Unit - 1

Open channel flow.

Difference between open channel ~~folow~~ pipes flow.

Open channel flow	Pine channel flow.
* The total energy is due to velocity & Position heads	* The total energy is due to velocity, pressure & position head.
* The flow has a free surface	* There is no free surface flow.
* Flow takes place due to the components of gravity force in the direction of flow	* The flow is due to Pressure
* ~~Cumber~~ computation is cumbersome due to non-uniform cross section	* computation is simple due to uniform cross section & even surface
* The hydrolic gradients coinsides with the free surface	* The hydraulic gradient is a function of pressure head and position head.
* The force is due to surface tension is negligible	* Force due to surface tension is dominent

Type of channels:

→ The channels are classified based on shape boundary characteristics crossection & formation.

Based on shape:

→ The channels are classified into rectangular triangular, trapezodal, circular, parabolic, wide rectangular, irregular & compound.

→ From this channels the rectangular, triangular, trapezodal & circular are more important.

Based on boundary character:

* Rigid or mobile boundary

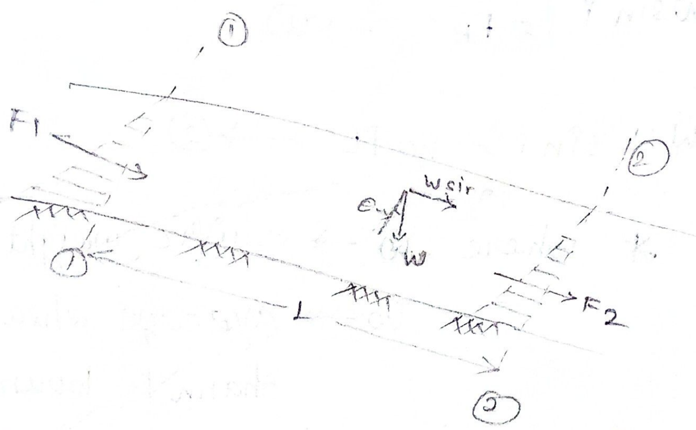
Based on cross section

* Prismatic
* Non-prismatic

Based on formation

* Man-made
* Natural

Chezy's formula for discharge :



- The longitudinal open channel with study & uniform flow of water
- The section divided into 1-1 , 2-2
- where , L = distance between two sections.
- F_1 & F_2 = Force due to water pressure in both sections.
- where wsin i = component weight of water b/w the section.
- where i = inclination of ubiet
- where A = wetted cross-section area of channel.
- F_R = A ~~po~~ friction resistance by the side of channels.
- As the flow is study and uniform the mass of the fluid is equilibrium.

$w \sin i = F_R \rightarrow (1)$

$WAL \sin i = \tau_0 PL \longrightarrow (2)$

* where $w \rightarrow$ specific weight of water
  $\tau_0 \rightarrow$ average shear stress at channel boundary
  $P \rightarrow$ wetted perimeter of the channel.

* The shear stress varies with square of velocity

$$\boxed{\tau_0 = f V^2}$$

$$WAL \sin i = \tau_0 PL$$

$$WAL \sin i = f V^2 PL$$

$$\boxed{V^2 = \frac{WAL \sin i}{f PL}}$$

$$V = \sqrt{\frac{WA\cancel{L} \sin i}{f P\cancel{L}}}$$

$$= \sqrt{\frac{WA \sin i}{f P}} \quad \left[\because C = \sqrt{\frac{w}{f}} \quad m = \sqrt{\frac{A}{P}}\right]$$

$$V = cm\sqrt{\sin i} \quad [\sin i = \tan i = i]$$

$$\boxed{V = mc\sqrt{i}}$$

where, c = chezy's constant

$Q = AV$

$\boxed{Q = A\, m C\sqrt{i}}$ $\boxed{Q = A C\sqrt{mi}}$

* There are various embrical formulas are for prepered for chezy's formula.

- Bazine's formula
- Kutter's formula
- Manning's formula.

Manning's formula:

↳ The simplified chezy's constant from manning's formula

$$\boxed{C = \frac{1}{N} m^{(1/6)}}$$

where, N = manning's constant.

Manning's formula for discharge:

$$Q = A\left(\frac{1}{n} m^{2/3}\, i^{1/2}\right)$$

The most economical trapezodal section

b = base width
z = slope (wetted slope
y = depth
Q = discharge.

Area, $A = (b + zy)y$
base width, $b = \left[\frac{A}{y} - \frac{z}{y}\right]$
wetted perimeter, $P = b + 2y\sqrt{z^2+1}$
$m = \frac{y}{2}$

Trapezoidal section:

$$A = (b + zy)\,y$$

$$b = \left(\frac{A}{y} - zy\right)$$

$$P = b + 2y\sqrt{z^2+1}$$

$$m = y/2 \text{ (or) } \frac{A}{P}$$

$$Q = Ac\sqrt{mi}$$

$$C = \frac{1}{N} m^{1/6}$$

$$\frac{b + 2zy}{2} = y\sqrt{z^2+1}$$

$$\cancel{\frac{b + 2nd}{2} = y\sqrt{n^2+1}}$$

Dimensions:

b = base width

y = depth

z = side slope

i = Bed slope

Q = discharge

C = chezy's constant

N = Manning.

1. A power channel of trapezoidal section has to be excavated through hard clay atleast cost determine the dimensions of the trapezoidal channel which has to carry a discharge of $14\ m^3/s$ and bed slope of the channel is $1/2500$ and side slope of the channel is $1/\sqrt{3}$. Then take the Mannings constant has 0.02

Given data :

$$Q = 14\, m^3/s$$

$$i = \frac{1}{2500}$$

$$I = \frac{1}{\sqrt{3}}$$

$$N = 0.02$$

Soln :

$$\boxed{\frac{b + 2Iy}{2} = y\sqrt{I^2+1}}$$

$$\frac{b + 2\left(\frac{1}{\sqrt{3}}\right)y}{2} = y\sqrt{\left(\frac{1}{\sqrt{3}}\right)^2+1}$$

$$\frac{b}{2} + \frac{\cancel{2}\frac{1}{\sqrt{3}}y}{\cancel{2}} = y\sqrt{1/3+1}$$

$$\frac{b}{2} + \frac{1}{\sqrt{3}}y = y\sqrt{\frac{1}{3}+1}$$

$$\frac{b}{2} + \frac{1}{\sqrt{3}}y = y\sqrt{\frac{4}{3}}$$

$$\frac{b}{2} + \frac{1}{\sqrt{3}}y = \frac{2}{\sqrt{3}}y$$

$$\frac{b}{2} = \frac{2}{\sqrt{3}}y - \frac{1}{\sqrt{3}}y$$

$$\frac{b}{2} = \frac{1}{\sqrt{3}}y$$

$$\boxed{b = \frac{2}{\sqrt{3}}y}$$

$$\boxed{A = (b + Iy)y}$$

$$A = \left[\frac{2}{\sqrt{3}}y + \frac{1}{\sqrt{3}}y\right]y$$

$$A = \left[\frac{3}{\sqrt{3}}y\right]y$$

$$A = \frac{3}{\sqrt{3}}y^2$$

$$A = \frac{\sqrt{3}\times\sqrt{3}}{\cancel{\sqrt{3}}} y^2$$

$$\boxed{A = \sqrt{3}\, y^2}$$

$c = \frac{1}{N} m^{1/6}$

$m = y/2$

$$\boxed{Q = A c \sqrt{m i}}$$

$$\boxed{c = \frac{1}{N} m^{1/6}}$$

$$Q = A \frac{1}{N} m^{1/6} \sqrt{m i}$$

$\frac{1}{6} + \frac{1}{2} = \frac{2+6}{12} = \frac{2}{3}$

$$Q = A \frac{1}{N} m^{1/6} m^{1/2} \sqrt{i}$$

$$Q = A \frac{1}{N} m^{2/3} \sqrt{i}$$

$$14 = \sqrt{3} y^2 \frac{1}{0.02} \left(\frac{y}{2}\right)^{2/3} \sqrt{i}$$

$$14 = \sqrt{3} y^2 \frac{1}{0.02} \left(\frac{y}{2}\right)^{2/3} \sqrt{\frac{1}{2500}}$$

$$14 = \sqrt{3} y^2 \frac{1}{\cancel{0.02}} \left(\frac{y}{2}\right)^{2/3} (\cancel{0.02})$$

$2 + \frac{2}{3}$

$\frac{6+2}{3}$

$$14 = \frac{\sqrt{3}}{1.58} y^{8/3}$$

1.58

$$y^{8/3} = \frac{14 \times 1.58}{\sqrt{3}}$$

$$y = \left(\frac{14 \times 1.58}{\sqrt{3}}\right)^{3/8}$$

$$y = 2.59 \text{ m}$$

3 m

$$\boxed{y = 2.59 \text{ m}}$$

$$\boxed{b = \frac{2}{\sqrt{3}} y}$$

$$= \frac{2}{\sqrt{3}} (2.59)$$

$$\boxed{b = 2.99 \text{ m}}$$

2. A trapezoidal channel has a side slope of 1/2 and bed slope 1 in 1500 the area of a section is $40 m^2$. Find the dimensions of the most economical section & also determine the discharge of the trapezoidal channel take the chezy's constant 60.

Given data:

$$z = \frac{1}{2}$$

$$i = \frac{1}{1500}$$

$$A = 40 m^2$$

$$C = 60$$

Soln:

$$\frac{b + 2zy}{2} = y\sqrt{z^2 + 1}$$

$$\frac{b + 2\left(\frac{1}{2}\right)y}{2} = y\sqrt{\left(\frac{1}{2}\right)^2 + 1}$$

$$\frac{b + y}{2} = y\sqrt{\frac{1}{4} + \frac{1}{1}}$$

$$\frac{b + y}{2} = y\sqrt{\frac{5}{4}}$$

$$\frac{b + y}{2} = y\frac{\sqrt{5}}{2}$$

$$\frac{\sqrt{5}}{1} = \frac{\sqrt{5}}{\sqrt{4}} = \frac{\sqrt{5}}{2}$$

$$\frac{b}{2} = \frac{y\sqrt{5}}{2} - \frac{y}{2}$$

$$\frac{b}{\cancel{2}} = \frac{y\sqrt{5} - y}{\cancel{2}}$$

$$b = y(\sqrt{5} - y)$$

$$\boxed{b = y(\sqrt{5} - 1)}$$

$$\boxed{b = 1.236\, y}$$

10

$$A = (b + zy)\,y$$

$$40 = \left[1.236y + \left(\frac{1}{2}\right)(y)\right] y \Rightarrow [1.236y + 0.5y]\,y$$

$$40 = 1.736y^2$$

$$y^2 = \frac{40}{1.736}$$

$$y^2 = 23.041$$

$$\boxed{y = 4.8\ m}$$

$$b = 1.236 \times 4.80$$

$$\boxed{b = 5.93\ m}$$

$$Q = AC\sqrt{mi}$$

$$m = y/2 = \frac{4.8}{2} = 2.4$$

(i)

$$Q = 40 \times 60 \sqrt{2.4 \times \frac{1}{1500}}$$

$$= 40 \times 60 \times 0.04$$

$$\boxed{Q = 96\ m^3/sec}$$

3. A trapezoidal channel width, base width of 3m & side slope 2/1 carries a discharge of $10\ m^3/s$ at a depth 1.5 m under uniform flow condition. the longitudinal slope of channel is 0.001. Find the shear stress & Mannings value.

Given data :

$Q = 10\ m^3/s$

$b = 3\ m$

$Z = 2$

$y = 1.5\ m$

$i = 0.001$

To find → shear stress (τ_0)

→ Manning value (N)

Soln:

$A = (b + Zy)\,y$

$= (3 + 2(1.5))1.5$

$= (3 + 3)1.5$

$\boxed{A = 9\ m^2}$

$P = b + 2y\sqrt{Z^2+1}$

$= 3 + 2(1.5)\sqrt{2^2+1}$

$= 3 + 6.708$

$\boxed{P = 9.7\ m}$

$Q = AC\sqrt{mi}$

$m = \frac{A}{P} = \frac{9}{9.7} = 0.927$

$Q = A(C)\sqrt{mi}$

$10 = 9(C)\sqrt{0.92 \times 0.001}$

$10 = 9C \times 0.030$

$10 = 0.27C$

$C = \frac{10}{0.27}$

$\boxed{C = 37}$

$$C = \frac{1}{N} m^{1/6}$$

$$37 = \frac{1}{N} (0.99)^{1/6}$$

$$37 = \frac{0.98}{N}$$

$$N = \frac{0.98}{37}$$

$$\boxed{N = 0.026}$$

$$\tau = \gamma \times m \times i$$

Shear stress $\tau_0 = \gamma \times m \times i$

$$= 9.81 \times 0.92 \times 0.001$$

$$\boxed{\tau_0 = 9.02 \times 10^{-3} \ N/m^2}$$

A trapezoidal channel having a bed width of 5m & side slope 2/1 is laid with a bed slope of 1 in 750. The discharge in the channel is 8.1 cumecs. Determine the normal depth. Assume manning's $n = 0.025$.

Given:

$b = 5m$ $\quad$ $n = 0.025$

$z = 2$

$i = \frac{1}{750}$

$Q = 8.1 \ m^3/sec$

Soln:

$$V = \frac{1}{N} m^{2/3} i^{1/2}$$

$$\frac{b + 2zy}{2} = y\sqrt{z^2+1}$$

$$m = \frac{A}{P} = \frac{(b + zy)y}{b + (2y\sqrt{z^2+1})}$$

$$\frac{5 + 2(2)y}{2} = y \cdot \sqrt{2^2+1}$$

$$\frac{5}{2} + \frac{4y}{2} = y(\sqrt{5})$$

$$\frac{5}{2} = y\sqrt{5} - 2y$$

$$\frac{5}{2} = y(\sqrt{5}-2)$$

$$\frac{5}{2} = y(0.236)$$

$$\frac{2.5}{0.236} = y$$

$$\boxed{y = 10.59\ m}$$

$$m = y/2 = \frac{10.59}{2} = 5.2$$

$m = \frac{A}{P}$

$$A = (b+2y)\,y$$

$$= [5 + 2(10.5)]\,10.5$$

$$= [26]\,10.5$$

$$\boxed{A = 273\ m^2}$$

$$Q = AC\sqrt{mi}$$

$$\cancel{= 273}$$

$$= A\frac{1}{N}m^{1/6}\sqrt{mi}$$

$$= A\frac{1}{N}m^{1/6}\,m^{1/2}\sqrt{i}$$

$$= A\frac{1}{N}m^{2/3}\sqrt{i}$$

$C = \frac{1}{N}m^{1/6}$

$$8.1 = 273\frac{1}{N}(5.2)^{2/3}\sqrt{1/450}$$

$$8.1 = 273\frac{1}{N}(3)(0.036)$$

$$8.1 = 29.484\frac{1}{N}$$

$$N = \frac{29.484}{8.1}$$

$$\boxed{N = 3.64}$$

$C = \frac{1}{N}m^{1/6}$

$N = \frac{\cancel{0.06}}{37}$

Result:

M

$$m = \frac{(b+2y)y}{b+(2y\sqrt{z^2+1})}$$ Ans

$$= \frac{(5+2y)y}{5+(2y\sqrt{2^2+1})}$$

$$= \frac{(5+2y)\,y}{5+4.47y}$$

$$Q = AV$$

$$= (5+2y)\,y \times \frac{1}{N}m^{2/3}i^{1/2}$$

$$8.1 = (5+2y)y \times \frac{1}{0.025}$$

$$\times\left[\frac{(5+2y)y}{5+4.47y}\right]^{2/3}\left(\frac{1}{450}\right)^{1/2}$$

$$= \frac{[(5+2y)y]^{5/3}}{(5+4.47y)^{2/3}}$$

$$Q = AC\sqrt{mi}$$

$$= 273\frac{1}{N}m^{1/6}\sqrt{mi}$$

$$= 273\frac{1}{0.025}m^{2/3}\sqrt{1/450}$$

$$= \frac{273}{0.025}m^{2/3}\sqrt{1/450}$$

$$8.1 = 10920\,m^{2/3}(0.036)$$

$$8.1 = 393.12\,m^{2/3}$$

$$0.02 = m^{2/3}$$

$$\boxed{0.002 = m}$$

Most economical Rectangular section:

Area, $A = b \times y$

base width, $b = \frac{A}{y}$ (13)

wetted perimeter, $P = \frac{A}{y} + 2y$

$P = b + 2y$

$y = \frac{b}{2}$

Hydraulic Radius, $m = \frac{A}{P}$

$m = \frac{by}{b+2y}$

$m = \frac{y}{2}$

4. Calculate the diamension of rectangular channel which requires minimum area to convey the water of discharge $10\,m^3/s$ the slope is being $1/1500$ & take the Manning's constant $N = 0.013$.

