OBJECT

Study of Pelton Wheel Turbine.

DESCRIPTION

Among the impulse water turbines, Pelton Turbine is the only being mostly used. It is also called free jet turbine & operates under a high head of water & it requires a comparatively less quantity of water. The water was conveyed from a reservoir to the turbine in the powerhouse through penstocks. The penstock is joined to a branch pipe fitted with the nozzle at the end. Water comes out from the nozzle as free & compact jet. The no. of nozzles reqd. depends on sp. speed. All the pressure energy of water is converted into velocity head. The water having high velocity is allowed to impinge in air, or buckets fixed round the circumference of a wheel, the latter being mounted on the shaft. The impact of water on the surface of the bucket produces a force which causes the wheel to rotate, thus supplying a torque or mechanical power on the shaft. The jet of water strikes the double hemispherical cup shaped bucket at the centre & is deviated on both sides, thus eliminating the end thrust.

The runner consists of a circular disc with a no. of buckets evenly spaced round its periphery. The buckets have a shape of double semi-ellipsoidal cups. Each buckets is divided into two symmetrical parts of sharp edged ridge known as splitter. One or more nozzles are mounted so that each directs a jet along a tangent to the circle through the center of buckets called pitch circle.

MAIN COMPONENTS & THEIR FUNCTIONS

GUIDE MECHANISM:

The mechanism controls the quantity of water passing through the nozzle & striking the buckets, thus meeting the variable demand of power. It maintains the speed of the wheel constant even when the head varies. The mechanism essentially consists of a spear fixed to the end of the shaft which is operated by governor, when the speed of the wheel increases, the spear is pushed into the nozzle thereby reducing the quantity of water to pass through the nozzle. Sometimes a sudden decrease in load takes place consequently water requirement of turbine suddenly falls.

The modern practice is to provide the guide mechanism with a deflector. The deflector is a plate connected to the spear rod by means of lever.

BUCKETS AND RUNNER

Each bucket is divided vertically into two parts by a splitter which is a sharp edge at the center, giving the shape of a double hemispherical cup. The splitter helps the jet to be divided, without shock, into two parts moving side ways in the opposite direction. The rear of the buckets should be shaped so as not to interface with the passage of water to the bucket preceding in order of rotation. The jet should be deflected backwards when leaving the buckets the angle of deflection being about 160º.

The buckets are bolted on to the circumference of a round disc farming the runner of the Pelton turbine. The runner is made up of cast iron, cast steel or stainless steel. Cast Iron is used to reduce cost in turbine designed for low heads
.

CASING

The casing of a Pelton turbine has no hydraulic function to perform. It is necessary only to prevent splashing & to lead the water to the tail race, & also as to safeguard against accidents.

The casing is cast as fabricated. It has to take a force of the jet projecting beyond the runner of overspread.

HYDRAULIC BRAKES

After shutting down the inlet valve of turbine, the large capacity runner will go on revolving for a considerable period. due to its inertia. This has necessiated the development of a brake to bring the turbine to a stand still in the shortest possible time. The brake consist of a small nozzle fitted in such a way that on being opened it directs a jet on the back of the buckets to bring the revolving runner quickly to rest. The least dia. of the brake jet is found to be 0.6 times the least dia. of the main jet.

VIVA QUESTIONS

1. Differentiate between impulse turbine and impulse reaction turbine.
2. Draw inlet-velocity triangle and out-let velocity triangle for Pelton Wheel Turbine.
3. What will happen if we replace double cup type vane by flat vanes.
4. How power can be calculated with the help of inlet triangle and outlet triangle.

EXPERIMENT NO. 02

Date

OBJECT

Study of Francis Turbine.

DESCRIPTION

Modern Francis Turbine is an inward mixed flow reaction turbine i.e. the water under pressure enters the runners from the guide vanes towards the centre in radial direction & discharge out of the runner axially. The Francis Turbine operates under medium heads & also requires medium quantity of water. It is employed in a medium head power plants. This type of turbine cover a wide range of heads i.e. 30-450 m. Water is brought down to the turbine & directed to a no. of stationary orifices fixed all round the circumference of the runner. These stationary orifices are commonly termed as guide vanes or wicket gates.

A part of the head acting on the turbine is transformed into K.E. & the rest remains as pressure head. There is a difference of pressure between the guide vanes & the runner which is called the reaction pressure & is responsible for the motion of the runner. That is why a Francis Turbine is also known as reaction turbine.

In this type of turbine the pressure at inlet is more than that at the outlet. This means the water in the turbine must flow in a closed conduit.

The movement of the runner is offered by the change of both the pressure & the kinetic energies of water. After doing its work the water is discharged to the tail race through a closed tube of gradually enlarging section known as the draft tube. The draft tube converts kinetic head to pressure head. About 70% conversion is possible.

DIFFERENT TYPES OF FRANCIS TURBINE

There are two main types of Francis Turbine:-

Closed Type
Open Flume Type

CLOSED TYPE FRANCIS TURBINE

In this type of the water is led to the turbine through the penstock whose end is connected to the spiral casing of the turbine. This spiral casing directs the water evenly to the guide vanes. The water then passes through the runner & finally goes to the tail race through the draft tube. The closed type Francis Turbine may be of two types, horizontal & vertical. The horizontal type is used for medium & high heads and the vertical type for medium & low heads.

OPEN FLUME TYPE FRANCIS TURBINE

In the open flume Francis Turbine a concrete chamber replaces the spiral casing. This type of turbine is used for 5-10 m heads. In many power plants axial flow turbine is fast replacing this type of turbine. These are however, still employed where the quantity of water is small & the fluctuation in head is more.

