***UNIT-IV***

**IMPACT OF JETS AND PUMPS: Impulse momentum equation,**

**Impact of Jet on stationary**

**moving vanes (flat and curved).**

**Pumps: Types of pumps, Centrifugal pumps: Main**

**components,**

**Working principle,**

**Multi stage pumps,**

**Performance and**

**characteristic curves**

***Impact of jet***

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The jet of water is directed to hit the vanes of a particular shape a force is exerted on the vane by

the jet.The amount of force depends on the diameter of the jet shape and the fluid flow rate it

also depends on whether thevane is moving or stationary. In this experiment we are concerned

about the stationary vane. The force on vane isgiven by the following formulas:

Flat Plate: Ft = ρ a v2

Hemispherical Ft=2 ρ a v2

Where a = area of jet in m2

ρ = density of water = 1000 kg/ m3

v = velocity of jet in m/s

Ft = Force acting parallel to the direction of jet

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***Impact of jet***

The liquid comes out in the form of a jet from the outlet of a nozzle which is fitted to a pipe

through which the liquid is flowing under pressure.A **jet** is a stream of fluid that is projected into

a surrounding medium, usually from some kind of a nozzle, aperture or orifice.[1] Jets can travel

long distances without dissipating.

Jet fluid has higher momentum compared to the surrounding fluid medium. In the case that the

surrounding medium is assumed to be made up of the same fluid as the jet, and this fluid has

a viscosity, the surrounding fluid is carried along with the jet in a process called entrainment.

***Force Exerted By Fluid Jet On Stationary Flat Plate***

The following cases of the impact of jet, i.e. the force exerted by the jet on a plate will be

considered considered:‐

1. Force exerted by the jet on a stationary plate

a) Plate is vertical to the jet

b) Plate is inclined to the jet

c) Plate is curve

2. Force exerted by the jet on a moving plate

a) Plate is vertical vertical to the jet

b) Plate is inclined to the jet

c) Plate is curved

***Force exerted by the jet on a stationary vertical plate***

Consider a jet o f water coming out from the nozzle strikes the vertical plate

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V = velocity of jet, d = diameter of the jet, a = area of x – section of the jet

The force exerted by the jet on the plate in the direction of jet.

Fx = Rate of change of momentum in the direction of force

Rate of change of momentum in the direction of force = initial momentum – final momentum /

time

= mass x initial velocity – mass x final velocity / time

= mass/time (initial velocity – final velocity)

= mass/ sec x (velocity of jet before striking mass/ sec x (velocity of jet before striking – final

velocity of jet after striking)

***Force of Jet Impinging On An Inclined Fixed Plate*:**

Consider a jet of water impinging normally on a fixed plate as shown in fig-2.

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Let, • Ɵ = Angle at which the plate is inclined with the jet

Force exerted by the jet on the plane = KN

Force exerted by the jet in a direction normal to the plate,  and the force exerted by

the jet in the direction of flow,

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Similarly.force exerted by the jet in a direction normal to flow,

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***Force Of Jet Impinging On A Moving Plate:***

Consider a jet of water imping normally on a plate. As a result of the impact of the jet, let the plate move

in the direction of the jet as shown in fig-3.



Let, v= Velocity of the plate, as a result of the impact of jet A little conversation will show that the relative

velocity of the jet with respect to the plate equal to **(V-v)** m/s. For analysis purposes, it will be assumed

that the plate is fixed and the jet is moving with a velocity of **(V-v)** m/s. Therefore force exerted by the jet,

***Force Of Jet Impinging On A Moving Curved Vane:***

Consider a jet of water entering and leaving a moving curved vane as shown in fig-4.