Given :

$Q = 10 m^3/s$

$i = 1/1500$

$N = 0.013$

Base width, $b = 2y$

Area, $A = by$

$= 2y \times y$

$A = 2y^2$

$Q = AC\sqrt{mi}$

$10 = 2y^2 \times C \times \sqrt{mi}$

Hydraalic radius

$m = y/2$

(16)

$C = \frac{1}{N}(m)^{1/6}$

$= \frac{1}{0.013} \times \left(\frac{y}{2}\right)^{1/6} \times (y)^{1/6}$

$C = 68.53\, y^{1/6}$

$\frac{13}{6} + \frac{1\times 3}{2\times 3}$

$10 = 2y^2 \times 68.53\, y^{1/6} \sqrt{m \times i}$

$\frac{13}{6} + \frac{1\times 3}{2\times 3}$

$10 = 137.06\, y^{13/6} \sqrt{mi}$

$10 = 137.06\, y^{13/6} \left(\frac{y}{2}\right)^{1/2} \sqrt{i}$

$10 = 137.06\left(\frac{1}{2}\right)^{1/2} y^{8/3} \sqrt{1/1500}$

~~$= 68.53 \times 0.025\, y^{8/3}$~~

$10 = 96.91 \times \sqrt{1/1500}\; y^{8/3}$

$10 = 2.50\, y^{8/3}$

$\frac{10}{2.5} = y^{8/3}$

$(4)^{3/8} = (y^{8/3})^{3/8}$

$\boxed{y = 1.68\ m}$

$b = 2y$

$b = 2 \times 1.6$

$\boxed{b = 3.2\ m}$

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5. A flow of 100 lit/s flows through a rectangular channel width of 0.6 m & having adjustable battom slope take chezy's constant. C = 56 & determine the bottom slope the depth of a channel is 0.3m & also find the flow rapid or smooth.

Given:

$b = 0.6$

$C = 56$

$Q = 100 \text{ lit/s} \Rightarrow 0.1 \text{ m}^3/\text{s}$

$y = 0.3 \text{ m}$

Soln:

$Q = AC\sqrt{mi}$

$A = b \times y$

$= 0.6 \times 0.3$

$\boxed{A = 0.18 \text{ m}^2}$

$m = \frac{A}{P}$

$P = b + 2y$

$0.6 + 2(0.3)$

$\boxed{P = 1.2 \text{ m}}$

$m = \frac{0.18}{1.2}$

$\boxed{m = 0.15}$

(16)

$$Q = AC\sqrt{mi}$$

$$0.1 = 0.18 \times 56 \times \sqrt{0.15 \times i}$$

$$\sqrt{i} = \frac{0.1}{3.9}$$

$$\sqrt{i} = 0.02$$

$$\boxed{i = 0.0004}$$

$$V = C\sqrt{mi}$$

$$V = 56\sqrt{0.15(4 \times 10^{-4})}$$

$$\boxed{V = 0.4}$$

$$Fr = \frac{0.4}{\sqrt{9.81 \times 0.3}}$$

$$\boxed{Fr = 0.23}$$

The most economical circular section.

2 conditions

1) Maximum mean velocity $= 128^\circ\, 45'$
2) Maximum discharge. $= 154^\circ$

Area $A = r^2\left(\theta - \frac{\sin 2\theta}{2}\right) - A = \pi/4 \times d^2$

depth $y = 0.81 D$ $\quad A = r^2\left[\theta - \frac{\sin 2\theta}{2}\right]$

$P = 2R\theta = D\theta$

$m = 0.3D$

value of θ $\quad 128^\circ 45$

$\theta = 154^\circ$

For

i) Max velocity $= 128^\circ 45 \times \pi/180$

ii) discharge $= 154^\circ$

6. The rate of flow of water through a circular channel dia 60 cm is 150 lit/s. find the slope of bed of the channel for max velocity. Assume $C = 60$

Given:

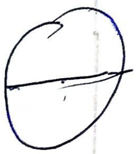
$D = 60cm \Rightarrow 0.6m$

$Q = 150 lit/sec \Rightarrow 0.15\ m^3/sec.$

To find

$A = \pi r^2 \Rightarrow \pi/4 \times d^2$

$r = \left(\frac{D}{2}\right)$



$\boxed{A = \frac{\pi D^2}{4}}$

$= \frac{\pi (0.6)^2}{4}$

$\boxed{A = 0.28\ m^2}$

D/2

Max velocity

$y = 0.81 D$

$= 0.8 \times 0.6$

$\boxed{y = 0.48 m}$

$\theta = 128°45' \times \frac{\pi}{180}$

$\boxed{\theta = 2.24 \text{ radian}}$

$Q = AC\sqrt{mi}$ $P = D\theta$

$m = \frac{A}{P}$

$P = D\theta$

$= 0.6 \times 2.247$

$\boxed{P = 1.34}$

$$m = \frac{0.28}{1.34}$$

$$\boxed{m = 0.208}$$

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Assume $C = 60$

$$Q = AC\sqrt{mi}$$

$$0.15 = 0.28 \times 60 \sqrt{0.208\, i}$$

$$0.15 = 7.66 \sqrt{i}$$

$$\sqrt{i} = \frac{0.15}{7.66}$$

$$i = (0.019)^2$$

$$\boxed{i = 3.61 \times 10^{-4}}$$

7. Determine the maximum discharge of water flow through circular channel of diameter 1.5 m then the bed slope of the channel is 1/1000 & take chezy's constant $C = 60°$

$154° 45' \times \pi/180$

Given data:

~~D = 1.8 m~~ $c = 60°$

Max. discharge

$D = 1.5\,m$

$i = \frac{1}{1000}$

Soln:

$\theta = 154° \Rightarrow 154° \frac{\pi}{180} = 2.68$ radian

$$Q = AC\sqrt{mi}$$

$$A = r^2 \left[\theta - \frac{\sin 2\theta}{2} \right]$$

$$= (0.75)^2 \left[2.68 - \frac{\sin 2(2.68)}{2} \right]$$

$$= (0.75)^2 \left(2.68 - \frac{\sin 5.36}{2} \right)$$

$$= (0.75)^2 (2.68 - 0.046)$$

$$= (0.75)^2 (2.634)$$

$$\boxed{A = 1.48 \, m^2}$$

$$m = \frac{A}{P}$$

$$P = 2r\theta = 2(0.75)(2.68)$$

$$\boxed{P = 4.02}$$

$$m = \frac{1.48}{4.02}$$

$$\boxed{m = 0.36}$$

$$Q = AC\sqrt{mi}$$

$$= 1.48 \times 60 \times \sqrt{0.36 \times 1/1000}$$

$$= 1.48 \times 60 \times 0.018$$

$$\boxed{Q = 1.68 \, m^3/sec}$$

Unit - 5

Centrifugal pump.

Classifications of pumps:

* The pumps are minelly classified into two types:

1. Roto dynamics pumps (or) Dynamic pressure pump.
2. Positive displacement pump.

* The rotodynamic pumps are classified into three different types based on flow of water.

1. Radial flow pump.
2. Axial flow pump.
3. Mixed flow pump.

* The positive displacement pumps are divided into two types.

1. Reciprocating pump.
2. Rotary pump

* The reciprocative pump is further classified into two types based on discharge

1. Piston (or) Plunger type
2. Diaphragm type.

* Based on the type of power rotatary pumps divided into

1. Gear type
2. Vane type
3. Screw type

Classification of centrifical pump

Based on the uppility design & constructional features the centrifugal pumps are classificated into

I. Shape & type of casting

1. Spiral casting
2. Whirl cool casting
3. Volume casting with guide plates

II. Based on working head.

1. Low head (height 15 m)
2. Medium head (height 15-40m)
3. High head (height above 40m)

III. Based on working stages.

1. Single state centrifucal pump
2. Multy stage centrifugal pump.

IV. Based on liquid.

1. Closed impeller pumps
2. Semi-closed impeller pump
3. Open-impeller pump

V. Based on specific speed

1. Low specific speed
2. Mediam specific speed
3. High specific speed.

VI. Number of enterence to the impeller

1. Single suction or single entery pumps
2. Double suction (or) Double entry pumps

Components of centrifugal pump.

1. Impullers
2. Casting.
3. Suction pipe, foot valve & strainer
4. Delivary pipe & delivery valve.

Type heads in pump:

1. Suction head, h_s
2. Delivery head, h_d
3. Static head, $H_{stat} = h_s + h_d$
4. Manometric head, $H_m = \frac{V_{w_2} u_2}{g} - (h_{Li} + h_{Lc})$

where, $V_{w_2} \rightarrow$ velocity at whirl at outlet

$u \rightarrow$ Tangential velocity of the impeller at outlet

$g \rightarrow$ Acceleration due to gravity

$h_{Li} \rightarrow$ Loss of head in the impeller

$h_{Lc} \rightarrow$ Loss of head in casing.

$$H_m = H_{stat} + \text{Losses in pipes} + \frac{V_d^2}{2g}$$

$$H_m = h_s + h_d + h_{fs} + h_{fd} + \frac{V_d^2}{2g}$$

Workdone by pump

$$\text{Workdone} = \frac{W}{g}\left(V_{w_2} U_2 \pm V_{w_1} U_1\right)$$

$$W = \rho g Q \quad , \quad U_1 = \frac{\pi D_1 N}{60}$$

$$Q = \pi D_1 B_1 \times V_{f_1} = \pi D_2 B_2 V_{f_2}$$

$$\delta = 90^\circ \; , \; V_{w_1} = 0$$

✓ $$\text{workdone} = \frac{WQ}{g}\left(V_{w_2} U_2\right)$$

Effeciency of pump :

Monometric efficiency (η mano)

$$\eta_{mono} = \frac{\text{Monometric head}}{\text{head imparted by impeller to liquid}} = \left(\frac{H_m}{\frac{V_{w_2} U_2}{g}}\right)$$

✓ $$= \left(\frac{g H_m}{V_{w_2} U_2}\right)$$

Volumetric efficiency (η_v)

$$\eta = \frac{\text{Discharge g liquid per second from the pump}}{\text{Quentity of liquid passing per second to the pump}}$$

Mechanical efficiency (η mech)

$$(\eta_{mech}) = \frac{\text{Power at the impeller}}{\text{power at the staff}}$$

✓ $$= \frac{w}{g}\left(\frac{V_{w_2} U_2}{1000}\right)$$

Output efficiency (or) overall efficiency (η_o)

$$\eta_o = \frac{\text{Power output of the pump}}{\text{Power into the pump.}}$$

$$\eta_o = \frac{wQH_m}{P}$$

Inlet velocity triangle $\theta \Rightarrow \tan\theta = \frac{V_{f1}}{U_1}$

Outlet velocity triangle $\phi = \tan\phi = \frac{V_{f2}}{U_2 - V_{w2}}$

1. The impeller of the centrifugal pump has external & internal diameter 500mm & 200 mm respectively the width of outlet 50mm & running of 1200 rpm. It works against a head of 48m, the velocity of flow through the impeller is constant & equall 3 m/s the vanes are set back at angle of 40° at outlet. Determine the i) Inlet ~~way~~ vane angle
ii) Workdone by impeller of water at m/s
iii) Manometeric efficiency.

Given data:

$D_1 = 200\text{ mm} \Rightarrow 0.2\text{ m}$ $\phi = 40°$

$D_2 = 500\text{ mm} \Rightarrow 0.5\text{ m}$

$B_2 = 50\text{ mm} \Rightarrow 0.05\text{ m}$

$N = 1200\text{ rpm}$

$H_m = 48\text{ m}$

$V_{f1} = V_{f2} = 3\text{ m/s}$

i) Inlet angle:

$$\tan\theta = \frac{V_{f1}}{u_1}$$

$$u_1 = \frac{\pi D_1 N}{60}$$

$$= \frac{\pi \times 0.2 \times 1200}{60}$$

$$\boxed{u_1 = 12.56 \text{ m/s}}$$

$$\tan\theta = \frac{V_{f1}}{u_1}$$

$$= \tan^{-1}\left(\frac{3}{12.56}\right)$$

$$\boxed{\theta = 13^\circ 26'}$$

ii) workdone by impeller of water:

$$\text{workdone} = \frac{wQ}{g} \times V_{w2} \times u_2$$

$$w = g = 9.81$$

$$Q = \pi \times D_1 B_1 V_{f1} = \pi D_2 B_2 V_{f2}$$

$$Q = \pi D_2 B_2 V_{f2}$$

$$= \pi \times 0.5 \times 0.05 \times 3$$

$$\boxed{Q = 0.2356 \text{ m}^3/\text{s}}$$

$$u_2 = \frac{\pi D_2 N}{60}$$

$$= \frac{\pi \times 0.5 \times 1200}{60}$$

$$\boxed{u_2 = 31.41 \text{ m/s}}$$

$$\tan\phi = \frac{V_{f2}}{u_2 - V_{w2}}$$

$$\tan 40^\circ = \frac{3}{(31.41 - V_{w2})}$$

$$31.41 - V_{w_2} = \frac{3}{\tan 40^\circ}$$

$$-V_{w_2} = 31.41 - \left(\frac{3}{\tan 40^\circ}\right)$$

$$\boxed{V_{w_2} = 27.8 \text{ m/s}}$$

$$\text{workdone} = \frac{gWQ}{g} \times V_{w_2} \times u_2$$

$$= \frac{9.81 \times 0.235}{9.81} \times 27.8 \times 31.41$$

$$\boxed{\text{workdone} = 205.20 \text{ kN-m}}$$

iii) Manometric efficiency:

$$\eta_{mano} = \frac{g H_m}{V_{w_2} \cdot u_2}$$

$$= \frac{9.81 \times 48}{27.8 \times 31.41}$$

$$= 0.53$$

$$\boxed{\eta_{mano} = 53\%}$$

2. The following data related to centrifugal pump outlet diameter of impeller 800mm & width of impeller vanes at outlet 100mm the angle of impeller vane at outlet 30° the impeller run at speed of 600rpm & it delivers 0.9 m³/s the efficiency head of 30m a 4050 kW motor is used to drive the pump. Determine manometric

efficiency ii) Machenical efficiency & overall efficiency of pump. Assume that the water entire the impeller vanes radially at inlet.

