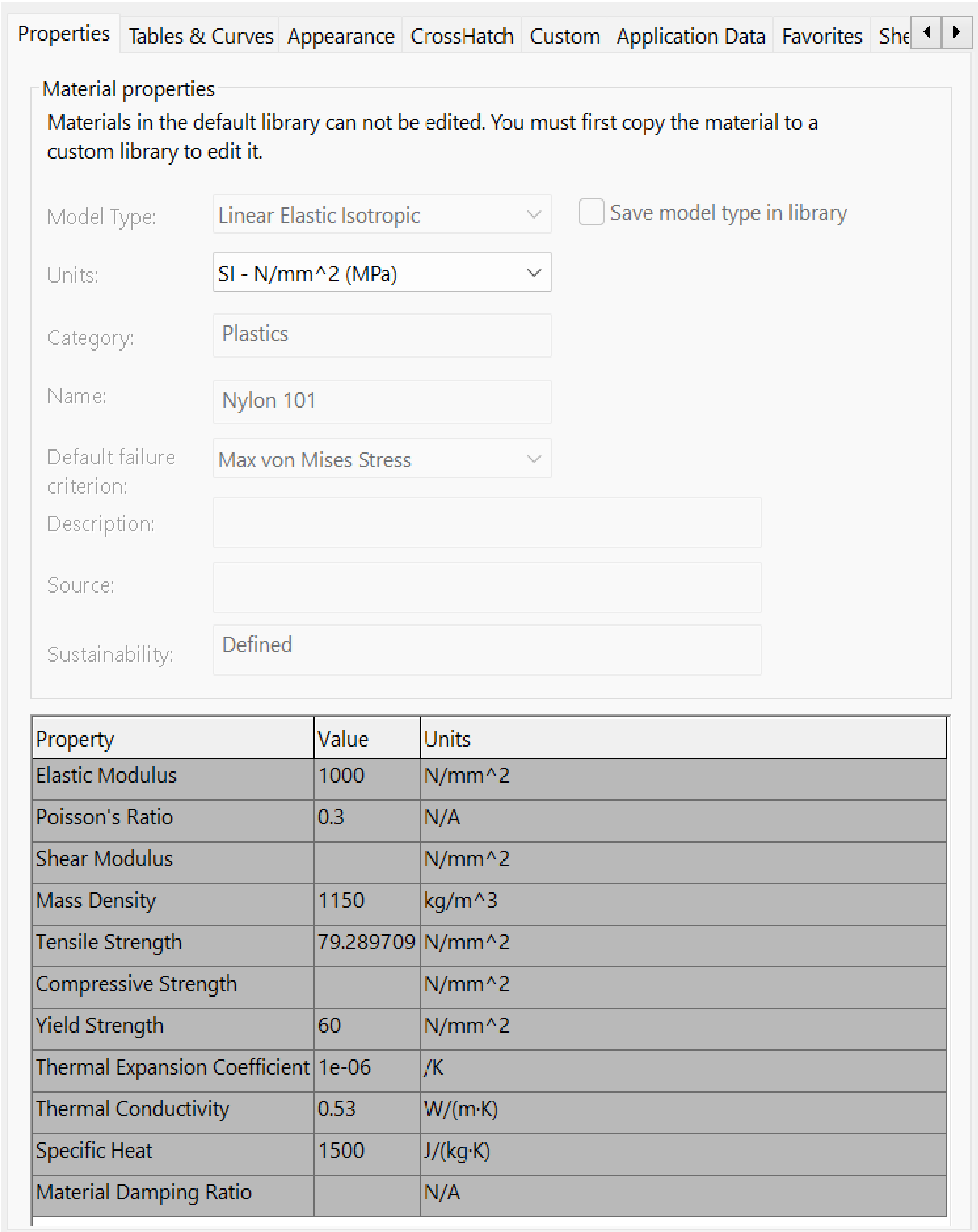
Description:

Source:

Sustainability: Defined

Property	Value	Units
Elastic Modulus	69000	N/mm^2
Poisson's Ratio	0.33	N/A
Shear Modulus	26000	N/mm^2
Mass Density	2705	kg/m^3
Tensile Strength	85	N/mm^2
Compressive Strength		N/mm^2
Yield Strength	75	N/mm^2
Thermal Expansion Coefficient	2.36e-05	/K
Thermal Conductivity	230	W/(m·K)
Specific Heat	900	J/(kg·K)
Material Damping Ratio		N/A