Let,



Let,

• V = Velocity of the jet (AC), while entering the vane,

• V1 = Velocity of the jet (EG), while leaving the vane,

• v1, v2 = Velocity of the vane (AB, FG)

• α = Angle with the direction of motion of the vane, at which the jet enters the vane,

• β = Angle with the direction of motion of the vane, at which the jet leaves the vane,

• Vr = Relative velocity of the jet and the vane (BC) at entrance (it is the vertical difference

between V and v)

• Vr1 = Relative velocity of the jet and the vane (EF) at exit (it is the vertical difference between

v1 and v2)

• Ɵ = Angle, which Vr makes with the direction of motion of the vane at inlet (known as vane

angle at inlet),

• β = Angle, which Vr1 makes with the direction of motion of the vane at outlet (known as vane

angle at outlet),

• Vw = Horizontal component of V (AD, equal to ). It is a component parallel to the direction of

motion of the vane (known as velocity of whirl at inlet),

• Vw1 = Horizontal component of V1 (HG, equal to ). It is a component parallel to the direction

of motion of the vane (known as velocity of whirl at outlet),

• Vf = Vertical component of V (DC, equal to ). It is a component at right angles to the direction

of motion of the vane (known as velocity of flow at inlet),

• Vf1 = Vertical component of V1 (EH, equal to ). It is a component at right angles to the

direction of motion of the vane (known as velocity of flow at outlet),

• a = Cross sectional area of the jet. As the jet of water enters and leaves the vanes tangentially,

therefore shape of the vanes will be such that Vr and Vr1 will be a long with tangents to the

vanes at inlet and outlet. The relations between the inlet and outlet triangles (until and unless

given) are: (i) V=v1 , and

(ii) Vr=Vr1 We know that the force of jet, in the direction of motion of the vane,

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***HEAD AND EFFICIANCES***

1. Gross head

2. Effective or Net head

3. Water and Bucket power

4. Hydraulic efficiency

5. Mechanical efficiency

6. Volume efficiency

7. Overall efficiency

***Concepts***

A pump is a device which converts the mechanical energy supplied into hydraulic energy by lifting water to higher levels.

***CENTRIFUGAL PUMP***

***Working principle***

If the mechanical energy is converted into pressure energy by means of centrifugal force acting on the fluid, the hydraulic machine is called centrifugal pump. The centrifugal pump acts as a reversed of an inward radial flow reaction turbineIts is used in places like agriculture, municipal (water and wastewater plants), industrial, power generation plants, petroleum, mining, chemical, pharmaceutical and many others.

***Main Parts of Centrifugal Pump***

### *1. Impeller*

It is a wheel or rotor which is provided with a series of backward curved blades or vanes. It is mounded on the shaft which is coupled to an external source of energy which imparts the liquid energy to the impeller there by making it to rotate.



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Impellers are divided into 3 types,

1. Open Impeller
2. Semi enclosed Impeller
3. Enclosed Impeller

### *2. Casing*

It is a pipe which is connected at the upper end to the inlet of the pump to the centre of impeller which is commonly known as eye. The double end reaction pump consists of two suction pipe connected to the eye from both sides. The lower end dips into liquid in to lift. The lower end is fitted in to foot valve and strainer.



Commonly three types of casing are used in centrifugal pump,

1. Volute Casing
2. Vortex Casing
3. Casing with Guide Blades

### *3. Delivery Pipe*

It is a pipe which is connected at its lower end to the out let of the pump and it delivers the liquid to the required height. Near the outlet of the pump on the delivery pipe, a valve is provided which controls the flow from the pump into delivery pipe.

### *****4. Suction Pipe with Foot Valve and Strainer*****

suction pipe is connected with the inlet of the impeller and the other end is dipped into the sump of water. At the water end, it consists of foot value and strainer. The foot valve is a one way valve that opens in the upward direction. The strainer is used to filter the unwanted particle present in the water to prevent the centrifugal pump from blockage.

## *****Working of Centrifugal Pump*****

The first step in the operation of a centrifugal pump is priming. Priming is the operation in which suction pipe casing of the pump and the position of fluid with the liquid which is to be pumped so that all the air from the position of pump is driven out and no air is left. The necessity of priming of a centrifugal pump is due to the fact that the pressure generated at the centrifugal pump impeller is directly proportional to density of fluid that is in contact with it.

