PROPELLER DESIGN

GROUP-1

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DESIGN STATEMENT

To design a propeller for an low speed aircraft (civil or military) with the following specifications

1. No. of passenger- 4
2. Service ceiling- 5 km
3. Flight speed- 300kmph

We found Cessna 172 RG as the nearest match to the design statement and used it as a reference airplane.

We used the Blade Element Theory to design the propeller

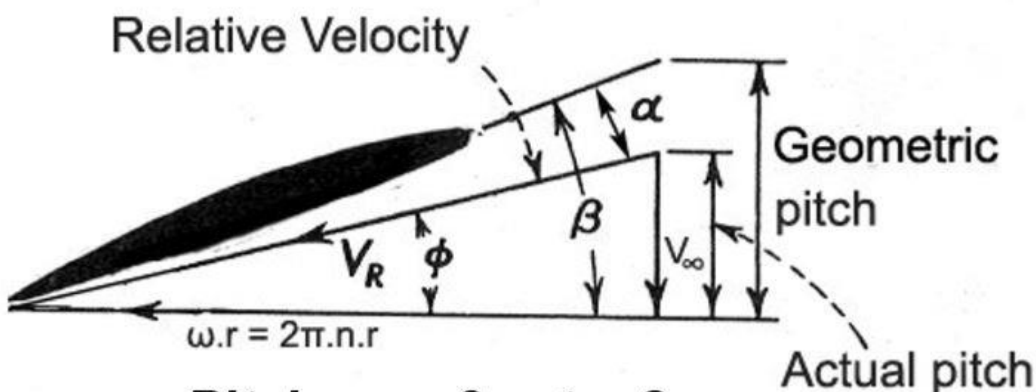
Engine Specifications:-

1. Power-180 BHP
2. RPM- 2700
3. Weight- 6258 pounds
4. No. of prop fans- 1
5. Cruise speed- 300 kmph

Design Specifications:-

1. Altitude - 5000m
2. Max flight Mach no - 0.23
3. Propeller diameter- 1.94m
4. No. of blades - 2
5. Advance ratio - 0.954

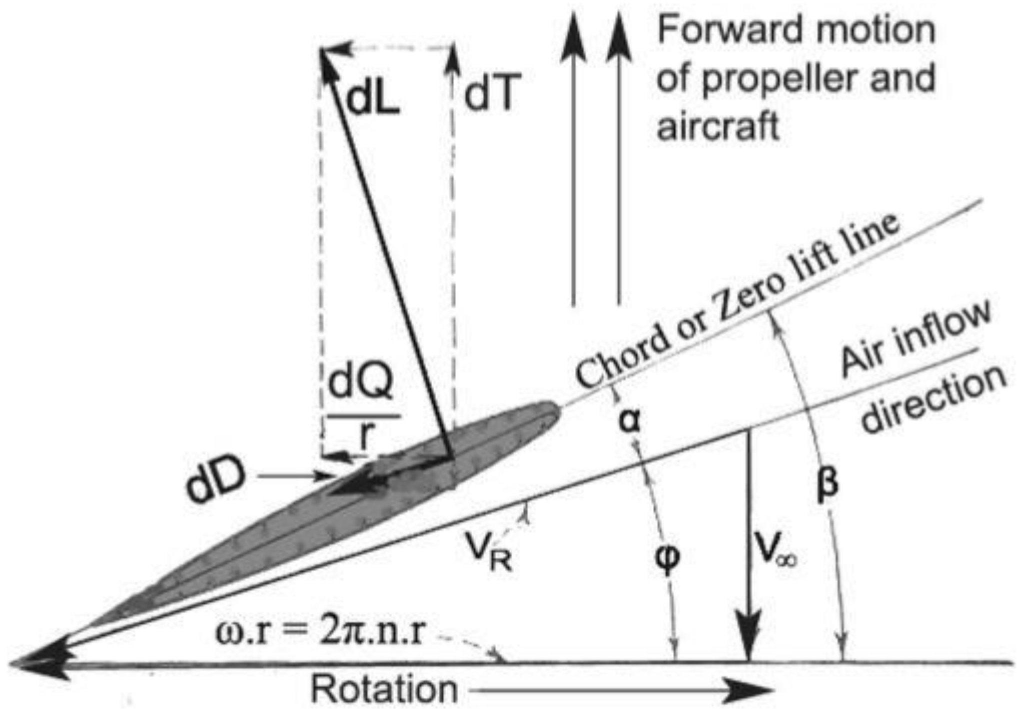
Blade Element Theory



Pitch , p = 2πr.tanβ

The difference between the *geometric pitch*, p , as defined above, and the *actual or effective pitch*, as the entire solid body of the blade move in unison, is called Slip

Angle of Attack, α ; blade setting angle, β ; effective pitch angle (flow angle), ϕ ; forward speed, V_∞,



The lift and the drag of a blade element are perpendicular and parallel to the relative wind direction coming on the blade element. These may be projected as forces : Tangential force (for Torque) and Thrust (axial force), in planes normal and parallel to the axis of rotation of the propeller respectively.

