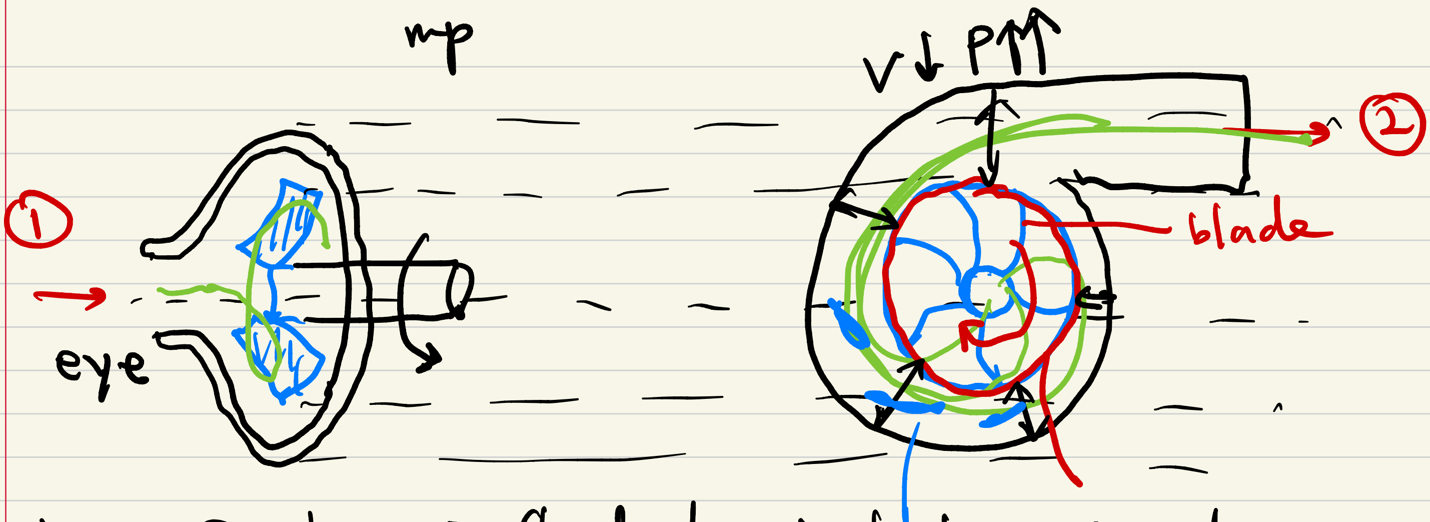


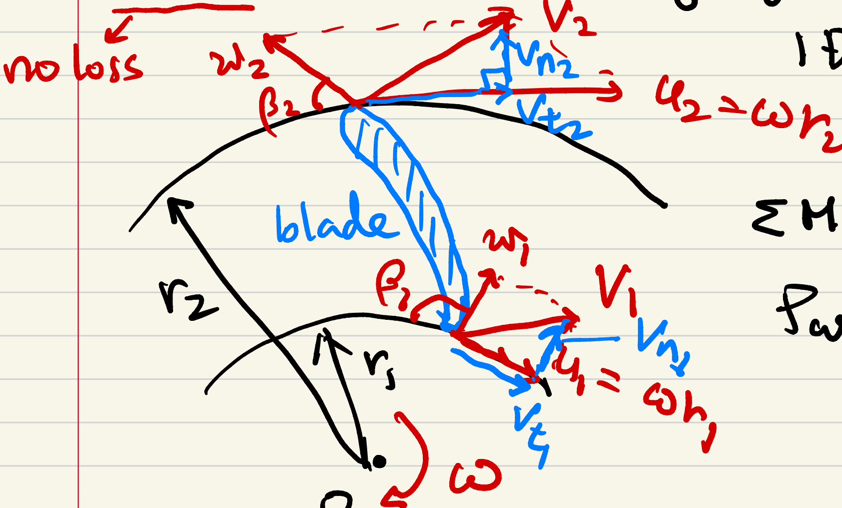
loss ① loss of fluid due to leakage in the impeller-casing clearance

② shock loss at the eye between inlet flow and blade entrance

③ friction loss in the blade passage

④ circulation loss at the exit of the blades

- "Euler" turbomachinery eqs.



