Boundary Layers, External flows

Reading

DGS sections 12.1 – 12.8.

Simple problems

Q.1. Sketch flow patterns that you would expect for flow past a cylinder at Reynolds numbers $\mathcal{R}e = 0.1, 15, 500, 5 \times 10^4, 5 \times 10^5$.

Q.2. A parachute of 10 m diameter when carrying a load W descends at a constant velocity of 5.5 m/s in atmospheric air at a temperature of 20 $degC$. Determine the load W if the drag coefficient for the parachute is 1.4.

Q.3. A wing of a small aeroplane is rectangular in plan having a span of 10 m and a chord of 1.2 m. In straight, level flight at 240 km/hr the lift force on the wing is 20 kN. If the lift/drag ratio is 10 calculate the coefficients of lift and drag.

Advanced problems :

Q.4. Electrical transmission towers are stationed at 500 m intervals and conducting cables 2.5 cm in diameter are slung between them. If a 60 km/hr wind is blowing across the wires, calculate the total force on a tower if each tower carries 20 such cables.

Will the wires start to sing, and if so, at what pitch?

($\rho_{air} = 1.2\text{kg/m}^3$, $\nu_{air} = 1.5 \times 10^{-5}$).

Q.5. A cylindrical chimney, 0.8 m in diameter and 30 m tall is subjected to a uniform 60 km/hr wind. If end effects and gusts may be neglected as a first approximation, estimate the bending moment exerted at the base of the chimney due to wind forces.

Q.6. A large ship may be approximated as a flat plate 200 m long submerged to a depth of 10 m. Below the waterline the hull is encrusted with barnacles which have an equivalent sand roughness height of 2 cm.

Calculate the power consumption of the vessel when it is travelling at 30 knots.

Estimate the maximum speed of the ship for the same power consumption after it has been cleaned and is hydraulically smooth.

Q.7. High altitude atmospheric measurements are often made using helium balloons, which provide a lift force per unit volume $(\rho_{air} - \rho_{He})g$. It is proposed to use a spherical balloon 4 m in diameter to lift a 20 kg instrument package. On release, the balloon quickly settles to a constant rise speed. Calculate this speed. (Take $\rho_{He} = 0.1626$ kg m^{-3}).

Q.8. A light aircraft has wings each of span 4.1 m and constant chord 1.2 m, designed using the NACA2412 airfoil (plots appended). The wings are set at an angle of 2° to the horizontal. If the aircraft is in level flight at sea level and is flying at 234 km/hr, calculate its total mass and the power necessary to sustain flight.

What is the minimum speed at which the plane can land? If the plane is equipped with flaps that increase the value of C_L by 0.4, how much slower can it land?

Q.9. The aircraft from the previous question is redesigned. The new wings have the same cross-section, but taper from 1.4 m to 1.0 m over their span. What is the new lift force?