ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY
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COURSE DELIVERY PLAN

Academic year	**:**	**2019-2020**
Year/Sem	**:**	**III/V**
Course Name	**:**	**HYDRAULIC MACHINERY**
Course Faculty	**:**	**VINOTH KUMAR C**

HYDRAULIC MACHINERY

MODULE1:

Principles of impingement of jets - Impact of jet on a stationary vertical plate, stationary inclined plate, stationary curved plate, hinged plate, moving vertical and inclined plates, moving curved plate and on series of moving flat and curved vanes fixed on the periphery of circular rim.

Impact of jets

Let us consider that we have one pipe through which liquid is flowing under pressure. Let us assume that a nozzle is fitted at outlet of pipe. Liquid which will come through the outlet of nozzle will be in the form of jet.

If a plate, which may be moving or fixed, is placed in the path of jet, there will be one force which will be exerted by the jet over the surface of plate. The force which will be exerted by the jet over the surface of plate, which might be moving or fixed, will be termed as impact of jet.

In order to determine the expression of force exerted by the jet over the surface of plate i.e. impact of jet, we will use the basic concept of Newton's second law of motion and impulse-momentum equation

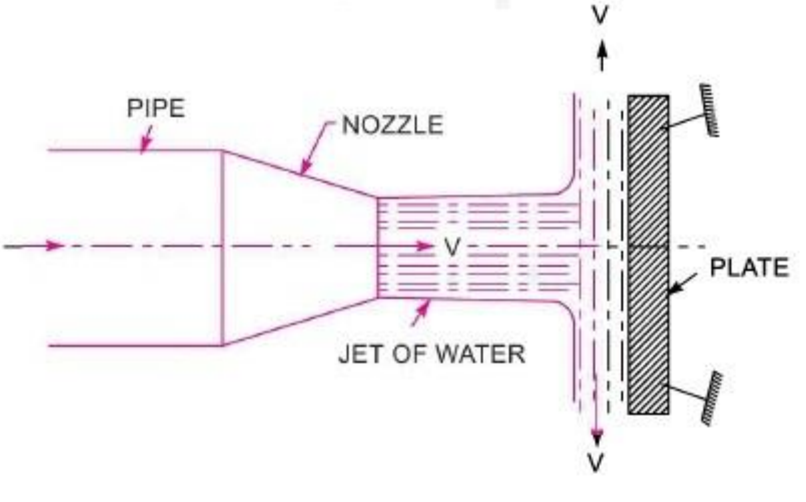
Force exerted by jet on stationary vertical plate

Let us consider a jet of water, which is coming from the outlet of nozzle fitted at the pipe, strikes a flat vertical flat plate as displayed here in following figure.

V = Velocity of the jet

d = Diameter of the jet

a = Area of cross-section of the jet = $(\pi/4) \times d^2$



The component of velocity of liquid jet, in the direction of jet, after striking will be zero.

Force exerted by liquid jet on the plate in the direction of jet will be determined by using the concept of impulse momentum equation

$$F_x = \text{Rate of change of momentum in the direction of force}$$
$$= \frac{\text{Initial momentum} - \text{Final momentum}}{\text{Time}}$$
$$= \frac{(\text{Mass} \times \text{Initial velocity} - \text{Mass} \times \text{Final velocity})}{\text{Time}}$$
$$= \frac{\text{Mass}}{\text{Time}} [\text{Initial velocity} - \text{Final velocity}]$$
$$= (\text{Mass/sec}) \times (\text{velocity of jet before striking} - \text{velocity of jet after striking})$$
$$= \rho a V[V - 0] \qquad (\because \ \text{mass/sec} = \rho \times a\, V)$$
$$= \rho a V^2$$

