$3 - \frac{1}{2} = \frac{6-1}{2} = \frac{5}{2}$

The discharge ratio

$$\frac{Q_p}{Q_m} = \frac{l_p^3/t_p}{l_m^3/t_m} = \frac{l_p^3}{l_m^3}\cdot\frac{t_m}{t_p} = \frac{l_p^3}{l_m^3}\cdot\frac{t_m}{t_m\sqrt{\lambda_l}}$$

$$= \lambda_l^3 \cdot \frac{1}{\sqrt{\lambda_l}} = \lambda_l^{5/2}$$

$$\therefore \frac{Q_p}{Q_m} = \lambda_l^{5/2} \Rightarrow \boxed{Q_p = Q_m \lambda_l^{5/2}}$$

The Force ratio

$$\frac{F_p}{F_m} = \frac{\gamma_p h_p l_p^2}{\gamma_m h_m l_m^2} = \frac{\gamma_p l_p l_p^2}{\gamma_m l_m l_m^2} \Rightarrow$$

$$\frac{F_p}{F_m} = \lambda^3 \Rightarrow \boxed{F_p = F_m \lambda_l^3}$$

Ship Model Tests 80

The resistance is the sum of the wave resistance (Free-surface or Fr-phenomenon) and the viscous resistance (Re-Phenomenon).

If $Re_m = Re_p$ and $\rho_p = \rho_m$, $\mu_p = \mu_m$

$$\frac{V_m l_m \rho_m}{\mu_m} = \frac{V_p l_p \rho_p}{\mu_p} \Rightarrow V_m = V_p \frac{l_p}{l_m} > V_p$$

If $Fr_m = Fr_p$ and $g_m = g_p$

$$\frac{V_m^2}{g_m l_m} = \frac{V_p^2}{g_p l_p} \Rightarrow V_m = V_p \sqrt{\frac{l_m}{l_p}} < V_p$$

Hence Re = criterion give higher V_m than For V_p, where as Fr- criterion give lower V_m than For V_p.

The procedure is to model for the phenomenon that is most difficult to predict analytically and to account for the other resistance by analytical means. Since the wave resistance is the most difficult problem, the model is tested according to the Fr-criterion and Viscous resistance, is accounted For analytically.

Procedure :

$$F_{DT} = F_{DV} + F_{DW}$$

total drag   viscous drag   wave drag

hence

$$F_{DT_m} = F_{DV_m} + F_{DW_m}$$
$$F_{DT_p} = F_{DV_p} + F_{DW_p}$$

① First make model tests according to the Fr-criterion and the total model drag (F_{DT_m}) is measured.

② Estimate the Viscous drag (F_{DV_m}) by analytical Calculations

③ Calculate $F_{DW_m} = F_{DT_m} - F_{DV_m}$

④ Using Fr-criterion Calculate F_{DW_p} From F_{DW_m}
($F_{DW_p} = F_{DW_m} \lambda_e^3$)

⑤ Calculate F_{DV_p} analytically

⑥ Calculate $F_{DT_p} = F_{DV_p} + F_{DW_p}$

EX A (10 m) model of an ocean tanker (500 m) long is dragged through fresh water at (3 m/s) with a total measured resistance of (103 N). The surface drag cofficient (C_f) for model and prototype are (0.245) and (0.0147) respectively, the equation ($F = C_f A V^2$). The ~~Model~~ wetted surface area of the model is (20 m^2). Find the total drag on the tanker and the power required at the prope shaft assuming an efficiency of (90%) for the prope.

Sol

step ① $F_{ovm} = C_{f_m} A_m V_m^2 = 0.245 * 20 * 3 = \underline{\underline{44.1\ N}}$

step ② $F_{owm} = F_{OTm} - F_{ov_m} = 103 - 44.1 = \underline{\underline{58.9\ N}}$

using Fr. criterion

step ③ $F_{owp} = F_{ow_m} \lambda_l^3 = 58.9 * \left(\frac{500}{10}\right)^3 = \underline{\underline{7362500\ N}}$

or

$V_p = V_m \sqrt{\lambda_l} = 3\sqrt{\frac{500}{10}} \Rightarrow V_p = 21.2\ m/s$

$\frac{F_{owp}}{F_{owm}} = \frac{\rho_p\, l_p^2 V_p^2}{\rho_m\, l_m^2 V_m^2} = \frac{(500)^2 * (21.2)^2}{(10)^2 * (3)^2} \Rightarrow \underline{\underline{F_{owp} = 7362500\ N}}$

$\frac{A_p}{A_m} = \frac{l_p^2}{l_m^2} = \frac{(500)^2}{(10)^2} \Rightarrow A_p = 20 * 2500 = \underline{\underline{50000\ m^2}}$

step ④ $F_{ovp} = C_{f_p} A_p V_p^2 = 0.0147 * 50000 * (21.2)^2 = \underline{\underline{330338.4\ N}}$

step ⑤ $F_{OTp} = F_{owp} + F_{ovp} \Rightarrow$

$\therefore F_{OTp} = 7362500 + 330338.4 = \underline{\underline{7692838.4\ N}}$

$\text{shaft power} = \frac{\text{output power}}{\eta} = \frac{F_{OTp} * V_p}{\eta} = \frac{7692838.4 * 21.2}{0.9}$

$\therefore \text{shaft power} = 181{,}209{,}082.3\ J$

$= 181.209082\ MJ$ ans.

EX A V-notch weir is vertical plate with a notch of angle ϕ cut into the top of it and placed across an open channel. The liquid in the channel is backed up and forced to flow through the notch. The discharge Q is some function of the elevation H of upsteram liquid surface above the bottom of the notch. In addition, the discharge depends upon gravity and upon the velocity of approach V_o to the weir. Determine the form of discharge equation.

Sol

$$F(Q, H, g, V_o, \phi) = 0.0$$

EX The losses $\Delta h/l$ per unit length of pipe in turbulent flow through a smooth pipe depend upon velocity V, diameter D, gravity g, dynamic viscosity μ and the density ρ. With dimensional analysis. Determine the general form of the equation.

Sol

$$F\left(\frac{\Delta h}{l}, V, D, \rho, \mu, g\right) = 0.0$$

EX A fluid flow situation depend upon the velocity V, the density ρ, several linear dimensions l, l_1, l_2, pressure drop Δp, gravity g, viscosity μ, surface tension σ and the bulk modulus of elasticity k. Apply dimensional analysis to these variable to find a set of π parameters

Sol

$$F(V, \rho, l, l_1, l_2, \Delta p, g, \mu, \sigma, k) = 0.0$$