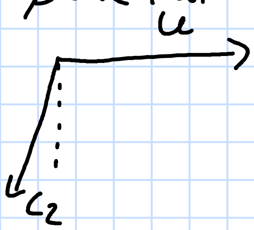
Energy conversions

Power:

$$P_{gr} = \rho Q g H_{gr}$$

Francis Turbine

$$P_R = \rho Q(u_1 c_{u1} - u_2 c_{u2})$$



Kaplan Turbine

$$P_R = \rho Q(u_1 c_{u1} - u_2 c_{u2})$$

$$U = u_1 = u_2$$

$$P_R = \rho Q U(c_{u1} - c_{u2})$$

Euler Turbomachine EQ

$$Power_{req} = \dot{m}(U_2 V_{\theta 2} - U_1 V_{\theta 1})$$

$$h = \frac{1}{g}(U_2 V_{\theta 2} - U_1 V_{\theta 2}$$

$Power_{req} > 0 \rightarrow$ Compressor

$Power_{req} < 0 \rightarrow$ Turbine

Pelton turbine

Power:

$$\Delta W = U w_1(1 - k\cos(\beta_2)) = U(c_1 - U)(1 - k\cos(\beta_2))$$

Runner Power:

$P_R = \rho Q U(c_{w1} - c_{w2})$ – Pelton

$P_R = \rho Q(u_1 c_{w1} - u_2 c_{w2})$ – General

Total available Power

$$P_n = \rho Q g H_n$$

Hydrolic efficiency

$$\eta_h = \frac{P_R}{P_N} = \frac{1}{gH_n}(u_1 c_{u1} - u_2 c_{u2})$$

Power of the Runner

$$P_R = \rho Q(u_1 c_{u2} - u_2 c_{u2})$$

Main Turbine equation

$$\eta_h H_n = \frac{1}{g}(u_1 c_{u_1} - u_2 c_{u2})$$

Total sum off losses

$$h_L = \frac{1}{2}(\zeta_1 c_1^2 + \zeta_2 c_2^2 + \zeta_2 c_2^2 + (1+\zeta_3) c_{1_3}^2 + E_1^2)$$

Total Sum of energy transfer

$$H_n = (1+\zeta_1)\frac{c_1^2}{2g} - \frac{c_2^2}{2g} + (1+\zeta_2)\frac{V_2^2}{2g} - \frac{V_1^2}{2g} + \frac{u_1^2}{2g} + \frac{u_2^2}{2g} + (1+\zeta_3)\frac{c_3^2}{2g} + \frac{\bar{E}_1^2}{2g}$$

$$\underline{c} = \frac{c}{\sqrt{2gH_n}} \qquad \underline{u} = \frac{u}{\sqrt{2gH_n}} \qquad \underline{V} = \frac{V}{\sqrt{2gH_n}}$$

Reduced main turbine equation

$$\eta = 2(\underline{u}_1 \underline{c}_{u1} - \underline{u}_2 \underline{c}_{u2})$$

Othrs:

$$\underline{h} = \frac{h_p}{H_n} \qquad \underline{Q} = \frac{Q}{\sqrt{2gH_n}} \qquad \underline{\omega} = \frac{\omega}{\sqrt{2gH_n}}$$

Speed Number

$$\frac{n_q}{89} = {}^*\underline{\Omega} = {}^*\underline{\omega}\sqrt{{}^*\underline{Q}}$$

Fluid Dynamics

Design of Pelton wheel

Absolute velocity from nozzle

$$C_1 = \sqrt{2gH_n}$$

$$\underline{C_1} = \frac{C_1}{\sqrt{2gH_n}} = 1$$

Circumferential speed

$$u_1 = \frac{C_{1u}}{2} = \frac{1}{2}\sqrt{2gH_n}$$

$$\underline{u_1} = \frac{u_1}{\sqrt{2gH_n}} = 0,5$$

Euler's Turbine equation

$$\eta_h = 2(\underline{u_1}\,\underline{C_{1u}} - \underline{u_2}\,\underline{C_{u2}})$$

In a perfect world:
with $\underline{C_{1u}} = 1$ $\quad C_{2u} = 0$

$$\eta_h = 2(0{,}5 \cdot 1 - 0{,}5 \cdot 0) = 1$$

we sett it to be:

$\eta = 0{,}96$

$0{,}99 \leq \underline{C_{1u}} \leq 0{,}995$

$\underline{u_1} = \frac{\eta}{2\underline{C_{1u}}} = \frac{0{,}96}{2 \cdot 1} = 0{,}48$

Diameter of water stream

$$d_s = \sqrt{\frac{4Q}{z\pi C_{1u}}}$$

z = number of nozzels
Q = flowrate
$C_{1u} = \sqrt{2gH_n}$

Ratio size bucket and nozzels

$$3{,}1 \leq \frac{B}{d_s} \leq 3{,}4$$

$B = 3{,}1\,d_s$	$z = 1$
$B = 3{,}2\,d_s$	$z = 2$
$B = 3{,}3\,d_s$	$z = 3\text{-}5$
$B > 3{,}3\,d_s$	$z = 6$

Runner diameter

$D = 10 \cdot d_s$	$H_n \leq 500m$
$D = 15 \cdot d_s$	$H_n = 1300m$

$D < 9{,}5 d_s$ must be unvoided

$D > 15\, d_s$ is veary high head pelton

Speed number

$$\underline{\Omega} = \underline{\omega}\sqrt{\underline{Q}\,Z}$$

$$\underline{Q} = \frac{\pi d_s^2}{4}\,\underline{c}_{1u}$$

$$\underline{\omega} = \frac{\omega}{\sqrt{2gH_n}}$$

with $\underline{c}_{1u}=1$, $\underline{u}_1=0{,}5$:

$$\underline{\Omega} = \frac{d_s}{D}\sqrt{\frac{\pi Z}{4}}$$

$$0{,}09 \leq \underline{\Omega} \leq 0{,}22$$

Dependency C_v

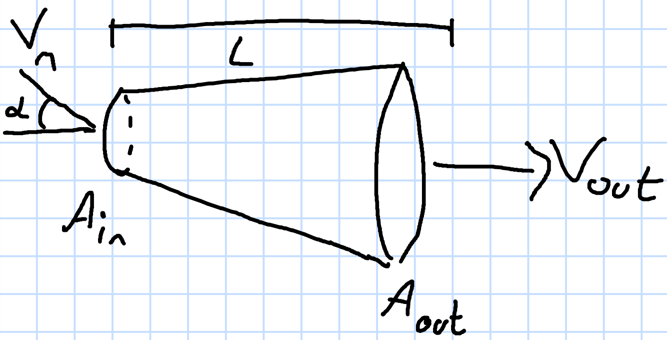
$$Q = \frac{\dot{m}}{\rho}$$

$$C_v = \frac{Q}{A\sqrt{2(p_{in}-p_{out})/\rho}}$$

$$C_v = \frac{\dot{m}}{A\rho\sqrt{2(p_{in}-p_{out})}}$$

Basics

Contol Volume



Extensive propertis:

Depend on system size or amount of material

ex: mass, energy

Intensive propertis

Not

ex: density, temp,

Change of ϕ of fluid dV

$$d\phi = \frac{\partial\phi}{\partial t}dt + \frac{\partial\phi}{\partial x_1}dx_1 + \frac{\partial\phi}{\partial x_2}dx_2 + \frac{\partial\phi}{\partial x_3}dx_3$$

$$dx_1 = V_1\,dt$$

$$\frac{d\phi}{dt} = \frac{\partial\phi}{\partial t}dt + \frac{\partial\phi}{\partial x_1}V_1 + \frac{\partial\phi}{\partial x_2}V_2 + \frac{\partial\phi}{\partial x_3}V_3$$

$$= \frac{d\phi}{dt} + (V\cdot\nabla)\phi$$

$$= \frac{\partial\phi}{\partial t} + \frac{\partial\phi}{\partial x_i}V_i$$

Fluid Dynamics:

Density :

$$\frac{d\rho}{dt} = \frac{\partial \rho}{dt}\Big|_p \frac{dT}{dt} + \frac{\partial \rho}{dt}\Big|_T \frac{dp}{dt}$$

$$\frac{dT}{dt} = \frac{E_{tot}}{m C_v} - \frac{\Sigma \dot{m}}{m}\left(T - T_{ref}\right)$$

$$\frac{dp}{dt} = \beta\left(\frac{\Sigma \dot{m}}{M} - \frac{1}{V}\frac{dV}{dt} - \frac{\alpha_T}{\rho}\frac{dT}{dt}\right)$$