Fig 4.1 Aluminium 1060 Alloy



Property	Value	Units
Elastic Modulus	1000	N/mm^2
Poisson's Ratio	0.3	N/A
Shear Modulus		N/mm^2
Mass Density	1150	kg/m^3
Tensile Strength	79.289709	N/mm^2
Compressive Strength		N/mm^2
Yield Strength	60	N/mm^2
Thermal Expansion Coefficient	1e-06	/K
Thermal Conductivity	0.53	W/(m·K)
Specific Heat	1500	J/(kg·K)
Material Damping Ratio		N/A

Fig 4.2 Nylon 101

4(a) 2500rpm:

Table 4.1 Simulation result of propeller length 134 mm & angle 10deg for 2500rpm:

MATERIAL	LENGTH (mm)	ANGLE (deg)	THRUST(N)	PRESSURE(Pa)	VELOCITY(m/s)
Aluminium	134	10	0.467	101318.84	4.966
Nylon	134	10	6.072	101454.92	20.052

Table 4.2 Comparing propellers of aluminium and nylon at 10deg for 134mm length and 2500rpm:

	ALUMINIUM	NYLON	DIFFERENCE
THRUST(N)	0.467	6.072	5.605
PRESSURE(Pa)	101318.84	101454.92	136.08
VELOCITY(m/s)	4.966	20.052	15.086

Based on the angle & rpm of propeller, the thrust, pressure, and velocity vary. Thrust production is mainly considered in Propeller design. The simulated values are calculated and errors are noted above. As the thrust of nylon blade of angle 10deg is higher and better than aluminium of angle 10deg. So, in the case above nylon is efficient and better to be used.

Table 4.3 Simulation result of propeller length 134 mm & angle 15deg for 2500rpm:

MATERIAL	LENGTH (mm)	ANGLE (deg)	THRUST(N)	PRESSURE(Pa)	VELOCITY(m/s)
Aluminium	134	15	1.778	101318.90	0.066
Nylon	134	15	3.425	101572.40	17.660

Table 4.4 Comparing propellers of aluminium and nylon at 15deg for 134mm length and 2500rpm:

	ALUMINIUM	NYLON	DIFFERENCE
THRUST(N)	1.778	3.425	1.647
PRESSURE(Pa)	101318.90	101572.40	253.5
VELOCITY(m/s)	0.066	17.660	17.594

Based on the angle & rpm of propeller, the thrust, pressure, and velocity vary. Thrust production is mainly considered in Propeller design. The simulated values are calculated and errors are noted above. As the thrust of nylon blade of angle 15deg is higher and better than aluminium of angle 15deg. So, in the case above nylon is efficient and better to be used.

Comparing the angle of cut of propeller's 10degree v/s 15degree:

By observing the thrust values of aluminium 10deg & 15deg and nylon 10deg & 15deg. The thrust production of nylon is higher in both the cases, so nylon is better to be used.

Table 4.5 Simulation result of propeller length 167 mm & angle 10deg for 2500rpm:

MATERIAL	LENGTH (mm)	ANGLE (deg)	THRUST(N)	PRESSURE(Pa)	VELOCITY(m/s)
Aluminium	167	10	3.960	101318.56	0.034
Nylon	167	10	92.422	101948.95	47.575

Table 4.6 Comparing propellers of aluminium and nylon at 10deg for 167mm length and 2500rpm:

	ALUMINIUM	NYLON	DIFFERENCE
THRUST	3.960	92.422	88.462
PRESSURE(Pa)	101318.56	101948.95	630.39
VELOCITY(m/s)	0.034	47.575	47.541

Based on the angle & RPM of propeller, the thrust, pressure, and velocity vary. Thrust production is mainly considered in Propeller design. The simulated values are calculated and errors are noted above. As the thrust of nylon blade of angle 10deg is higher and better than aluminium of angle 10deg. So, in the case above nylon is efficient and better to be used.

