Sec-D

Types of Turbines :-

Hydraulic turbines with the combination of the generators are used to achieve the main objective of converting water energy into electric power.
Hydraulic features like pressure, head, flow direction, speed and power and discharge serve to distinguish b/w different turbines.

(A) Classification Based on Pressure :-

one more important criterion for classification of Hydraulic turbines is whether the pressure of liquid changes or not while it flows through the rotor of the Hydraulic turbines.
Based on the pressure change, Hydraulic turbines can be classified as -

a) Impulse Turbines
b) Reaction turbines

(B) classification Based on the Head -

~~available~~

Acc. to the head available to the inlet of turbine, hydraulic turbines may be classified as —

a) Low head turbine (< 15 m) – Kaplan Turbine

b) medium head turbine (15 – 50 m) – Francis Turbine

c) High head turbines (50 m onwards) – Pelton wheel turbine

(C) Classification Based on flow Direction

a) Axial flow turbines
b) Radial flow turbines
c) mixed flow turbines

(D) Classification Based on ~~[illegible]~~ specific speed. —

Acc. to the specific speed - - - -

a) low specific speed turbines (< 15) – Pelton wheel
b) medium specific speed " ($15 < N_s < 50$) – Francis
c) High specific speed (> 50) — Kaplan

Water can pass through the Hydraulic turbine in different flow paths. Based on the flow path of the liquid, turbines can be categorized into three types —

Ⓔ classification Based on the fluid used —

a) water turbine (Pelton wheel, francis, kaplan)

b) Gas turbine

c) steam turbine

Ⓕ classification Based on Discharge —

Turbines can also be spoken of as low discharge, medium discharge and high discharge turbines

Characteristics :- specific speed :- $N_s = N \cdot \frac{\sqrt{P}}{H}$

N_s = specific speed, N = rotation speed of (rpm), P = power developed (kW), H = effective head (m).

Selection of turbine :-

The major problem facing the engg. is to select the type of turbine which will give max. economy.
The following factors have the bearing on the selection of the right type of turbine which will be discussed below.

① **Rotational speed** – In all modern hydraulic power plants, the turbines are directly coupled to the generator to reduce the transmission losses and also produces electricity. The generator generates the power at constant voltage and frequency and therefore the generator has to operate at its synchronous speed.

② **Specific speed** – Low specific (speed) machines such as impulse turbine is required when the available head is high for the given speed and power output. On the other hand, the turbines with high specific speed are required for low heads.

③ **Maximum Efficiency** – The max efficiency of the turbine developed depends upon the type of turbine used.

(5) Head (6) Types of water (7) Runaway speed
(8) cavitation (9) No. of unit
(10) over all cost

(4) Part load Efficiency :- full load is defined as the load under which a turbine develops its max. efficiency and anything above that is over load and anything ~~that is~~ below that is known as part load.

The speed N for synchronous running is given by

$N = 120\, f/P$

f = frequency cycle/sec

P = No. of poles

Specific Speed :

The specific speed is the most useful parameter for the selection of the turbine for a given condition.

The specific speed of a turbine is defined as the speed at which the turbine runs developing 1kW (unit power) under a head of one meter.

The equation for the specific speed of a turbine can be obtained by using the principle of similarity

[Note: g not considered]

$$P = \eta_o \times \frac{\rho \times g \times Q \times H}{1000}$$ [∴ ρ and η_o are constant]

$\therefore P \propto g \times Q \times H$ — (1)

Let D = Diameter of the turbine

N = speed of the turbine

N_s = specific speed of the turbine

u = tangential velocity of " "

V = Absolute velocity of water

The absolute velocity, tangential velocity and head on the turbine are related as

$u \propto V$, where $V \propto \sqrt{H}$

$\propto \sqrt{H}$

$V \propto \sqrt{H}$

~~$u = \pi D N$~~ and $u \propto \sqrt{H}$. — eqn -(a)

But $u = \frac{\pi D N}{60}$ $\therefore u \propto D \cdot N$ —(b)

from eqn (a) and (b)

$\sqrt{H} \propto D \cdot N$ or $D \propto \frac{\sqrt{H}}{N}$

APCO

Date :

Page :

But the tangential velocity u is given by:-

$Q \propto$ Area x velocity.

Area $\propto B \times D$.
$\propto D^2$

velocity $\propto \sqrt{H}$

Therefore

$Q \propto D^2 \times \sqrt{H}$

$\propto \left(\frac{\sqrt{H}}{N}\right)^2 \times \sqrt{H}$ $\left[D = \frac{\sqrt{H}}{N}\right]$

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

Substituting the value of Q in eqn (1) we get

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

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

$P = k \frac{H^{5/2}}{N^2}$ —(2) where k is constant of proportionality.