The main performance parameters thrust T, (produced by the propeller), torque, Q and power, P (required to be supplied to maintain operation at a given rpm, n and atmospheric air density, ρ), may be defined as follows,

T = ρ.n^2.D^4.CT

Q = ρ.n^2.D^5.CQ

P = ρ.n^3.D^5.CP

where, CT, CQ, CP are the thrust, torque and power coefficients of the propeller

The propeller efficiency is given by the usual output power to input power ratio, ηP= (T V∞) / P = (T V∞) / (2πnQ)

Thus, ηP= J.CT/ CP

Where, CP= 2.π.CQ

From equation it can be shown that for a constant power input and a constant efficiency, the thrust generated by the propeller is proportional to inverse of the velocity. This means that the thrust would, mathematically, go to infinity as the forward velocity nears zero. Conversely, efficiency approaches zero at near static condition, typical of aircraft take-off condition. These singularities do not happen in real operation, and the theoretical ‘possibilities’ are overruled by practical real flow situations.

DESIGNING THE PROPELLER

Ambient conditions at 5000m:-

Temp.- 255.69K

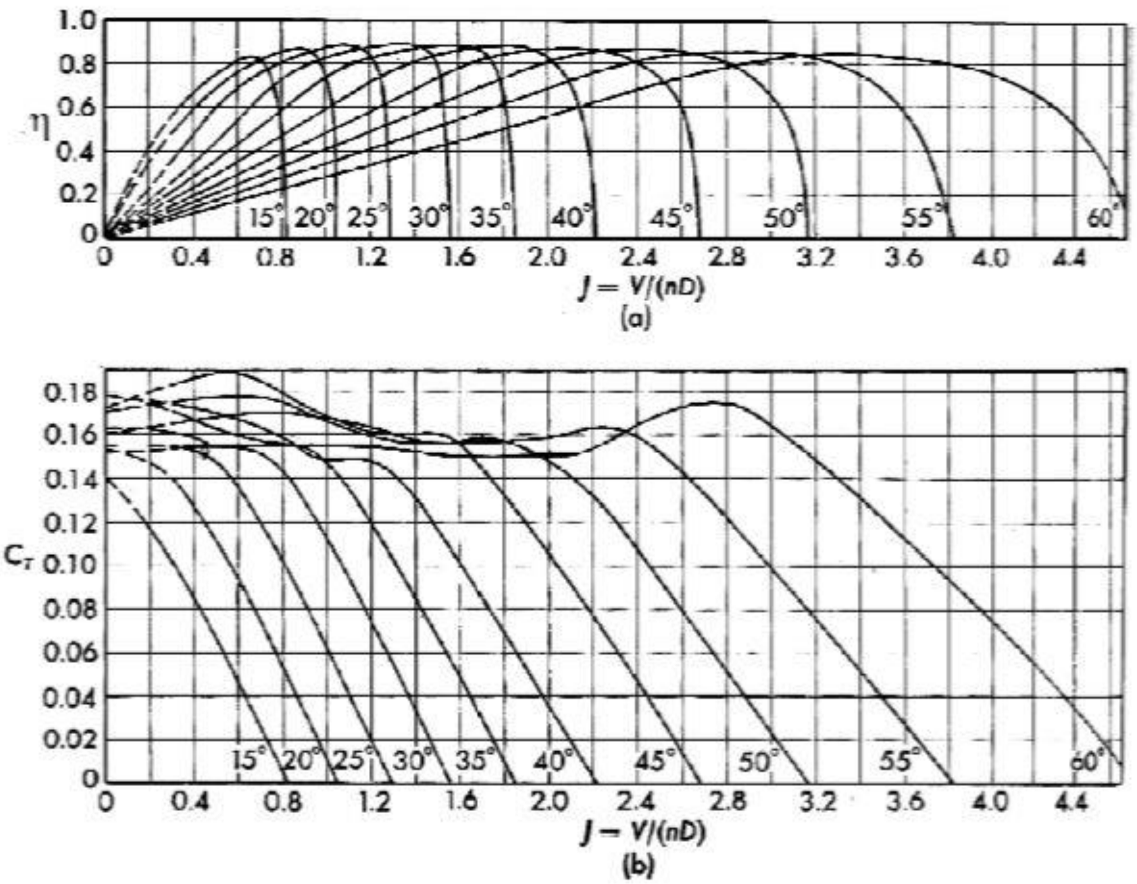
Pressure- $5.4*10^4$ Pa

Density- 0.736 kg/m^3

Dynamic viscosity- $1.628*10^{-5}$ Ns/m^2

The design point for the propeller is 0.75R. The Cp was then calculated and then an efficiency value was assumed. Then calculated the Ct from the Ct equation.