Given data:

$D_2 = 800 mm \Rightarrow 0.8 m$

$B_2 = 100 mm \Rightarrow 0.1 m$

$\phi = 30°$

$N = 600 rpm$

$Q = 0.9 m^3/s$

$H_m = 30 m$

$P = 4\cancel{5}50 KW$

Soln:

$$\eta_{mano} = \frac{g H_m}{V_{w2} U_2}$$

$$U_2 = \frac{\pi D_2 N}{60}$$

$$= \frac{\pi (0.8)(600)}{60}$$

$$\boxed{U_2 = 25.13 m/s}$$

~~$\tan\phi = V_{f2}$~~

$$Q = \pi D_2 B_2 V_{f2}$$

$$0.9 = \pi \times 0.8 \times 0.1 V_{f2}$$

$$V_{f2} = \frac{0.9}{0.251}$$

$$\boxed{V_{f2} = 3.58 m/s}$$

$$\tan\phi = \frac{V_{f2}}{U_2 - V_{w2}}$$

$$\tan 30° = \frac{3.58}{25.13 - V_{w2}}$$

$$25.13 - V_{w2} = \frac{3.58}{\tan 30^\circ}$$

$$V_{w2} = 25.13 - 6.2$$

$$V_{w2} = 18.93 \text{ m/s}$$

$$\eta_{mano} = \frac{gH_m}{V_{w2} u_2}$$

$$= \frac{9.81 \times 30}{18.93 \times 25.13}$$

$$= 0.61$$

$$\boxed{\eta_{mano} = 61\%}$$

ii) Mechanical efficiency:

$$\eta_{mech} = \frac{9.81}{9.}\frac{w}{g}\left(\frac{V_{w2} u_2}{1000}\right)$$

$$= \frac{9.81}{9.81}\left(\frac{18.93 \times 25.13}{1000}\right)$$

$$\eta_{mech} = 0.475$$

$$\boxed{\eta_{mech} = 47.5\%}$$

iii) overall efficiency

$$\eta_o = \frac{wQH_m}{P}$$

$$= \frac{9.81 \times 0.9 \times 30}{450 \cancel{\times 10^3}}$$

$$= 0.58$$

$$\boxed{\eta_o = 58\%}$$

3. The centrifugal pump is running at the speed of 1000 rpm & working against a head of 20m. The rate flow through the pump is $0.2\ m^3/s$. The outlet vane angle of impeller is $45°$ & velocity of the flow at outlet is $2.5\ m^3/s$, if the manometric effeciency of the pump is 80%. calculate the dia & width of the impeller & outlet.

Given data:

$N = 1000$ rpm

$H_m = 20\ m$

$Q = 0.2\ m^3/s$

$\phi = 45°$

$\eta_{mano} = 80\%$

$V_{f2} = 2.5\ m^3/s$

To find:

Diameter of impeller & outlet - (D_2)

width of impeller & out - (B_2)

Soln:

$$u_2 = \frac{\pi D_2 N}{60}$$

$$u_2 = \frac{\pi D_2\ 1000}{60}$$

$$u_2 = 52.35\ D_2$$

$$\tan\phi = \cancel{\frac{V_{f2}}{u_2}}\ \frac{V_{f2}}{u_2 - V_{w2}}$$

$$\tan 45° = \frac{2.5}{52.35\ D_2 - V_{w2}}$$

$$52.35 D_2 - V_{w2} = \frac{2.5}{\tan 45^\circ}$$

$$-V_{w2} = \left(\frac{2.5}{\tan 45}\right) - 52.35 D_2$$

$$-V_{w2} = 2.5 - 52.35 D_2$$

$$V_{w2} = -2.5 + 52.35 D_2.$$

$$V_{w2} = 52.35 D_2 - 2.5.$$

$$\eta_{mano} = \frac{g H_m}{V_{w2} U_2}$$

$$0.80 = \frac{9.81 \times 20}{(52.35 D_2 - 2.5)(52.35 D_2)}$$

$$0.80 = \frac{9.81 \times 20}{2740.52 D_2^2 - 130.87 D_2}$$

$$2740.52 D_2^2 - 130.87 D = \frac{196.2}{0.80}$$

$$2740.52 D_2 - 130.8 D_2 = \sqrt{245.2}$$

$$2609.7 D_2 = 15.65$$

$$D_2 = \frac{15.65}{2609.7}$$

$$\boxed{D_2 = 5.9 \times 10^{-3}}$$

~~2970.~~

$$2740.52 D_2^2 \times 0.80 = \frac{9.81 \times 20}{130.87 D_2}$$

$$2192.41 D_2 = \sqrt{}$$

$$D^{1/2}$$

~~B2ee~~

$$Q = \pi D_2 B_2 V_{f2}$$

$$0.2 = \pi \times 5.9 \times 10^{-3} \times B_2 \times 2.5$$

$$0.2 = 0.046 B_2$$

$$B_2 = \frac{0.2}{0.046}$$

$$B_2 = \frac{0.2}{0.04}$$

$$\boxed{B_2 = 5m}$$

Losses in centrifugal pump:

1. ~~Hydraulic loss~~
2. Hydraulic losses

A hydraulic loss is acquire in two ways such as losses in pump & other loss

~~Hydraulic~~

1. Hydraulic losses in pipe

* shapck or eddy loss at the entry to & exist from the impeller
* Losses due to friction in the impellers
* Riation & eddy losses in the guide vanes or diffuser & casing.

Other hydraulic losses

* Friction & other minor loss in the suction pipe.
* Friction & other minor losses in the delivery pipe.

2. Mechanical losses

* Due to friction b/w fixed & rotating parts in the gearing & stuffing boxes.
* Disk friction power loss due to friction b/w rotating face of the impeller & the liquid.

3. Leakage loss.

* This loss due to loss of liquid from the pump & recirculation of the liquid in the impellers.

Design asspects of centrifugal pump:

1. Speed ratio

The speed ratio is ratio of peripheral speed at outlet to the theoretical velocity of jet corresponding to manometric head.

$$\boxed{K_u = \frac{u_2}{\sqrt{2gH_m}}}$$

The value of K_u varies from 0.95 to 1.25

2. Flow ratio

It is the ratio b/w velocity of the flow at exist to the theoretical velocity of the jet corresponding to manometric head.

$$K_f = \frac{V_{f2}}{\sqrt{2gH_m}}$$

The value K_f varies from 0.1 to 0.25

3. Outlet diameter of the impeller.

$$D_2 = \frac{84.6\, K_u \sqrt{H_m}}{\pi N}$$

4. Inlet diameter of the impeller

$$D_1 = 0.5 D_2$$

5. Least diameter of the impeller:

$$D_2 = \frac{97.68 \sqrt{H_m}}{N}$$

6. Diameter of suction pipe:

$$D_s = \sqrt{\frac{4Q}{\pi V_s}}$$

7. Diameter of delivery pipe:

$$D_d = \sqrt{\frac{4Q}{\pi V_d}}$$

Manometric head (Hm)

Hm = (total head at out let of pump) − (total head at inlet of the pump)

$$H_m = \left(\frac{P_2}{w} + \frac{V_2^2}{2g} + Z_2\right) - \left(\frac{P_1}{w} + \frac{V_1^2}{2g} + Z_1\right)$$

Velocity of water

velocity of water entire in the vane.

$$V_1 = \sqrt{V_{f1}^2 + V_{w1}^2}$$

velocity of water leaving the vane.

$$V_2 = \sqrt{V_{f2}^2 + V_{w2}^2}$$

4. For a centrifugal pump suction lift is 2m delivery height 30m head loss in the suction & delivery pipe due to friction are 0.8 & 3 m respectivily. The dia of both suction & delivery pipe is 5cm. Find the power of the prime motor the overall efficieny is 70%. & Manometric efficiency is 85%. also determine the negative head at suction

& passive head at delivery side the actual head developed is 40m.

Given data:

$h_s = 2m$

$h_d = 30m$

$h_{fs} = 0.8\ m$

$h_{fd} = 3m$

$d_d = d_s = 5cm \Rightarrow 0.05\ m$

~~dd =~~

$\eta_o = 70\%$

$\eta_{mano} = 85\%$

$H = 40m$.

$V_d = 14.56$

To find

i) Power

ii) H_s - negative

iii) H_d - positive.

Soln:

$$\eta_o = \frac{WQH_m}{P}$$

$$P = \frac{WQH_m}{\eta_o}$$

To find manometric head

$H_m \Rightarrow$ $\eta_{mano} = \frac{\text{Actual head}}{\text{Manometric}}$

$$0.85 = \frac{40}{H_m}$$

$$H_m = \frac{40}{0.85}$$

$$\boxed{H_m = 47.05\ m}$$

To find discharge Q

$$Q = A \times V$$

$$= \frac{\pi d_d^2}{4} \times V_d^2$$

$= \frac{\pi}{4} (0.05)^2 \times 14.56$

$Q = 0.029\ m^3/s$

$P = \frac{wQH_m}{\eta_o}$

$P = \frac{9.81 \times 0.029 \times 47.06}{0.7}$

$\boxed{P = 19.13\ kw}$

Negative head

$H_s = H_{atm} - (h_s + h_{fs})$

$= 10.3 - (2 + 0.8)$

$\boxed{H_s = 7.5\ m}$

Positive head at delivery side :-

$H_S = H_{atm} + (h_d + h_{fd})$

$= 10.3 + (30 + 3)$

$\boxed{H_s = 43.3\ M}$

5. A centrifugal pump has a suction lift of 1.54m & delivery tank is at 13.5m above the pump. The velocity of water in the delivery pipe is 1.5 m/sec. The radial velocity of flow through the wheel 3m/s. The tangent to the wheel is exit from the wheel max & angle of 120 with direction of motion.

Assuming that the water enter's radially & neglecting friction other losses. Determine the i) velocity of wheel at exist ii) velocity head & pressure head at exist iii) find the direction of fixed guide anglo:

Given data:

$h_s = 1.5\ m$

$h_d = 13.5\ m$

$V_d = V_2 = 1.5\ m/s$

$V_{f2} = 3\ m/s$

$\phi = 180° - 120° = 60°$

soln:

i) velocity of wheel:

$$\tan \phi = \frac{V_{f2}}{U_2 - V_{w2}}$$

$$\tan 60° = \frac{3}{U_2 - V_{w2}}$$

$$U_2 - V_{w2} = \frac{3}{\tan 60}$$

$$\boxed{U_2 - V_{w2} = 1.732\ m/s}$$

$$V_{w2} = \sqrt{V_2^2 - V_{f2}^2}$$

$$= \sqrt{1.5^2 - 3^2}$$

$$\boxed{V_{w2} = 3.35\ m/s}$$

$$U_2 - 3.35 = 1.732$$

$$\boxed{U_2 = 5.082\ m/s}$$

ii) velocity head & pressure head velocity head from bernoulli's.

$$H_2 = \frac{V_2^2}{2g}$$

$$= \frac{1.52}{2 \times 9.81}$$

$$\boxed{H_2 = 0.15 \text{ m}}$$

6. An axial flow pump running at 620 rpm delivers 1.5 m³/s against a head of 5.2 m. The speed ratio is 2.5. The flow ratio 0.5. The overall efficiency is 0.8. Determine the power required & the blade angles at the root & tip & the diffuser blade inlet angle. Inlet whirl is zero.

Given data:

~~speed~~ $N = 620$ rpm.

$Q = 1.5 \text{ m}^3/\text{s}$

$H_m = 5.2$ m

flow ~~speed ratio~~, $k_f = 0.5$

speed ratio = 2.5

$\eta_o = 0.8$

$V_{w1} = 0$

Soln:

$$P = w Q H_m$$

$$= 9.81 \times 1.5 \times 5.2$$

$$P = 76.52 \text{ kW}$$

$$\eta_o = \frac{\text{Power in output}}{\text{power in input}}$$

$$0.8 = \frac{76.52}{\text{Power in input.}}$$

$$\text{Power in input} = \frac{0.8}{76.52} \quad \frac{76.52}{0.8}$$

$$= 95.65 \text{ kW}$$

Flow velocity $\quad V_{f1} = k_f \sqrt{2gH}$

$$= 0.5\sqrt{2 \times 9.81 \times 5.2}$$

$$= 0.5 \times 10.10$$

$$V_{f1} = V_{f2} = 5.05 \text{ m/s}$$

Blade velocity $\quad u_1 = u_2 = 2.5\sqrt{2 \times 9.81 \times 5.2}$

$$= 2.5 \times 10.10$$

$$= 25.25 \text{ m/s}$$

$$\tan\theta = \frac{V_{f1}}{u_1}$$

$$\tan\theta = \frac{5.05}{25.25}$$

$$\tan\theta = 0.2.$$

$$\boxed{\theta = 11^\circ 18'}$$

$$P = \frac{\text{workdone} \times N}{60}$$

$$P = \frac{w V_{w2}\, u \times N}{60}$$

$$76.52 = \frac{9.81 \times V_{w2} \times 25.25 \times 620}{60}$$

$$V_{w2} = \frac{\cancel{9.8} \cdot 60 \times 76.52}{9.81 \times 25.25 \times 620}$$

$$\boxed{V_{w2} = 0.03 \text{ m/s}}$$

From outlet velocity triangle

$$\tan\phi = \frac{V_{f2}}{u_2 - V_{w2}}$$

$$\tan\phi = \frac{5.05}{25.25 - 0.03}$$

$$\phi = \tan^{-1}\left(\frac{5.05}{25.22}\right)$$

$$= \tan^{-1}(0.2002)$$

$$= \cancel{11.39^\circ}$$

$$= 11'.39$$

$$\boxed{\phi = 11^\circ.19'}$$

$$\tan\beta = \frac{V_{f2}}{V_{w2}} = \frac{5.05}{0.03} = 168.33$$

$$\beta = \tan^{-1}(168.33)$$

$$= 89.65$$

$$\boxed{\beta = 89^\circ 39'}$$

7. The dimensionless specific speed of a centrifugal pump is 0.06. Static head is 32m. Flow rate is ~~0~~ 50 l/s. The suction & delivery pipes are each of diameter 15cm. The friction factor is 0.02. Total length is 60m & other losses equal 4 times ~~the~~ velocity head in the pipe. The vanes are forward curved at 120°. The width is one tenth of

the diameter. There is a 7% reduction in flow area due to the blade thickness. The manometric efficiency is 80%. Determine the impeller diameter if inlet is radial.

