# K.D.K. College of Engineering

## Department of Civil Engineering

### Vision of the Department

A Center for Civil Engineering Education for shaping Quality Technical Professional with Societal Focus

### Mission of the Department

**M1** To transform young minds into competent Civil Engineers by providing quality technical education

**M2.** To impart employability and professional skill to contribute to national infrastructure, for the benefit of society and environment

**M3.** To create conducive environment for lifelong learning imbibed with ethical values and leadership qualities

Laboratory Manual

# FLUID MECHANICS-II

## SIXTH SEMESTER

## B.E. CIVIL

**KDK College of Engineering**

**Department of Civil Engineering**

# FLUID MECHANICS –II

BECVE603P

**Evaluation Scheme: (25-Internal/25-External) (P-2 Hrs/Week); Total Credits - 1**

1. Study of flow around immersed bodies.

2. Determination of Darcy-Weisbach friction factor for given pipes.

3. Determination of Manning's or Chezy's constant for an open channel.

4. Developing specific energy diagram for a rectangular channel.

5. Study of GVF profiles.

6. Study of hydraulic jump in a horizontal rectangular channel.

7. Study and performance of Francis turbine.

8. Study and performance of Pelton Wheel turbine.

9. Study and performance of Centrifugal pump.

10. Study and performance of Reciprocating pump.

11. Problem on pipe network analysis manually and using application software.

# FLOW AROUND IMMERSED BODIES

**AIM** : To study the flow around immersed bodies.

**THEORY** :

In various Engineering fields we encounter with the problems, which involve the flow of fluid around submerged bodies/objects. Some of the examples are : -

i) Motion of very small objects or bodies such as fine sand particles in air or water.

ii) Very large bodies such as air planes, submarines, automobiles, ships etc. moving through air or water and

iii) The structure such as buildings, bridges etc. which are submerged in air or water.

**Force Exerted by a Flowing Fluid on a Body :-**

Whenever there is a relative motion between a real fluid and a body, the fluid exerts a force on the body. The body exerts an equal and opposite force on the fluid. If the body is moving at a constant velocity in a stationary fluid, the fluid motion is unsteady, because at a given point in a space, the velocity change with time. However if the body is stationary and a fluid flows at a constant velocity, it is steady motion. The magnitude of the force is same in both the cases.

A body wholly immersed in a real fluid may be subjected to the following two kinds of forces due to relative motion between the body and the fluid.

(1) **Drag Force** :- The component of force in the direction of flow (free stream) on a submerged body is called as drag force $F_D$.

(2) **Lift Force** :- The component of force at right angle to the direction of flow is called as lift for ce $F_L$.

For a body moving through a fluid of mass density (), at a uniform velocity (U), the mathematics expressions for the calculations of the drag and lift may also be written as follows.

$$\frac{FL}{\frac{1}{2}\xi u^2 * A}$$

$FD = CD.\ A\ \xi \mu^2 / 2$

$FL = CL.\ A\ \ \xi \mu^2 / 2$

Where, CD= Coefficient of drag (dimensionless)

CL = Coefficient of lift (dimensionless)

ξ = Density of fluid

U = Uniform velocity of fluid w.r. to Body

A = Some characteristic area

$$\text{The coefficient of drag } C_D = \frac{FL}{\frac{1}{2}\xi u^2 * A}$$

$$\text{The coefficient of drag } C_L = \frac{FL}{\frac{1}{2}\xi u^2 * A}$$

A) Examples of immersed bodies having drag and lift forces :

(1) A tall chimney exposed to wing.

(2) Flow of water pass a bridge pier.

(3) Flow of fluid past blades, in fans, blowers compressors, turbies etc.

(4) Motion of aeroplanes, submarines, torpedoes etc.

B) Examples of bodies where both drag and lift forces are produced :

(1) Propeller blades (2) Aerofoil

(3) Hydro files (4) Rotating cylindrical bodies

(5) Kites etc.

Case 0 (I) Thin plate parallel to flow :-

When a thin plate is placed parallel to the direction of flow. The pressure drag will be zero and the total drag is entirely due to shear stress and thus equal to friction drag or shear drag.

(I) Drag force FD $= CD\frac{\xi^{-u^2}}{2} * A$

$(II)$Lift force FL $= CL * \frac{\xi^{-u^2}}{2} * A$

(III) Resultant force FR $= \sqrt{(FD)2 + (FL)2}$

$(IV)$Power extерted by the air stream on the plate

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$(IV)$Power exterted by the air stream on the plate

P = FD * U

Case – (II) When the same plate is held with its axis normal to the direction of flow

When the same plate is held with its axis normal to the direction of flow, the friction drag will be zero. (φ=0) and the flow separates at the edge forming a turbulent wake behind the plate. In this case the total drag will be due o pressure force only.