At last we calculated "*beta*" from the Ct – J plot



And then the efficiency was found out from the plot, if it matched with the assumed efficiency then stop otherwise assume different efiiciency

After iteration the efficiency was found out to be 0.81. We next calculated "phi" and the angle of attack.

Calculations:-

$J = V_{INF}/nd = 0.954$

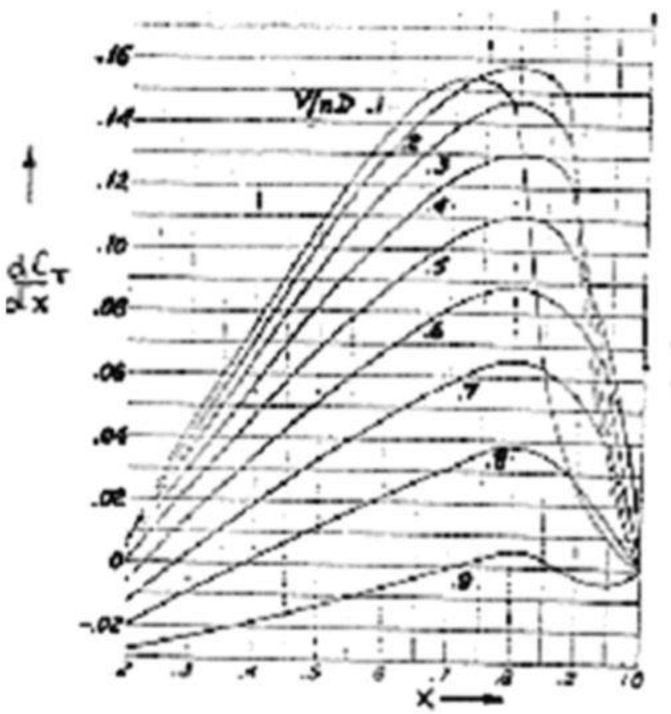
$C_p = \frac{P}{\rho * n^3 * d^5} = 0.073$

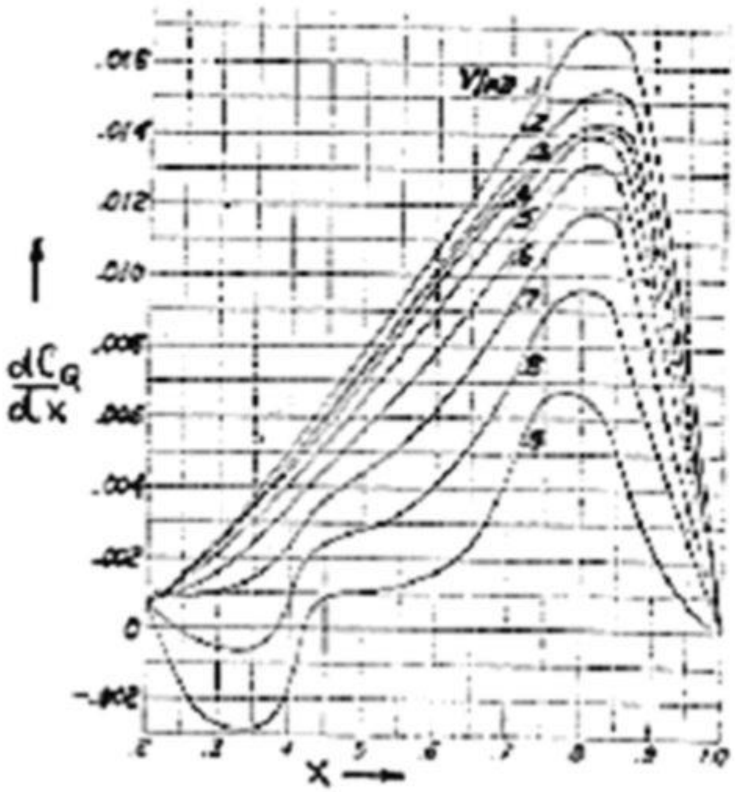
After iteration $\eta = 0.81$ at design point