Given:

$N = 0.06$

$h_s = 32\,m$

$Q = 50\ l/s \Rightarrow 0.05\ m^3/s$

$d_s = d_d = d = 15\,cm \Rightarrow 0.15\,m$

$4f = 0.02$

$l = 60\,m$

$\phi = 180° - 120° = 60°$

$B_2 = \frac{1}{10} D_2 = 0.1 D_2$

$\eta_{mano} = 80\%$

soln:

$$V = \frac{Q}{A} = \frac{Q}{\frac{\pi d^2}{4}} = \frac{4Q}{\pi d^2} = \frac{4 \times 0.05}{\pi \times 0.15^2} = 0.283\ m/s$$

$$\text{Total loss of head} = \frac{f l V^2}{2gd} + \frac{4V^2}{2g}$$

$$= \frac{0.02 \times 60 \times 0.283^2}{2 \times 9.81 \times 0.15} + \frac{4 \times 0.283}{2 \times 9.81} = 4.89\ m$$

$$H = 32 + 4.89 = 36.48\ m$$

$$N_s = \frac{N\sqrt{Q}}{(H)^{3/4}}$$

$$0.06 = \frac{N\sqrt{0.05}}{(36.48)^{3/4}} \Rightarrow (36.48)^{3/4} \times 0.06 = N\sqrt{0.05}$$

$14.843 \times 0.06 = N \times 0.223$

$0.89058 = N \times 0.223$

$N = \frac{0.89058}{0.223}$

$N = 3.993$

$$N = 3.983\ rpm$$

$$Q = \pi D_2 B_2 \times V_{f2}$$

$$0.05 = \pi \times D_2 \times 0.1 D_2 \times V_{f2}$$

$$V_{f2} = \frac{0.159}{D_2^2}$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times D_2 \times 3.983}{60} = 0.209 D_2$$

$$\eta_{mano} = \frac{gH_m}{V_{w_2} u_2}$$

$$0.8 = \frac{9.81 \times 36.48}{V_{w_2} \times 0.209 D_2}$$

$$V_{w_2} = \frac{2140.36}{D_2}$$

$$\tan \phi = \frac{f_2}{u_2 - V_{w_2}}$$

$$\tan 60^\circ = \frac{(0.159 / D_2^2)}{0.209 D_2 - \frac{2140.36}{D_2}}$$

$$= \frac{(0.159/D_2^2)}{\frac{0.209 D_2^2 - 2140.36}{D_2}}$$

$$= \frac{0.159}{D_2 \cancel{^2}} \times \frac{\cancel{D_2}}{0.209 D_2^2 - 2140.36}$$

$$= \frac{0.\cancel{159}}{}$$

$$1.732 D_2 (0.209 D_2^2 - 2140.36) = 0.159$$

$$0.362 D_2^3 - 3707.1 D_2 = 0.159$$

$$0.362 D_2^3 - 3707.1 D_2 - 0.159 = 0$$

$$D_2 = 0.0000425 M$$

$$\boxed{D_2 = 0.0425 \text{ mm}}$$

8. A multistage centrifugal pump has four identical impellers of 40cm in diameter & 2.5cm wide at outlet. The vanes are curved back at the outlet at 30° & they reduce the circumferential area by 15%. The manometric efficiency is 85%. & overall efficiency is 75%. Determine the head generated by the pump when running at 1200 rpm & discharging 0.06 m^3/s. Also find the shaft power & torque exerted.

Given:

$n = 4$

$D_2 = 40cm \Rightarrow 0.4\ m$

$B_2 = 2.5cm \Rightarrow 0.025\ m$

$\phi = 30°$

Reduction in area at outlet $= 15\% = 0.15$

$\eta_{mano} = 85\% = 0.85$

$N = 1200\ rpm.$

$Q = 0.06\ m^3/s.$

$\eta_o = 75\% = 0.75$

Soln:

$Q = \pi D_2 B_2 V_{f2}$

$0.06 = 0.85 \times \pi \times 0.4 \times 0.025 \times V_{f2}$

$V_{f2} = 2.25\ m/s$

$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.4 \times 1200}{60} = 25.13\ m/s$

From outlet velocity traingle,

$\tan\phi = \frac{V_{f2}}{u_2 - V_{w2}}$

$$\tan 30^\circ = \frac{2.25}{25.15 - V_{w_2}}$$

$$25.15 - V_{w_2} = \frac{2.25}{\tan 30^\circ}$$

$$V_{w_2} = 21.23 \text{ m/s}$$

$$\eta_{mano} = \frac{g H_m}{V_{w_2} U_2}$$

$$0.85 = \frac{9.81 \times H_m}{21.23 \times 25.13}$$

$$H_m = 46.23 \text{ m}$$

Total head delivered by 4 pumps.

$$H_{total} = n \times H_m = 4 \times 46.23 = 184.92 \text{ m}$$

Power output, $P = w Q H_{total}$

$$= 9.81 \times 0.06 \times 184.92$$

$$= 108.84 \text{ kW}$$

$$\eta_o = \frac{\text{Power output}}{\text{Power input}}$$

$$0.75 = \frac{108.84}{\text{power input}}$$

$\cancel{T = 60}$

$$= 145.12 \text{ kW}$$

$$T = \frac{60 P}{2 \pi N}$$

$$T = \frac{60 \times 145.12}{2\pi \times 1200}$$

$$T = 1.16 \text{ kNm}$$

Reciprocating pump:

This pump is a positive displacement pump it capporates on a principle of actual displacement of pushing liquid by a piston or plunger that reciprocates in a closelly fitting cylinders

This reciprocating pump generally employed for light oil pumping feeded samall boilers contensting return & Hydraulic P.

classification ~~on~~ Reciprocating pump:

This pumps are classified based on fluid is being in contact with piston or plunger & number of cylinder provide.

* According to fluid behing in contanct with plision or plunger.

1) single acting pump
2) Double acting pump

* According the number of cylinder provided

1) Single cylinder pump
2) Double cylinder pu
3) Trible cylinder
4) Duplex double

Quant pump

Main components of reciprocating

1) A piston are a plunger that reciprocate in a cylinder.

2) Suction & delivery pipe with not return walves. A suction walve in the suction & delivery valve in the delivery pipe.

3) Cranke & connecting rod machenism

<u>single acting pump:</u>

Weight of water delivered:

$$W = wQ = \frac{wALN}{60}$$

Q = discharge

$$Q = \frac{ALN}{60}$$

Volume of water delivered;

= Area x length of stroke.

= A x L

Workdone per second:

$$w(hs+hd) = \frac{wALN}{60}(hs+hd)$$

$$\boxed{W = \frac{WALN}{60}}$$

Double acting pump:

1) $Q = \frac{2ALN}{60}$

2) work done $= \frac{2WALN}{60}$

3) Power P $= \frac{2WALN}{60}(hs+hd)$

Slip of pump:

slip $= Q_{th} - Q_{act}$

% slip $= \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100$

$cd = \frac{Q_{act}}{Q_{th}}$

1. The single acting reciprocating pump running at a speed of 60rpm & delivers 0.53 m^3 of water per minitue. the dia of piston is 200mm & the stock length is 300mm. The suction & delivery heads are 4m & 12m respectively. Determine the i) Theoretical discharge
ii) coefficient of discharge
iii) Percentage of slip
iv) Power require to rente the pump.

Given data:

$N = 60$ rpm

$Q = 0.53 m^3/minute$ $8.83 \times 10^{-3} m^3/s$

$D = 200$ mm

$L = 300$ mm

$hs = 4m \rightarrow 4000$ mm

$hd = 12m \rightarrow 12000$ mm

To find : i) $Q_{th} = \frac{ALN}{60}$

ii) $Cd = \frac{Q_{act}}{Q_{th}}$

iii) % of slip $= \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100$

iv) $P = \frac{wALN}{60} \times (h_s + h_d)$

Soln:

(i) Q_{th}

$$Q_{th} = \frac{ALN}{60}$$

$$= \frac{\frac{\pi}{4} \times (200)^2 \times 300 \times 60}{60}$$

$$\boxed{Q_{th} = 9.4 \times 10^6 \; mm^3}$$

$$\boxed{\cancel{Q_{th} = 9.4 \times 10^3 \; m^3/s}}$$

ii) $Cd = \frac{Q_{act}}{Q_{th}} = \frac{8.83 \times 10^6}{9.42 \times 10^6} = 0.937$

iii) % of slip $= \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100$

$$= \frac{9.42 \times 10^6 - 8.83 \times 10^6}{9.42 \times 10^6} \times 100$$

$$\boxed{\text{\% of slip} = 6.26\%}$$

iv) $P = \frac{wALN}{60} \times (h_s + h_d)$

$$= \frac{9.81 \times \left(\frac{\pi}{4} \times 200^2\right) \times 300 \times 60}{60} \times (4000 + 12000)$$

$$\boxed{P = 1.47 \times 10^{12}}$$

2 A single acting reciprocating pump at running speed of 50 rpm & delivery of 0.04 The dia of piston is 0.2 m & stock length is 0.4 m determine the theoretical discharge of the pump & coefficient of discharge is iii) slip of the pump & percentage of slip. consider the suction & delivery heads are 2 m & 3 m.

Given:

$d = 0.2\,m$ $N = 50\,rpm$

$l = 0.4\,m$

$Th = 0.0105\,m^3/s$

$Co\text{-}ef = 0.952$

$slip = 4.76\%$

$Q = 0.04$

$hs = 2\,m$

$hd = 3\,m$

Soln:

$$Q_{th} = \frac{ALN}{60}$$

$$= \frac{\frac{\pi d^2}{4} \times L \times N}{60}$$

$$= \frac{\frac{\pi (0.2)^2}{4} \times 0.4 \times 50}{60}$$

$$= \frac{0.012}{} = 0.01047\,m^3/s \simeq 0.0105\,m^3/s$$

$= \cancel{0.010}$

$\cancel{Q_{th} = 10.47 \times 10^{-3}}\ m$

$Q_{act} = 0.01$

$$cd = \frac{Q_{act}}{Q_{th}} = \frac{0.01}{0.01047} = \cancel{\ldots}\,0.955$$

$$\%\ \text{of slip} = \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100$$

$$= \frac{0.01047 - 0.01}{0.01047} \times 100$$

$$= \cancel{0.044}$$

$$= \cancel{4.489}$$

$$\boxed{\%\ \text{of slip} = 4.76\ \%}$$

$$P = \frac{WALN}{60} \times (hs + hd)$$

$$= \frac{9.81 \times \frac{\pi d^2}{4} \times L \times N}{60} (hs + hd)$$

$$= \frac{9.81 \times \frac{\pi (0.2^2)}{4} \times 0.4 \times 50}{60} (2+3)$$

$$= 0.1027\ (5)$$

$$\boxed{P = 0.51365}$$

3. A single acting reciprocating pump running at a speed of 100 rpm. The diameter of plunger is 250mm & stock length is 350mm the discharge of the pump is 0.02 m^3/s. Determine the theoritical discharge, ii) coeff of discharge & percentage of slip:

Given data:

$N = 100$ rpm

$d = 250$ mm $\Rightarrow 0.25$ m

$l = 350$ mm $\Rightarrow 0.35$ m

$Q = 0.02\ m^3/s$

soln:

i) Theoritical discharge

$$Q_{th} = \frac{ALN}{60}$$

$$= \frac{\frac{\pi (0.25)^2}{4} \times 0.35 \times 100}{60}$$

$$\boxed{Q_{th} = 0.0286\ m^3/s}$$

ii) coefficient of discharge:

$$Cd = \frac{Q_{act}}{Q_{th}}$$

$$= \frac{0.02}{0.028}$$

$$\boxed{Cd = 0.714}$$

iii) % of slip

$$= \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100$$

$$= \frac{0.028 - 0.02}{0.028} \times 100 = \boxed{28.57\%}$$

4 A single acting reciprocating pump acting at speed of 60rpm & deliveries 0.02 m^3/s of water. The diameter of the piston is 250 mm, stock length is 450 mm. Determine theoretical discharge, coeff of dischare, % of slip, power required run pu. take the delivery & suction head are 30mm & 40mm.

$h_d = 30mm = 0.03$
$h_s = 40mm = 0.04$

~~Sol~~
Given:

$N = 60rpm$,
$Q = 0.02 m^3/s$
$d = 250mm \Rightarrow 0.25m$
$l = 450mm \Rightarrow 0.45m$

i) Theoretical discharge?

$$Q_{th} = \frac{ALN}{60}$$

$$= \frac{(\pi(0.25^2)/4)\times 0.45\times 60}{60}$$

$$Q_{th} = 0.022 \, m^3/s$$

(ii)

$$C_d = \frac{Q_{act}}{Q_{th}} = \frac{0.02}{0.022} = 0.909$$

(iii) % of slip

$$= \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100$$

$$= \frac{0.022 - 0.02}{0.022} \times 100$$

$$= 9.09\,\%$$

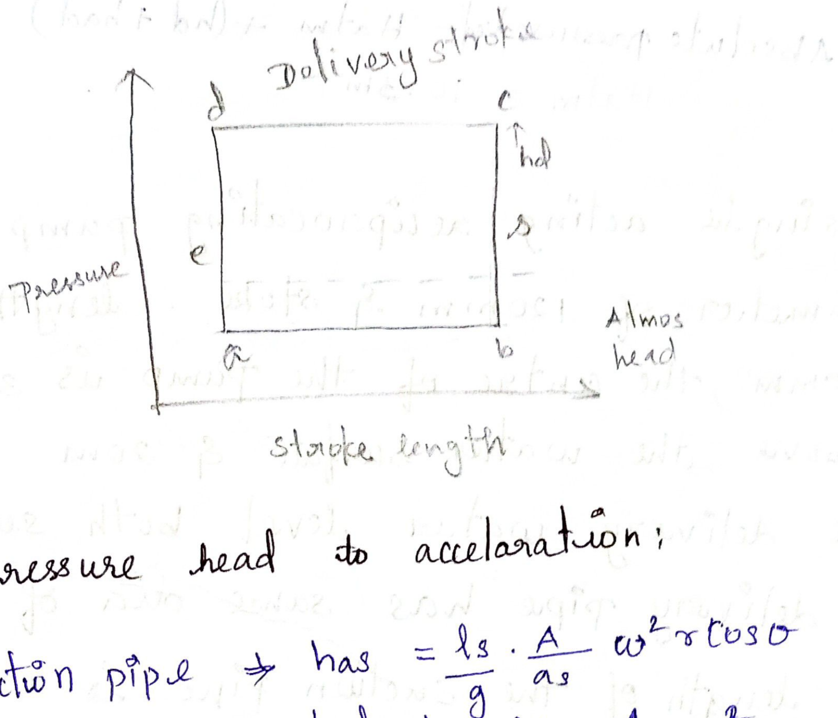
iv) Power required the run pump.

$$P = \frac{WALN}{60}(hs + hd)$$

$$= \frac{9.81 \times (\pi(0.03^2)/4) \times 0.45 \times 60}{60}(0.03 + 0.04)$$

$$= 0.216\,(0.07)$$

$$\boxed{P = 0.015}$$



Pressure head to accelaration;

i) Suction pipe ⇒ $has = \frac{ls}{g} \cdot \frac{A}{as} \omega^2 r \cos\theta$

ii) Delivery pipe ⇒ ~~had~~ $had = \frac{ld}{g} \cdot \frac{A}{ad} \omega^2 r \cos\theta$

$A = \frac{\pi}{4} D^2$ ⇒ D = Diameter plunger or piston

$a = \frac{\pi}{4} d^2$ ⇒ d = diameter of pipe.

ls = length of suction pipe

ld = length of delivery pipe

r = crank radius

$= \frac{L}{2}$ L = stroke length

$\omega = \frac{2\pi N}{60}$

Pressure head at beginning (midde, End)

i) Biginning $\rightarrow \theta = 0°$
ii) Middle $\rightarrow \theta = 90°$
iii) End $\rightarrow \theta = 180°$

