5/27 – Ch.11

6/1 부터 실시간 zoom으로 수업 : 주로의 commercial package에 관한 질의응답 위주

질문 – 실시간
eTL 녹여놓의로] → 답변 zoom 실시간

(6/3) – **연습문제 풀이 시간** ⟸

6/8 – commercial package

6/10 – " "

(6/11) 6:30pm – 9:30pm 기말시험] 종강

6/15, 6/17 수업 없음.

Ch. 11 Turbomachinery (터보기계)
Fluid machinery (유체기계)

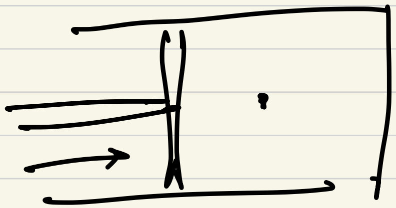
① pumps : those which add energy to fluid
② turbines : " " extract " from "

→ usually connected to a rotating shaft
↙ turbo machinery
(turbo: spin, whirl)

- working fluid is liquid → pump
  gas → fan : Δp↑ is small
  blower : Δp is up to 1atm.
  compressor : " above "

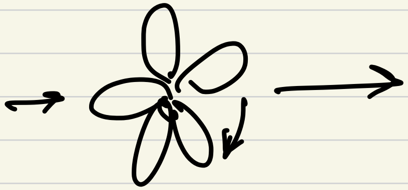
- Classification of pumps

① positive-displacement pump (PDP)



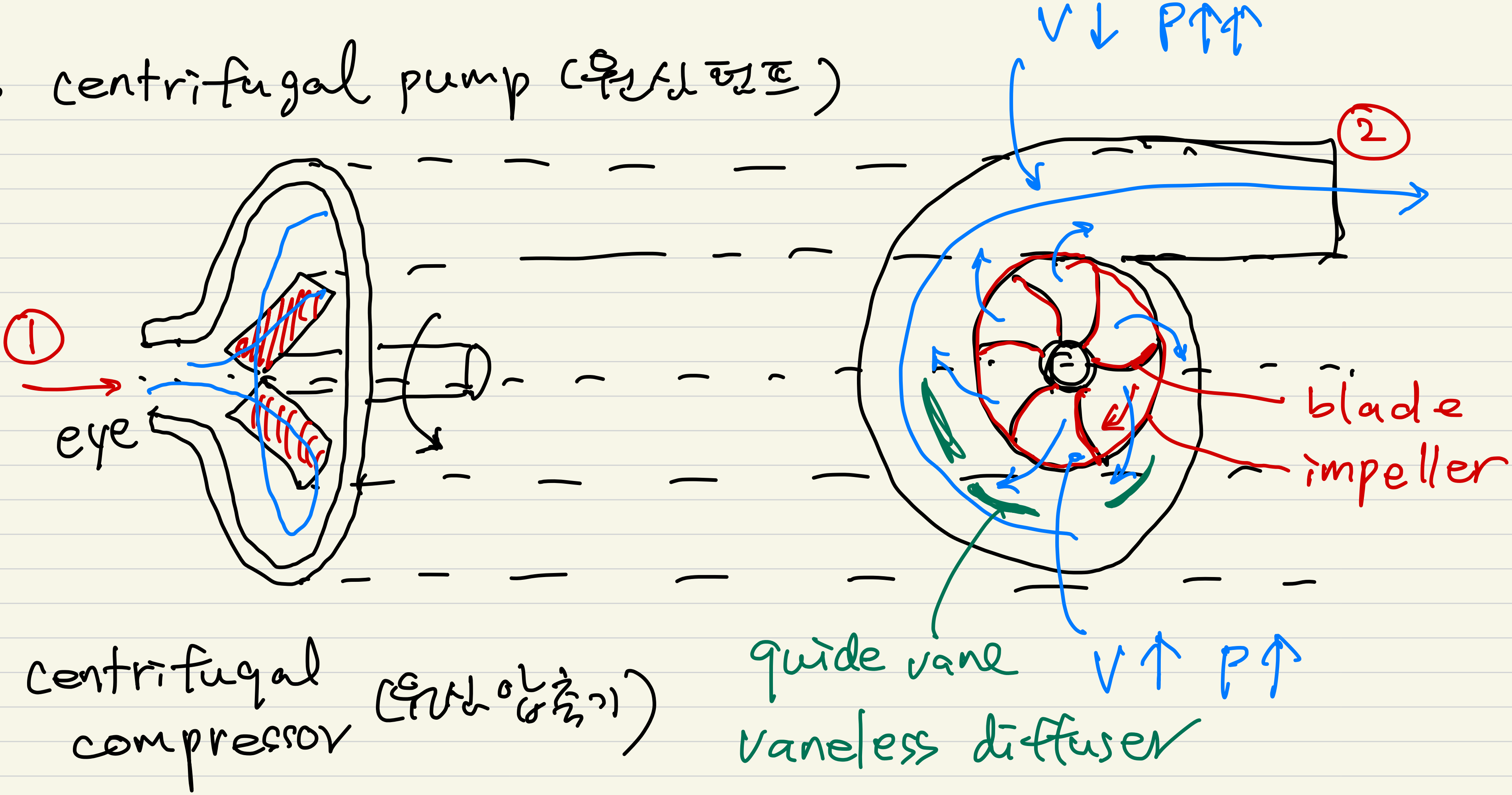
forces the fluid along one direction
by volume change → $\Delta p \uparrow$
effective in handling high ν fluid