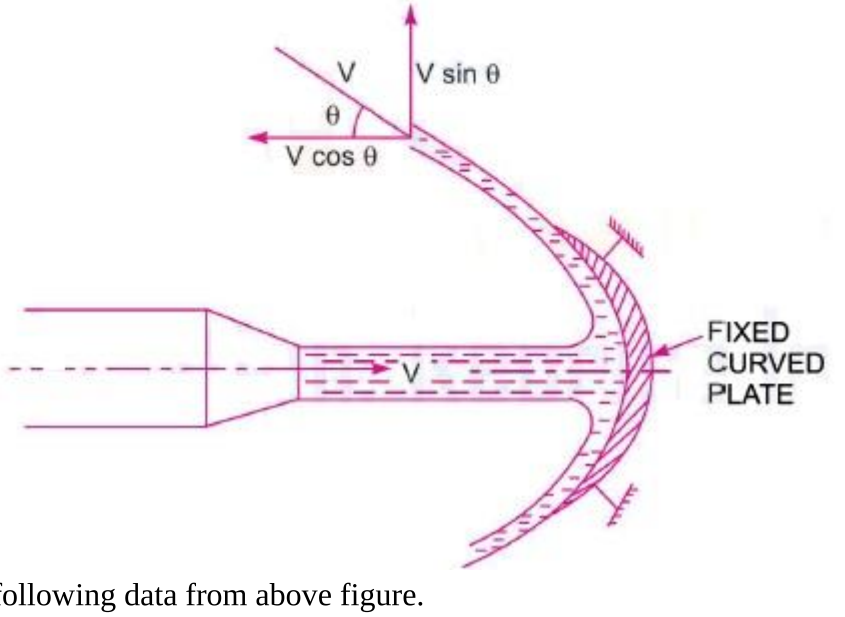
Force exerted by jet on stationary curved plate

We will see here three conditions as mentioned here.

1. Jet strikes the curved plate at the center
2. Jet strikes the curved plate at one end tangentially when the plate is symmetrical
3. Jet strikes the curved plate at one end tangentially when the plate is symmetrical

Jet strikes the curved plate at the center

Let us consider that a jet of water strikes a fixed stationary curved plate at its center as displayed here in following figure.



Let us assume the following data from above figure.

V = Velocity of the jet

d = Diameter of the jet

a = Area of cross-section of the jet = $(\pi/4) \times d^2$

θ = Angle made by jet with x- axis

Let us assume that the plate is smooth and there is no loss of energy due to impact of water jet. Water jet, after striking the stationary curved plate, will come with similar velocity in a direction tangentially to the curved plate.

We will resolve the velocity at the outlet of curved plate in its two components i.e. in the direction of jet and in a direction perpendicular to the jet.

Component of velocity of water jet in the direction of jet = $- V \cos \theta$

We have taken negative sign because velocity at the outlet is in the opposite direction of the water jet coming out from nozzle.

Component of velocity of water jet perpendicular to the jet = $V \sin \theta$

Force exerted by the water jet in the direction of jet

F_X = Mass per second x $[V_{1x} - V_{2x}]$

Where,
V_{1x} = Initial velocity in the direction of jet = V
V_{2x} = Final velocity in the direction of jet = $- V \cos \theta$

$F_X = \rho a V \times [V + V \cos \theta]$

$$\mathbf{F_X = \rho a V^2 \times [1 + \cos \theta]}$$

Force exerted by the water jet in the direction perpendicular to the jet

F_Y = Mass per second x $[V_{1y} - V_{2y}]$

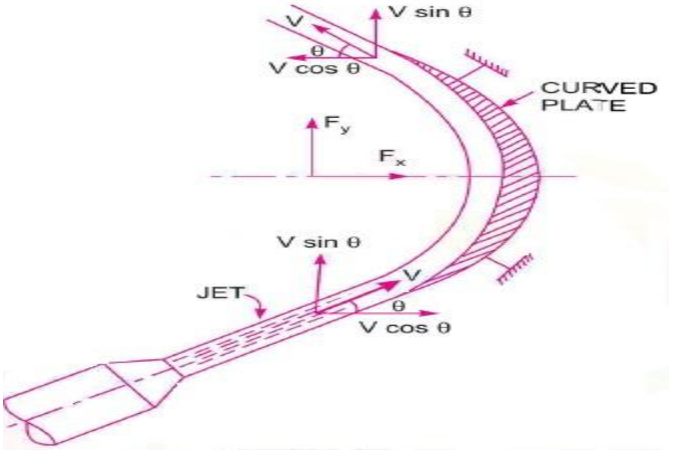
Where,
V_{1y} = Initial velocity in Y direction = 0
V_{2y} = Final velocity in Y direction = $V \sin \theta$

$F_Y = \rho a V \times [0 - V \sin \theta]$

$$\mathbf{F_Y = - \rho a V^2 \sin \theta}$$

Jet strikes the curved plate at one end tangentially when the plate is symmetrical

Let us consider that a jet of water strikes a fixed stationary curved plate at its one end tangentially, when the plate is symmetrical, as displayed here in following figure.



Let us assume the following data from above figure.

V = Velocity of jet

θ = Angle made by jet with x - axis at inlet tip of the curved plate

Let us assume that the plate is smooth and there is no loss of energy due to impact of water jet. Water jet, after striking the stationary curved plate, will come at the outlet tip of the curved plate with similar velocity i.e.

V in a direction tangentially to the curved plate.