1D flow

angular mtm conser.:

$$\Sigma M_o = T = \rho Q (r_2 V_{t_2} - r_1 V_{t_1})$$

$$P_w = \rho g H Q = \omega T \quad (\eta = 1)$$

$$= \rho Q (\omega r_2 V_{t_2} - \omega r_1 V_{t_1})$$

$$= \rho Q (u_2 V_{t_2} - u_1 V_{t_1})$$

$$\Rightarrow \boxed{H = \frac{P_w}{\rho g Q} = \frac{1}{g}(u_2 V_{t_2} - u_1 V_{t_1})}$$

not a ft of V_n.

$$V^2 = u^2 + w^2 - 2u\underbrace{w\cos\beta}_{= u - V_t}$$

$$\rightarrow uV_t = \frac{1}{2}(V^2 + u^2 - w^2)$$

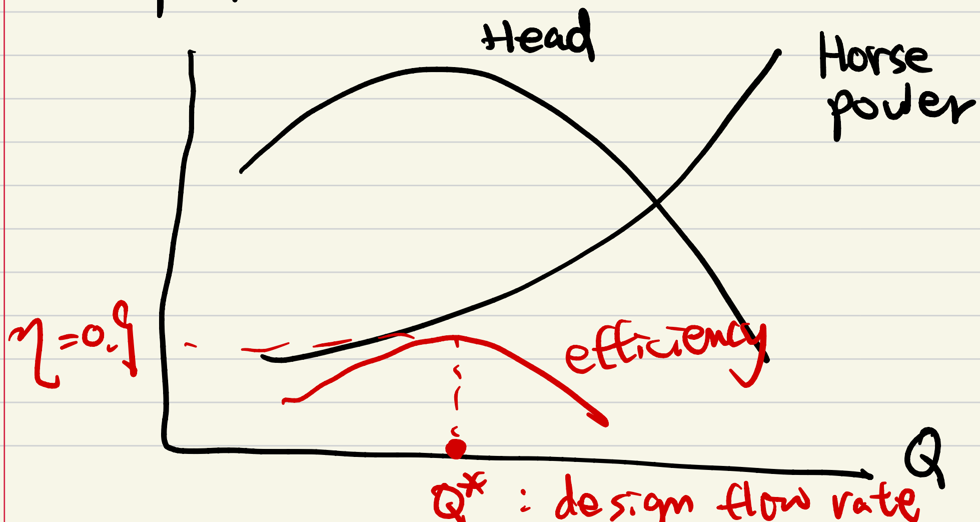
$$\Rightarrow \quad H = \frac{1}{2g}\left[(V_2^2 - V_1^2) + (u_2^2 - u_1^2) - (w_2^2 - w_1^2) \right]$$

$$= \left(\frac{p}{\rho g} + \frac{V^2}{2g} + z \right)_2 - \left(\frac{p}{\rho g} + \frac{V^2}{2g} + z \right)_1$$

$$\Rightarrow \quad \boxed{\frac{p}{\rho g} + z + \frac{w^2}{2g} - \frac{r^2 \omega^2}{2g} = \text{const}}$$

Bernoulli eq in rotating coord.

