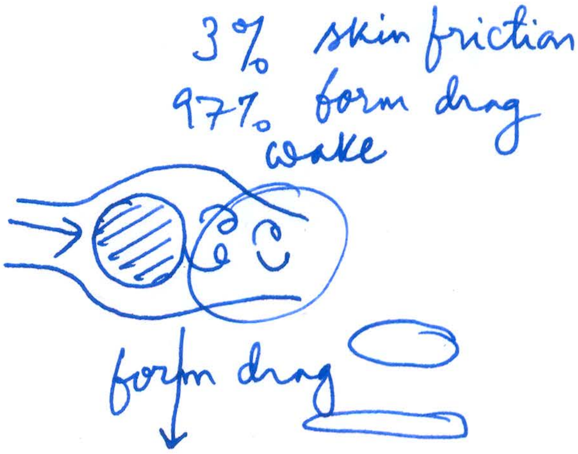
$P_a = \dot{m}\left(\omega + \frac{V_2^2}{2}\right)$

$P = (\dot{m} - \Delta\dot{m})\left(\omega + \frac{V_2^2}{2}\right)$

$\Delta\dot{m}$ = leakage flow

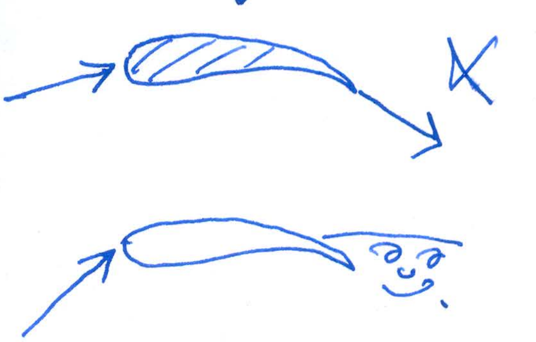
P_n = Net Power

= P − hydraulic losses



P_r = Rotor Power

= P_n − Exit losses



P_s = Power of shaft

= P_r − Mechanical losses

η_v = Volumetric efficiency

$$= \frac{(\dot{m} - \Delta\dot{m})\left(\omega + \frac{V_2^2}{2}\right)}{\dot{m}\left(\omega + \frac{V_2^2}{2}\right)} = \frac{P}{P_a} = \frac{\dot{m} - \Delta\dot{m}}{\dot{m}}$$

η_h = Hydraulic efficiency

$$= \frac{P_r}{P} = \frac{P_r}{P_n} \cdot \frac{P_n}{P} = \epsilon \cdot \frac{P_n}{P}$$

ϵ = utilisation factor

η_m = Mechanical efficiency

$$= \frac{P_s}{P_r}.$$

Overall efficiency

$$\eta_o = \frac{P_s}{P_a} = \frac{P_s}{P_r} \cdot \frac{P_r}{P} \cdot \frac{P}{P_a}$$

$$= \eta_m \times \eta_h \times \eta_v$$

Ex A flow rate of $3\ m^3/s$ of water is available at a height of 110m at a project site. Due to losses in the supply line, the head available at the inlet to the powerhouse is estimated to be only 101m of water. The leakage losses in the powerhouse are negligible. Mechanical losses account for 150 kW. Frictional losses in the rotor blades may be taken as 250 kW. The exit velocity of water from the turbine is 4.5 m/s. Calculate the hydraulic, mechanical and overall efficiency of the plant. Take $\rho = 1000\ kg/m^3$, $g = 9.81\ m/s^2$.