$C_t = \eta C_p / J = 0.061$

$\beta = 23^0$ from C_T –J plot and $\alpha = 1^0$

We assumed the Thrust Torque distribution by taking the analogy from the actual Thrust Torque distribution as shown below





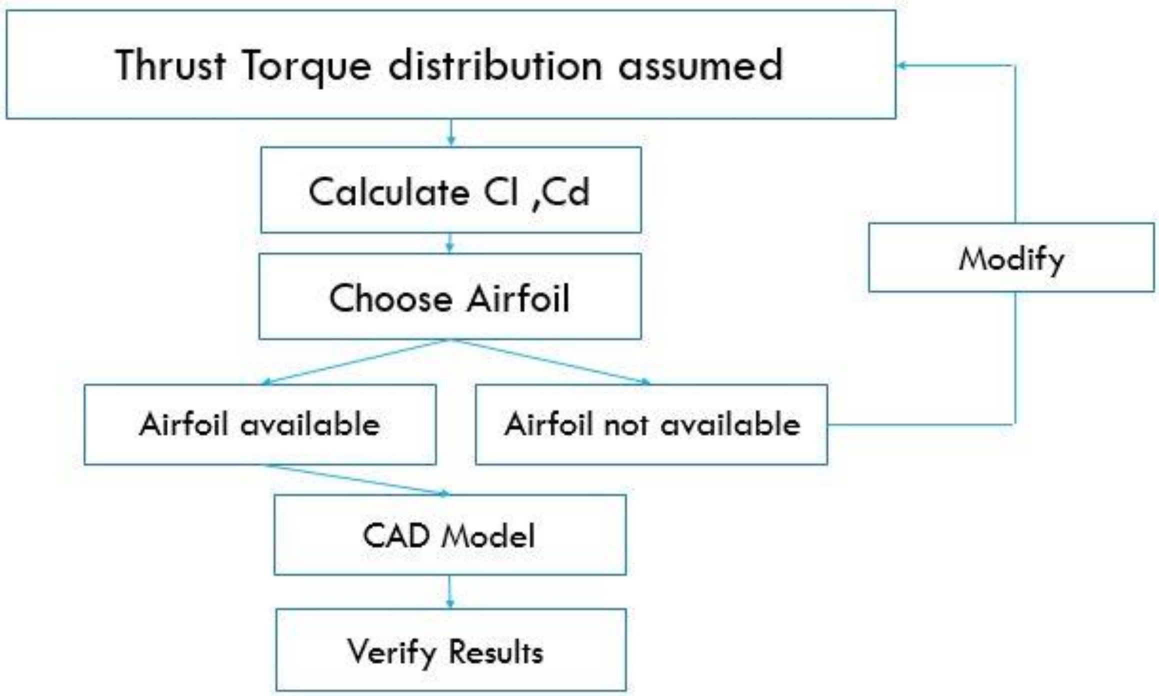
We assumed that the induced angle and the induced velocity to be zero.(Downwash theory not considered)

The efficiency at the design point is 0.81.

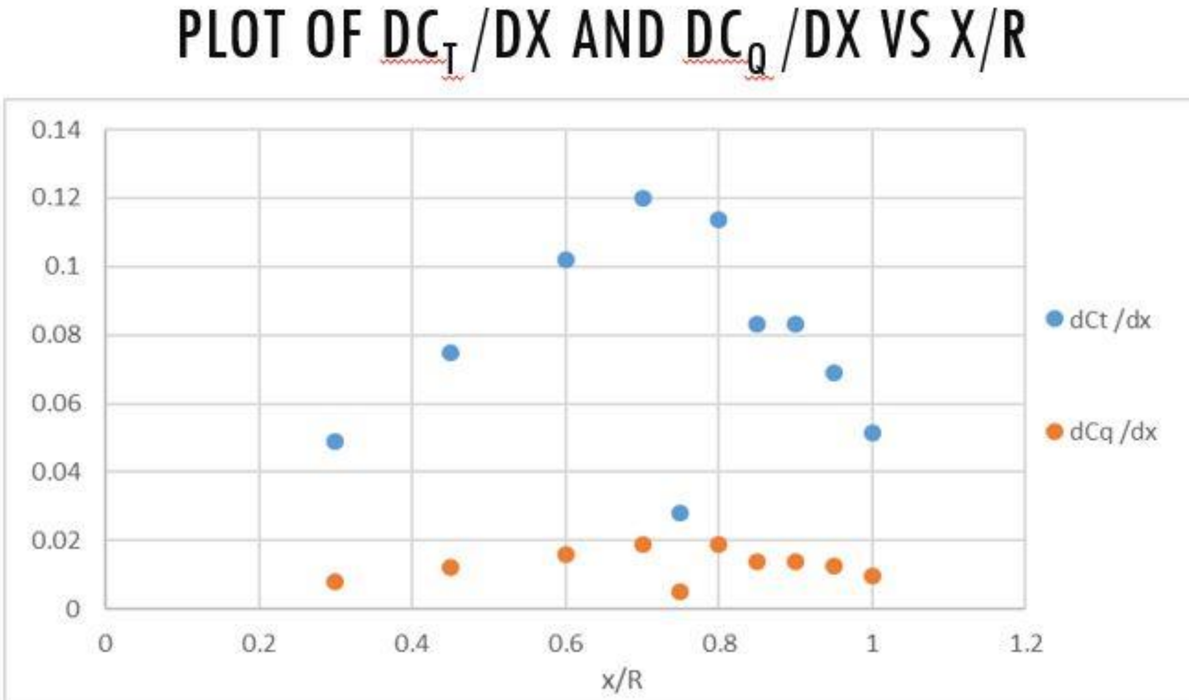
We also assumed that the chord is constant along the length