MAIN COMPOENENTS OF MODERN FRANCIS TURBINE

PENSTOCK

Penstock is the waterway to carry water from the reservoir to the turbine casing. Trashracks are provided at the inlet of penstock in order to obstruct the debris entering in it. The penstock sections were manufactured in quarters & welded at the site, due to transport difficulties.Stiffening , anchor rings & pads were welded to the penstock at the site. The welding seams were inspected by X-rays & the penstock was tested at twice the operating pressure.

SPIRAL CASING OR SCROLL CASING

To avoid loss of efficiency, the flow of water from the penstock to the runner should be such that it will not form eddies. In order to distribute the guide water around the guide ring evenly, the scroll casing is designed with a cross-sectional area reducing uniformity around the circumference, maximum at the entrance & nearly zero at the tip. This gives a spiral case & hence the casing is named as spiral casing. In the case of big units, the inside circumference of the casing has stay vanes each directing the water provided with inspection holes & also with pressure gauge connections.

GUIDE MECHANISM

The guide vanes or wicket gates as they sometimes called are fixed between two rings in the form of a wheel, known as guide wheel. The guide vanes have a cross-section known as aerofoil section. This particular cross-section allows water to pass over them without forming eddies & with minimum friction loss.

RUNNER & TURBINE MAIN SHAFT

The flow in the runner of a modern Francis turbine is not purely radial but a combination of radial & axial. The flow is inward i.e. from the periphery towards the centre. The width of the runner depends upon its specific speed. The high sp. speed runner is wider than the one which has low sp. speed. So the former has to work with a large amount of water. The runners may be classified as (I) slow (ii) medium and (iii) fast, depending upon the sp. speed.

The runner is keyed to the shaft which may be vertical or horizontal. The turbine is accordingly specified as vertical or horizontal type. The shaft is generally made of steel & is forged. It is provided with collar far transmitting the axial thrust.

DRAFT TUBE

The water after doing work on the runner passes on to the tail race through a draft tube which is a welded steel plate pipe or a concrete tunnel, its cross-section gradually increasing towards the outlet. The draft tube is a conduit which connects the runner exit to the tail race. The tube should be drowned-aprrox 1m below the lowest tail race level, Different types of draft tubes are:-

Moody's spreading type
Simple Elbow type
Straight divergent tube
Elbow type with circular inlet.

VIVA QUESTIONS

1. What is the difference between mixed flow type and radial flow type reaction turbine.
2. Draw the inlet and outlet velocity triangle for Francis Turbine.
3. How you are calculating power developed by francis turbine with the help of velocity triangles.
4. What is the effect of vane angle on power developed.
5. Draw various characteristic curves for Francis turbine.

EXPERIMENT NO. 03

Date

OBJECT

Study of Kaplan Turbine.

DESCRIPTION

The Propeller shaped runner evolved from the Francis mixed flow runner fulfills the need for a faster unit using a large quantity of flow with low head. The turbine having a propeller-shaped runner is known as propeller turbine. which is an axial flow reaction turbine. It operates in an entirely closed conduit from inlet to tail race. The flow velocity or passages of propeller turbine operate with very high velocities, so cavitation is likely to occur. It is due to cavitation that the maximum permissible head of such a turbine is restricted.

Propeller turbine has fixed runner blades as in case of Francis turbine. Thus Kalpan turbine is just a propeller turbine in which the runner blades are made adjustable. The propeller turbine can be employed economically when it has to work constantly under full load, otherwise Kalpan turbine will be preferred. Kalpan turbine is used where comparatively low head & large quantity of water is available.

There is a considerable space between the ends of guide vanes & the leading edge of runner. The direction of flow changes from radial to axial in this space. The guide vanes impart the whirl component to the flow & the runner blades remove the whirl making the discharge purely axial & transforming the whirl into useful power.

MAIN COMPOENENTS OF MODERN FRANCIS TURBINE

PENSTOCK

Penstock is the waterway to carry water from the reservoir to the turbine casing. Trashracks are provided at the inlet of penstock in order to obstruct the debris entering in it. The penstock sections were manufactured in quarters & welded at the site, due to transport difficulties. Stiffening & anchor rings & pads were welded to the penstock at the site. The welding seams were inspected by X-rays & the penstock was tested at twice the operating pressure.

SPIRAL CASING OR SCROLL CASING

To avoid loss of efficiency, the flow of water from the penstock to the runner should be such that it will not form eddies. In order to distribute the guide water around the guide ring evenly, the scroll casing is designed with a cross-sectional area reducing uniformity around the circumference, maximum at the entrance & nearly zero at the tip. This gives a spiral case & hence the casing is named as spiral casing. In the case of big units, the inside circumference of the casing has stay vanes each directing the water provided with inspection holes & also with pressure gauge connections.

GUIDE MECHANISM

The guide vanes or wicket gates as they are sometimes called are fixed between two rings in the farm of a wheel, known as guide wheel. The guide vanes have a cross-section known as aerofoil section. This particular cross-section allows water to pass over them without forming eddies & with minimum friction loss.

RUNNER & TURBINE MAIN SHAFT

The flow in the runner of a modern kaplan turbine is not purely radial but completely axial. The width of the runner depends upon its sp. speed. The high sp. speed runner is wider than the one which has low sp. speed. So the former has to work with a large amount of water. The runners may be classified as (I) slow (ii) medium and (iii) fast, depending upon the sp. Speed.

The runner is keyed to the shaft which may be vertical or horizontal. The turbine is accordingly specified as vertical or horizontal type. The shaft is generally made of steel & is farged. It is provided with collar far transmitting the axial thrust.

DRAFT TUBE

The water after doing work on the runner passes on to the tail race through a draft tube which is a welded steel plate pipe or a concrete tunnel, its cross-section gradually increasing towards the outlet. The draft tube is a can quit which connects the runner exit to the tail race. The tube should be downed-aprrox lm below the lowest tail race level, Different types of draft tubes are :

Moody's spreading type
Simple Elbow type
Straight divergent tube
Elbow type with circular inlet.