Force exerted by the water jet in the x - direction

F_X = Mass per second x [$V_{1x} - V_{2x}$]

Where,

V_{1x} = Initial velocity in the x direction = V Cos θ

V_{2x} = Final velocity in the x direction = - V Cos θ

$F_X = \rho$ a V x [V Cos θ + V Cos θ]

$$\mathbf{F_X = 2\ \rho\ a\ V^2\ Cos\ \theta}$$

Force exerted by the water jet in the Y- direction

F_Y = Mass per second x [$V_{1y} - V_{2y}$]

Where,

V_{1y} = Initial velocity in Y direction = V Sin θ

V_{2y} = Final velocity in Y direction = V Sin θ

$F_Y = \rho$ a V x [V Sin θ - V Sin θ]

$$\mathbf{F_Y = 0}$$

Jet strikes the curved plate at one end tangentially when the plate is unsymmetrical

Let us consider that a jet of water strikes a fixed stationary curved plate at its one end tangentially, when the plate is unsymmetrical, as displayed here in following figure.

V = Velocity of jet

θ = Angle made by tangent with x - axis at inlet tip of the curved plate

ϕ = Angle made by tangent with x - axis at outlet tip of the curved plate

Let us assume that the plate is smooth and there is no loss of energy due to impact of water jet. Water jet, after striking the stationary curved plate, will come at the outlet tip of the curved plate with similar velocity i.e. V in a direction tangentially to the curved plate.

Force exerted by the water jet in the x - direction

F_X = Mass per second x [V_{1x} –V_{2x}]

Where,

V_{1x} = Initial velocity in the x direction = V Cos θ

V_{2x} = Final velocity in the x direction = - V Cos ϕ

$F_X = \rho a V \times [V \cos\theta + V \cos\phi]$

$$\mathbf{F_X = \rho\, a\, V^2\, [\cos\theta + \cos\phi]}$$

Force exerted by the water jet in the Y- direction

F_Y = Mass per second x [V_{1y} –V_{2y}]

Where,

V_{1y} = Initial velocity in Y direction = V Sin θ

V_{2y} = Final velocity in Y direction = V Sin ϕ

$F_Y = \rho a V \times [V \sin\theta - V \sin\phi]$

$$\mathbf{F_Y = \rho\, a\, V^2 \times [\sin\theta - \sin\phi]}$$

MODULE2:

Turbines - classification- impulse turbines - Pelton wheel - Reaction turbines - Francis and Kaplan Turbines - draft tubes - Governing of a Francis turbine - Performance of turbines - specific speed and their significance.

Introduction

Most of the electrical generators are powered by turbines. Turbines are the primemovers of civilisation. Steam and Gas turbines share in the electrical power generation is about 75%. About 20% of power is generated by hydraulic turbines and hence thier importance. Rest of 5% only is by other means of generation.

Hydraulic power depends on renewable source and hence is ever lasting. It is also non polluting in terms of non generation of carbon dioxide.

ClassificationofTurbines

The main classification depends upon the type of action of the water on the turbine. These are

(i) Impulse turbine
(ii) Reaction Turbine.

(i)In the case of impulse turbine all the potential energy is converted to kinetic energy in the nozzles. The impulse provided by the jets is used to turn the turbine wheel. The pressure inside the turbine is atmospheric.

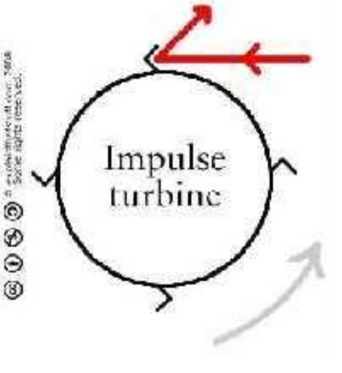
This type is found suitable when the available potential energy is high and the flow available is comparatively low. Some people call this type as tangential flow units. Later discussion will show under what conditions this type is chosen for operation.

(ii)In reaction turbines the available potential energy is progressively converted in the turbines rotors and the reaction of the accelerating water causes the turning of the wheel.

These are again divided into radial flow, mixed flow and axial flow machines. Radial flow machines are found suitable for moderate levels of potential energy and medium quantities of flow. The axial machines are suitable for low levels of potential energy and large flow rates. The potential energy available is generally denoted as “head available”. With this terminology plants are designated as “high head”, “medium head” and “low head” plants

Reaction Turbine

In a reaction turbine, the blades sit in a much larger volume of fluid and turn around as the fluid flows



past them. A reaction turbine doesn't change the direction of the fluid flow as drastically as an impulse turbine: it simply spins as the fluid pushes through and past its blades

If an impulse turbine is a bit like kicking soccer balls, a reaction turbine is more like swimming—in reverse. Let me explain! Think of how you do freestyle (front crawl) by hauling your arms through the water, starting with each hand as far in front as you can reach and ending with a "follow through" that throws your arm well behind you.