Pressure head $= h_s + h_{as}$

Absolute pressure head $= H_{atm} - (h_s + h_{as})$

Absolute pressure head $= H_{atm} + (h_d + h_{ad})$

$H_{atm} = 10.3m$

5. A single acting reciprocating pump as a diameter of 120mm & stoke length of 300mm, the centre of the pump is 3m above the water surface & 20m below the delivery water level both suction & delivery pipe has same dia of 75 mm & length of the suction pipe is 5m & length of the delivery pipe is 10m if the pump is working at 35 rpm. Find
i) Pressure head for piston at beginning, middle & end of suction & delivery pipe.
ii) Power required to run the pump take the atmospheretic pressure 10.3 m

Given data:

diameter, $D = 120\,mm \Rightarrow 0.12\,m$

stroke length, $L = 300\,mm \Rightarrow 0.3\,m$

Crank radius, $r = \frac{L}{2} = \frac{0.3}{2} = 0.15\,m$

suction head, $h_s = 3\,m$

delivery head, $h_d = 20\,m$

$d_s = d_d = 75\,mm \Rightarrow 0.075\,m$

suction length, $l_s = 5\,m$

delivery length, $l_d = 10\,m$

$N = 35\,rpm$

$H_{atm} = 10.3\,m$

soln:

Pressure head on suction pipe

i) Beginning.

$$\omega = \frac{2\pi N}{60}$$

$$h_{as} = \frac{l_s}{g} \cdot \frac{A}{a_s} \omega^2 r \cos\theta$$

$$= \frac{5}{9.81} \cdot \frac{\frac{\pi}{4}(0.12)^2}{\frac{\pi}{4}(0.075)^2} \cdot \left(\frac{2\pi\, 35}{60}\right)^2 \times 0.15$$

$$= \frac{5}{9.81} \cdot \frac{0.0113}{4.417 \times 10^{-3}} \cdot (3.6651)^2 \times 0.15$$

$$\omega = \frac{2\pi N}{60}$$

$$= 0.5096 \times \overset{2.56}{\cancel{25.582}} \times (3.6651)^2 \times 0.15$$

$$\boxed{h_{as} = 2.63\,m}$$

Pressure head $= h_s + h_{as}$

$= 3 + 2.63$

$= 5.63\ m$

Atmospheric pressure $= H_{atm} - (h_s + h_{as})$

$= 10.3 - 5.63$

$= 4.67\ m$

ii) Middle

$h_{as} = 0$

Press. head $= \cancel{H_{atm}}\ h_s + h_{as}$

$= 3 + 0 = 3\ m$

Atm. pressure $= H_{atm} - (h_s + h_{as})$

$= 10.3 - 3$

$= 7.3\ m$

iii) End :

$$h_{as} = \frac{l_s}{g} \cdot \frac{A}{a_s} \omega^2 r \cos\theta$$

$\theta = 180°$

$$\omega = \frac{2\pi N}{60}$$

$$h_{as} = \frac{5}{9.81} \cdot \frac{\pi (0.12^2)/4}{\pi (0.075^2)/4} \cdot \left(\frac{2\pi 35}{60}\right)^2 \times 0.15 \times -1$$

$h_{as} = -2.63\ m$

$$\text{press. head} = h_s + h_{as}$$
$$= 3\cancel{8} - 2.63$$
$$= 0.37\ m$$

$$\text{Atm. pressure} = H_{atm} - (h_s + h_{as})$$
$$= 10.3 - 0.37$$
$$= 9.93\ m$$

Pressure head on delivery pipe

i) Beginning

$$\theta = 0$$
$$\omega = \frac{2\pi N}{60}$$

$$h_{ad} = \frac{l_d}{g} \frac{A}{a_d} \omega^2 r \cos\theta$$

$$= \frac{10}{9.81} \cdot \frac{\frac{\pi}{4}(0.12)^2}{\frac{\pi}{4}(0.075)^2} \left(\frac{2\pi 35}{60}\right)^2 \times 0.15 \times)$$

$$= 1.019 \times 2.56 \times (3.665)^2 \times 0.15$$

$$\boxed{h_{ad} = 5.258\ m}$$

$$\text{Pressure head} = h_d + h_{ad}$$
$$= 20 + 5.26$$
$$= 25.26\ m$$

$$\text{Atm pressure} = 10.3 + 25.26$$
$$= \cancel{14.96}$$
$$= 35.56\ m$$

ii) Middle

$h_{ad} = 0$

Press. head $= h_d + h_{ad}$

$= 20+0$

$= 20\,m$

Atm. pressure $= H_{atm} + (h_d + h_{ad})$

$= 10.3 + 20$

$= 30.3\,m$

iii) End:

$\theta = 180$

$(\cos 180^\circ = -1)$

$$h_{ad} = \frac{l_d}{g} \frac{A}{a_d} \omega^2 r \cos\theta$$

$$= \frac{10}{9.81} \cdot \frac{\pi (0.12)^2/4}{\pi (0.075)^2/4} \cdot \left(\frac{2\pi \times 35}{60}\right)^2 \times 0.15 \times -1$$

$h_{ad} = -5.26\,m$

Press. head $= h_d + h_{ad}$

$= 20 - 5.26$

$= 14.74\,m$

Atm. pressure $= H_{atm} + (h_d + h_{ad})$

$= 10.3 + 14.74$

$= 25.04\,m$

6. A single acting reciprocating pump has a diameter of 200mm & stock length of 450mm the suction head is 4.5m & delivery head is 15m the diameter of the suction pipe is 50mm & delivery pipe is 70mm the length of the suction & delivery pipe are 5m & 15m the pump runs at a speed of 55 rpm, the atmospheric head of water is 10.3m. Find pressure head at ~~delivery~~ suctions delivery pipe at beginning, middle and end.

Given:

$D = 200mm \Rightarrow 0.2\,m$

$L = 450mm \Rightarrow 0.45\,m$

$r = \frac{0.45}{2} = 0.225\,m$

$h_s = 4.5\,m$

$h_d = 15\,m$

$d_s = 50mm \Rightarrow 0.05\,m$

$d_d = 70mm \Rightarrow 0.07\,m$

$l_s = 5\,m$

$l_d = 15\,m$

$N = 55\,rpm$

$H_{atm} = 10.3\,m$

To find

Pressure head at suction & delivery in middle, beginning, end.

soln:

Pressure head at suction:

(i) Beginning $\theta = 0$

$\omega = \frac{2\pi N}{60}$

$$h_{as} = \frac{l_s}{g} \cdot \frac{A}{a_s} \cdot \omega^2 r \cos\theta$$

$$= \frac{5}{9.81} \cdot \frac{\pi (0.2^2)/4}{\pi (0.05)^2/4} \cdot \left(\frac{2\pi\, 55}{60}\right)^2 \times 0.225 \times 1$$

$$= 0.509 \times 16 \times 33.172 \times 0.225 \times 1$$

$h_{as} = 60.8\ m$

Pressure head $= h_s + h_{as}$

$= 4.5 + 60.8$

$= 65.3\ m$

Atm. pressure $= H_{atm} - (h_s + h_{as})$

$= 10.3 - 65.3$

$= -55\ m$

ii) Middle: $\theta = 90°$

$h_{a\theta} = 0$

Pressure head $= h_s + h_{as}$

$= 4.5\ m$

Atm. pressure $= H_{atm} - (h_s + h_{as})$

$= 10.3 - 4.5$

$= 5.8\ m$

iii) End

$\theta = 180$

$$h_{as} = \frac{l_s}{g} \cdot \frac{A}{a_s} \cdot \omega^2 r \cos\theta$$

$$= \frac{5}{9.81} \cdot \frac{\pi (0.2)^2/4}{\pi (0.05)^2/4} \cdot \left(\frac{2\pi \times 55}{60}\right)^2 \times 0.225 \times -1$$

$h_{as} = -60.8\,m$

Press. head $= h_s + h_{as}$

$= 4.5 - 60.8$

$= -56.3\,m$

Atm pressure $= H_{atm} - (h_s + h_{as})$

$= 10.3 + 56.3$

$= 66.6\,m$

Pressure head on delivery pipe:

i) Beginning:

$\theta = 0$

$$h_{ad} = \frac{l_d}{g} \cdot \frac{A}{a_d} \times \omega^2 r \cos\theta$$

$$= \frac{15}{9.81} \cdot \frac{\pi (0.2)^2/4}{\pi (0.07)^2/4} \cdot \left(\frac{2\pi\, 55}{60}\right)^2 \times 0.225 \times 1$$

$= 1.529 \times 8.163 \times 33.172 \times 0.225$

$h_{ad} = 93.16\,m$

Press. head $= h_d + h_{ad}$

$= 15 + 93.16$

$= 108.16$

Atm. pressure = Hatm + (hd + had)

= 10.3 + 108.16

= 118.46 m

ii) Middle :

had = 0

pressure head = hd + had

= 15 + 0

= 15 m

Atm pressure = Hatm + (hd + had)

= 10.3 + 15.

= 25.3 m

(iii) End :

$\theta = 180$

$(\cos 180° = -1)$

$had = \frac{ld}{g} \times \frac{A}{ad} \times \omega^2 r \cos\theta$

$= \frac{15}{9.81} \times \frac{\pi (0.2)^2/4}{\pi (0.07)^2/4} \times \left(\frac{2\pi 55}{60}\right)^2 \times 0.225 \times -1$

had = - 93.16 m

Press. head = hd + had

= 15 - 93.16

= - 78.16 m

Atm pressure = Hatm + (hd + had)

= 10.3 + (-78.16) = -67.86 m

Unit - 4

Turbines

Turbines :

Pelton wheel turbine.

velocity diagram.

At inlet → $V_{r1} = V_1 - u_1$

$V_{w1} = V_1$

At outlet → $V_{r2} = V_{r1}$

$V_{w2} = V_{r2} \cos\phi - u_2$

$= V_{r2} \cos\phi - u$

for slow runner $\beta < 90°$, V_{w2} is Negative

Medium runner $\beta = 90°$, $V_{w2} = 0$

fast runner $\beta > 90°$, V_{w2} = positive

Force exerted by water :

$$F = \rho a V_1 (V_{w1} + V_{w2})$$

Workdone per second

$$\Rightarrow \frac{1}{g} (V_{w1} + V_{w2}) \times u.$$

Energy supplied $= \frac{1}{2} m V_1^2$

$m = \rho a V_1$

K.E of Jet per second $= \frac{1}{2} (\rho a V_1) \times V_1^2.$

Losses :

Loss ratio will be $\frac{u}{V_1}$

less than the theoretical value = 0.5

Head & efficiencies of pelton wheel

1) Gross head (H_g)

Difference b/w water level at the reservior level at the tailrace.

2) Net head (H)

$$H = H_g - h_f - h$$

$$h_f = \frac{4fLV^2}{2gD}$$

h = Height of the nozzle above tailrace

3) water power :

Power supplied by water jet is water power $= WQH = \rho gQH$

H = Net head

Power developed by the bucket wheel is bucket power.

$$= \rho a V_1 (V_{w_1} \pm V_{w_2}) u$$

$$= \rho Q (V_{w_1} \pm V_{w_2}) u$$

Hydraulic efficiency:

$$\eta_h = \frac{2u(V_1 - u)[1 + \cos\phi]}{V_1^2}$$

Design aspects of pelton wheel:

1) velocity on jet:

At inlet ⇒ $V_1 = C_v\sqrt{2gH}$

C_v = co-efficient of velocity

= 0.98 to 0.99

H = Net head

2) Velocity of wheel:

$u = K_u\sqrt{2gH}$

K_u = speed ratio

= 0.43 to 0.48

3) Mean diameter of wheel (D)

$$u = \frac{\pi D N}{60}$$

$$D = \frac{60u}{\pi N}$$

mean diameter is also known as pitch diameter.

4) Jet ratio (m)

$m = \frac{D}{d}$; D = mean diameter

d = diameter of jet

m = varies b/w 11 to 15, m = 12 is adopted.

5) Bucket dimensions:-

Axial width, B = 3d to 4d

Radial length, L = 2d to 3d

depth, T = 0.8d to 1.2d

Angle, ϕ = 10° to 20°

b) Number of buckets : $Z = \frac{D}{2d} + 15$

I) No. of Jets: $= \frac{\text{Total discharge}}{\text{discharge for one jet}} = \frac{Q}{q}$ $q = A_1 \times V_1$

1. A pelton wheel having semi circular buckets functions under a head of 150m & consumes 0.06 m3/sec of water. If 450mm Diameter of wheel turns 800 rpm. Calculate the power available at the nozzle & also find the hydraulic efficiency of the wheel. Assume the coefficient of velocity as unity.

Given;

$H = 150m$

$Q = 0.06\, m^3/s$

$D = 450mm = 0.45\, m$

$N = 800\, rpm$

$C_v = 1$, $\phi = 0'$

i) $P = wQH$

ii) $\eta_h = \frac{2u(V_1 - u)}{V_1^2}[1 + \cos\phi]$

$P = wQH$

$= 9.81 \times 0.06 \times 150$

$P = 88.29\, kw$

$\eta_h = \frac{2u(V_1 - u)}{V_1^2}[1 - \cos\phi]$

$u = \frac{\pi DN}{60} = \frac{\pi \times 0.45 \times 800}{60}$

$u = 31.41$

$$V = C_v\sqrt{2\times g\times H}$$

$$= 1\sqrt{2\times 9.81\times 150}$$

$$V_1 = 54.24$$

$$\eta_h = \frac{2\times 31.41[54.24-31.41]}{(54.24)^2}[1+\cos 0]$$

$$\eta_h = 97\%.$$

2. A pelton wheel turbine runs under a head of 400m & 1000 rpm it develops a power of 5000kW. Find the least diameter of jet & pitch diameter of wheel. The overall efficiency of the turbine is 85% & the coefficient of velocity $C_v = 0.99$ & speed ratio is 0.45. Also find the number of buckets & number of jets required in the pelton wheel.

Given:

$H = 400m$

$N = 1000 rpm$

$P = 5000 kW$

$\eta_o = 85\%$

$C_v = 0.99$

$k_u = 0.45$

To find

$d = ?$

$D = ?$

No. of b = ?

No. of Jet =

$$u = \frac{\pi D N}{60}$$

$$= \frac{\pi \times D \times 1000}{60}$$

$$u = k_u \times V_1$$

$$V_1 = C_V \sqrt{2gH}$$

$$= 0.99 \sqrt{2 \times 9.81 \times 400}$$

$$= 87.702$$

$$u = k_u V_1$$

$$= 0.45 \times 87.70$$

$$u = 39.49$$

39. $$u = \frac{\pi D N}{60}$$

$$39.49 = \frac{\pi \times D \times 1000}{60}$$

$$D = \frac{39.49 \times 60}{1000 \times \pi}$$

$$\boxed{D = 0.75\ m}$$

$$Q = A V_1$$

$$= \frac{\pi}{4} d^2 \times V_1$$

$$\eta_o = \frac{P}{w \times Q \times H}$$

$$0.85 = \frac{5000}{9.81 \times Q \times 400}$$

$$Q = \frac{5000}{9.81 \times 0.85 \times 400}$$

$Q = 1.499 m^3/sec$

$$\boxed{Q = 1.5\ m^3/s}$$

$Q = A V_1$

$Q = \frac{\pi d^2}{4} \times V_1$

$1.5 = \frac{\pi}{4} d^2 \times 87.70$

$d^2 = \frac{1.5 \times 4}{87.70 \times \pi}$

$d = 0.02$

$$\boxed{d = 0.147 m}$$

No. of buckets

$z = \frac{D}{2d} + 15$

$= \frac{0.75}{2 \times 0.147} + 15$

$z = 17.5 \simeq 18$

No. of jets

$= \frac{\text{Total discharge}}{\text{discharge for one jet}}$

discharge for one jet $= q$

$q = A \times V_1$

$= \frac{\pi}{4} d^2 \times V_1$

$= \frac{\pi}{4} \times (0.147)^2 \times 87.70$

$q = 1.48\ m^3/s$

$$\text{No. of jet} = \frac{Q}{q}$$

$$= \frac{1.5}{1.48}$$

$$= 1.01 \simeq 1$$

3. A ~~p~~ water jet on pelton wheel is 8cm in diameter & has velocity of 93 m/s the rotation speed of wheel is 600 rpm & deflection angle of the jet is 170° if the speed ratio is 0.47 determine the diameter of the wheel & power developed.