Adjustment of Kalpan Blades

Kalpan runner Blades unlike the Francis can be adjusted to vary passage area between the two blades. This can be done while the turbine is in operation, by means of a servomotor mechanism operating inside the hollow coupling of turbine & generator shaft. Servomotor mechanism consists of a cylinder with a piston working under the pressure on either side. The piston is connected to the upper end of a regulating rod or blade operating rod, the up & down movement of which turns the blade. Regulating rod passes through the turbine main shaft which is made hollow for this purpose, movement of this rod is controlled by governor.

Motion of the regulating rod is transmitted to the blade through suitable link mechanism enclosed in the runner hub. The oil head to supply the pressurized oil to the servomotor through the hollow generator shaft is mounted on the exciter.

VIVA QUESTIONS

1. Differentiate between Francis and Kaplan Turbine.
2. Draw the inlet and outlet velocity triangles for Kaplan turbine.
3. Calculate the power developed by Kaplan turbine from velocity triangles.
4. What is whirl component and flow component of absolute velocity. What is the difference between them.
5. What is function of Draft Tube in reaction turbines.

EXPERIMENT NO. 04

Date

OBJECT

Study of Governing mechanism in Impulse & Impulse – reaction Turbine.

THEORY

The quantity of water rejected from the turbine nozzle and from striking the buckets may be regulated in one of the following ways:

→ SPEAR REGULATION
→ DEFLECTOR REGULATION
→ COMBINED SPEAR & DEFLECTION CONTROL

The spear & deflector in all cases are operated by the servometer mechanism.

(i) **Spear Regulation**: To and fro movement of the spear. Inside the nozzle alter the cross-sectional area of stream, thus making it possible to regulate the rate of flow according to the load. Spear regulation is satisfactory when a relatively large penstock feeds a small turbine & the fluctuation of load is small with the sudden fall in load, the turbine nozzle has to be closed suddenly which may create water hammer in the penstock.

(ii) **Deflection Regulation**: The deflector is generally a plate connecting to the oil pressure governor by means of levers. When it is required to deflect the jet, the plate can be brought in between the nozzle & buckets hereby diverting the water away from the runner and directing into the tail race.

GOVERNING IMPULSE TURBINES BY DOUBLE REGULATION SYSTEM

Water is constant but the load fluctuates. The spear, position can be adjusted by hand. As the nozzle has always the constant opening, it involves considerable wastage of water & can be used only when supply of water is abundant.

(iii) Combined spear deflector Regulation: As both of the above methods have some disadvantages, the modern turbines are provided with double regulation which is the combined spear & deflection control. Double regulation means regulation of speed & pressure. The speed is regulated by spear & the pressure is regulated by deflection arrangement.

The jet deflector controlled directly by governor, deflects jet from runner within a very short period so that no further energy is imparted to the latter. The deflector engages until the spear has been adjusted to a new position of equilibrium. The closing of the spear can thus be started to avoid undue pressure rise, whilst only the short time which the deflector requires to act need be considered in determining speed rise and flywheel momentum. The flywheel momentum is sufficient to deal with a sudden increase in load.

GOVERNING OF REACTION TURBINE :

The guide blades of a reaction turbine are pivoted & connected by servers & links to the regulating rods connected to a regulating lever. The regulating lever is keyed to a regulating shaft which is turned by the servomotor piston of oil pressure governor.

The penstock feeding the turbine inlet has a relief valve better known as pressure Regulator. When the guide vanes have to be suddenly closed, the relief valve opens & diverts the water directly to the tail race. It's function is so similar to that of deflection in Pelton turbines. Thus the double regulation which is the simultaneous operation of two elements is accomplished by moving the guide vanes & relief vanes in Francis turbine by governor.

VIVA QUESTIONS

1. Why governing is necessary in turbines.
2. What is Synchronous speed.
3. What is the difference between governing in reaction turbine and in impulse turbine.
4. What are the advantages you are getting with the help of Governing.

EXPERIMENT NO. 05

Date

OBJECT

To perform constant head test on pelton wheel turbine.

APPARATUS REQUIRED

Tachometer

Formula used:

(1) Head over the turbine
H = Pressure gauge reading (Kg /cm^2)×10 m..

(2) Water flow rate

$$Q = Cd \times a_1 \times a_2 \times \sqrt{\frac{2gh_w}{a_1^2 - a_2^2}}\ m^3/\sec$$

Where a1 = Inlet area of venturimeter (dia. 0.05m)

= 1.963×010^{-3} m^2

a_2 = Throat area of venturimeter(dia. 0.038m)
= 1.13x 10^{-3} m^2
Cd =co-efficient of discharge = 0.98
hw = Water head across venturimeter
= Manometer difference (h) = 12.6 m of water

(3) Power supplied to turbine.

P_{in} = wQH watts
where w = 9810 N / m^3

Brake power

$$B.P. = \frac{2\pi NT}{60}\ \text{watts}$$

Where N = turbine speed in rpm
And T = torque
= (Spring balance difference in kg) x 9.81x (0.128 + 0.006)Nm.

(5) Specific speed Ns = $\frac{N\sqrt{P_{in}}}{H^{5/4}}$ (where P_{in} is in KW)

(6) Overall efficiency of Turbine -

$$\eta_o = \frac{B.P.}{P_{in}} \times 100\%$$

PROCEDURE

(1) Fill up sufficient water in the sump tank.
(2) Keep the Venturimeter valves closed.
(3) Close nozzle by operating the spear, press "Green" button of starter, so that pump start running.
(4) Observe direction of pump rotation during starting. It should be clockwise, as seen from fan end .If it is reverse, interchange any two phases in supply line. If direction of pump is correct, pressure gauge will read the pressure about 4-4.5 kg/cm^2 . If it is reverse, pressure gauge will read 1-2 kg/cm^2.
(5) First open air valves then open the venturimeter valves, remove all the air bubbles and close the air valves slowly and simultaneously so that mercury does not run away into water. Slowly open the nozzle. Turbine will start rotating adjust the spear at 1/4 opening.
(6) Load the rope brake with 0.5 kg load, note down the speed.
(7) Go on adding the load, without disturbing spear position, Note down head, speed, discharge and load each time.
(8) Repeat the procedure for 1/2, 3/4 and full spear opening. This is a constant head test.