When the plate is held at an angle to the direction of flow, the total drag will be equal to the sum o pressure drag and friction drag.

$$FD = CD * \frac{\xi U^2}{2} . A$$

$$FL = CL * \frac{\xi U^2}{2} . A$$

$$FR = FR = \sqrt{(FD)^2 + (FL)^2}$$

**Case – III Stream line body** :- A body whose surface coincides with the stream line when placed in flow, is called as stream line body. In this case flow separation takes place only at the trailing edge near most part of the body. The wake formation zone behind a streamlined body is very small, as consequence, of which the pressure drag will be very small. In such a case although due to great surface of the body the skin friction increases but the net effect is as significant reduction of total drag. Body may be streamlined at low velocities but may not be so at higher velocities, also when placed in particular position inflow but may not be so when placed position.

$$FD = CD * \frac{\xi U^2}{2} . A$$

$$FL = CL * \frac{\xi U^2}{2} . A$$

$$FR = FR = \sqrt{(FD)^2 + (FL)^2}$$

# DETERMINATION OF DARCY WEISBATCH FRICTION FACTOR

**AIM** : To determine Darcy Weisbatch friction factor for the given pipe assembly.

**APPARATUS** : Uniform horizontal pipe of known diameter, measuring tank, stopwatch, scale manometer etc.

**FORMUALA** :

1. Head loss due to friction hf = h (Sm/SL – 1)
2. Velocity of flow of water V = Q/A in (m/sec)
3. Coefficient of friction  $f = 2.hf.g.D / V^2$

**THEORY**

**Need and Scope** : In a fluid carrying system there will be some losses due to friction. In a water distribution system, one should find out the total losses due to friction besides other losses in order to decide the required height of overhead tank and also to choose, the capacity of pump required Analysis of head loss due to friction is necessary to arrive at the head to be maintain at the supply point so that a certain minimum head of flow is made available at the tail end of distribution system.

The experiment is carried out to determine the value of friction factor (f) for given pipe and to study the variation of head loss and `f'. We know that `f' develops on the diameter and relative roughness of pipe, velocity of flow, Viscosity and mass density of liquid.

**Experimental Setup :**

The apparatus required consist of a uniform horizontal pipe of a known diameter, the measuring tank with piezometer and stopwatch. The mercury manometer is connected to this pipe, for measuring the loss of head (hf), occurring is a length (l) of the pipe. The experimental setup is as shown in figure.

**PROCEDURE :**

1. Measure the distance (L) between two pressure tappiness accurately.
2. Measure length and breadth of the tank.
3. Connect the `U' the manometer to the pressure tapping of the pipe of which the coemeter to allow the water into the two limbs of manometer and let.
4. Water flow through the pipe with a small discharge.
5. The water is collected in the tank. Note the time required to collect and raise the water in the measuring tank by about 10 cm.
6. Take the reading on manometer in left and right limb.
7. Adjust the valve to increase the discharge and similarly take 5 to 6 sets of readings.

**PRECAUTIONS :-**

1. The connection of nipples must be air – tight.
2. The air valves of manometer should be opned to remove air tubbles if any.
3. The pressure tappings of manometer must be operated simultaneously.
4. Manometer readings should be taken carefully.

**RESULT :-**

The average value of friction for the given portion of pipe is found out of to be

**CONCLUSIONS :**

The friction factor is not constant.

It depends upon the roughness condition pipe surface.

It depends upon the Reynolds's Number of the flow.

It depends upon the diameter of pipe.

It depends upon the velocity of flow.

**OBSERVATION :**

(i) Length of collecting tank L =

(ii) Width of collecting tank B =

(iii) Time taken for water level torise by 10cm =

(iv) Specific gravity of manometric liquid Sm =

(v) Specific gravity of water S =

(vi) Length of pipe between pressure gauge =

(vii) Diameter of pipe for which coeff. Friction is to be determined

D1 = 3.8 cm

D2 = 2.5 cm

**OBSERVATION TABLE :**

| S.N. | Raise of Water in Tank (H) (m) | Time in (Sec.) (t) | Volume of Tank (M3) (L*B*H) | Discharge (Q) (M3/sec.) | Velocity (v) = Q/A M/Sec. | Manometer Reading | | | Manometric head (hf) hf=h(Sm/SL-l) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Left (m) | Right (m) | Diff.(h) | |

## DETERMINATION OF MANNINGS AND CHEZY'S CONSTANT FOR RECTANGULAR CHANNEL

**AIM :**

To determine Chezy's and Mannings Constant for a Rectangular Channel.

**APPARATUS :**

Titting Flume apparatus, Venturimeter, manometer, Measuring Point Gauge and Scale etc.