Given:

$d = 8\ cm \Rightarrow 0.8\ m$ ~~m~~

$V = 93\ m/s$

$N = 600\ rpm$

$\phi = 170°$

$K_u = 0.47$

$D = ?$

$P = ?$

Soln:

$$u = \frac{\pi D N}{60}$$

$$D = \frac{u \times 60}{\pi N}$$

$$u = K_u V_1$$

$$= 0.47 \times 93$$

$$u = 43.71\ m/s$$

$$D = \frac{43.71 \times 60}{\pi \times 600}$$

$$\boxed{D = 1.39\ m}$$

$\phi = 180° - 170° = 10°$

$V_{r1} = V_1 - u$

$= 93 - 43.71$

$$\boxed{V_{r1} = 49.29\ m/s}$$

$V_{r2} = 0.85\, V_{r1}$

$V_{r2} = 41.89\ m/s$

$V_{w2} = V_{r2} \cos\phi - u_2$

$= 41.89 \cos 10° - 43.71$

$= -2.45$

Area of jet,

$$a = \frac{\pi}{4} d^2$$

$$= \frac{\pi}{4} \times (0.8)^2$$

$$= 5.0265 \times 10^{-3}\ m^2.$$

$P = \rho \times a V_1 \times (V_{w1} + V_{w2})\, u$

$= 1000 \times 5.0265 \times 10^{-3} \times 93\,(93 + 4.83)\, 43.71$

$= 1998.95\ kW$

$$\boxed{P = 2\ MW}$$

4) A pelton wheel working at a head of 500m reduces 13000 kW power at 430 r.p.m If the efficiency of beam 85%. & coefficient of velocity is 0.98 & speed ratio of 0.46. Determine the discharge of the turbine and dia of beam & dia of nozzel.

Given:

$H = 500\ m$

$P = 13000\ kW$

$N = 430\ rpm$

$\eta_o = 85\%$

$C_v = 0.98$

$k_u = 0.46$

Soln:

velocity of jet, $V_1 = C_v \sqrt{2gH}$

$= 0.98 \times \sqrt{2 \times 9.81 \times 500}$

$= 97.1\ m/s$

velocity of wheel, $u = k_u \sqrt{2gH}$

$= 0.46 \times \sqrt{2 \times 9.81 \times 500}$

$= 45.56\ m/s$

$u = \frac{\pi D N}{60}$

$45.56 = \frac{\pi \times D \times 430}{60}$

$D = 2.024\ m$

$\eta_o = \frac{P}{wQH}$

$0.85 = \frac{13000}{9.81 \times Q \times 500}$

$\boxed{Q = 3.12\ m^3/s}$

Q = Area of jet × velocity of jet

$Q = \frac{\pi}{4} \times d^2 \times V_1$

$3.12 = \frac{\pi}{4} \times d^2 \times 97.1$

$d^2 = 0.0409$

$\boxed{d = 0.2022\, m}$

5\. A double jet pelton wheel is required to generate 7500 kW at a head at 400 m. The jet is deflected through 165° & the relative velocity of the jet is reduced by 50%. why passing over the bucket. Determine the dia of each jets & total flow & forse ~~at~~ extrated by jet. Assume the generator efficiency is 95% & overall effeciency 80%. the coefficiency is ~~of~~ % velocity is 0.97 & speed rato 0.46.

Given:

No. of jets = 2

$P = 7500\, kW$

$H = 400\, m$

$\phi = 165°$

Reduction of relative velocity due to friction $\}$ = 15%

$\eta_{gen} = 95\% \Rightarrow 0.95$

$\eta_o = 80\% \Rightarrow 0.8$

$C_v = 0.97$

$K_u = 0.46$

Soln:

$V_1 = C_V \sqrt{2gH}$

$= 0.97 \sqrt{2 \times 9.81 \times 400}$

$= 85.93 \ m/s$

$\eta_o = \frac{P}{WQH}$

$0.8 = \frac{(7500/0.95)}{9.81 \times Q \times 400}$

$Q = 2.52 \ m^3/sec$

Q = No. of jet × Area × velocity of jet.

$2.52 = 2 \times \frac{\pi}{4} \times d^2 \times 85.93$

$d^2 = 0.0187$

$d = 0.1368 \ m \Rightarrow 136.8 \ mm$

$u = k_u \sqrt{2gH}$

$= 0.46 \times \sqrt{2 \times 9.81 \times 400}$

$\boxed{u = 40.75 \ m/s}$

$V_{w_1} = V_1 = 85.93 \ m/s$

$V_{r_1} = V_{w_1} - u_1$

$= 85.93 - 40.75$

$\boxed{V_{r_1} = 45.18 \ m/s}$

$\phi = 180° - 165°$

$= 15°$

$V_{r2} = 0.85\, V_{r1}$

$= 0.85 \times 45.18$

$\boxed{V_{r2} = 38.4\ m/s}$

$V_{w2} = V_{r2}\cos\phi - u_2$

$= 38.4 \times \cos 15^\circ - 40.75$

$\boxed{V_{w2} = -3.66\ m/s}$

$F = \rho Q\,(V_{w1} \pm V_{w2})$

$= 1000 \times \frac{2.52}{2} \times (85.93 - 3.66)$

$= 103660.2\ N$

$\boxed{F = 103.66\ kN}$ //

Francis turbine

work done & efficiencies

$\text{workdone} = \rho Q\,(V_{w1}u_1 \pm V_{w2}u_2)$

$= \frac{wQ}{g}\,(V_{w1}u_1 \pm V_{w2}u_2)$

Q = Discharge through the runner

V_{w1} & V_{w2} = velocity of whirl

u_1 & u_2 = Tangential velocity.

Hydraulic efficiency (η_h)

$$\eta_h = \frac{\frac{wQ}{g}(V_{w1}u_1)}{wQH} = \frac{V_{w1}u_1}{gH}$$

Hydraulic input of turbine $= wQH$

$V_{w_2} \neq 0 \qquad \eta_h = \dfrac{(V_{w_1}u_1 \pm V_{w_2}u_2)}{gH}$

η_h ranges from .85 to 95%

Mechanical efficiency (η_{mech})

$$\eta_{mech} = \frac{P}{\frac{wQ}{g}(V_{w_1}u_1)}$$

$V_{w_2} \neq 0$

$$\eta_{mech} = \frac{P}{(V_{w_1}u_1 \pm V_{w_2}u_2)}$$

Overall efficiency (η_o)

$$\eta_o = \frac{\text{shaft power}}{\text{water power}} = \frac{P}{wQH}$$

$\eta_o = \eta_{mech} \times \eta_h \Rightarrow$ value ranges from 80 to 90%

Degree of reaction :

$$R = \frac{\text{Increase in relative kinetic energy in moving table}}{\text{stage work output}}$$

$$= \frac{\frac{V_{r_2}^2 - V_{r_1}^2}{2}}{u(V_{w_1} + V_{w_2})} = \frac{V_{r_2}^2 - V_1^2}{2u(V_{w_1} + V_{w_2})}$$

Design aspects of francis turbine:

Ratio of width to diameter $n = \frac{B}{D}$

Flow ratio (k_f):

$$k_f = \frac{V_{f1}}{\sqrt{2gH}}$$

$k_f \Rightarrow 0.15$ to 0.3

speed ratio (k_u)

$$k_u = \frac{u}{\sqrt{2gH}}$$

$k_u = 0.6$ to 0.9

Design procedure:

step1: Required discharge (Q) determined from the relation

$$\eta_o = \frac{P}{wQH}$$

step 2: Total area $A = k_t \pi D_1 B_1$

$k_t = 0.95$

flow velocity $V_{f1} = \frac{Q}{k_t \pi D_1 B_1}$ $\quad \therefore n = \frac{B}{D}$ $\quad \boxed{B = nD}$

$$V_{f1} = \frac{Q}{k_t \pi n D_1^2}$$

Also $V_{f1} = k_f \sqrt{2gH}$.

$$k_f \sqrt{2gH} = \frac{Q}{k_t n \pi D_1^2}$$

$$D_1 = \sqrt{\left(\frac{Q}{K_f\, K_t\, \pi n \sqrt{2gH}}\right)}$$

step 3: Tangential velocity $u_1 = \frac{\pi D_1 N}{60}$

step 4: Whirl velocity (V_{w_1}) $\eta_h = \frac{V_{w_1} u_1}{gH}$.

$$V_{w_1} = \frac{\eta_h\, gH}{u_1}$$

Step 5: Angle of guide blade runner blade θ

$$\tan\alpha = \frac{V_{f_1}}{V_{w_1}} \qquad \tan\theta = \frac{V_{f_1}}{V_{w_1} - u_1}$$

step 6: Runner diameter. $D_2 = \frac{D_1}{2}$; $u_2 = \frac{u_1}{2}$.

step 7: The flow velocity of exist (V_{f_2}).

$$\frac{V_{f_1}}{V_{f_2}} = \frac{\cancel{K_{f_2}}\, K_{t_2}\, \pi D_2 B_2}{K_{t_1}\, \pi D_1 B_1}$$

$V_{f_1} = V_{f_2}$, $K_{t_1} = K_{t_2}$, $D_1 = 2D_1 + B_2 = 2B_1$.

Step 8: Radial discharge $\beta = 90°$ is assumed
Runner blade angle ϕ from outlet velocity triangle.

$$\tan\phi = \frac{V_{f_2}}{u_2}$$

Step 9: Number of vanes varies from 16 to 24.

6. The francis's turbine has a inlet diameter of 2 m & outlet diameter of 1.2 m the breath of blades is constant at 0.2 m the runner rotates at speed of 250 rpm with a discharge of 8 m^3/sec the discharge is radially outwards at outlet calculate the angle guides at inlet & blade angle at out let.

Given data:

$D_1 = 2m$ $\qquad \eta_h = 0.95$

$D_2 = 1.2m$

$B_1 = B_2 = 0.2 m$

$N = 250 rpm$

$Q = 8 m^3/s$

soln:

$$\tan\alpha = \frac{Vf_1}{Vw_1}$$

$$\tan\phi = \frac{Vf_2}{u_2}$$

$$Vf_1 = \frac{Q}{k_t \pi D_1 B_1}$$

$$= \frac{8}{0.95 \times \pi \times 2 \times 0.2}$$

$$Vf_1 = 6.4 m/s$$

ϕ.

$$V_{w1} = \frac{\eta_h g H}{u_1}$$

$$u_1 = \frac{\pi D_1 N}{60}$$

$$= \frac{\pi \times 2 \times 250}{60}$$

$$u_1 = 26.17$$

$$V_{f1} = k_f \sqrt{2gH}$$

$$6.7 = 0.3\sqrt{2 \times 9.81 \times H}$$

$$6.7 = 0.3 \times \sqrt{2 \times 9.81} \times (H)^{1/2}$$

$$(H)^{1/2} = \frac{6.7}{0.3\sqrt{2 \times 9.81}}$$

$$H = \left(\frac{6.7}{0.3\sqrt{2 \times 9.81}}\right)^2$$

$$H = 25.41 \text{ m}$$

$$V_{w1} = \frac{\eta_h g H}{u_1}$$

$$= \frac{0.95 \times 9.81 \times 25.41}{26.17}$$

$$V_{w1} = 9.05$$

$$\tan\alpha = \frac{V_{f1}}{V_{w1}}$$

$$= \frac{6.7}{9.05}$$

$$\alpha = \tan^{-1}\left(\frac{6.7}{9.05}\right)$$

$$\boxed{\alpha = 36°30'}$$

$V_{f2} = ?$

$$\frac{V_{f1}}{V_{f2}} = \frac{k t_2 \pi D_2 B_2}{k t_1 \pi D_1 B_1} = \frac{D_2}{D_1} \quad (\because k t_2 = k t_1,\ \cancel{D_2 = D_1},\ B_2 = B_1)$$

$$\frac{V_{f1}}{V_{f2}} = \frac{1.2}{2.0}$$

$$\frac{6.7}{V_{f2}} = 0.6$$

$$V_{f2} = \frac{6.7}{0.6}$$

$$V_{f2} = 11.16.$$

$$u_2 = \frac{\pi D_2 N}{60}$$

$$= \frac{\pi \times 1.2 \times 250}{60}$$

$$u_2 = 15.70$$

$$\tan\phi = \frac{V_{f2}}{u_2}$$

$$\tan\phi = \frac{11.16}{15.70}$$

$$\phi = \tan^{-1}\left(\frac{11.16}{15.70}\right)$$

$$\boxed{\phi = 35°25'}$$

7. The following data refers to an the ext. inward flow reaction turbine internal & external diameter 1.2 m & 0.6 m the velocity of the flow is consent the 2.5 m/s the value of head is 22 m the guide blade angle is 10° the vanes are radial at inlet assume that the discharge at the outlet is also radial calculate the speed of turbine, vane angle at outlet, Hydraulic effeciency.

8. The inwer flow turbine with an over all effeciency 80% is require to develop 150 kw power, head is 8 m, the peripheral velocity $u_1 = 0.36\sqrt{2gH}$ & radial velocity of flow $v_{f1} = 0.96\sqrt{2gH}$ & speed of 150 rpm hydraulic losses 22% of available energy assuming the radial discharge. To find

1. guide blade angle at inlet,
2. vane angle at outlet,
3. Diameter of wheel,
4. Width of the wheel at inlet.