OBSERVATION TABLE

(1) Spear opening = ____________ Manometer Reading = ____________
Pressure gauge reading = ___________ kg/cm^2

Sl. No.	Spring balance reading (kg)	Turbine speed (RPM)	Head H (m)	Discharge Q (m^3/sec)	Input power Pin (watts)	B.P. (watts)	η_o

1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								

(2) Spear opening = ____________ Manometer Reading = ____________
Pressure gauge reading = ___________ kg/cm²

Sl. No.	Spring balance reading (kg)	Turbine speed (RPM)	Head H (m)	Discharge Q (m^3/sec)	Input power Pin (watts)	B.P. (watts)	η_o
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							

(3) Spear opening = ____________ Manometer Reading = _____________
Pressure gauge reading = ___________ kg/cm²

Sl. No.	Spring balance reading (kg)	Turbine speed (RPM)	Head H (m)	Discharge Q (m^3/sec)	Input power Pin (watts)	B.P. (watts)	η_o
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							

(4) Spear opening = ____________ Manometer Reading = ____________
Pressure gauge reading = ___________ kg/cm²

Sl. No.	Spring balance reading (kg)	Turbine speed (RPM)	Head H (m)	Discharge Q (m^3/sec)	Input power Pin (watts)	B.P. (watts)	η_o
1. 2. 3. 4. 5. 6. 7. 8.							

CALCULATIONS

GRAPHS

(1) N Vs B.P. for all openings.
(2) N Vs η_o for all openings.
(3) N Vs Q for all openings.

RESULT

1. B.P. is maximum at ------RPM for ------- opening
2. Overall efficiency is maximum at ------------RPM for ---------------------opening.

PRECAUTIONS

1. While putting 'ON' the pump see that the nozzle is closed by the spear and load on the brake drum is released.
2. Use clean water in the tank.
3. Operating all the controls and switches gently.
4. Lubricate all bearings, before experiment.
5. Drain the water after completion of Experiment.

DISCUSSIONS

VIVA QUESTIONS

1. What is surge tank ?
2. What hydraulic efficiency of a turbine ?
3. What is the use of turbine casing ?

4. What is a spear ?
5. What is a penstock?

EXPERIMENT NO. 06

OBJECT

To perform constant speed test on Pelton Wheel Turbine.

APPARATUS REQUIRED

Tachometer
Formula Used
1. Head over the turbine.
   H = Pressure gauge reading (kg/cm^2) x 10 m.
   Water flow rate

   $$Q = C_d \times a_1.a_2 \times \frac{\sqrt{2gh_w}}{\sqrt{a_1^2 - a_2^2}} \, m^3/\text{sec}$$

   Where a_1 = Inlet area of venturimeter(dia.0.05m) = 1.963 x10^{-3} m^2
   a_2 =Throat area of venturimeter (dia 0.038m)=1.13 x 10^{-3} m^2
   Cd = Co-efficient of discharge = 0.98
   hw = water head across venturimeter manometer difference h x 12.6 m of water.

Power supplied to turbine

Pin = wQH watts

where w = 9810 N/m^3

Brake power

B.P. = 2πNT / 60 watts

Where N = Turbine speed in rpm
T = Torque (spring balance difference in kg) x 9.81 x (0.128 + 0.06) N-m

Specific speed

$$Ns= \frac{N\sqrt{P_{in}}}{H^{5/4}}$$ (where p is in KW)

Overall efficiency of turbine

$$\eta s = \frac{B.P.}{P_{in}} \times 100\%$$

EXPERIMENTAL PROCEDURE

1. Fill up sufficient water in the sump tank .
2. Keep the venturimeter valves closed.
3. Close nozzle by operating the spear, press 'Green' button starter, so that pump starts running.
4. Observe direction of pump rotation during starting. It should be clockwise, as seen from fan end .If it is reverse, interchange any two phases in supply line. If direction of pump is correct, pressure gauge will read the pressure about 4-4.5 kg/cm^2 . If it is reverse, pressure gauge will read 1-2 kg/cm^2.
5. First open air valves then open the venturimeter valves, remove all the air bubbles and close the air valves slowly and simultaneously so that mercury does not run away into water.
6. Slowly open the nozzle. Turbine will start rotating adjust the spear so that turbine is rotating at 1000 RPM.
7. Put the load using loading stud. Open the nozzle, so that turbine is again rotating at 1000 rpm.
8. Note down the reading in observation table.
9. Repeat step (7) and (8).
10. Repeat step (7), (8) and (9) for different speeds say 800 rpm, 600rpm, 500 rpm.
11. This is a constant speed test.

OBSERVATION TABLE

Sl. No.	Spring balance reading (kg)	Turbine speed (RPM)	Mano meter differe nce(m)	Pressure gauge reading (kg/cm^2)	Discharge Q (m^3/sec)	Input power Pin (watts)	B.P. (watts)	η_o	Specific speed Ns
1. 2. 3. 4. 5. 6. 7. 8. 9.									
1. 2. 3. 4. 5. 6. 7. 8. 9.									
1. 2. 3. 4. 5. 6. 7. 8. 9.									

CALCULATIONS

GRAPHS

(1) η_o Vs B.P. .
(2) η_o Vs Q
(3) B.P. Vs Q

RESULT

The value of minimum discharge required to rotate the turbine from rest is ----------------- m^3/sec.