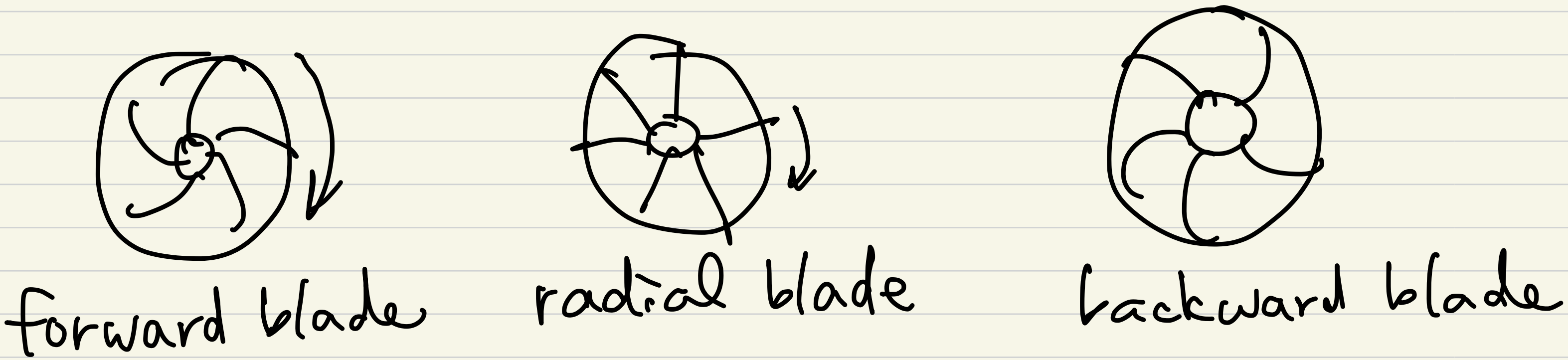
② dynamic pump : adds momentum to fluid by means of
fast moving blades or vanes or
certain special designs



no closed volume
higher flow rate
steady discharge

• centrifugal pump (원심펌프)





- Efficiency

Net head : $H \equiv \left(\frac{p}{\rho g} + \frac{V^2}{2g} + z\right)_2 - \left(\frac{p}{\rho g} + \frac{V^2}{2g} + z\right)_1$

$= h_s - h_f$

shaft loss

usually $V_2 \simeq V_1$, $z_2 - z_1 < 1\,m$ neglect

$\rightarrow H \simeq \frac{p_2 - p_1}{\rho g} = \frac{\Delta p}{\rho g}$

power delivered to fluid $P_w = \rho g H Q$ Q: discharge

(water horse power)

Power required to drive the pump

bhp $= \omega T$

(brake horse power) ω: shaft angular vel.

T: torque

Efficiency $\eta = \frac{P_w}{bhp} = \frac{\rho g H Q}{\omega T} < 1 \quad \sim 0.9$

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.