7. Given:

$D_1 = 1.2\,m$

$D_2 = 0.6\,m$

$V_{f1} = V_{f2} = 2.5\,m/s$

$H = 22\,m$

$\alpha = 10°$

Soln::

Runner vanes are radial at inlet;

$\therefore \theta = 90°$

$\therefore V_{w1} = u_1$

Discharge is radial

$\therefore V_{w2} = 0, V_2 = V_{f2} = 2.5\,m/s$

$\tan\alpha = \frac{V_{f1}}{u_1}$ $(\because V_{w1} = u_1)$

$\tan 10° = \frac{2.5}{u_1}$

$u_1 = 14.18\,m/s$

$u_1 = \frac{\pi D_1 N}{60}$

$14.18 = \frac{\pi \times 1.2 \times N}{60}$

$N = 225.68\,rpm$

$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.6 \times 225.68}{60}$

$u_2 = 7.09\,m/s.$

from outlet velocity triangle,

$$\tan\phi = \frac{V_{f2}}{u_2} = \frac{2.5}{7.09}$$

$$\phi = \tan^{-1}(0.353)$$

$$\phi = 19°26'$$

$(\because V_{w1} = u_1)$

overall efficiency,

$$\eta_0 = \frac{P}{wQH}$$

$$0.8 = \frac{150}{9.81 \times Q \times 8}$$

$$Q = 2.39\ m^3/s$$

$$Q = \pi D_1 B_1 V_{f1}$$

$$2.39 = \pi \times 0.57423 \times B_1 \times 12.08$$

$$B_1 = 0.11013\ m$$

$$B_1 = 110.13\ mm$$

Hydraulic efficiency,

$$\eta_h = \frac{V_{w1} u_1}{gH}$$

$$= \frac{14.18 \times 14.18}{9.81 \times 22}$$

$$= 0.9317$$

$$\eta_h = 93.17\%$$

8) Given data:

$\eta_0 = 80\% = 0.8$

$P = 150\ kW$

$H = 8\ m$

$u_1 = 0.36\sqrt{2gH}$

$V_{f1} = 0.96\sqrt{2gH}$

$N = 150\ rpm$

Hydraulic losses $= 22\%$ of available energy

$\therefore V_{w2} = 0;\ V_{f1} = V_{f2}.$

soln:

$u_1 = 0.36\sqrt{2gH}$

$= 0.36\sqrt{2\times 9.81\times 8}$

$u_1 = 4.51$ m/s

$V_{f1} = 0.96\sqrt{2gH}$

$= 0.96\sqrt{2\times 9.81\times 8}$

$= 12.03$ m/s

Hydraulic efficiency,

$$\eta_h = \frac{\text{Head at inlet} - \text{Hydraulic losses}}{\text{Head at inlet}}$$

$$= \frac{H - 0.22H}{H}$$

$$= \frac{0.78H}{H}$$

$= 0.78$

$\eta_h = 78\%$

$$\eta_h = \frac{V_{w1}u_1}{gH}$$

$$0.78 = \frac{V_{w1}\times 4.51}{9.81\times 8}$$

$V_{w1} = 13.57$ m/s

$$\tan\alpha = \frac{V_{f1}}{V_{w1}} = \frac{12.03}{13.57}$$

$\alpha = \tan^{-1}(0.887)$

$\alpha = 41^\circ 34'$

$$\tan\theta = \frac{V_{f1}}{V_{w1} - u_1}$$

$$= \frac{12.03}{13.57 - 4.51}$$

$$= \tan^{-1}(1.328)$$

$$\theta = 53^\circ 1'$$

$$u_1 = \frac{\pi D_1 N}{60}$$

$$4.57 = \frac{\pi \times D_1 \times 150}{60}$$

$$D_1 = 0.57423\, m$$

$$D_1 = 574.23\, mm$$

$$\eta_0 = \frac{P}{WQH}$$

$$0.8 = \frac{150}{9.81 \times Q \times 8}$$

$$Q\ \cancel{BQ} = 2.39\, m^3/s$$

$$Q = \cancel{\pi} D_1 B_1 V_{f1}$$

$$= \pi \times 0.57423 \times B_1 \times 12.03$$

$$= 0.11013\, m$$

$$Q = 110.13\, mm$$

1. A single acting reciprocating pump as a diameter of 200mm & has a stock length of 450mm the suction head is 4.5m & delivery head is 15 m the diameter of the suction pipe & delivery pipe is 50mm & 40mm. The length of the suction & delivery 5m & 15m. the pump runs at speed of 55 rpm, the atmospheric head of water is 10.3 m. Find the pressure at beginning, middle & end.

2. A Francis turbine has a inlet dia. of 2m & outlet diameter of 1.2m the breath of the blade is constent at 0.2m the runner rotates at speed of 250 rpm with a discharge of 8 m3/s, the discharge is radially outwards at outlet calculate the angle of guide & at inlet & blade angle at outlet.

3. Write a step by step design procedure for Francis turbine & derive the formula for work done & efficieny of Francis turbine.

4. Draw a with a neat sketch explain the main parts & working principal of kaplan turbine.

5. A double jet pleton wheel is required to generate the power of 450 kw & at the head of 400m the jet is deflected to 165° angle.

& the relative velocity of the jet is reduced by 50% while passing over the bucket. Determine the dia of each jet & total flow & the force extracted by jet assume the generated efficiency 98% and overall efficiency 80%. the coeff. of velocity 0.97 speed ratio 0.46.

Kaplan turbine

Working properties of kaplan turbine.

i) Expression of workdone
ii) Expression for efficiency
iii) Power developed

All are same as francis turbine.

In case of kaplan turbine

$n = \frac{D_b}{D_o}$ D_b = Dia of hub
D_o = Dia of outer

$\boxed{n = 0.5, 0.6}$

Discharge:

$$Q = \text{Area of flow} \times \text{velocity of flow}$$
$$= \frac{\pi}{4}(D_o^2 - D_b^2) \times V_f$$
$$= \frac{\pi}{4}(D_o^2 - D_b^2) \times K_f \sqrt{2gH}$$
$$Q = \frac{\pi}{4} D_o^2 (1 - n^2) \times K_f \sqrt{2gH}$$

Peripheral velocity (u)

It varies from ratio of point under consideration.

velocity of flow (V_f)

$V_{f1} = V_{f2} = V$. It is constant.

A Kaplan turbine delivery 40 MW of power under a head 40 m & runs at 150 rpm. the hub diameter is 3m & runner tip diameter is 6m the overall efficiency is 90%. determine the blade angle at hub & tip and also at the diameter of 4m. also find the speed ratio & flow ratio based on tip velocity assume the hydraulic effeciency as 95%.

Given data:

$P = 40 MW \Rightarrow 40000 kW$

$H = 40 m$

$D_b = 3 m$

$N = 150 rpm$

$D_o = 6 m$

$\eta_o = 90\%$

$\eta_h = 95\%$

Soln:

case (i)

Overall efficiency

$$\eta_o = \frac{P}{wQH}$$

$$0.9 = \frac{40000}{9.81 \times Q \times 40}$$

$$\boxed{Q = 113.26 \, m^3/s}$$

$$Q = \frac{\pi}{4}(D_o^2 - D_b^2) V_{f1}$$

$$113.26 = \frac{\pi}{4}(6^2 - 3^2) V_{f1}$$

$$\boxed{V_{f1} = 5.34 \text{ m/s}}$$

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 6 \times 150}{60}$$

$$\boxed{u_1 = 47.12 \text{ m/s}}$$

Hydraulic efficiency

$$\eta_h = \frac{V_{w1} u_1}{gH}$$

$$0.95 = \frac{V_{w1} \times 47.12}{9.81 \times 40}$$

$$\boxed{V_{w1} = 7.5 \text{ m/s}}$$

Runner vane angle

$$\tan(180° - \theta) = \frac{V_{f1}}{u_1 - V_{w1}}$$

$$= \frac{5.34}{47.12 - 7.5}$$

$$\boxed{\theta = 172°\,19'}$$

Blade angle, $\tan \alpha = \frac{V_{f1}}{V_{w1}}$

$$= \tan^{-1}\left(\frac{5.34}{7.5}\right)$$

$$\boxed{\alpha = 35°\,27'}$$

speed ratio $K_u = \frac{u_1}{V_1}$

flow ratio $K_f = \frac{V_{f1}}{V_1}$

$$V_1 = \sqrt{V_{f1}^2 + V_{w1}^2}$$

$$= \sqrt{5.34^2 + 7.5^2}$$

$$\boxed{V_1 = 9.21 \text{ m/s}}$$

$$K_u = \frac{47.12}{9.21}$$

$$\boxed{K_u = 5.12}$$

$$K_f = \frac{5.34}{9.21}$$

$$\boxed{K_f = 0.58}$$

Case (ii)

if tip diameter is 4 m

$$D_1 = D_0 = 4 \text{ m}$$

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 4 \times 150}{60}$$

$$\boxed{u_1 = 31.42 \text{ m/s}}$$

Runner vane $\tan(180^\circ - \theta) = \frac{V_{f1}}{u_1 - V_{w1}}$

$$= \frac{5.34}{(31.42 - 7.5)}$$

$$\theta = 167^\circ 26'$$

Blade vane angle same as case (i)

A Kaplan turbine ~~dot~~ develops a power of 44145 kW of power. The overall efficiency is 68% under a head of 25 m the speed ratio is 1.6 the the flow ratio is 0.5 if the hub dia is 0.35 times the runner diameter. Find the diameter of the runner & speed speed of turbine.

Given data:

$P = 44145\ kW$

$\eta_o = 68\% \Rightarrow 0.68$

$H = 25 m$

$K_u = 1.6$

$K_f = 0.5$

$D_b = 0.35\ D_o$

Soln:

$$Q = \frac{\pi}{4}\left(D_o^2 - D_b^2\right) V_{f1}$$

$$V_{f1} = K_f \sqrt{2gH}$$

$$= 0.5\sqrt{2 \times 9.81 \times 25}$$

$$\boxed{V_{f1} = 11.07\ m/s}$$

$$\eta_o = \frac{P}{wQH}$$

$$0.68 = \frac{44145}{9.81 \times Q \times 25}$$

$$\boxed{Q = 264.70\ m^3/s}$$

$$Q = \frac{\pi}{4}(D_o^2 - D_b^2) \times V_{f_1}$$

$$264.70 = \frac{\pi}{4}\left[D_o^2 - (0.35\,D_o)^2\right] \times 11.07 \text{ m/s}$$

$$\left[D_o^2 - (0.35\,D_o)^2\right] = \frac{264.70 \times 4}{\pi \times 11.07}$$

$$(1 - 0.1225)\,D_o^2 = 30.44$$

$$0.8775\,D_o^2 = 30.44$$

$$D_o^2 = (30.44 / 0.8775)$$

$$D_o^2 = 34.68$$

$$\boxed{D_o = 5.88 m}$$

$$u_1 = K_u\sqrt{2gH}$$

$$= 1.6\sqrt{2 \times 9.81 \times 25}$$

$$u_1 = 35.43 \text{ m/s}$$

$$u_1 = \frac{\pi D_1 N}{60}$$

$$35.43 = \frac{\pi \times 5.89 \times N}{60}$$

$$N = \frac{60 \times 35.43}{\pi \times 5.89}$$

$$\boxed{N = 114.88 \text{ rpm}}$$

A kaplone turbine develops 20000kw at head of 35m & at a rotational speed of 420 rpm. The outer dia of blade is 2.5 m & hub diameter is 0.85 m. if the overall effeciency & hydraulic efficiency is 85% & 88% respectively. calculate the discharge & blade angle and flow angle of outlet.

<u>Given data:</u>

$P = 20000\,kw$

$H = 35m$

$N = 420\,rpm$

$D_o = 2.5\,m$

$D_b = 0.85m$

$\eta_o = 85\% \Rightarrow 0.85$

$\eta_h = 88\% \Rightarrow 0.88$

<u>Soln:</u>

$$\eta_o = \frac{P}{w.Q\,H}$$

$$0.85 = \frac{20000}{9.81 \times Q \times 35}$$

$$\boxed{Q = 68.53\ m^3/s}$$

$$\tan(180° - \theta) = \frac{Vf_1}{Vw_1 - u_1}$$

$$Q = \frac{\pi}{4}(D_o^2 - D_b^2) \times Vf_1$$

$$68.53 = \frac{\pi}{4}(2.5^2 - 0.85^2)\,Vf_1$$

$$Vf_1 = \frac{\cancel{4.341}\ 68.53}{\cancel{b}\ \ 4.341}$$

$$\boxed{V_{f1} = 15.79 \ m/s}$$

$$u_1 = \frac{\pi D_1 N}{60}$$

$$= \frac{\pi \, \cancel{(0.85)} (2.5) \, 450}{60}$$

$$\boxed{u_1 = 54.98 \ m/s}$$

$$\eta_h = \frac{V_{w1} u_1}{g H}$$

$$0.88 = \frac{V_{w1} \times 54.98}{9.81 \times 35}$$

$$\boxed{V_{w1} = 5.49 \ m/s}$$

$$\tan(180^\circ - \theta) = \frac{V_{f1}}{V_{w1} - u_1}$$

$$\tan(180^\circ - \theta) = \frac{15.79}{5.49 - 54.98}$$

$$180^\circ - \theta = \tan^{-1}(-0.319)$$

$$180^\circ - \theta = -17^\circ 49'$$

$$\cancel{180^\circ \; 91.69} =$$

$$180^\circ - 17.69 = \theta$$

$$\boxed{\theta = 162^\circ 48'}$$

$$\tan \alpha = \frac{V_{f1}}{u_1 - V_{w1}}$$

$$= \frac{15.79}{54.98 - 5.49}$$

$$\tan \alpha = \frac{V_{f1}}{V_{w1}}$$

$$= \tan^{-1}\left(\frac{15.79}{5.49}\right)$$

$$= \cancel{\tan^{-1}}$$

$$\boxed{\alpha = 70°49'}$$

Unit-3

Gradually varied flow:

Derivation of dynamic equation of G.V.F

$$H = z + y + \frac{V^2}{2g}$$

Diff w.r.to x

$$\frac{dH}{dx} = \frac{dz}{dx} + \frac{dy}{dx} + \frac{d}{dx}\left(\frac{V^2}{2g}\right)$$

H = Total head

z = Dadum head

y = depth of flow

$\frac{V^2}{2g}$ = velocity or kinetic head.

slope of energy line: $\frac{dH}{dx} = -S_e$

slope of channel bottom: $\frac{dz}{dx} = -S$

$$-S_e = -S + \frac{dy}{dx} + \frac{d}{dx}\left(\frac{V^2}{2g}\right)$$

Multiply & devide by dy on right hand side 3rd term.

$$-s_e = -s + \frac{dy}{dx} + \frac{d}{dy}\left(\frac{V^2}{2g}\right)\frac{dy}{dx}$$

$$-s_e = -s + \frac{dy}{dx} + \frac{d}{dy}\left(\frac{Q^2}{2gA^2}\right)\frac{dy}{dx}$$ $\left(\because Q = AV,\ V = \frac{Q}{A}\right)$

$$-s_e = -s + \frac{dy}{dx} + \left\{-\left(\frac{2Q^2}{2gA^3}\right) \times \frac{dA}{dy} \times \frac{dy}{dx}\right\}$$

$$-s_e = -s + \frac{dy}{dx} + \left\{-\left(\frac{Q^2}{gA^3}\right) \times \frac{dA}{dy} \times \frac{dy}{dx}\right\}$$

$$s - s_e = \frac{dy}{dx}\left\{1 - \left(\frac{Q^2}{gA^3}\right)\frac{dA}{dy}\right\}$$

$$\because \frac{dA}{dy} = b$$

$$\boxed{\frac{dy}{dx} = \frac{s - s_e}{1 - \left(\frac{Q^2}{gA^3}\right)b}}$$

General differential equation for G.V.F / dynamic equation of G.V.F.

$$\frac{Q^2 b}{gA^3} = \frac{\cancel{A}V^2 b}{gA\cancel{^3}} = \frac{V^2 b}{gA}$$

$$= \frac{V^2}{g\left(\frac{A}{b}\right)} = \frac{V^2}{gD} = F^2$$

for number $F = \frac{V}{\sqrt{gD}}$

for rectangular channel hydraulic mean radius

$$D = \frac{\cancel{b}y}{\cancel{b}} = y$$

$$\boxed{F = \frac{V}{\sqrt{gy}}}$$

$$\frac{dy}{dx} = \frac{s - s_e}{1 - \left(\frac{V^2}{gy}\right)} = \frac{s - s_e}{1 - F^2}$$

$$\frac{dy}{dx} = \frac{s - s_e}{1 - F^2}$$

Above equation is used classify different types of surface profile.