PRECAUTIONS

1. While putting 'ON' the pump see that the nozzle is closed by the spear and load on the brake drum is released.
2. Use clean water in the tank.
3. Operate all the control and switches gently.
4. Lubricate the bearing, before Experiment.
5. Drain the water after completion of experiment.

DISCUSSION

VIVA QUESTIONS

1. In impulse turbine the fluid pressure energy is converted into which type of energy ?
2. Which type of metal is used to make the buckets of turbine ?
3. What is the condition for hydraulic efficiency of a Pelton wheel to be maximum ?
4. Draw the outlet velocity triangle of Pelton Wheel Turbine?

EXPERIMENT NO. 07

Date

OBJECT

To perform test on Multistage Centrifugal Pump and draw its Characteristic curves.

SPECIFICATION

1. Centrifugal pump – 50' 40 (2" ,1 1 / 2") mm size pump mono block, drive motor 3 phase, induction motor, 5 HP.
2. Measuring tank – 500mm X 500mmX 500 mmheight
3. Sump tank – 900mmX 900mm X 650mm height
4. Pressure gauge 0-7 Kg / cm^2 to measure the head
5. Vacuum gauge 0 – 760mm Hg to measure suction vacuum.
6. Energy meter
7. Stop watch.

Formula used:

1. Discharge head (hd) = Pd x 10m of water
2. Where Pd = Discharge pressure in Kg / cm^2
3. Discharge Q = $\frac{Volume of\ tank}{t_m} = \frac{0.5 \times 0.5 \times 0.2}{t_m} m^3/\sec$
4. Where t_m = time to fill water up to 20cm rise in measuring tank.
5. Suction head (hs) = $\frac{Ps \times 13.6}{1000} m$

Where

Ps =Suction vaccum = mm of Hg .

Total head = H = hs + hd + 2 m of water

Where

2 m of water = Total loss of head in suction and delivery pipe .

Output power (or water power)

Wp = (w QH) /1000 KW.

Where

w = Specific weight of water =9810 N / m^3

Q =discharge (m^3 / Sec)

H =Total head

Electrical input I .P . = $\frac{10 \times 3600}{t_e \times 240} KW$, Where ,240 = Energy meter constant

t_e = Time required for 10 revolution of energy meter disc in Seconds.

Overall efficiency of the pump

$$\eta_o = \frac{Wp}{Ip} 100\,\%$$

ABOUT TESTING

Centrifugal pumps are basically roto dynamic pumps which develops dynamic pressure for liquid. In centrifugal pumps liquid in impeller is made to rotate by external force, so that it is thrown away from the centre of rotation. As constant supply of liquid is as made available at the centre of rotation, supply liquid can be supplied at higher level.

Normally, head produced by a single impeller depends upon the peripheral speed of the impeller. In order to produce higher heads, either rotational speed of diameter of impeller has to be increased, which increases stresses in the material of impellers. Hence, two pumps in series can be used to produce higher heads. Now this method is replaced by multistage pumps. In multistage pumps, two or more impellers are arranged on a single shaft so that liquid discharged by first stage impeller, at certain head passes to eye of next stage impeller, where the head is increased, till the liquid finally enters into delivery pipe.

The test rig consists of a two stage centrifugal pump driven by a three phase induction motor. An energy meter provided measures electrical input to the motor and a measuring tank provided enables to measure the discharge of the pump. A gate valve is fitted at the discharge side of the pump to vary the head. Thus performance of the pump can be estimated at various heads.

PROCEDURE

1. Fill up water in the tank (around 350 lits.)
2. Open gate valve (priming) top of the pump. Fill up water so that air in the pump will be releases. Close the gate valve.
3. Shut off the discharge valve.
4. Start the pump. As discharge valve is closed, no discharge will be observed, but pressure gauge is showing some reading. This is called ‘shut off head’ of the pump.
5. Now slowly open the discharge valve so that discharge is observed.
6. Note down the discharge head (by pressure gauge on discharge pipe) and suction Vacuum.
7. Note down time required for 20cm water collection in measuring tank.
8. Note down the time required for 10 revolutions of energy meter.

9. Repeat the procedure by varying the discharge valve opening, and fill up the observation table.

OBSERVATION TABLE

S.No	Time for 10 revolutions of energy meter t_e (sec)	Discharge pressure Pd (Kg /cm^2)	Suction vacuum Ps (mm)	Time for 20 cms rise t_m (sec)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

CALCULATION For calculation use separate sheets.

RESULT TABLE

S. No.	Total Head H (m)	Discharge Q (m^3/Sec)	Output Power KW	Input Power (KW)	Efficiency %

GRAPH

Operating characteristic curves

1. Discharge Q Vs Total head H
2. Discharge Q Vs Overall efficiency η_o
3. Discharge Q Vs Power Output Wp

RESULTS

From the operating characteristic curves, it is noted that

(1) Shut of head of pump (head at zero discharge) is …………m
(2) Maximum efficiency occurs at the discharge of…………..m^3/Sec and Is………..% .
(3) Maximum power input to pump is……………KW
(4) Maximum discharge of pump is……………..m^3/Sec

PRECAUTIONS

1. Priming is must before starting the pump. Pump should never be run empty
2. Observe the direction of rotation of pump. If it reverse, interchange any two of the three connections of motor.
3. Use clean water in the sump tank.
4. Do not disturb the pressure gauge connections.

DISCUSSION

VIVA QUESTIONS

1. What is Euler head ?What is the effect of number of vanes of impeller on efficiency ?
2. What is cavitation ?
3. Define specific speed ?
4. Why centrifugal pumps primed ?
5. What are the hydraulic losses in the centrifugal pump

EXPERIMENT NO. 08

Date

OBJECT

To perform test on Reciprocating pump and draw its characteristic curves.

ABOUT TEST RIG

Reciprocating pump is positive displacement plunger pump .It is often used where relatively small quantity of water is be handled and delivery pressure is quite large. Reciprocating pump are widely used as Automobile service station, or as metering and dosing pump.

