NAME

Fluids-ID

Quiz 12. A prototype ship is 35 m long and designed to cruise at $11\ m/s$. Its drag force is to be estimated by a 1 m long model ship pulled in a tow tank. (a) Find the speed of model to satisfy Froude number similarity, (b) Estimate the ratio of drag force, $D_{model}/D_{prototype}$, by using drag coefficient similarity.

$$\text{Froude number,} \ Fr = V/\sqrt{gL}$$

$$\text{Drag coefficient,} \ C_D = \frac{D}{\frac{1}{2}\rho V^2 L^2}$$

where L is the length of ship, D is the drag force and V is the speed of ship.

Solution:

(a) Given the scale ratio $\alpha = \frac{L_{model}}{L_{prototype}} = \frac{1}{35}$, Froude scaling is

$$Fr = \frac{V_{model}}{\sqrt{gL_{model}}} = \frac{V_{prototype}}{\sqrt{gL_{prototype}}}$$

(+3 points)

$$V_{model} = V_{prototype}\sqrt{\frac{L_{model}}{L_{prototype}}} = V_{prototype} \times \sqrt{\alpha} = \frac{11}{\sqrt{35}} = 1.86\ m/s$$

(+2 points)

(b) Using the speed of model estimated with Froude number,

$$C_D = \frac{D_{model}}{\frac{1}{2}\rho V_{model}^2 L_{model}^2} = \frac{D_{prototype}}{\frac{1}{2}\rho V_{prototype}^2 L_{prototype}^2}$$

(+3 points)

$$\frac{D_{model}}{D_{prototype}} = \left(\frac{V_{model}}{V_{protptype}}\right)^2 \left(\frac{L_{model}}{L_{prototype}}\right)^2 = \left(\sqrt{\alpha}\right)^2 (\alpha)^2 = \left(\frac{1}{35}\right)^3 = \frac{1}{42900} = 2.331 \times 10^{-5}$$

(+2 points)