Multiply eq devid by dy on right hand side 3rd term.

$$-S_e = -S + \frac{dy}{dx} + \frac{d}{dy}\left(\frac{V^2}{2g}\right)\frac{dy}{dx}.$$

$(\because Q = AV$
$V = \frac{Q}{A})$

$$-S_e = -S + \frac{dy}{dx} + \frac{d}{dy}\left(\frac{Q^2}{2gA^2}\right)\frac{dy}{dx}.$$

$$-S_e = -S + \frac{dy}{dx} + \left\{-\left(\frac{2Q^2}{2gA^3}\right) \times \frac{dA}{dy} \times \frac{dy}{dx}\right\}$$

$$-S_e = -S + \frac{dy}{dx} + \left\{-\left(\frac{Q^2}{gA^3}\right) \times \frac{dA}{dy} \times \frac{dy}{dx}\right\}$$

$$S - S_e = \frac{dy}{dx}\left\{1 - \left(\frac{Q^2}{gA^3}\right)\frac{dA}{dy}\right\}$$

$$\therefore \frac{dA}{dy} = b$$

$$\boxed{\frac{dy}{dx} = \frac{S - S_e}{1 - \left(\frac{Q^2}{gA^3}\right)b}}$$

General differential equation for G.V.F / dynamic equation of G.V.F.

$$\frac{Q^2 b}{gA^3} = \frac{\cancel{A^2}V^2 b}{gA^{\cancel{3}}} = \frac{V^2 b}{gA}$$

$$= \frac{V^2}{g\left(\frac{A}{b}\right)} = \frac{V^2}{gD} = F^2$$

Froude number $F = \frac{V}{\sqrt{gD}}$

for rectangular channel hydraulic mean radius

$$D = \frac{\cancel{b}y}{\cancel{b}} = y$$

$D = \frac{A}{b}$

$$\boxed{F = \frac{V}{\sqrt{gy}}}$$

$$\frac{dy}{dx} = \frac{S - S_e}{1 - \left(\frac{V^2}{gy}\right)} = \frac{S - S_e}{1 - F^2}$$

$$\frac{dy}{dx} = \frac{S - S_e}{1 - F^2}$$

Above equation is used classify different types of surface profile.

Dynamic equation of lateral outflow:

i) spatially varied flow with decreasing discharge

ii) spatially varied flow with increasing.

Decreasing discharge	Increasing discharge.
$H = z + y + \frac{\alpha V^2}{2g}$	Momentum change of body b/w 1 & 2
$H = z + y + \frac{\alpha Q^2}{2gA^2}$	= Momentum − Momentum due to lateral spillway
Diff with x	= slope of energy line
$\frac{dH}{dx} = \frac{dz}{dx} + \frac{dy}{dx} + \frac{\alpha}{2g}\left(\frac{2Q}{A^2}\frac{dQ}{dx} - \frac{2Q^2}{A^3}\frac{dA}{dx}\right)$	$= \frac{dH}{dx} - \frac{V_f - \alpha V}{gA} q$
$\frac{dH}{dx} = -S_e \qquad \frac{dz}{dx} = -S$	$= -S_e$
slope of energy line, slope of channel bottom	$V_f = 0, \; V = \frac{Q}{A}$
$\frac{dQ}{dx} = q$ = Discharge per unit width.	$\frac{dH}{dx} + \left(\frac{\alpha Q}{gA^2}\right) q = -S_e$
$\frac{dA}{dx} = T\left(\frac{dy}{dx}\right)$	$\frac{dH}{dx} = -S_e, \; \frac{dz}{dx} = -S, \; \frac{dA}{dx} = T\left(\frac{dy}{dx}\right)$
$-S_e = -S + \frac{dy}{dx} + \left[\left(\frac{\alpha Q}{gA^2}\right) q\right] - \left[\frac{\alpha Q^2}{gA^3} T\left(\frac{dy}{dx}\right)\right]$	$-S_e = -S + \frac{dy}{dx} + \left[\left(\frac{\alpha Q}{gA^2}\right) q\right] - \left[\frac{\alpha Q^2}{gA^3} T\left(\frac{dy}{dx}\right)\right] + \left(\frac{\alpha Q}{gA^2}\right) q$
$\frac{dy}{dx} - \left[\frac{\alpha Q}{gA^3} T\left(\frac{dy}{dx}\right)\right] = S - S_e - \left[\left(\frac{\alpha Q}{gA^2}\right) q\right]$	$\frac{dy}{dx} = \frac{S - S_e - \left(\frac{2\alpha Q q}{gA^2}\right)}{1 - \frac{\alpha Q^2 T}{gA^3}}$
$\frac{dy}{dx} = \frac{S - S_e - \left(\frac{\alpha Q q}{gA^2}\right)}{1 - \frac{\alpha Q^2 T}{gA^3}}$	$F^2 = \frac{Q^2 T}{gA^3}$
$\boxed{\frac{dy}{dx} = \frac{S - S_e - \frac{\alpha Q q}{gA^2}}{1 - \alpha F^2}}$	$\boxed{\frac{dy}{dx} = \frac{S - S_e - \left(\frac{2\alpha Q q}{gA^2}\right)}{1 - \alpha F^2}}$

$$\boxed{L = \frac{E_2 - E_1}{S - S_e}}$$

$$E = y + \frac{V^2}{2g}$$

$d + \frac{V^2}{2g}$

$$V = \frac{Q}{A}$$

$$P = b + 2y$$

$$A = b \times y$$

$$Q = A \frac{1}{n} R^{2/3} S^{1/2}$$

$$R = \frac{A}{P} = \frac{WA}{WP}$$

3 unit

1. A river of 100m width & 3m depth has a stable bed & vertical bank with a surface slope of 1 in 3000. Estimate the length of back water curve produced by afflux of depth 2m. Assuming maning constant $N = 0.035$ & Chezy's constant $C = 65$.

Given data:

$$\boxed{y_2 - y_1 = 2m}$$

$b = 100m$

$y = 3m$

$S = \frac{1}{3000}$

$y_2 - y_1 = 2m$

$N = 0.035$

$C = 65$

$L = ?$

Soln:

$$l = \frac{E_2 - E_1}{S - S_0}$$

$$E_1 = y + \frac{V_1^2}{2g}$$

$$V_1 = \frac{Q}{A_1}$$

$$A = b \times y.$$

$$= 100 \times 3$$

$$\boxed{A = 300 m^2}$$

$$P = b + 2y$$

$$= 100 + 2(3)$$

$$\boxed{P = 106 m}$$

$$R = \frac{A}{P}$$

$$= \frac{300}{106}$$

$$\boxed{R = 2.830 m}$$

$$Q = A \times \frac{1}{n} R^{2/3} S^{1/2}$$

$$= 300 \times \frac{1}{0.035} (2.830)^{2/3} \left(\frac{1}{3000}\right)^{1/2}$$

$$\boxed{Q = 313.1 m^3/s}$$

$$V_1 = \frac{Q}{A}$$

$$= \frac{313.1}{300}$$

$$\boxed{V_1 = 1.01 m/s}$$

$$E_1 = 3 + \frac{(1.01)^2}{2 \times 9.81}$$

$$\boxed{E_1 = 3.05 m}$$

$$y_2 - y_1 = 2 m$$

$$y_2 = 2 + y_1 = 2 + 3.$$

$$\boxed{y_2 = 5 m}$$

$$A = b \times y_2$$
$$= 100 \times 5$$
$$\boxed{A = 500 m^2}$$

$$P = b + 2y_2$$
$$= 100 + 2(5)$$
$$\boxed{P = 110 m}$$

$$Q = A \frac{1}{n} R^{2/3} S^{1/2}$$

$$R = \frac{A}{P} = \frac{500}{110} = 4.54 m$$

$$Q = 500 \times \frac{1}{0.035} (4.54)^{2/3} \left(\frac{1}{3000}\right)^{1/2}$$

$$\boxed{Q = 715.11 m^3/s}$$

$$V_2 = \frac{Q}{A}$$
$$= \frac{715.11}{500}$$
$$\boxed{V_2 = 1.430 m/s}$$

$$E_2 = y_2 + \frac{V_2^2}{2g}$$
$$= 5 + \frac{(1.43)^2}{2 \times 9.81}$$

$$\boxed{E_2 = 5.10 m}$$

$$y = \frac{y_1 + y_2}{2}$$
$$= \frac{3+5}{2}$$

$$\boxed{y = 4 m}$$

$A = b \times y = 100 \times 4 = 400 m^2$

$R = \frac{A}{P} = \frac{400}{108} = 3.7 m$

$P = b + 2y = 100 + 2(4) = 108 m$

$Q = A \frac{1}{n} R^{2/3} Se^{1/2}$

$313.9 = 400 \times \frac{1}{0.035} (3.7)^{2/3} (se)^{1/2}$

$(se)^{1/2} = \frac{313.9 \times 0.035}{400 \times (3.7)^{2/3}}$ $se^{1/2} (\quad)^2$

$\boxed{Se = 1.318 \times 10^{-4}}$

$L = \frac{E_2 - E_1}{S - se}$

$= \frac{5.10 - 3.05}{\left(\frac{1}{3000}\right) - (1.34 \times 10^{-4})}$

~~L = 8026.7 m~~

$\boxed{L = 10284.2 m}$

2. The normal depth of flow of water in a rectangular channel 2m & wide is 1.2m the bed slope of the channel is 0.0006 & manning's constant N = 0.015. Find critical depth, at a certain section the same channel depth is 0.9m & the second section depth is 0.85m. Find the distance b/w 2 section also find the second section is down stream or upstream.

Given data:

a) depth ⇒ $b = 2m$

$y = 1.2m$

$S = 0.0006$

$n = 0.015$

Soln: $y_c = \frac{q^2}{g} \Rightarrow \boxed{q = \frac{Q}{b}}$

$Q = A \, 1/n \, R^{2/3} S^{1/2}$

$A = b \times y$

$= 2 \times 1.2$

$\boxed{A = 2.4 m^2}$

$P = b + 2y$

$= 2 + 2(1.2)$

$\boxed{P = 4.4 m}$

$R = \frac{A}{P}$

$= \frac{2.4}{4.4}$

$\boxed{R = 0.54 m}$

$Q = A \frac{1}{n} R^{2/3} S^{1/2}$

$= 2.4 \times (0.0006)^{1/2} \times 0.54^{2/3} \times \frac{1}{0.015}$

$\boxed{Q = 2.59 m^3/s}$

$q = \frac{Q}{b}$

$= \frac{2.6}{2}$

$\boxed{q = 1.3}$

$\boxed{y_c = \frac{q^2}{g} = \frac{(1.3)^2}{9.81}}$

$\boxed{y_c = 0.17}$ //

b) $y_1 = 0.9$

$y_2 = 0.85$

$E_1 = y_1 + \frac{V^2}{2g}$, $E_2 = y_2 + \frac{V_2^2}{2g}$

$V_1 = \frac{Q}{A}$, $V_2 = \frac{Q}{A}$

$A = b \times y_1$

$= 2 \times 0.9$

$\boxed{A = 1.8 m^2}$

$P = b + 2y_1$

$= 2 + 2(0.9)$

$\boxed{P = 3.8 m}$

$A = b \times y_2$

$= 2 \times 0.85$

$\boxed{A = 1.7 m^2}$

$P = b + 2y_2$

$= 2 + 2(0.85)$

$\boxed{P = 3.7 m}$

$R = \frac{A}{P}$

$= \frac{1.8}{3.8}$

$\boxed{R = 0.47}$

$R = \frac{A}{P}$

$= \frac{1.7}{3.7}$

$\boxed{R = 0.459}$

$$Q = A\frac{1}{n}R^{2/3}S^{1/2}$$

$$= 1.8\frac{1}{0.0158}(0.47)^{2/3}(0.0006)^{1/2}$$

$$Q = 1.77\ m^3/s$$

$$Q = A\frac{1}{n}R^{2/3}S^{1/2}$$

$$= 1.7\frac{1}{0.015}$$

$$V_1 = \frac{Q}{A}$$

$$= \frac{1.77}{1.8}$$

$$V_1 = 0.98\ m/s$$

$$E_1 = y_1 + \frac{V_1^2}{2g}$$

$$= 0.9 + \frac{(0.98)^2}{2\times 9.81}$$

$$= 0.9 + 0.04$$

$$\boxed{E_1 = 0.94\ m}$$

$$E_2 = y_2 + \frac{V_2^2}{2g}$$

$$Q = A\frac{1}{n}R^{2/3}S^{1/2}$$

$$= 1.7\frac{1}{0.015}(0.459)^{2/3}(0.0006)^{1/2}$$

$$\boxed{Q = 1.65\ m^3/s}$$

$$V_2 = \frac{Q}{A}$$

$$= \frac{1.65}{1.7}$$

$$\boxed{V_2 = 0.97\ m/s}$$

$$E_2 = y_2 + \frac{V_2^2}{2g}$$

$$= 0.85 + \frac{(0.97)^2}{2\times 9.81}$$

$$\boxed{E_2 = 0.89\ m}$$

$$Q = A\frac{1}{n}R^{2/3}S^{1/2}$$

$$y = \frac{y_1+y_2}{2}$$

$$= \frac{0.9}{0.85} \quad \frac{0.9+0.85}{2}$$

$$\boxed{y = 0.875}$$

$$A = b\times y =$$

$$= 2\times 1.05$$

$$\boxed{A = 1.75\ m^2}$$

$$P = b + 2y$$

$$= 2 + 2(1.05)$$

$$\boxed{P = 3.75\ m}$$

$$R = \frac{A}{P}$$

$$= \frac{2.1}{4.1} \quad \frac{1.75}{3.75}$$

$$\boxed{R = 0.46\ m}$$

$$Q = A \frac{1}{n} R^{2/3} Se^{1/2}$$

$$\cancel{2.61} = 1.75 \frac{1}{0.015} (0.46)^{2/3} Se^{1/2}$$

$$Se^{1/2} = \frac{2.61 \times 0.015}{1.75 \times (0.46)^{2/3}}$$

$$\cancel{= 6.48 \times 10^{-4}}$$

$$\boxed{Se = 1.39 \times 10^{-3}}$$

$$L = \frac{E2 - E1}{S - Se}$$

$$= \frac{0.89 - 0.94}{0.0006 - 1.39 \times 10^{-3}}$$

$$= \frac{-0.05}{-7.9 \times 10^{-4}}$$

$$\boxed{L = 63.29 \text{ m}}$$

ii) $$\boxed{\frac{dy}{dx} = \frac{S - Se}{1 - \frac{V^2}{gy}}}$$

$$V = \frac{Q}{A}$$

$$= \frac{2.631}{2 \times 0.875}$$

$$\boxed{V = 1.50 \text{ m/s}}$$

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$$\frac{dy}{dx} = \frac{(0.0006 - 1.39 \times 10^{-3})}{1 - \frac{(1.50)^2}{9.81 \times 0.875}}$$

$$\boxed{\frac{dy}{dx} = -1.07 \times 10^{-3}}$$

$\frac{dy}{dx}$ is in negative

Hence it is downstream.