SNS COLLEGE OF TECHNOLOGY, COIMBATORE-35

DEPARTMENT OF FOOD TECHNOLOGY

Fluid Mechanics and Machinery –

UNIT IV TURBINES Topic - Problems on Specific speed

DISCUSSION BEFORE SOLVING NUMERICALS: -

1. The selection of turbines depends on the SPECIFIC SPEED

Specific Speed-Turbine having high specific speed is selected. High speed means a smaller size of the turbine. Francis turbines run at higher speeds (50—250) than those of pelton wheels (8—50), Kaplan turbine have the greatest specific speed (250—1000).

2. Define specific speed of a turbine and write down its expression.

The specific speed of a turbine may be defined as the speed of an imaginary turbine, identical with the given turbine which will develop a unit power under a unit head.

It is given by

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

N = Speed of the runner in r.p.m.

H =Head of water

P = Power produced.

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3. Derive the expression for specific speed of turbine. What is the range of specific speed for reaction turbine?

Ans. Power available at turbine shaft

$$P = wQH \times \eta_0$$

Since η_0 and w are constant: $P \propto QH$ … (1)

The tangential velocity u, the flow velocity v_f the absolute velocity v and the head H on the turbine are related as

$$u \propto v_f \propto v \propto \sqrt{H}$$

Now

$$Q = Av_f \propto D^2 v_f \propto D^2 \sqrt{H}$$

Also

$$u = \frac{\pi DN}{60} ; D \propto \frac{u}{N} \propto \frac{\sqrt{H}}{N}$$

$$Q \propto \frac{H}{N^2} \sqrt{H} \propto \frac{H^{3/2}}{N^2}$$

Substituting this value in expression (1)

$$P \propto \frac{H^{3/2}}{N^2} \times H \propto \frac{H^{5/2}}{N^2} ;$$

$$P = k \frac{H^{5/2}}{N^2} \qquad \dots (2)$$

Where k is constant of proportionality

Now taking H =1, P= 1, then $N = N_s$ (specific speed)

$$1 = k \frac{(1)^{5/2}}{N_s^2} \quad \text{or} \quad k = N_s^2$$

Expression (ii) may be written as

$$P = N_s^2 \frac{H^{5/2}}{N^2} ;$$

Specific speed, $N_s = \frac{N\sqrt{P}}{H^{5/4}}$

Specific speed for Francis turbine = 50 — 250.

Specific speed for Kaplan turbine = 250 — 850.

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4. A Francis turbine works under a head of 25 m producing 3675 kW at 150 r.p.m. Determine the (a) Unit power and unit speed of the turbine (b) Specific speed of the turbine and (c) Power developed by this turbine if the speed is reduced to 100 r.p.m.

Solution. P= 3675 kW

H=25m

N = 150 r.p.m.

Unit power and unit speed

Unit power:

$$P_u = \frac{P}{H^{3/2}} = \frac{3675}{(25)^{3/2}} = 29.4 \text{ kW}$$

Unit speed:

$$N_u = \frac{N}{\sqrt{H}} = \frac{150}{\sqrt{25}} = 30 \text{ r.p.m.}$$

Specific speed of the turbine

$$N_s = \frac{N\sqrt{P}}{H^{5/4}} = \frac{150 \times \sqrt{3675}}{(25)^{5/4}}$$

= 162.66

=163 r.p.m.

Power developed if the speed reduced to 100 r.p.m.

We know that

$$\frac{N_1}{\sqrt{H_1}} = \frac{N_2}{\sqrt{H_2}}$$

$$\frac{150}{\sqrt{25}} = \frac{100}{\sqrt{H}}$$

$$\sqrt{H_2} = \frac{100}{150} \times \sqrt{25}$$

$$H_2 = \left(\frac{100}{150} \times \sqrt{25}\right)^2 = 11.12 \text{ m}$$

Also

$$\frac{P_1}{H_1^{3/2}} = \frac{P_2}{H_2^{3/2}}$$

$$\frac{3675}{(25)^{3/2}} = \frac{P_2}{(11.12)^{3/2}}$$

$$P_2 = \frac{3675 \times (11.12)^{3/2}}{(25)^{3/2}} = 1090.2 \text{ kW}$$

5.In a Francis turbine of very low specific speed, the velocity of flow from inlet to exit of the runner remains constant. If the turbine discharges radially, show that the degree of reaction p can be expressed as

$$\rho = \frac{1}{2} - \frac{1}{2}\left[\frac{\cot\theta}{(\cot\alpha - \cot\theta)}\right]$$

where a and θ are the guide and runner vane angles respectively and the degree of reaction p is equal to the ratio of pressure drop to the hydraulic work done in the runner, assuming that the losses in the runner are negligible.

Solution. Applying Bernoulli's equation between the inlet and exit of the runner and neglecting the potential difference, we get

$$\frac{p}{w} + \frac{V^2}{2g} = \frac{P_1}{w} + \frac{V_1^2}{2g} + \frac{V_w u}{g}$$

(for radial discharge)

Where $\frac{p}{w}$ and $\frac{p_1}{w}$ are the pressure heads at the inlet aid the exit of the runner respectively.

Thus pressure head drop due to hydraulic work done in the runner is given by

$$\frac{p}{w} - \frac{p_1}{w} = \frac{V_1^2}{2g} - \frac{V^2}{2g} + \frac{V_w u}{g}$$

Now

$$\rho = \frac{\left(\frac{p}{w} - \frac{p_1}{w}\right)}{\frac{V_w u}{g}}$$

Or

$$\rho = \frac{\frac{V_1^2}{2g} - \frac{V^2}{2g} + \frac{V_w u}{g}}{\frac{V_w u}{g}}$$

Or $$\rho = 1+1+\frac{1}{2}\left[\frac{V_1^2 - V^2}{V_w u}\right] \quad \ldots (1)$$

For radical discharge

$$V_1 = V_{f1} = V_f$$

Also $$V_w = V\cos\alpha$$

$$V_f = \sin\alpha$$

$$u = V_w - V_f \cot\theta$$

Or u =V [cos a-sin a cot θ]

And $$V_1 = V_f = V\sin\alpha$$

Thus, introducing these values in equation (i) above and simplifying it, we get.

$$\rho = \frac{1}{2} - \frac{1}{2}\left[\frac{\cot\theta}{\cot\alpha - \cot\theta}\right]$$