Condition for transmission of maximum power through nozzle:-

$$H = h_f + \frac{v^2}{2g} = \frac{4fLV^2}{2\times g D} + \frac{v^2}{2g}$$

$$\frac{v^2}{2g} = H - \frac{4fLV^2}{2g D.}$$

Power transmitted through the nozzle $\Rightarrow \frac{1}{2}\rho a v^3$

$$= \frac{1}{2}\rho . a v . v^2 \Rightarrow \frac{1}{2}\rho a v \left[2g\left(H - \frac{4fLV^2}{2g D}\right)\right].$$

$$= w . a v\left[H - \frac{4fLV^2}{2g D}\right]$$

Cont. eqn $AV = a . v \Rightarrow V = \frac{a v}{A.}$

$$P = w . a v\left[H - \frac{4fL}{2g D}\frac{a^2 v^2}{A^2}\right].$$

$$P = f(v) \Rightarrow \frac{dP}{dv} = 0$$

$$H - 3\times\frac{4fL}{2gD} . \frac{a^2 v^2}{A^2} = 0 \qquad \frac{a^2 v^2}{A^2} = V^2$$

$$H - 3\,\frac{4fLV^2}{2g D} = 0$$

$$H - 3h_f = 0, \quad \boxed{h_f = H/3}$$

diameter of nozzle for transmitted maxm power.

$$H = h_f + \frac{v^2}{2g}, \qquad H = 3h_f.$$

$$3h_f = h_f + \frac{v^2}{2g}. \Rightarrow 2h_f = \frac{v^2}{2g}$$

$$2\times\frac{4fL\, a^2 v^2}{2\times g\, D . A^2} = \frac{v^2}{2g} \Rightarrow \frac{A^2}{a^2} = \frac{8fL}{D}$$

$$\boxed{\frac{A}{a} = \sqrt{\frac{8fL}{D.}}}$$

$$\frac{\frac{\pi}{4} D^2}{\frac{\pi}{4} \cdot d^2} = \sqrt{\frac{8fL}{D}} \Rightarrow \frac{D^4}{d^4} = \frac{8fL}{D}$$

$$d = \left(\frac{D^5}{8fL}\right)^{1/4}$$

Water hammer in pipe! – water hammer is also known as hydraulic shock.

In a long pipe, when the flowing water is suddenly brought to rest by closing the valve or by any similar cause, there will be a sudden rise in pressure due to momentum of water being destroyed. A pressure wave is transmitted along the pipe. The phenomenon of sudden rise in pressure is known as water hammer or hammer blow.

Pressure rise depend on – the velocity of flow, length of pipe, speed at which valve is closed, elastic properties of pipe material as well as the flowing fluid.

Gradual closure of valve – $t > \frac{2L}{C}$ $\left[P = \frac{\rho L V}{t}\right]$

Instantaneous closure of valve – $t < \frac{2L}{C}$.

C → velocity of pressure wave.

Instantaneous closure of rigid pipe →

$$P = \rho V C$$

$$C = \sqrt{\frac{K}{\rho}}$$

Instantaneous closure of elastic pipe!. K → Bulk modulus of elasticity of water

$$P = V \times \sqrt{\frac{\rho}{\left(\frac{1}{K} + \frac{D}{E \cdot t}\right)}}$$

t → Thickness

E → Modulus of elasticity of pipe

Time required by pressure wave to travel from the valve to the tank and from tank to valve.

$$t = \frac{2L}{c}.$$

Q- In a pipe 600 mm diameter and 3000 m length, provided with a valve at its end, water is flowing with a velocity of 2 m/s. Assuming velocity of pressure wave c = 1500 m/s find -

(a) The rise in pressure if the valve is closed in 20 seconds.

(b) The rise in pressure if the valve is closed in 2.5 seconds. (Assume pipe is rigid, K of water = 2 GN/m²).

Soln

(a) t = 20 second, $t = \frac{2L}{c} = \frac{2\times 3000}{1500} = 4S.$

$t > \frac{2L}{c}$ (Gradual).

$$P = \frac{\rho L V}{t} = \frac{1000 \times 3000 \times 2}{20} = 300\times 10^3 \text{ N/m}^2$$
$$= 300 \text{ kN/m}^2$$

(b) $t < \frac{2L}{c}$ (Instantaneous).

$$c = \sqrt{\frac{K}{\rho}} = \sqrt{\frac{2\times 10^9}{1000}} = 1414.2 \text{ m/s}.$$

$$\frac{2\times 3000}{1414.2} = 4.24 \text{ S}.$$

$t < \frac{2L}{c}$..

$$P = \rho V C = 2 \times 1000 \times 1414.2 = 2828.4 \text{ kN/m}^2$$

Q. A 2500 m long pipe line is used for transmission of power. 120kW power is to be transmitted through the pipe in which water having a pressure of 4000 kN/m² at inlet is flowing. If the pressure drop over the length of pipe is 800 kN/m² and f = .006 find (32)

(a) Diameter of pipe

(b) Efficiency of transmission.

Sol^n

$$P = \rho g H \Rightarrow H = \frac{P}{\rho g} = \frac{4000 \times 10^3}{9.81 \times 10^3} = 407.7\,m.$$

Pressure drop 800 kN/m²

$$h_f = \frac{800 \times 10^3}{9.81 \times 10^3} = 81.5\,m.$$

Co-eff. of friction = 0.006

Head available at the end of pipe = H − h_f = 407.7 − 81.5

= 326.2 m.

$$P = w Q (H - h_f)$$

$$10^3 \times 120 = 9.81 \times 10^3 \times Q \times 326.2$$

$$Q = \frac{120}{9.81 \times 326.2} = .0375\,m^3/s$$

$$Q = \frac{\pi}{4} D^2 \times V$$

$$.0375 = \frac{\pi}{4} \times D^2 \times V$$

$$V = \frac{.0477}{D^2}$$

$$h_f = \frac{4 f L V^2}{2 g D}.$$

$$81.5 = \frac{4 \times .006 \times 2500 \times \left(\frac{.0477}{D^2}\right)^2}{2 \times D \times 9.81}$$

$$D^5 = \frac{4 \times .006 \times 2500 \times (.0477)^2}{81.5 \times 2 \times 9.81}$$

$$D = 153.5 \text{ mm.}$$

$$\eta = \frac{H - h_f}{H} = \frac{407.7 - 81.5}{407.7} = .8 = 80\%.$$