Sheet:3

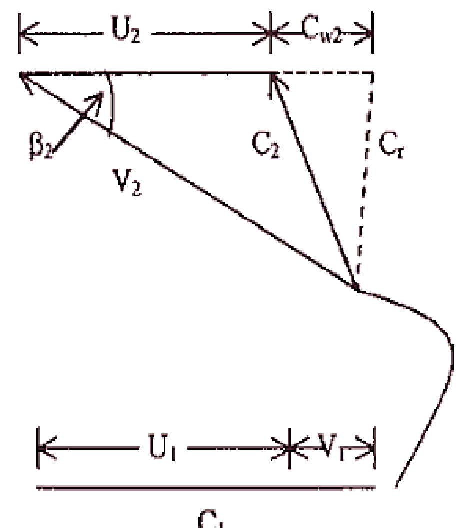
1- A generator is to be driven by a Pelton wheel with a head of 220 m and discharge rate of 145 L/s. The mean peripheral velocity of wheel is 14 m/s. If the outlet tip angle of the bucket is 160º, find out the power developed.

Using Euler's equation, work done per weight mass of water per sec.

$$= (C_{w1}U_1 - C_{w2}U_2)$$

Therefore

$$\text{Work done / s} = (C_{w1}U_1 + C_{w2}U_2) \text{ Nm / s}$$



From inlet velocity triangle

$$C_{w1} = C_1 \text{ and } \frac{C_1^2}{2g} = H$$

Hence, $C_1 = \sqrt{2gH} = \sqrt{2 \times 9.81 \times 220} = 65.7$ m/s

Relative velocity at inlet is

$$V_1 = C_1 - U_1 = 65.7 - 14 = 51.7 \text{ m/s}$$

From outlet velocity triangle

$$V_1 = V_2 = 51.7 \text{ m/s(neglecting friction)}$$

and cos $\beta_2 = \frac{U_2 + C_{w2}}{V_2}$ or

$$\cos(20) = \frac{14 + C_{w2}}{51.7}$$

Therefore

$$C_{w2} = 34.58 \text{ m/s}$$

Hence, work done per unit mass of water per sec.

$$= (65.7)(14) + (34.58)(14) = 1403.92 \text{ Nm}$$

$$\text{Power developed} = \frac{(1403.92)(145)}{1000} = 203.57 \text{ kW}$$

2- A Pelton wheel is supplied with 0.035 m^3/s of water under a head of 92 m. The wheel rotates at 725 rpm and the velocity coefficient of the nozzle is 0.95. The efficiency of the wheel is 82% and the ratio of bucket speed to jet speed is 0.45. Determine the following: 1. Speed of the wheel 2. Wheel to jet diameter ratio 3. Dimensionless power specific speed of the wheel.

3- A generator is driven by a small, single-jet Pelton turbine designed to have a power specific speed $\Omega_{SP} = 0.20$. The effective head at nozzle inlet is 120m and the nozzle velocity coefficient is 0.985. The runner rotates at 880 rev/min, the turbine overall efficiency is 88% and the mechanical efficiency is 96%. If the blade speed to jet speed ratio, $\nu = 0.47$, determine (i) the shaft power output of the turbine; (ii) the volume flow rate; (iii) the ratio of the wheel diameter to jet diameter..

<u>Solution.</u> (1) With eqn (9.1) the power specific speed is $\Omega_{sp} = \dfrac{\Omega\sqrt{P/\rho}}{(gH_e)^{\frac{5}{4}}}$

where $\Omega = \dfrac{\pi}{30}N = 92.15$ rad/s. Hence,

$$P = \rho\left[\frac{\Omega_{sp}}{\Omega}(gH_e)^{5/4}\right]^2 = 10^3\left[\frac{0.2}{92.15}(9.81\times120)^{1.25}\right]^2 = 224{,}000 \text{ W}$$

$$\therefore P = \underline{224 \text{ kW}}$$

(2) The overall efficiency is given by $\eta_0 = P/(\rho g Q H_e)$

$$\text{hence } Q = \frac{P}{\rho g \eta_0 H_e} = \frac{224\times10^3}{10^3\times9.81\times0.88\times120} = \underline{0.2162 \text{ m}^3/\text{s}}$$

(3) The jet velocity is given by:

$$c_1 = K_N\sqrt{2gH_e} = 0.985\sqrt{2\times9.81\times120} = 47.79 \text{ m/s}$$

The blade speed is: $U = \nu c_1 = 0.47\times47.79 = 22.46$ m/s

$$D = \frac{2U}{\Omega} = \frac{2\times22.46}{92.15} = 0.4875 \text{ m}$$

As $Q = \dfrac{\pi}{4}d^2c_1$ then $d = \sqrt{\dfrac{4Q}{\pi c_1}} = \sqrt{\dfrac{4\times0.2162}{\pi\times47.79}} = 0.07589$

$$\therefore \frac{D}{d} = \underline{6.423}$$

4- A multi-jet Pelton turbine with a wheel 1.47m diameter, operates under an effective head of 200m at nozzle inlet and uses $4m^3/s$ of water. Tests have proved that the wheel efficiency is 88% and the velocity coefficient of each nozzle is 0.99. Assuming that the turbine operates at a blade speed to jet speed ratio of 0.47, determine (i) the wheel rotational speed; (ii) the power output and the power specific speed; (iii) the bucket friction coefficient given that the relative flow is deflected 165°; (iv) the required number of nozzles if the ratio of the jet diameter to mean diameter of the wheel is limited to a maximum value of 0.113.

5- A Francis turbine operates at its maximum efficiency point at $\eta_0 = 0.94$, corresponding to a power specific speed of 0.9rad. The effective head across the turbine is 160m and the speed required for electrical generation is 750rev/min. The runner tip speed is 0.7 times the spouting velocity, the absolute flow angle at runner entry is 72deg from the radial direction and the absolute flow at runner exit is without swirl. Assuming there are no losses in the guide vanes and the mechanical efficiency is 100%, determine (i) the turbine power and the volume flow rate; (ii) the runner diameter; (iii) the magnitude of the tangential component of the absolute velocity at runner inlet; (iv) the axial length of the runner vanes at inlet..

6- The power specific speed of a 4MW Francis turbine is 0.8, and the hydraulic efficiency can be assumed to be 90%. The head of water supplied to the turbine is 100m. The runner vanes are radial at inlet and their internal diameter is three quarters of the external diameter. The meridional velocities at runner inlet and outlet are equal to 25 and 30%, respectively, of the spouting velocity. Determine (i) the rotational speed and diameter of the runner; (ii) the flow angles at outlet from the guide vanes and at runner exit; (iii) the widths of the runner at inlet and at exit. Blade thickness effects can be neglected.

7- A propeller turbine develops 12,000 hp, and rotates at 145 rpm under a head of 20 m. The outer and hub diameters are 4 m and 1.75 m, respectively. Calculate the inlet and outlet blade angles measured at mean radius if overall and hydraulic efficiencies are 85% and 93%, respectively