 

After the pump is primed the delivery valve is still kept closed and electric motor is started to rotate the impeller. The delivery valve is kept closed in order to reduce valve is opened the liquid is made to flow in an outward radial direction there by vanes of impeller at the outer circumference with high velocity at outer circumference due to centrifugal action vacuum is created.

This cause liquid from sump to rush through suction pipe to eye of impeller thereby replacing long discharge from center circumference of the impeller is utilized in lifting liquid to required height through delivery pipe.

## *****Types of Centrifugal Pumps*****

Centrifugal Pumps are classified into many types based on many categories, they are

### *****Based on number of impellers in the pump,*****

1. Single stage pump
2. Two-stage pump
3. Multi-stage pump

### *****Based on orientation of case-split,*****

1. Axial split Pump
2. Radial split Pump

### *****Based on type of impeller design*,****

1. Single suction Pump
2. Double suction Pump

***Application of Centrifugal Pumps***

1. Oil & Energy – pumping crude oil, slurry, mud; used by refineries, power generation plants
2. Industrial & Fire Protection Industry – Heating and ventilation, boiler feed applications, air conditioning, pressure boosting, fire protection sprinkler systems.
3. Waste Management, Agriculture & Manufacturing – Wastewater processing plants, municipal industry, drainage, gas processing, irrigation, and flood protection
4. Pharmaceutical, Chemical & Food Industries – paints, hydrocarbons, petro-chemical, cellulose, sugar refining, food and beverage production
5. Various industries (Manufacturing, Industrial, Chemicals, Pharmaceutical, Food Production, Aerospace etc.) – for the purposes of cryogenics and refrigerants.

***Performance Characteristics of Pumps***

The fluid quantities involved in all hydraulic machines are the flow rate (Q) and the head (H), whereas the mechanical quantities associated with the machine itself are the power (P), speed (N), size (D) and efficiency (h ). Although they are of equal importance, the emphasis placed on certain of these quantities is different for different pumps. The output of a pump running at a given speed is the flow rate delivered by it and the head developed. Thus, a plot of head and flow rate at a given speed forms the fundamental performance characteristic of a pump. In order to achieve this performance, a power input is required which involves efficiency of energy transfer. Thus, it is useful to plot also the power P and the efficiency h against Q.

Over all efficiency of a pump (h ) = Fluid power output / Power input to the shaft = rgHQ / P

Type number or Specific speed of pump,

nS = NQ1/2 / (gH)3/4 (it is a dimensionless number)

***Centrifugal pump Performance***

In the volute of the centrifugal pump, the cross section of the liquid path is greater than in the impeller, and in an ideal frictionless pump the drop from the velocity V to the lower velocity is converted according to Bernoulli's equation, to an increased pressure. This is the source of the discharge pressure of a centrifugal pump.

If the speed of the impeller is increased from N1 to N2 rpm, the flow rate will increase from Q1 to Q2 as per the given formula:



The head developed(H) will be proportional to the square of the quantity discharged, so that



The power consumed(W) will be the product of H and Q, and, therefore



These relationships, however, form only the roughest guide to the performance of centrifugal pumps.

***Characteristic curves***

Pump action and the performance of a pump are defined interms of their *characteristic curves*. These curves correlate the capacity of the pump in unit volume perunit time versus discharge or differential pressures. These curves usually supplied by pump manufacturers are for water only.

These curves usually shows the following relationships (for centrifugal pump).

·        A plot of capacity versus differential head. The differential head is the difference in pressure between the suction and discharge.

·        The pump efficiency as a percentage versus capacity.

·        The break horsepower of the pump versus capacity.

The net poisitive head required by the pump versus capacity. The required NPSH for the pump is a characteristic determined by the manufacturer.

Centrifugal pumps are usually rated on the basis of head and capacity at the point of maximum efficiency.





