Hydraulic Machinery

Que. No. 1 a) Why does pelton wheel does not posses any draft tube?

The exit water from the runner is passed through a diverging tube known as Draft Tube.

As the reaction turbine works under pressure a close conduit is required to connect the runner exit to tail race.

The pressure of water coming out of runner is always less than atmospheric pressure in reaction turbine therefore water cannot be directly discharged to the atmosphere Therefore the diverging tube or passage made of steel or concrete is fitted at the exit of the turbine. The diverging nature of the pipe increases the pressure of the exit water and allows to discharge to tail race. This is not in the case of pelton turbine so pelton turbine does not posses any Draft Tube.

b) What is Cavitations? How can it be avoided in reaction turbine?

When the pressure in any part of flow passing through the turbine reaches the vapor pressure of the flowing liquid, the liquid starts vaporizing and very small bubbles of vapor in very large number are formed. These formed bubbles are carried along the flow and on reaching the high pressure region these bubbles suddenly collapse as the vapor condenses into liquid. Because of the sudden collapse of bubbles the surrounding liquid rushes into fill them. The liquid moving from all directions collides at the centre and creates very high local pressure. The solid surface in the vicinity of the region is also subjected to this pressure and damages the surface which fails by fatigue and surface is pitted. This phenomenon is known as Cavitations.

c) What is priming? Why is it necessary?

The filling of the suction pipe, impeller casing and delivery pipe up to delivery valve by the liquid from outside source before starting the pump is known as priming of the pump.

The air is removed and that portion is filled with liquid to be pumped.

The work done by the impeller of the pump per Newton weight is known as the head developed by pump. This is given by VU/2. This equation indicates that head developed is independent of the density of the liquid. If the pump is running in the air head developed will be in terms of meters of air and if the pump is running in the water head developed will be in terms of meters of water. But as the density of the air is very low as compared with water the head generated in terms of head of air is very low as compared to head of water and this head is not sufficient to suck the water by the pump from the sump. To avoid this difficulty Priming is necessary.

d) What are the uses of Air Vessels?

Air vessel is the closed chamber containing compressed air at the top and liquid at the bottom. It has the following uses.

It provides uniform discharge from pump.

A considerable amount of work is saved as frictional resistance in suction and delivery pipes are considerably reduced.

The chances of cavitations or separation are considerably reduced

The pump can run at higher speed and provides higher discharge without risk of separation.

The length of suction pipe bellow the air vessel can be increased without risk of separation.

e) Enumerate the losses which occur when a centrifugal pump operates.

The various losses occurring during the operation of centrifugal pump may be classified as following-

Hydraulic Losses

Mechanical Losses

Leakage Losses

Hydraulic Losses: The hydraulic losses that may occur in a centrifugal pump installation may be consists of the following-

Shock or eddy losses at the entrance to and the exit from impeller.

Friction losses in the impeller.

Friction and eddy losses in the guide vanes.

Mechanical Losses: The mechanical losses occure in the centrifugal pump on account of the following-

Disc friction between impeller and liquid which fills the clearance space.

Mechanical friction of the nain bearings and glands.

Leakage Losses: In centrifugal pump as ordinarily built, it is not possible to provide a completely water tight seal between the delivery and suction space.

As such there is always a certain amount of liquid which slips or leaks from the high pressure to the low pressure points in the pump and it never passes through the delivery pipe.

The liquid which escapes or leaks from a high pressure zone to low pressure zone carries with it energy which is subsequently wasted in eddies. This loss of energy due to leakage is called as leakage loss.

Que. No.2 b) Explain Characteristic curves of Turbine.

The water turbine has to work under variable head and quantity as per avaibility and accordingly the power developed varies. Many times according to load on the turbine, the quantity of water supplied is varied. Generally the speed is maintained constant with the help of Governor. As the above mentioned factors vary the efficiency of the turbine also varies. Therefore it is necessary to know the behavior of the water turbine or its model under the varying conditions.

Variation behavior of the water turbine is represented in form of graphs and these graphs are popularly known as Characteristic Curves.

The main Characteristic Curves are as following-

- Constant head curves.
- Constant speed curves.
- Constant efficiency curves.

For drawing these curves the head is maintained constant and unit power (Pu), unit speed (Nu) and unit discharge (Qu) and overall efficiency for different gate openings are considered.

The following three figures explain the characteristic curves for pelton wheel, fransis turbine and Kaplan turbine.

Que. No. 4 b) Explain the effect of acceleration in suction and delivery pipes on indicator digram.

Indicator digram for single acting reciprocating pump is the representation of pressure head during suction stroke and delivery stroke or for one complete rotation of the crank.

Effect of acceleration in suction and delivery pipes on indicator diagram:

The pressure head variation in the suction pipe due to acceleration is given by-

$H_{as} = L_s A/ G_{as} * w^2 r. \cos \theta$

When,

$\theta = 0$ $H_{as} = L_s A/ G_{as} * w^2 r.$ (Because $\cos \theta = 1$)

$\theta = 90$ $H_{as} = 0$ (Because $\cos \theta = 0$)

$\theta = 180$ $H_{as} = - L_s A/ G_{as} * w^2 r.$ (Because $\cos \theta = -1$)

It is now oblivious that the suction head in the cylinder does not remain constant during the suction stroke as considered in ideal indicator diagram. But it will be always the sum of suction head in the cylinder and the pressure head variation in the cylinder due to acceleration.

At the beginning of the suction when $\theta = 0$ then H_{as} is positive and pressure head in the cylinder is equal to $L_s A/ G_{as} * w^2 r$

At the middle of the stroke, when $\theta = 90$ then H_{as} is zero and pressure head in the cylinder is equal to zero.