Kaplanturbine

The Kaplan turbine is a propeller-type water turbine which has adjustable blades. It was developed in 1913 by the Austrian professor Viktor Kaplan, who combined automatically - adjusted propeller blades with automatically-adjusted wicket gates to achieve efficiency over a wide range of flow and water level.

The Kaplan turbine was an evolution of the Francis turbine. Its invention allowed efficient power production in low- head applications that was not possible with Francis turbines.

Kaplan turbines are now widely used throughout the world in high-flow, low-head power production. The Kaplan turbine is an inward flow reaction turbine, which means that the working fluid changes pressure as it moves through the turbine and gives up its energy. The design combines radial and axial features.

The inlet is a scroll-shaped tube that wraps around the turbine's wicket gate. Water is directed tangentially through the wicket gate and spirals on to a propeller shaped runner, causing it to The outlet is a specially shaped draft tube that helps decelerate the water and recover kinetic energy.

Francis Turbine

The Francis turbine is a type of water turbine that was developed by James B. Francis in Lowell, MA. It is an inward-flow reaction turbine that combines radial and axial flow concepts.

Francis turbines are the most common water turbine in use today. They operate in a head range of ten meters to several hundred meters and are primarily used for electrical power production.

The inlet is spiral shaped. Guide vanes direct the water tangentially to the turbine wheel, known as a runner. This radial flow acts on the runner's vanes, causing the runner to spi n. The guide vanes (or wicket gate) may be adjustable to allow efficient turbine operation for a range of water flow conditions.

As the water moves through the runner, its spinning radius decreases, further acting on the runner. For an analogy, imagine swinging a ball on a string around in a circle; if the string is pulled short, the ball spins faster due to the conservation of angular momentum. This property, in addition to the water's pressure, helps Francis and other inward-flow turbines harness water energy efficiently. Water wheels have been used historically to power mills of all types, but they are inefficient.

DRAFT TUBES

A draft tube is a type of tube that connects the exit of the water turbine to the tailrace. The tailrace is the water channel that takes the water out of the turbine. It is usually located at the outlet or exit of the turbines and converts the kinetic energy of the water at the outlet of the turbine to static pressure

MODULE 3:

Centrifugal pump - description and working - Head, discharge and efficiency of a centrifugal pump - pressure rise in the pump - minimum starting speed of a pump - cavitation - priming - multistage pumps - characteristic curves. Reciprocating pump - Description and working - types - discharge and slip - power required to drive the pump - Indicator diagram - Air vessel - work done against friction with and without air vessels. Working principle and use of the following hydraulic pumps and machines - Deep well pumps - submersible and jet pumps, special pumps - Gear pump - screw pump, sewage pump, miscellaneous machines - Hydraulic press - hydraulic accumulator - Hydraulic ram.

Centrifugal Pumps

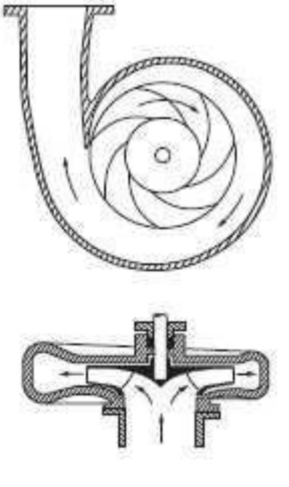
These are so called because energy is imparted to the fluid by centrifugal action of moving blades from the inner radius to the outer radius. The main components of centrifugal pumps are (1) the impeller, (2) the casing and (3) the drive shaft with gland and packing.

Additionally suction pipe with one way valve (foot valve) and delivery pipe with delivery valve completes the system.

The liquid enters the eye of the impeller axially due to the suction created by the impeller motion. The impeller blades guide the fluid and impart momentum to the fluid, which increases the total head (or pressure) of the fluid, causing the fluid to flow out.

The fluid comes out at a high velocity which is not directly usable. The casing can be of simple volute type or a diffuser can be used as desired. The volute is a spiral casing of gradually increasing cross section. A part of the kinetic energy in the fluid is converted to pressure in the casing.

Figure shows a sectional view of the centrifugal pump.



Volute type centrifugal pump.

Gland and packing or so called stuffing box is used to reduce leakage along the drive shaft. By the use of the volute only a small fraction of the kinetic head can be recovered as useful static head.