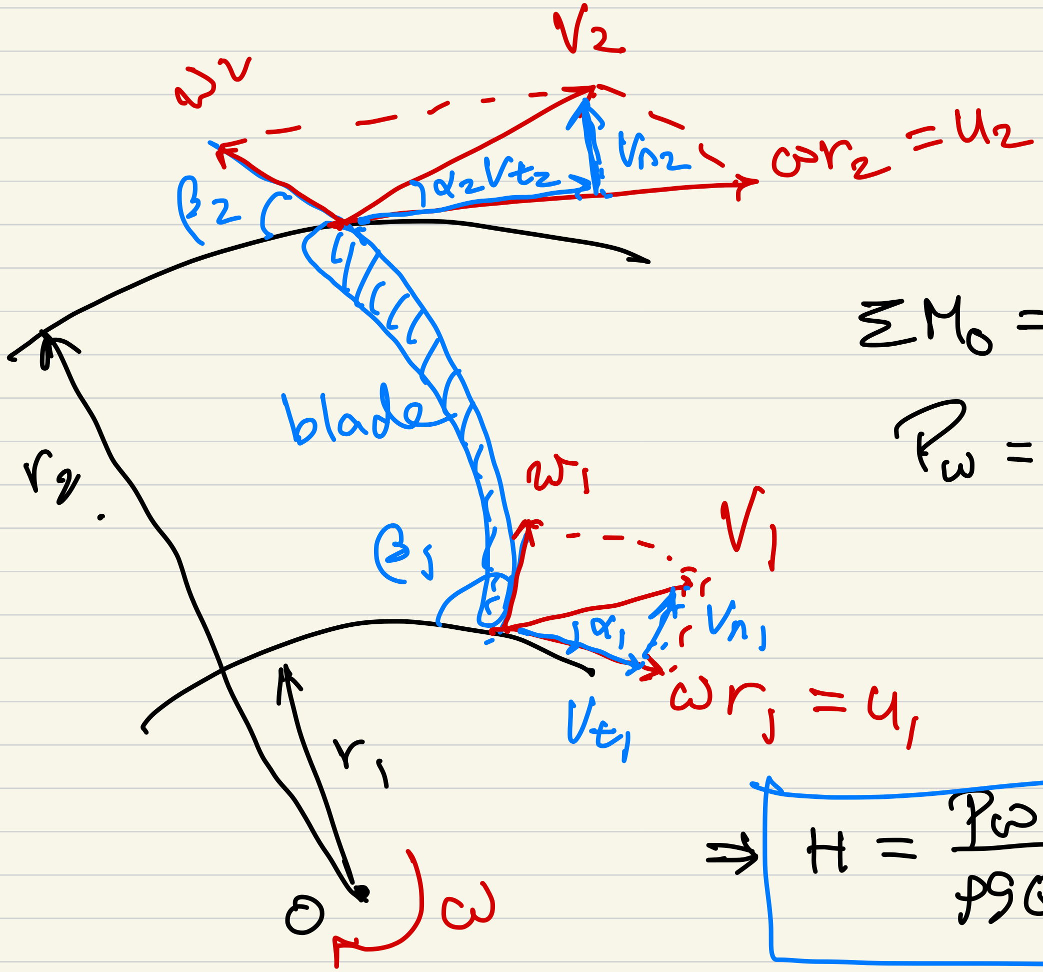
③ friction loss in the blade passage

④ circulation loss at the exit of the blades

• "Euler" turbomachine eqs.

~~friction~~

1-D flow



angular mtm cons :

$$\Sigma M_0 = T = \rho Q (r_2 V_{t_2} - r_1 V_{t_1})$$

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

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

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

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

↑ not ft. of V_n.