If $P = 1$, $H = 1$, the speed $N =$ specific speed N_s, substitute the values in above eqn, we get

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

$N_s^2 = k$ —(3)

APCO
Date
Page

So, $P = N_s^2 \dfrac{H^{5/2}}{N^2}$

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

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

Expression for unit power :-

Unit power is defined as the power developed by the turbine under a head of 1 (one) meter.
It is denoted by the symbol P_u.

The expression for unit power can be obtained as —
H = Head of water on the turbine
P = Power developed by the turbine under a head of H.
Q = Discharge through the turbine under a head H.

The overall efficiency is given by

$$\eta_0 = \frac{\text{Power developed}}{\text{water power}} = \frac{P}{\frac{\rho \times g \times Q \times H}{1000}}$$

$$P = \frac{\eta_0 \times \rho \times g \times Q \times 1000}{1000}$$ [remaining constant]

$$P \propto' Q \times H$$
$$\propto \sqrt{H} \times H \qquad [\because Q \propto \sqrt{H}]$$
$$\propto H^{3/2}$$

$P = K_1 H^{3/2}$ — ① where K_1 = constant of proportionality

when $H = 1m$, $P = P_u$ then

$\therefore P_u = K_1 (1)^{3/2} = K_1$

Substitute the value of K_1 in eq ①, we get

$$P = P_u H^{3/2}$$

$$\boxed{P_u = \frac{P}{H^{3/2}}}$$

Unit speed (N_u):- This is the speed of a turbine working under a unit head.

$N_u = \frac{N}{\sqrt{H}}$

APCO

Date

Page

Expression for unit discharge :-

This is defined as the volume of water passing through the turbine under a head of 1 m.
It is generally denoted by Q_u.

$$Q = AV.$$
$$Q \propto \sqrt{H} \quad \text{as } V = \sqrt{2gH}$$

and A is constant for given turbine.

Therefore

$$Q = K_2 \sqrt{H} \qquad -① $$

where K_2 = constant of proportionality.

from unit discharge definition
if $H = 1$; and $Q = Q_u$.

$$Q_u = K_2 \sqrt{1}$$
$$Q_u = K_2$$

Substitute the value of K_2 in eqⁿ ①
we get

$$Q = Q_u \sqrt{H}$$
$$Q_u = \frac{Q}{\sqrt{H}}$$

$$\boxed{Q_u = \frac{Q}{\sqrt{H}}}$$

Cavitation :-

Cavitation is defined as the phenomenon of formation of vapour bubbles and sudden collapsing of the vapour bubbles

Effects :-

The following are the effects of cavitation.

* The metallic surfaces are damaged and cavities are formed on the surface.
* Damage to the pumps and turbines
* Reduce turbine capacity
* Reduce turbine efficiency.
* Due to sudden collapsing of vapour bubbles, considerable noise and vibrations are produced.

How we avoid Cavitation -

Cavitation in turbines leads to erosion as well as vibrations and must be avoided by the careful shaping of all blade passages and of the exit passage or draft tube.

To avoid cavitation, the min. pressure in the passage of a liquid flow, should always be more than the vapour pressure of the liquid at the working ~~tem~~ temperature.

APCO
Date :
Page :

Thomas Cavitation Factor –

Prof. D. Thoma suggested a dimensionless number, called after his name Thomas cavitation factor σ (sigma), which can be used for determining the region where cavitation takes place in turbines.

The mathematical expression for the Thoma's cavitation factor is given by –

$$\sigma = \frac{H_b - H_s}{H} = \frac{(H_{atm} - H_v) - H_s}{H}$$

where

H_b = Barometric pressure head of water in m.

H_{atm} = Atmospheric pressure head in m.

H_v = Vapour pressure head of water in m.

H_s = Suction pressure at the outlet of the turbine in m. or height of the turbine runner above the tail water surface

H = Net head on the turbine in m.

vertical divergent draft tube also known as conical draft tube.

APCO
Date :
Page :

Draft tube :-

Reaction Turbines must be completely enclosed because a pressure difference exists b/w the water in the turbine and atmosphere.
Therefore, it is necessary to connect the turbine outlet by means of a pipe known as draft tube upto tail race level.

Types -

Depending on the shape and alignment, draft tubes are classified as follows -

① vertical divergent draft tube :-
The draft tube has the shape of a cone. This is generally provided for low specific speed. The cone angle is not to exceed 8°.
This will lead to the eddy formation bringing down the efficiency of the draft tube.

② Elbow Type draft tube -
This draft tube is often preferred in most of the Power plants where the setting of vertical draft tube does not permit.
This draft tube affords to discharge the water horizontally to the tail race.

(3) Moody Draft tube :-

This is a bell mouthed draft tube or a conical tube with a solid conical central core.
The whirl of discharged water is very much reduced in this arrangement.