At the end of the stroke, when $\theta = 180$ then H_{as} is negative and pressure head in the cylinder is equal to $-L_s A/ G_{as} * w^2 r$

Therefore Indicator Digram for suction and delivery stroke is as shown in figure-

Que. No. 5 ***b) Explain with Neat sketch Rotary Displacement pumps.***

A positive displacement pump causes a fluid to move by trapping a fixed amount of it then forcing (displacing) that trapped volume into the discharge pipe. A positive displacement pump can be further classified according to the mechanism used to move the fluid:

Positive Displacement Pumps has an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pumps as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses. The volume is constant given each cycle of operation.

- **Rotary-type**, internal gear, screw, shuttle block, flexible vane or sliding vane, helical twisted roots (e.g. the Wendelkolben pump) or liquid ring vacuum pumps.

Positive displacement rotary pumps are pumps that move fluid using the principles of rotation. The vacuum created by the rotation of the pump captures and draws in the liquid. Rotary pumps are very efficient because they naturally remove air from the lines, eliminating the need to bleed the air from the lines manually.

Positive displacement rotary pumps also have their weaknesses. Because of the nature of the pump, the clearance between the rotating pump and the outer edge must be very close, requiring that the pumps rotate at a slow, steady speed. If rotary pumps are operated at high speeds, the fluids will cause erosion. Rotary pumps that experience such erosion eventually show signs of enlarged clearances, which allow liquid to slip through and detract from the efficiency of the pump.

Positive displacement rotary pumps can be grouped into three main types. Gear pumps are the simplest type of rotary pumps, consisting of two gears laid out side-by-side with their teeth enmeshed. The gears turn away from each other, creating a current that traps fluid between the teeth on the gears and the outer casing, eventually releasing the fluid on the discharge side of the pump as the teeth mesh and go around again. Many small teeth maintain a constant flow of fluid, while fewer, larger teeth create a tendency for the pump to discharge fluids in short, pulsing gushes.

Screw pumps are a more complicated type of rotary pumps, featuring two screws with opposing thread —- that is, one screw turns clockwise, and the other counterclockwise. The screws are each mounted on shafts that run parallel to each other; the shafts also have gears on them that mesh with each other in order to turn the shafts together and keep everything in place. The turning of the screws, and consequently the shafts to which they are mounted, draws the fluid through the pump. As with other forms of rotary pumps, the clearance between moving parts and the pump's casing is minimum.

Que. No 6 ***b) What is radial and axial thrust in cetrifugal pump? Explain methods used to balance them?***

Radial Thrust

A centrifugal pump consists of a set of rotating vanes, enclosed within a housing or casing and used to impart energy to a fluid through centrifugal force. Thus, stripped of all refinements, a centrifugal pump has two main parts:

1. A rotating element including an impeller and shaft

2. A stationary element made up of a casing, stuffing box and bearings

In a centrifugal pump the liquid is forced by atmospheric or other pressure into a set of rotating vanes. These vanes constitute an impeller which discharges the liquid at its periphery at a higher velocity. This velocity is converted to pressure energy by means of a volute or by a set of stationary diffusion vanes (Fig 1.2) surrounding the impeller periphery. Pumps with volute casings are generally called volute pumps, while those with diffusion vanes are called diffuser pumps. Diffuser pumps were once quite commonly called turbine pumps, but this term has recently been more selectively applied to the vertical deep-well centrifugal diffuser pumps usually referred to as vertical turbine pumps. For any percentage of capacity, radial reaction is a function of total head and of the width and diameter of the impeller. Thus a high-head pump with a large-diameter impeller will have a much greater radial reaction force at partial capacities than a low-head pump with a small-diameter impeller. A zero radial reaction is not often realised; the minimum reaction occurs at design capacity.

In a centrifugal pump design, shaft diameter and bearing size can be affected by allowable deflection as determined by shaft span, impeller weight, radial reaction forces and the torque to be transmitted. Formerly, standard designs compensated for reaction forces if maximum-diameter pump impellers were used only for operations exceeding 50% of design capacity.

For sustained operations at lower capacities, the pump manufacturer, if properly advised, would supply a heavier shaft, usually at a much higher cost. Sustained operation at extremely low flows, without informing the manufacturer at the time of purchase, is a much more common practice today. The result is broken shafts, especially on high-head units. Because of the increasing operation of pumps at reduced capacities, it has become desirable to design standard units to accommodate such conditions. One solution is to use heavier shafts and bearings. Except for low-head pumps in which only a small additional load is involved, this solution is not economical. The only practical answer is a casing design that develops a much smaller radial reaction force at partial capacities. One of these is the double-volute casing design, also called twin volute or dual-volute.

Axial Thrust in Single-Stage Pumps

The pressures generated by a centrifugal pump exert forces on both its stationary and rotating parts. The design of these parts balances some of these forces, but separate means may be required to counter-balance others. Axial hydraulic thrust is the summation of unbalanced impeller forces acting in the axial direction. As reliable large-capacity thrust bearings are not readily available, axial thrust in single-stage pumps remains a problem only in larger units. Theoretically, a double-suction impeller is in hydraulic axial balance with the pressures on one side equal to, and counter-balancing the pressures on, the other (Fig 2.1). In practice, this balance may not be achieved for the following reasons:

The suction passages to the two suction eyes may not provide equal or uniform flows to the two sides.

1. External conditions such as an elbow being too close to the pump suction nozzle may cause unequal flows to the suction eyes.

2. The two sides of the discharge casing may not be symmetrical, or the impeller may be located off-centre. These conditions will alter the flow characteristics between the impeller shrouds and casing, causing unequal pressures on the shrouds.

3. Unequal leakage through the two leakage joints will tend to upset the balance.

Combined, these factors create definite axial unbalance. To compensate for this, all centrifugal pumps, even those with double-suction impellers, incorporate thrust bearings.