$$V^2 = u^2 + w^2 - 2uw\cos\beta$$

$$w\cos\beta = u - V_t$$

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

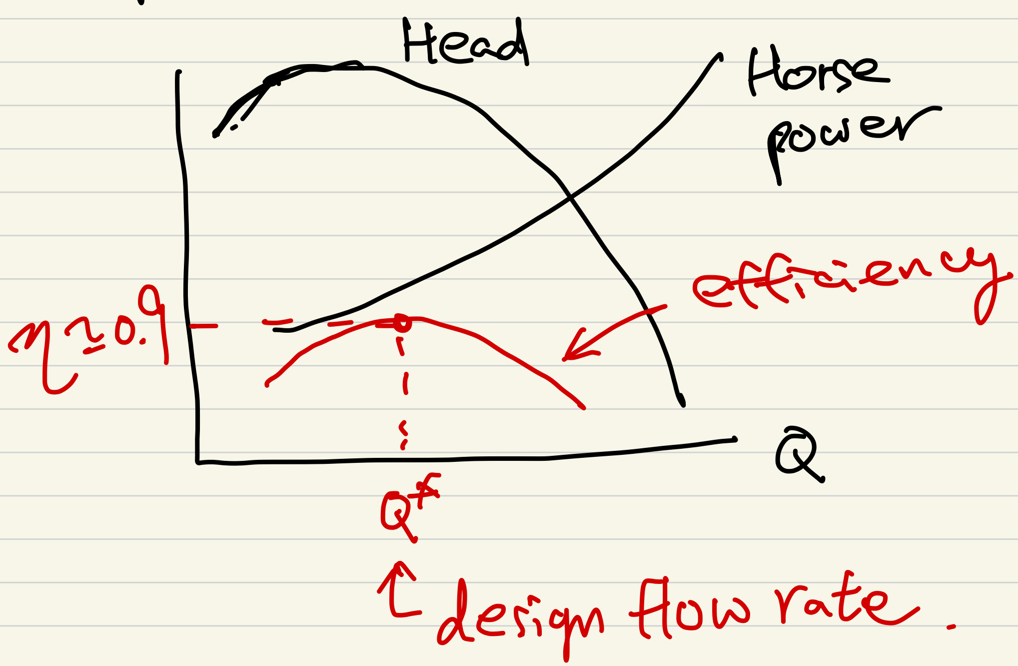
$$\Rightarrow H = \frac{1}{2g}\left[(V_2^2 - V_1^2) + (u_2^2 - u_1^2) - (w_2^2 - w_1^2) \right]$$

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

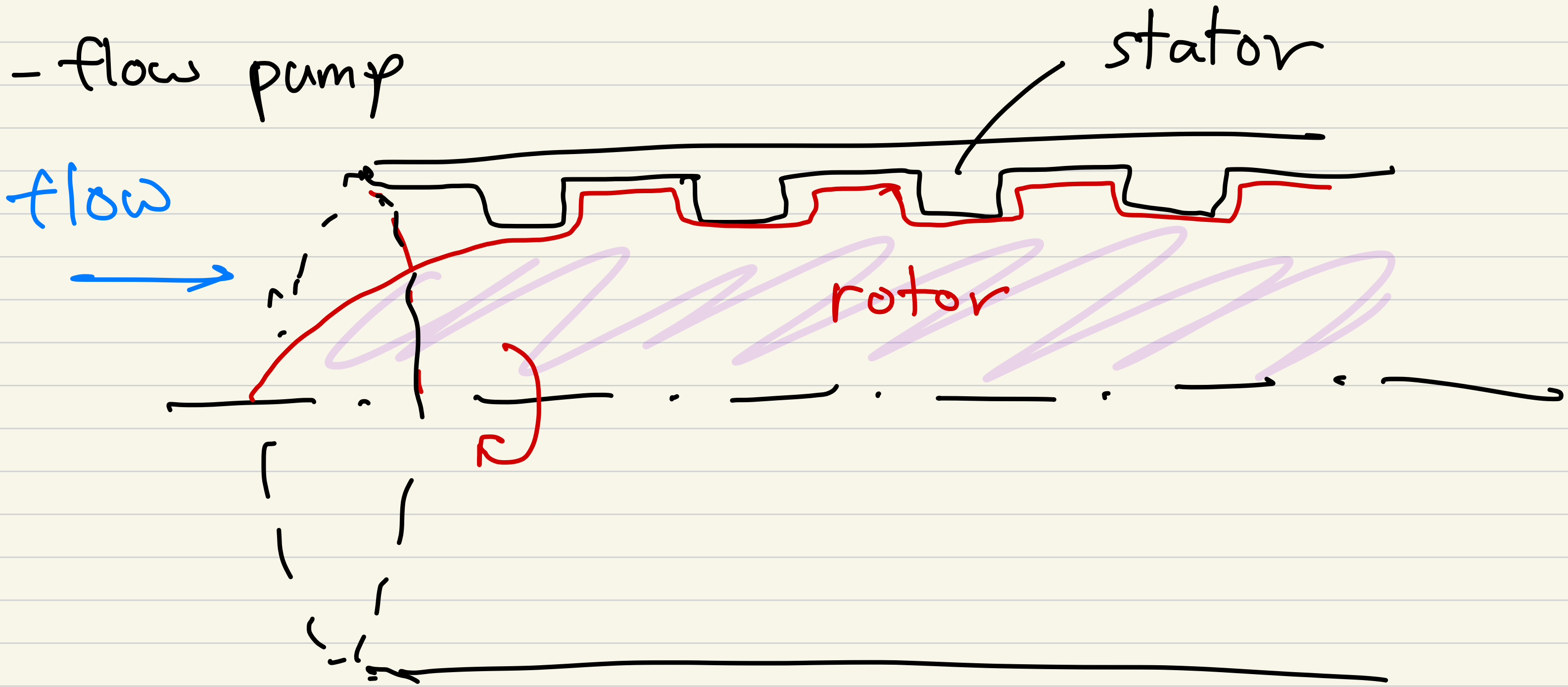
$$\Rightarrow \boxed{\frac{p}{\rho g} + z + \frac{w^2}{2g} - \frac{r^2\omega^2}{2g} = \text{const}}$$