We partitioned the blade into 10 equal sections

The Entire process for selecting the airfoils at different sections is described in the following flow chart



The following plots for the Thrust and the Torque distribution were assumed



The following formulae's were used for calculating the lift and drag of the airfoils

$$L = T \cos \phi + \tau/r \sin \phi$$

$$D = \tau/r - T \sin \phi$$

$$C_l = \frac{L}{\frac{1}{2} * \rho * v^2 * c * 0.07}$$

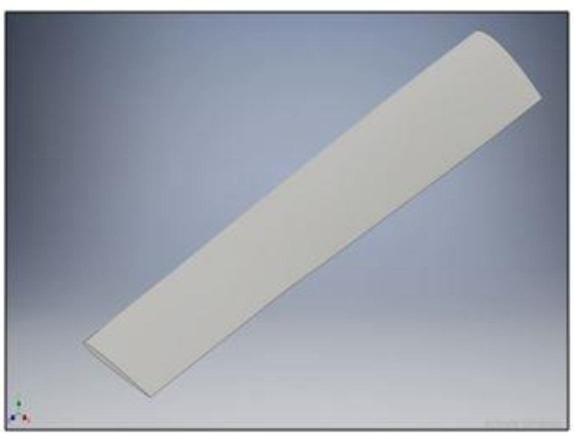
$$C_d = \frac{D}{\frac{1}{2} * \rho * v^2 * c * 0.07}$$

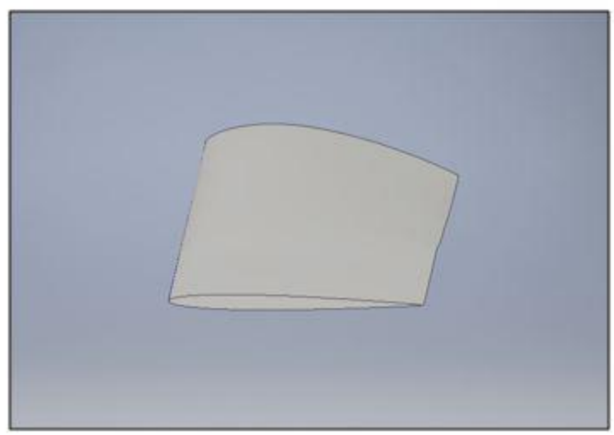
The following is the list of the airfoils used in the propeller blade

AEROFOIL SELECTION

x/R	α (degree	airfoil	C_l	C_d
0.3	7.2	NACA 641	1.28	0.008
0.45	6.5	NACA 442	1.03	0.0115
0.6	4	NACA 442	0.855	0.0113
0.7	2.5	NACA 441	0.759	0.0109
0.75	1	NACA 241	0.16	0.0076
0.8	1	NACA 241	0.56	0.0077
0.85	1	NACA 241	0.366	0.0083
0.9	0.9	NACA 141	0.3306	0.0074
0.95	0.9	NACA 140	0.25	0.01
1	0.9	NACA 000	0.1683	0.009

The final CAD models of the designed propeller





The following are the final results

	ENGINE SUPPLY	PROPELLER REQUIREMENT	ERROR
THRUST	1288.62 N	1340 N	3.8 %
TORQUE	474.724 Nm	400 Nm	15.74 %
MAX POWER	134226 W	113097.33 W	