

# AE 234/711 Aircraft Propulsion

## Tutorial 3 - Propellers

1. Express the propeller efficiency in terms of  $J$ .
2. Verify that the power coefficient ( $C_P$  and advance ratio ( $J$ ) are dimensionless.
3. Show that the optimum condition for propeller blade performance is

$$\left. \frac{V_a}{\omega r} \right|_{opt} = -\frac{C_D}{C_L} + \sqrt{\left(\frac{C_D}{C_L}\right)^2 + 1}$$

where the propeller efficiency takes the value

$$\eta_{prop}|_{opt} = \left( \left. \frac{V_a}{\omega r} \right|_{opt} \right)^2$$

4. A light utility aircraft employs a 180hp normally-aspirated piston engine, with a 6ft diameter propeller. Assuming the ideal actuator disk power is 75% of the above, ascertain the static thrust at SSL conditions, and also at flight speeds of 60 and 120 ft/s.

- $V_a = 0.0$  m/s: Thrust is 4.027 kN,  $w = 25.01$  m/s,  $V_e = 50.02$  m/s
- $V_a = 18.3$  m/s: Thrust is 3.069 kN,  $w = 14.53$  m/s,  $V_e = 47.34$  m/s
- $V_a = 36.6$  m/s: Thrust is 2.264 kN,  $w = 7.91$  m/s,  $V_e = 52.39$  m/s

5. Consider a twin-engine airplane that is powered by propeller engines. Let the flight speed be 120 ft/s. The propeller has a tip radius of  $R = 6$  ft. Consider the propeller blade airfoil to have the following characteristics:

$$c_l = a_o \alpha, \text{ where } a_o = 5.7 \text{ rad}^{-1}, \text{ and } c_{l_{max}} = 1.2$$

$$c_d = 0.01 + 0.02 (c_l - 0.15)^2, \text{ where we maintain } c_l \geq 0.15$$

Let the hub radius by  $r_h = 0.2R$ . If the propeller is rotating at an rpm of 2500, what should be the pitch angle variation along the propeller?

L/D optimum is 42.9,  $\alpha_{opt}$  is 0.15 rad or 8.6°

- $r/R = 0.2$ ,  $v_{th} = 96$  m/s,  $\phi = 20.9^\circ$ ,  $\beta = 29.5^\circ$
- $r/R = 0.5$ ,  $v_{th} = 239$  m/s,  $\phi = 8.7^\circ$ ,  $\beta = 17.3^\circ$
- $r/R = 0.7$ ,  $v_{th} = 335$  m/s,  $\phi = 6.2^\circ$ ,  $\beta = 14.8^\circ$
- $r/R = 1.0$ ,  $v_{th} = 479$  m/s,  $\phi = 4.4^\circ$ ,  $\beta = 13.0^\circ$