A diffuser can diffuse the flow more efficiently and recover kinetic head as useful static head. A view of such arrangement is shown in figure Diffuser pump are also called as turbine pumps as these resembles Francis turbine with flow direction reversed.

Reciprocating Pumps

Introduction

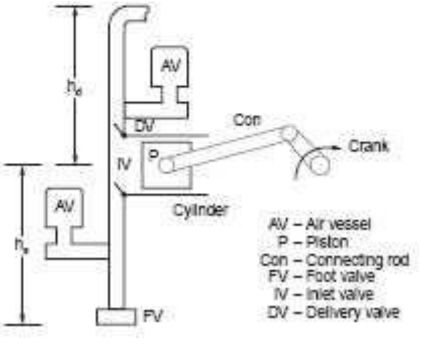
There are two main types of pumps namely the dynamic and positive displacement pumps. Dynamic pumps consist of centrifugal, axial and mixed flow pumps. In these cases pressure is developed by the dynamic action of the impeller on the fluid.

Momentum is imparted to the fluid by dynamic action. This type was discussed in the previous chapter. Positive displacement pumps consist of reciprocating and rotary types. These types of pumps are discussed in this chapter. In these types a certain volume of fluid is taken in an enclosed volume and then it is forced out against pressure to the required application.

DescriptionAnd Working

The main components are:

1. Cylinder with suitable valves at inlet and delivery.
2. Plunger or piston with piston rings.
3. Connecting rod and crank mechanism.
4. Suction pipe with one way valve.
5. Delivery pipe.
6. Supporting frame.

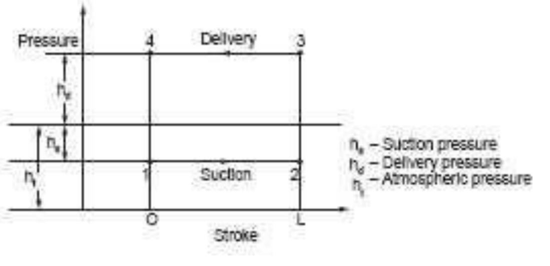


The action is similar to that of reciprocating engines. As the crank moves outwards, the piston moves out creating suction in the cylinder. Due to the suction water/fluid is drawn into the cylinder through the inlet valve. The delivery valve will be closed during this outward stroke.

During the return stroke as the fluid is incompressible pressure will developed immediately which opens the delivery valve and closes the inlet valve. During the return stroke fluid will be pushed out of the cylinder against the delivery side pressure. The functions of the air vessels will be discussed in a later section. The volume delivered per stroke will be the product of the piston area and the stroke length.

IndicatorDiagram

A graph that indicates changes in pressure with respect to volume within the cylinder of a reciprocating engine is known as an indicator diagram.



Air Vessels

The air vessel is used as an accumulator to store compressed air, to separate condensate through cooling and to compensate for pressure fluctuations in a compressed air distribution system. In water supply systems, air vessels are used as hydrophors and also as safety components to avoid surge pressure.

Rotary pumps

Rotary pumps are a type of positive displacement pump where for each revolution, a fixed volume of fluid is moved. Rotary pumps are most commonly used to circulate lubricating oil in mechanical equipment or to provide pressure for hydraulic operating systems. The oil used in these systems is usually cleaned by filtering. The pumped fluid lubricates the pump's internal gears and bearings.

There are 4 types of Rotary Pumps:

Screw Pump.

Gear Pump.

Lobe Pump.

Vane Pump

Hydraulic press

A hydraulic press works on the principle of Pascal's law, which states that when pressure is applied to a confined fluid, the pressure change occurs throughout the entire fluid. Within the hydraulic press, there is a piston that works as a pump, that provides a modest mechanical force to a small area of the sample.

CAVITATION

Cavitation is a phenomenon in which the static pressure of a liquid reduces to below the liquid's vapour pressure, leading to the formation of small vapor-filled cavities in the liquid. When subjected to higher pressure, these cavities, called "bubbles" or "voids", collapse and can generate shock waves that may damage machinery.

multistage pumps

Multistage pumps are defined as pumps in which the fluid flows through several impellers fitted in series. The head of a single-stage centrifugal pump is largely governed by the type of impeller and the circumferential speed

Deep Well Pumps

The majority of individuals in urban and suburban regions have nearly continual access to drinkable, clean water. However, millions of houses in more rural regions rely on wells for their water supply. A well pump, which is a type of industrial pump, is an electromechanical device that is placed after a well has been drilled or dug. Its job is to transport water from your well to your home. An impeller of centrifugal pump, driven by an electric motor, propels water from your well through a jet or pipe.