- Pump performance curves for constant shaft rotation speed

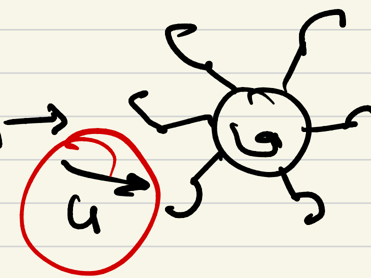


- Axial-flow pump

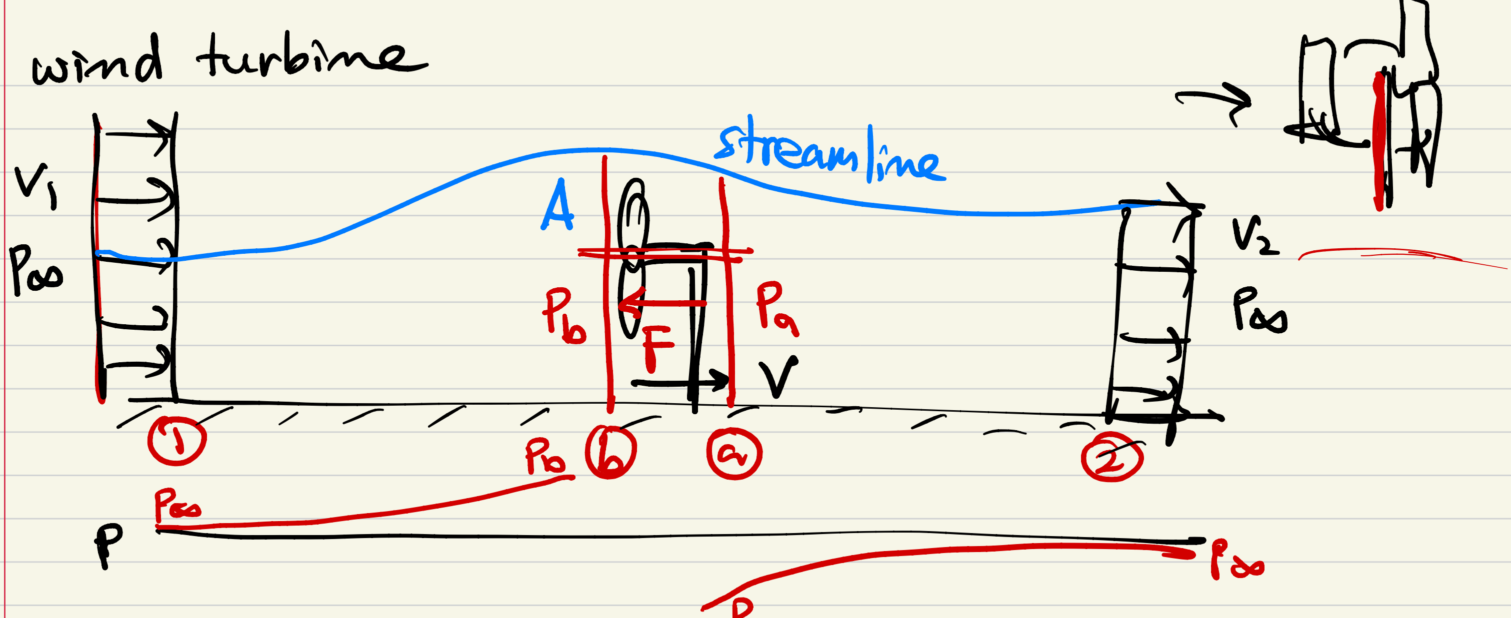
- Turbines

① reaction turbine : blade

② impulse 〃 : high-speed stream



- wind turbine



Idealized wind turbine theory

① - ② : $\Sigma F_x = -F = \dot{m}(V_2 - V_1)$ $\qquad V_a \doteq V_b = V$ ($\because$ A const)

ⓑ - ⓐ : $\Sigma F_x = -F + (P_b - P_a)A = \dot{m}(V_a - V_b) = 0$

$\rightarrow F = (P_b - P_a)A = \dot{m}(V_1 - V_2) = \rho A V (V_1 - V_2)$

Bernoulli eq : $P_\infty + \frac{1}{2}\rho V_1^2 = P_b + \frac{1}{2}\rho V^2$: ① — ⓑ

$P_a + \frac{1}{2}\rho V^2 = P_\infty + \frac{1}{2}\rho V_2^2$: ⓐ — ②

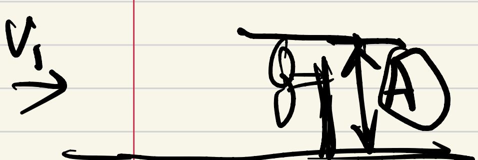
$\rightarrow P_b - P_a = \frac{1}{2}\rho(V_1^2 - V_2^2) = \rho V(V_1 - V_2)$

$\Rightarrow V = \frac{1}{2}(V_1 + V_2)$

Power $P = F \cdot V = \rho A V(V_1 - V_2)V = \frac{1}{4}\rho A(V_1^2 - V_2^2)(V_1 + V_2)$

Given V_1, max P ?

$\frac{\partial P}{\partial V_2} = 0 \Rightarrow V_2 = \frac{1}{3}V_1 \rightarrow P_{max} = \frac{8}{27}\rho A V_1^3$



$P_{available} = \frac{1}{2}\dot{m}V_1^2 = \frac{1}{2}\rho A V_1^3$

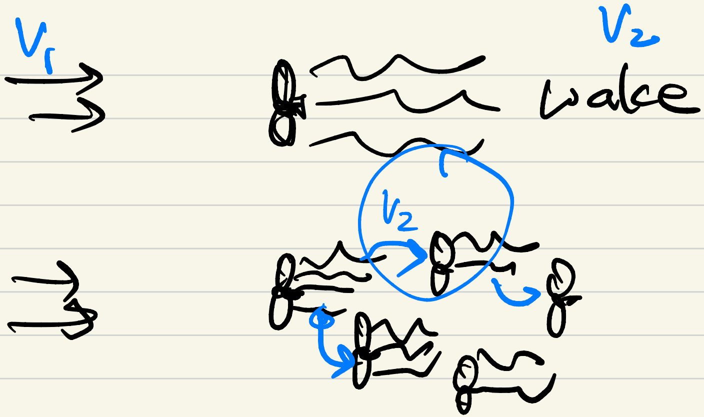
$(\dot{m} = \rho A V_1)$

$\neq \rho A V$

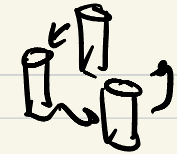
Power efficiency $C_p = \frac{P}{P_{avail}}$

(Betz number)

$$\boxed{C_{p\,max} = \frac{8/27}{1/2} = \frac{16}{27} = 0.593}$$



Wind farm

VAWT → 

$\boxed{\text{HAWT}}$ →