Bernoulli eq. in rotating coord.

- Pump performance curves for const. shaft rotation speed



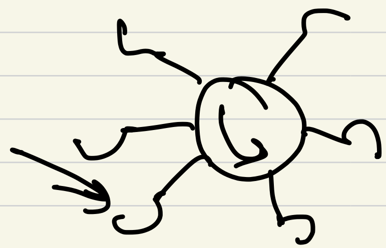
- Axial-flow pump



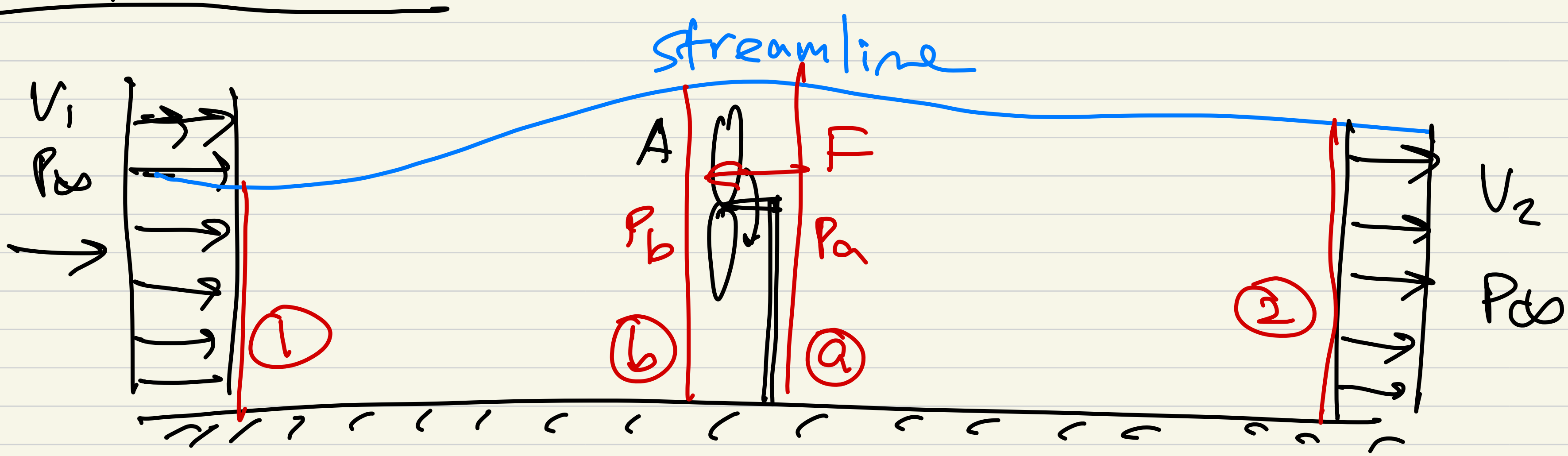
- Turbines

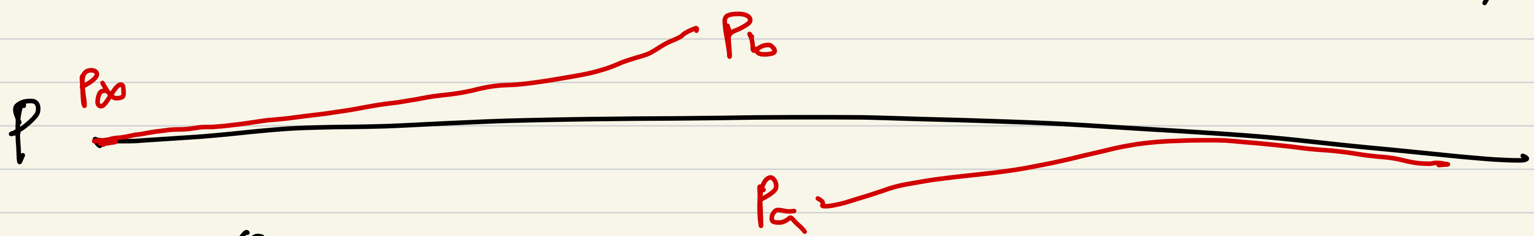
① reaction turbine : blade

② impulse " : high-speed stream



wind turbine





"Idealized" wind turbine theory

① - ② : $\sum F_x \simeq -F = \dot{m}(V_2 - V_1)$ $\qquad V_a \simeq V_b = V$

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

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

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