Table 4.7 Simulation result of propeller length 167 mm & angle 15deg for 2500rpm:

MATERIAL	LENGTH (mm)	ANGLE (deg)	THRUST(N)	PRESSURE(Pa)	VELOCITY(m/s)
Aluminium	167	15	17	102576.44	15.360
Nylon	167	15	0.839	102433.70	43.730

Table 4.8 Comparing propellers of aluminium and nylon at 15deg for 167mm length and 2500rpm:

	ALUMINIUM	NYLON	DIFFERENCE
THRUST(N)	17	0.839	16.161
PRESSURE(Pa)	102576.44	102433.70	142.74
VELOCITY(m/s)	15.360	43.730	28.37

Based on the angle & rpm of propeller, the thrust, pressure, and velocity vary. Thrust production is mainly considered in Propeller design. The simulated values are calculated and errors are noted above. As the thrust of aluminium blade of angle 10deg is higher and better than nylon of angle 10deg. So, in the case above aluminium is efficient and better to be used.

Comparing the angle of cut of propeller's 10degree v/s 15degree:

By observing the thrust values of aluminium 10deg & 15deg and nylon 10deg & 15deg. The thrust production of nylon is higher, so nylon is better to be used.

4(b) 3500rpm:

Table 4.9 Simulation result of propeller length 134 mm & angle 10deg for 3500rpm:

MATERIAL	LENGTH (mm)	ANGLE (deg)	THRUST(N)	PRESSURE(Pa)	VELOCITY(m/s)
Aluminium	134	10	20.386	101319.54	0.114
Nylon	134	10	42.665	101820.80	32.585

Table 4.10 Comparing propellers of aluminium and nylon at 10deg for 134mm length and 3500rpm:

	ALUMINIUM	NYLON	DIFFERENCE
THRUST(N)	20.386	42.665	22.279
PRESSURE(Pa)	101319.54	101820.80	501.26
VELOCITY(m/s)	0.114	32.585	32.471

Based on the angle & RPM of propeller, the thrust, pressure, and velocity vary. Thrust production is mainly considered in Propeller design. The simulated values are calculated and errors are noted above. As the thrust of nylon blade of angle 10deg is higher and better than aluminium of angle 10deg. So, in the case above nylon is efficient and better to be used.

Table 4.11 Simulation result of propeller length 134 mm & angle 15deg for 3500rpm:

MATERIAL	LENGTH (mm)	ANGLE (deg)	THRUST(N)	PRESSURE(Pa)	VELOCITY(m/s)
Aluminium	134	15	0.611	101319.23	0.012
Nylon	134	15	2.708	101803.79	18.705

Table 4.12 Comparing propellers of aluminium and nylon at 15deg for 134mm length and 3500rpm:

	ALUMINIUM	NYLON	DIFFERENCE
THRUST(N)	0.611	2.708	2.097
PRESSURE(Pa)	101319.23	101803.79	484.56
VELOCITY(m/s)	0.012	18.705	18.693

Based on the angle & RPM of propeller, the thrust, pressure, and velocity vary. Thrust production is mainly considered in Propeller design. The simulated values are calculated and errors are noted above. As the thrust of nylon blade of angle 10deg is higher and better than aluminium of angle 10deg. So, in the case above nylon is efficient and better to be used.

Comparing the angle of cut of propeller's 10degree v/s 15degree:

By observing the thrust values of aluminium 10deg & 15deg and nylon 10deg & 15deg. The thrust production of nylon is higher in both the cases, so nylon is better to be used.

Table 4.13 Simulation result of propeller of length 167 mm & angle 10deg for 3500rpm:

MATERIAL	LENGTH (mm)	ANGLE (deg)	THRUST(N)	PRESSURE(Pa)	VELOCITY(m/s)
Aluminium	167	10	13.542	101318.74	0.057
Nylon	167	10	102.422	101948.95	47.422

Table 4.14 Comparing propellers of aluminium and nylon at 10deg for 167mm length at 3500rpm:

	ALUMINIUM	NYLON	DIFFERENCE
THRUST(N)	13.542	102.422	88.88
PRESSURE(Pa)	101318.74	101948.95	630.21
VELOCITY(m/s)	0.057	47.422	47.365

Based on the angle & rpm of propeller, the thrust, pressure, and velocity vary. Thrust production is mainly considered in Propeller design. The simulated values are calculated and errors are noted above. As the thrust of nylon blade of angle 10deg is higher and better than aluminium of angle 10deg. So, in the case above nylon is efficient and better to be used.