The test rig consists of a single cylinder, double acting reciprocating pump mounted over the sump. The pump is driven by a.c. motor with stepped cone pulley. An energy meter measures electrical input to motor. Measuring tank is provided to measure discharge of the pump. The pressure and vacuum gauge provided to measure the delivery pressure and suction vacuum respectively.

Specifications :

1. Reciprocating pump F- 38.1mm bore, stroke length 45.3mm, double acting with air vessel on discharge side, suction F-31mm, discharge F-25mm.
2. A.C. motor, 3 H.P. speed variations controlled by a stepped cone pully.
3. Measuring tank 400mm x 400mm x 450mm height provided with gauge tube and swiveling joint in piping for diverting the flow into measuring tank or sump tank.
4. Sump tank 600mm x 900mm x 600mm height.
5. Measurement -
   (a) Pressure gauge - 0.7 kg/ cm^2 for discharge pressure.
   (b) Vacuum gauge- 0.760mm Hg for suction vacuum.
   (c) 3-phase Energymeter for motor input measurement.

Formula Used:

Volume per stroke = [π.D.^{2}L/4]2- (piston rod volume)

Theoretical discharge

Qth = $\frac{1.03\times10^{-4}\times N_p}{60} m^3/\text{sec}$

where Np = Speed of pump in RPM

Suction head

Hs = Suction vacuum of Hg (in meters) (r_{hg} / r_w - 1)

where r_{hg} = Sp. Gravity of mercury = 13.6

r_w = Sp. Gravity of water = 1

Hs = 12.6 x suction vacuum of Hg (in meters)

Delivery head

Hd = Discharge pressure (kg/cm^2) x 10 meter of water (as 10 meter of water = 1 kg/cm^2)

Total head

H_T = Hs + Hd +3meter

where loss of head in piping and fitting is assumed to be 3meter.

Actual Discharge

Qa = $\frac{0.01}{t} m^3/\text{sec}$

where t = time required for 10 liters rise in measuring tank in sec.

Out put power of pump

Op = $\frac{wQ_aH_T}{1000} KW$

where w = specific weight of water 9810 N/m^3

Qa = Discharge in m^3/ sec.

H_T = Total head in meter.

Input power to pump

Let time required for 10 revolutions of energymeter be te second then,

Ip = $\frac{10}{te}\times\frac{3600}{150} KW$

where energymeter constant is 150 revolution / KWH.

Taking motor efficiency 80% we have input shaft power

S.P = Ip x 0.8

Overall efficiency of pump

$\eta_o = \frac{OP}{SP} \times 100\ \%$

Coefficient of discharge of pump.

Cd = $\frac{Actual Discharge}{Theoretical Discharge} = \frac{Q_a}{Q_T}$

Slip = $\frac{Q_T - Q_a}{Q_T} x100\,\%$

11.Slip = Qth-Qa/Qth

PROCEDURE

1. Fill up the sufficient water in sump tank.
2. Fill up the air vessel for about 2/3rd capacity.
3. Open the gate valve in the discharge pipe of the pump fully.
4. Close the gate valve and drain valve of the measuring tank.
5. Check nut bolts & the driving belt for proper tightening.
6. Divert the outlet pipe into funnel and slowly increase the pump speed, slightly close the discharge valve . Note down the various readings in the observations table.
7. Repeat the procedure for different gate valve opening. Take care that discharge pressure does not rise above 4 kgf/cm^2.
8. Change the speed and take readings for different gate valve opening. Repeat the procedure for different speed and complete the observation table.

OBSERVATION TABLES

Sr. no.	Speed NpRPM	Suction vacuum (mm of Hg)	Discharge pressure (kg /cm^2)	Tm sec	Te sec	Discharge(m^3/sec)	IP KW	OP KW	η_o=
1									
2									
3									
4									
5									
6									
7									
8									
9									

1 2 3 4 5 6 7 8 9									
1 2 3 4 5 6 7 8 9									

Tm=time for 10 litres rise in measuring tank
Te=time for 10 revolutions of energy meter.

GRAPHS

1. Operating characteristic curves
   (a) Head Vs Discharge
   (b) Head Vs Input power
   (c) Head Vs Efficiency
2. Main characteristic curves
   (a) Speed Vs Discharge

RESULT & DISCUSSION

PRECAUTIONS

1. Operate all the controls gently.
2. Never allow to rise the discharge pressure above 4 kg/cm^2.
3. Always use clean water for experiment.
4. Before starting the pump ensure that discharge valve is opened fully.

VIVA QUESTIONS

1. Define slip, percentage slip and negative slip of reciprocating pump ?
2. What are the uses of air vessel ?
3. Where reciprocating pumps are used ?
4. What is indicator diagram

EXPERIMENT NO. 09

Date

OBJECT

To perform test on Gear Pump and draw its characteristic curves.

ABOUT TESTING

Gear pump is positive displacement type pump. Gear pumps are widely used for hydraulic power packs used in machine tools of testing machines; because of simplicity of construction and compactness. Also even the pump is positive displacement type; the discharge through pump is continuous. This is an advantage over the reciprocating plunger type pump, being a positive displacement pump. It can discharge pressure than rotary centrifugal pumps. The test rig consists of a gear pump connected to sump tank. A valve provided on discharge side of pump controls the discharge pressure. Various measurement are provided so that performance of pump can be evaluated.

SPECIFICATIONS

1. Gear pump--1/2"BSP connection rated speed 1440 rpm motor1HP,1440rpm, 3 phase with 3 speed cone pulley and V- belt.
2. .Measurement &controls
   a. Vacuum gauge at suction of pump.
   b. Pressure gauge at discharge line of pump 0-10.6 Kg /cm^2
   c. Energy meter for motor input measurement.
   d. Measuring tank with stop clock for discharge measurement.
   e. Gate valve for discharge pressure control.
   f. Valves to direct the oil either to sump tank or measuring tank.
   g. Pressure relief valve at discharge slide.
3. Sump tank 160 litre. capacity.