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

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

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

Given V_1, max $\mathbb{P}$

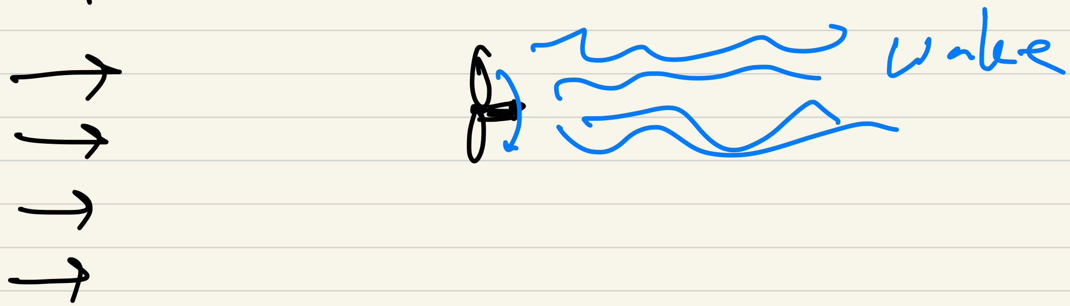
$$\frac{\partial \mathbb{P}}{\partial V_2} = 0 \rightarrow V_2 = \frac{1}{3}V_1 \rightarrow \mathbb{P}_{max} = \frac{8}{27}\rho A V_1^3$$

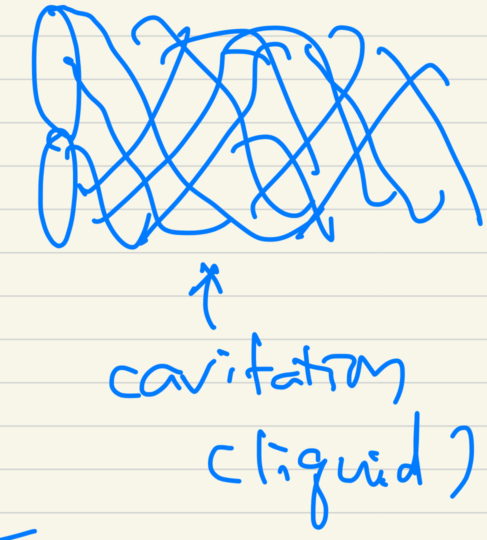
$$\mathbb{P}_{available} = \frac{1}{2}\dot{m} V_1^2 = \frac{1}{2}\rho A V_1^3$$

Power efficiency $c_p = \frac{\mathbb{P}}{\mathbb{P}_{avail}}$

$$c_{p_{max}} = \frac{8/27}{1/2} = \frac{16}{27} = 0.593$$ (Betz number)

top view





wind farm