Table 4.15 Simulation result of propeller of length 167mm & angle 15deg for 3500rpm:

MATERIAL	LENGTH (mm)	ANGLE (deg)	THRUST(N)	PRESSURE(Pa)	VELOCITY(m/s)
Aluminium	167	15	18.485	101318.77	0.062
Nylon	167	15	0.839	102433.70	43.730

Table 4.16 Comparing propellers of aluminium and nylon at 15deg for 167mm length at 3500rpm:

	ALUMINIUM	NYLON	DIFFERENCE
THRUST(N)	18.485	0.839	17.646
PRESSURE(Pa)	101318.77	102433.70	1114.93
VELOCITY(m/s)	0.062	43.730	43.668

Based on the angle & RPM of propeller, the thrust, pressure, and velocity vary. Thrust production is mainly considered in Propeller design. The simulated values are calculated and errors are noted above. As the thrust of aluminium blade of angle 10deg is higher and better than nylon of angle 10deg. So, in the case above aluminium is efficient and better to be used.

Comparing the angle of cut of propeller's 10degree v/s 15degree:

By observing the thrust values of aluminium 10deg & 15deg and nylon 10deg & 15deg. The thrust production of nylon is higher, so nylon is better to be used.

Table 4.17 Simulation result of propeller length 150mm of angle 15degree at 2500rpm and 3500rpm:

MATERIAL	LENGTH (mm)	RPM	ANGLE (deg)	THRUST (N)	PRESSURE (Pa)	VELOCITY (m/s)
Aluminium	150	2500	15	0.343	100806.42	-11.465
Aluminium	150	3500	15	2.780	100027.52	-4.034

Table 4.18 Simulation results of all the propellers for different lengths and angles at 2500rpm

MATERIAL	LENGTH (mm)	ANGLE (deg)	THRUST (N)	PRESSURE (Pa)	VELOCITY (m/s)
Aluminium	134	10	0.467	101318.84	0.066
Aluminium	134	15	1.778	101318.90	0.066
Aluminium	167	10	3.960	101318.56	0.034
Aluminium	167	15	0.839	102433.70	43.730
Nylon	134	10	6.072	101454.92	20.052
Nylon	134	15	3.425	101572.40	17.660
Nylon	167	10	92.422	101948.95	47.575
Nylon	167	15	0.839	102433.70	43.730

Table 4.19 Simulation results of all the propellers for different lengths and angles at 3500rpm

MATERIAL	LENGTH (mm)	ANGLE (deg)	THRUST (N)	PRESSURE (Pa)	VELOCITY (m/s)
Aluminium	134	10	20.386	101319.54	0.114
Aluminium	134	15	0.611	101319.23	0.012
Aluminium	167	10	13.542	101318.74	0.057
Aluminium	167	15	18.485	101318.77	0.062
Nylon	134	10	42.665	101820.80	32.585
Nylon	134	15	2.708	101803.79	18.705
Nylon	167	10	102.422	101948.95	47.422
Nylon	167	15	0.839	102433.70	43.730

- From the table 4.18, nylon of length 167mm and angle of 10deg has produced the simulation thrust of 92.422N.

- From the table 4.19, nylon of length 167mm and angle of 10deg has produced the simulation thrust of 102.422N.

Conclusion:

- The blades designed of different lengths (134mm & 167mm) and angle (10deg & 15deg) and CFD analysis performed in Solid works, and results are dragged out at 2500 and 3500rpm.
- Those results were compared to previous(standard) data...
- The CFD thrust analysis of propeller 150 mm gave a thrust of 0.343N at 2500rpm, and thrust of 2.780N at 3500rpm, a bit more compared to the previous(standard) data.
- Thrust production is mainly considered in propeller design & for practical usage.
- Amongst all the propeller, Nylon of length 167mm produces a thrust of 92.422N at 2500rpm and thrust of 102.422N at 3500rpm, shows up to be produced highest thrust under simulation.
- However here, numerical analysis differs from experimental analysis.
- Thus, further experimentation/investigation suggested in order to improve the result.

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