FORMULA USED

Flow rate (discharge)

$$Q = \frac{5\times10^{-3}}{T_m} m^3/\sec$$

Where Tm = time required for 5 litre Discharge .

Discharge head

Hd = P x12.5 m head of oil

Where P = discharge pressure in Kg / cm^2

Specific weight of oil = 7850 N /m^3.
Output power

OP = $\frac{wQH}{1000}KW$

Where w = Specific weight of oil =7850 (N /m^3)
Q = Discharge m^3/sec
H =Total head = Hs +Hd

Suction Head Hs = $\frac{Vacuum(mmofHg)}{1000} \times \frac{132435}{7850}$

= 17 x Vacuum of oil

Shaft Power = Input power x 0.7
Efficiency of the motor is 70%.
Input Power

IP = $\frac{5}{T_e} \times \frac{3600}{500} KW$

Where Te =Time required for 5 revolution of energymeter and
500 = Energymeter constant

Efficiency of Pump η_o = $\frac{OP}{SP} \times 100\%$

% Slip = $\frac{(N \times Vs) - Q}{N \times Vs \times 60} 100\%$

Where Vs =Swept volume per revolution
= 5.25 x 10^{-6} m^3
and N = Rotational speed of the pump(rpm)

PROCEDURE

1. Fill up sufficient clean oil in the tank (SAE – 40, at least 35 lits).Before putting the oil , the tank must be clean .
2. Rotate the belt by hand to check for freeness of operation .
3. Ensure that pressure control valve is fully open .
4. Make the electrical connections .
5. Keep the valve open which directs the oil to sump, open.
6. Now start the motor .
7. Set the discharge pressure with the help of valve and note down the observations .
8. Repeat the procedure for different pressures .
9. Take similar observations by changing the pump speed .

OBSERVATION TABLES

Sr. no.	Speed Nr.p.m.	Suction Vacuum (mm of hg)	Discharge Pressure Kg / cm^2	Tm Sec	Te sec	Discharge m^3/sec	I.P. KW	OP K.W.	H_o	
1 2 3 4 5 6 7 9										
1 2 3 4 5 6 7 8 9										

Tm = time for 5 litre of oil in measuring tank in sec.
Te = time for 5 revolutions of energy meter in sec.

CALCULATIONS

Use separate sheets for calculations

RESULT **1.** Efficiency of Gear –Pump is ------------------ .

PRECAUTION

1. Never keep the sump lid open .
2. Always fill up clean oil in the sump .
3. Always use SAE-40 oil for the sump .
4. Never disturb the setting of pressure relief valve .
5. Never use the heads above 7 kg/ cm^2 of pressure gauge .
6. Always operate all the controls gently .

VIVA QUESTIONS

1. Where gear pumps are used ?
2. What is the importance of regulating valve in a gear pump ?
3. What is the difference between gear pump and centrifugal pump?
4. what are the advantages of gear pupm over reciprocating pump?

EXPERIMENT NO. 10

Date

OBJECT

Study Of Various Hydraulic Systems

THEORY

Hydraulic Accumulator

It is a device used to store the energy of liquid under pressure & make this energy available to hydraulic M/C such as pressure, lifts & cranes. This is supplied from hydraulic accumulator.

Capacity of Accumulator = $p \times A \times L$
Where
p=pressure
A=cross sectional area
L=Stroke or lift of ram

Hydraulic press

It is used to lift heavy loads by a small force. It works on Pascal's Law i.e. the intensity of pressure in a static fluid is transmitted equally in all direction.

When force F is applied pressure produced which acts equally in all direction. By Pascal's Law:-

$W = F/a \times A$

where A = Area of ram
a = Area of piston

Hydraulic press was first built in 1785 by Ernest Bramah. Since then, hydraulic power has been in use for heavy operations is cranes lifts & capstans with the development of electric power, the hydraulic applications were replaced until more recent times when hydraulic power has come into prominence again.

Hydraulic Ram:

It is the pump which raised water without any external power for its operation. When large quantity of water is available at a small height a small quantity of water can be raised to a great height with the help of hydraulic ram. It works on the principle of water hammer.

The Air lift pump:

The air lift pump is a device which is used for lifting water from a well or sump by using compressed air. The compressed air is made to mix with the water. The density of water is reduced the density of this mixture is much less than that of pure water. Hence a very small of column of pure water is used in this.

Hydraulic Coupling:

The fluid or hydraulic coupling is a device used for transmitting power from driving shaft to driven shaft with the help of fluid. There is no mechanical connection between the two shafts. It consists of radial pump impeller mounted on a driver shaft A & a radial pump impeller flow reaction turbine mounted on the driver shaft B. Both the impeller & runner are identical in shape & they together form a casing which is completely enclosed & filled with oil.

Hydraulic torque converter

The hydraulic torque converter is a device used for transmitting increasing torque at the driver shaft may be more or less than the torque available at the driver shaft with an efficiency at about 90%.

VIVA QUESTIONS

1. What is the difference between Hydraulic Torque converter and Fluid coupling.
2. Write difference between Hydraulic Ram and Hydraulic Press.
3. What are the Functions of Hydraulic accumulator.
4. What are the the functions of Air lift pump.

EXPERIMENT NO. 11

Date

OBJECT

To Examine the fundamental characteristics of flow under a sluice gate through the application of continuity, momentum, energy and similarity relationships.

PRACTICAL RELEVANCE

Sluice gates are used in open channels as rate control devices and thus a basic understanding of the flow characteristics provides information for the hydraulic and structural design of gated systems.Such systems are commonly found in irrigation canals and in water cooling systems of steel plants, aluminium plants etc.