$Q = 3\ m^3/s$ $\quad H = 101\ m$

$P_a = P$

$P_a = \rho Q g H$

$= 1000 \times 3 \times 9.81 \times 101\ W$

$= 2972.4\ kW$

$P_n = P -$ hydraulic losses

$= (2972.4 - 250)\ kW$

$= 2722.4\ kW$

$\frac{1}{2}\dot{m}V_2^2$

$\frac{1}{2} \times 1000 \times 3 \times (4.5^2) / 1000\ kW$

$P_r = P_n - \frac{1}{2}\dot{m}V_2^2$

$= 2696\ kW$

$\eta_v = 100\%$

$\eta_h = \frac{P_r}{P} = \frac{2696}{2972.4} = 90.6$

$\eta_m = \frac{P_s}{P_r} = \frac{2546}{2696} = 94.4$

$P_s = P_r -$ mechanical losses

$= (2696 - 150)\ kW = 2546\ kW$

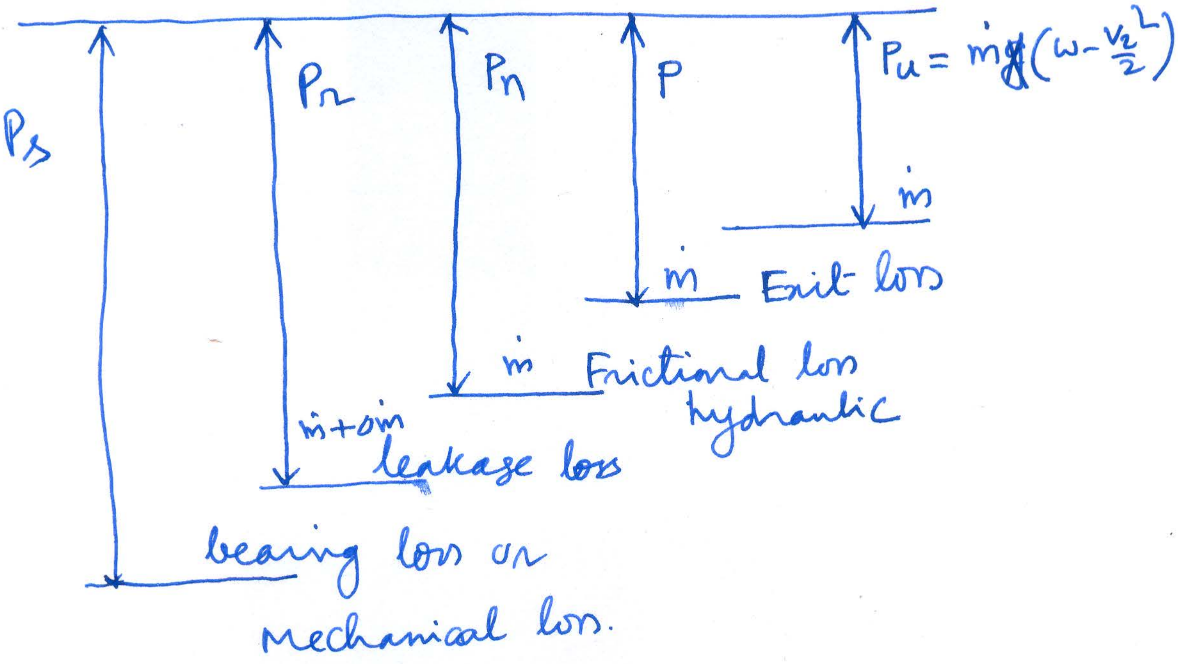
$\eta_o = 0.85$

$$-\dot{W} = \dot{m}\left(\frac{p_2}{\rho} + \frac{V_2^2}{2} + gz_2\right) - \dot{m}\left(\frac{p_1}{\rho} + \frac{V_1^2}{2} + gz_1\right)$$

$$|-\omega| = \left(\frac{p_2}{\rho} + \frac{V_2^2}{2} + gz_2\right) - \left(\frac{p_1}{\rho} + \frac{V_1^2}{2} + gz_1\right)$$

$$P = \rho Q g H$$

$$\omega = gH$$



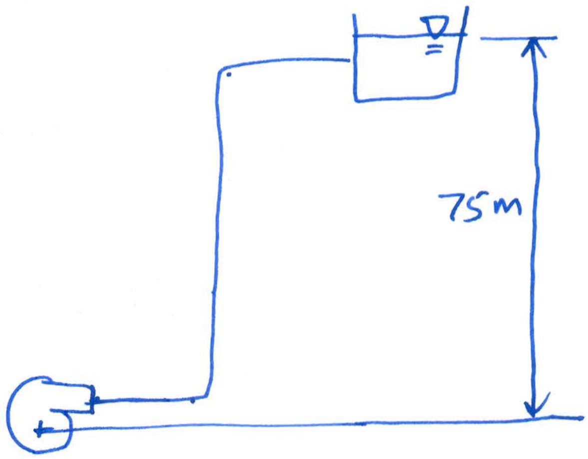
$$\eta_o = \frac{P}{P_s} = \frac{P}{P_n} \times \frac{P_n}{P_r} \times \frac{P_r}{P_s}$$

$$= \eta_h \times \eta_v \times \eta_m$$

25/7/17

Ex Water is required to be pumped to the overhead tank of a building of vertical height 75 m from the sump level. The total equivalent length of the delivery pipe is 80 m. The pipe diameter is 50 mm, its friction factor is 0.024. Determine the power required to pump water at a rate of 10 lps. The mechanical losses of the pump are equal to 0.2 kW. The hydraulic efficiency of the pump is 93.6%. Assume leakage and return flow losses as 0.2 lps. Also find η_m, η_v and η_o. Take $\rho = 1000\ kg/m^3$.

$g = 9.81\ m/s^2$



$$h_l = f \cdot \frac{l_e}{d} \cdot \frac{V_2^2}{2g}$$

V_2