4. The impeller of a centrifugal pump is of 300mm diameter and 50mm width at theperiphery and has blades whose tip angle incline backwards 60 from the radius. Thepump deliveries 17m3/min of water and the impeller rotates at 1000Rpm. Assuming that the pump is designto admit radically. calculatea)Speed and direction ofwater as it leaves the impeller,b)Torque exerted by the impeller on waterc)Shaft power required



***Multistage Centrifugal Pumps***

A centrifugal pump containing two or more impellers is called a multistage centrifugal pump. The impellers may be mounted on the same shaft or on different shafts.If we need higher pressure at the outlet we can connect impellers in series.If we need a higher flow output we can connect impellers in parallel.All energy added to the fluid comes from the power of the electric or other motor force driving the impeller.

***RECIPROCATING PUMPS***

***Working principle***

If the mechanical energy is converted into hydraulic energy (or pressure energy) by sucking the liquid into a cylinder in which a piston is reciprocating (moving backwards and forwards), which exerts the thrust on the liquid and increases its hydraulic energy (pressure energy), the pump is known as reciprocating pump



***Main ports of a reciprocating pump***

1.A cylinder with a piston, piston rod, connecting rod and a crank,

2. Suction pipe

 3.Delivery pipe,

4. Suction valve   and

5.Delivery valve.

 



***Slip of Reciprocating Pump***

Slip of a reciprocating pump is defined as the difference between the theoretical discharge and the actual discharge of the pump.

 ***Efficiency Pump***



***Characteristic Curves Of Reciprocatring Pumps***

1.According to the water being on contact with one side or both sides of the piston

(i.) Single acting pump         (ii.) Double-acting pump

2.According to the number of cylinders provided

(i.) Single acting pump                                    (ii.) Double-acting pump    (iii.) Triple-acting pump

 ***Slip of pump***

Capacity is the total liquid displacement of the pump less slip. Slip is the quantity of fluid that

leaks from the higher-pressure discharge to the lower-pressure suction. Slip occurs because all

rotary pumps require clearances between the rotating elements and pump housing.

***Reciprocating pumps Vs centrifugal pumps***

The advantages of reciprocating pumps in general over centrifugal pumps may be summarized as follows:

1.     They can be designed for higher heads than centrifugal pumps.

2.     They are not subject to air binding, and the suction may be under a pressure less than atmospheric without necessitating special devices for priming.

3.     They are more flexible in operation than centrifugal pumps.

4.     They operate at nearly constant efficiency over a wide range of flow rates.

The advantages of centrifugal pumps over reciprocating pumps are:

1.     The simplest centrifugal pumps are cheaper than the simplest reciprocating pumps.

2.     Centrifugal pumps deliver liquid at uniform pressure without shocks or pulsations.

3.       They can be directly c onnected to motor derive without the use of gea rs or belts.

4.       Valves in the discharg e line may be completely closed without injurin g them.

5.       They can handle liquid s with large amounts of solids in suspension.

***Selection of Pumps***

The following factors influence the choice of pump for a particular operation:

1.     *The quantity of liquid to be handled*: This primarily affects the size of the pump anddetermines whether it is desirable to use a number of pumps in parallel.

2.     *The head against which the liquid is to be pumped*. This will be determined by thedifference in pressure, the vertical height of the downstream and upstream reservoirs and by the frictional losses which occur in the delivery line. The suitability of a centrifugal pump and the number of stages required will largely be determined by this factor.

3.     *The nature of the liquid to be pumped*. For a given throughput, the viscosity largelydetermines the frictional losses and hence the power required. The corrosive nature will determine the material of construction both for the pump and the packing. With suspensions, the clearance in the pump must be large compared with the size of the particles.

4.     *The nature of power supply*. If the pump is to be driven by an electric motor orinternal combustion engine, a high-speed centrifugal or rotary pump will be preferred as it can be coupled directly to the motor.

5.     *If the pump is used only intermittently,*corrosion troubles are more likely than withcontinuous working.

***Performance Characteristics of a Pump***

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