PROCEDURE

1. Select a suitable value of gate opening.
2. Bleed the air from all the tubes connecting the piezometer openings on the gate and the flume bed to the manometers.
3. Determine the rate of flow through the flume.
4. Determine the gate piezometric heads hi by recordings the readings of the gate piezometers and the flume bed static pressure h_b by recordings of flume bed piezometers.
5. Using the movable pointer gauge ,determine the coordinates of the free water surface both at the upstream and down stream of the sluice gate. Also note the upstream and down stream free surface water levels h1 and h2 respectively.
6. Place a total head tube at the mid point of the vena contracta. Record the total head reading.

CALCULATION :

Calculate the following

1. The flow rate Q and hence the flow rate per unit width of the channel Q/w by using the data of either the volumetric or gravimetric method used in the experiment.
2. Upstram and down stream water surface coordinates x/b and h/b.
3. Pressure coefficient on the face of the gate,

$$\frac{P_i}{\rho g b} = \frac{h_i}{b}$$

and Pi/ρgb vs h/b

4. Pressure coefficient on the base of the channel,

$$\frac{P_b}{\rho g b} = \frac{h_b}{b}$$

and plot Pb/ρgb vs x/b.

5. Force per unit width on the gate by using the momentum equation /the pressure distribution.In order to evaluate the integral make graphical integration of the pressure diagram . Compare the results of the two.
6. Determine the coefficient of s of contraction Cc and discharge Cd for various values of h/b ratios by using the following formulae:

$$C_c = \frac{\text{Depth of water at venacontracta}}{\text{Gate opening}} = h_2/b$$

And $C_d = q / q_{th} = q (h_1 + h_2) / \sqrt{2g\, h_1 . h_2}$

VIVA VOCE QUESTIONS

1. What is Euler's equation of fluid flow ?
2. What do you mean by Control surface ?
3. Is control volume isolated system ?
4. What do you mean by integral momentum equation?
5. What are the assumption made in Bernoulli's equation ?

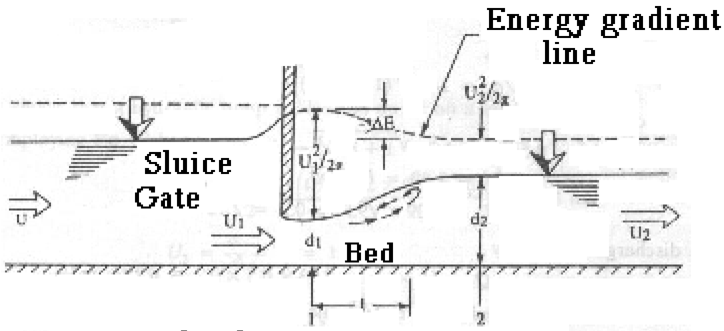
EXPERIMENT NO . 12

OBJECT Date

To study the salient features of a hydraulic jump in a horizontal rectangular open channel and to compare the experimental results with the prediction based on a one dimensional flow analysis .

ABOUT TESTING

A hydraulic jump is formed if super critical free surface flow is caused to change into a sub critical flow as a result of an obstruction placed in the passage or by change in the slope of the channel bed . The phenomenon of a hydraulic jump is accompanied by a sudden rise in depth of liquid surface ,increase in the level of turbulence, pronounced mixing and dissipation of energy .Hydraulic umps are therefore, employed to achieve
(i) dissipation of energy at the foot of the spillway and in many other hydraulic structures wherein large velocities would result in scouring of the river bed .
(ii)mixing of fluids in a chemical plant where a jump is formed in the primary liquid and a secondary liquid and a secondary liquid is dropped from the above.
Study of the jump phenomenon in a laboratory would help to discover the interesting features in a schematic way.



Hydraulic Jump Formation

PROCEDURE

1. Check that the floor of the channel or flume is horizontalAdjust the of the depth gauge so that it corresponds to the level of the bed of channel or flume.
2. Start the Flow and regulate it to obtain maximum possible flow . Be careful to avoid spillage of water over the side walls of the channel or flume .
3. Adjust the height of the upstream sluice gate to obtain the depth d_1 just ownstream of the gate such that$F_{r1}> 1$.
4. Adjust the height of the end obstruction such that a hydraulic jump occurs in the channel .
5. When condition above have become steady , measure :
   (a) the depth , d_1 just in front of the hydraulic jump ,
   (b) the depth , d_2 behind the hydraulic jump at a section where the flow is approximately uniform ,
   (c) the rate of flow , Q
6. Keeping the flow rate constant as adjusted in step 2 , repeat steps 3 to 5 for six different values as possible ,always keeping $F_{r1} >1$. F_{r1} should adjusted by varying d_1 by changing of the sluice gate
7. Vary that no jump can occur for d1 slightly larger then or equal to dc
8. observe the jump by suitably injecting fine potassium permanganate crystals

RESULTS

1. For each run , calculate the initial and final velocities U_1 and U_2 sin the channel ,the upstream and downstream Froude numbers F_{r1} and F_{rv} the upstream ,and downstream specific energies E_{S1} and E_{S2} the experimental and theoretical energy loss ΔE ,and d_2 /d_1.
2. plot the theoretical curves of d_2 /d_1 vs F_{r1}. $\Delta E / E_{S1}$ vs F_{r1}. Superimpose the experimental points on these curves .
3. P= F_{r2} against F_{r1} and compare the experimental result with the theoretical result .

4.Plot the specific energy $E_S = d + U^2 / 2g$ as the abscissa against d as the ordinate for the particular value of q used in the experiment .Calculate the losses for each case from this graph .

VIVA VOCE QUESTIONS

1. What is hydraulic gradient line ?
2. What is the condition of flow such that hydraulic jump will occur ?
3. What do you mean by strength of jump ?
4. What is critical depth ?
5. How strength of hydraulic jump is indicated ?