**FORMULA :**

$$V = c\sqrt{RS}$$
$$V = R^{2/3} S^{1/2} N$$
$$Q_{act.} = (C_d a_1 a_2 \sqrt{2gh} / \sqrt{(a_1)^2 - (a_2)^2}$$
$$R = A / p = \frac{\text{Wetted Area}}{\text{Wetted Perimeter}} = \frac{B * Y}{(B + 2Y)}$$


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| | | | |
|---|---|---|---|
| Where, | V | = | Velocity of flow of water is channel |
| | C | = | Chezy's Constant |
| | R | = | Hydraulic Radius |
| | N | = | Manning's constant |
| | S | = | Bed slope of Channel |
| | Qact | = | Acutal discharge through Channel |
| | $a_1$ | = | Inlet area of Venturimeter |
| | a2 | = | throat area of Venturimeter |
| | Y | = | Depth of flow of water through channel |
| | B | = | Width of Channel |
| | Cd | = | Coeff. Of discharge. |

**THEORY :**

When water flows in an open channel resistance is affered to it, which results in causing a loss o energy. The resistance encountered by the flowing water is generally counteracted by the components o gravity force acting on the body of the water in the direction of motion. A uniform flow will be developed I the resistance is balanced by the gravity forces. The magnitude of the resistance, when other physical factor of the channel are kept uncharged, depends upon the velocity of flow. When water enters the channel, the velocity and hence resistance are smaller hand the gravity forces. Which results in an accelerating flow in the upstream reach of the channel. The velocity and resistance increase gradually until a balance between the resistance and gravity forces is reached. From this point onwards, the flow becomes uniform. The mos widely used uniform flow formulae are the 'Chezy's and manning's formulae.

Essential Features of Uniform flow in a channel :

1) The depth of flow, wetted area, Velocity of flow and discharge are constant at every section along the Channel reach.
2) The total energy line, water surface and channel bottom are all parallel i.e. their sloped are all equal. $S_f = S_W = S_0 = S$

   Whre, $S_f$ = energy line slope, $S_W$= water surface slope, $S_o$ = Channel bottom slope.

The Chezy's Formula : -

The Chezy's formula,

$$V = c\sqrt{RS}$$

Where,

R = Hydraulic Radius, C = Chezy's Constant, S = Bed slope of Channel

**The Mannings Formula :-**

In 1889, an Irish Engineer Robert Manning presented a formula according to which the mean velocity (V) of uniform flow in a channel is expressed in terms of a coefficient of roughness "n OR N" called manning's `N' hydraulic radius `R' and channel slope `s'.

$$V = 1/N\ R^{2/3}\ S^{1/2}.$$

Owing to its simplicity of form and to the satisfactory result it yields in practice, the manning's formula ha how becomes the most widely used of all the imperial formula for the computation of uniform flow in open channel.

If the Manning's formula, is compared with the Chezy's formula, it can be seen that,

$$C = 1 / NR^{1/6}.$$

**PROCEDURE :**

1. The assembly of the experiment is prepared in proper way.
2. The initial level of water in the measuring tank in noted down.
3. The slope of channel bottom si found out.
4. Find the bottom width of channel.
5. Now the experiment is started by opening the value and taking the readingof the bottom to the top o the water level for various flow of water by adjusting intel valve.
6. From various conditions of slope, the flow occurring in the measuring tank is found out.
7. From the data, the value of Chezy's & Mannings constant are found out.

**OBSERVATION :**

(i) Intel diameter of Venturimeter ($d_1$) = 7.7 cm

(ii) Throat diameter of Venturimeter ($d_2$) = 5.57 cm

(iii) Width of channel (B) = 30 cm

(iv) Length of channel (L) =

**OBSERVATION TABLE :**

| **S.N.** | **Slope** | **Manometric Reading** | | **Differec. (cm)** | **Head (h) (Cm)** | **Pt. Gaguage reading** | | **Difference. (Cm)** |
|---|---|---|---|---|---|---|---|---|
| | | Left Re. (Cm) | Right Re. (Cm) | | | Initial (Cm) | Final (Cm) | |
| | | | | | | | | |

| **Actual Discharge (Aq) (cm3/sec)** | **Depth of water (Y) (cm)** | **Velocity Q / A cm/sec** | Where, $K = Cd \times a_1 \times a_2 \times \sqrt{2g} / (a_1^2 - a_2^2)^{1/2}$ <br> $R = \frac{A}{P}$ <br> **Cm** | **C** | **N** |
|---|---|---|---|---|---|
| | | | | | |

**SAMPLE CALCULATION :**

(i) h = 12.6 x

(ii) Q = Cd x a1 x a2 (2gh) ½

= K (H)1/2

Where, $K = Cd \times a_1 \times a_2 \times \sqrt{2g} / (a_1^2 - a_2^2)^{1/2}$

(iii) V = Q / A  A = B x Y

(iv) R = A/P

(v) $V = C (R \times S)^{1/2}$

(vi) $V = 1 / N \times R^{2/3} \times S^{1/2}$

**RESULT :**

By performing the above experiment, the different values of Chezy and Manning's constants an found out according to the different head and bed slope condition.

**CONCLUSION :**

The values of Chezy's and Manning's constants are different for each setup of reading because the depends upon the value of head of water, bed slope condition, hydraulic radius, velocity of flow etc. and these parameters are changing for each time. So their average reading cannot be taken.

**PRECAUTIONS :**

1. Manometer reading should be noted accurately.
2. While measuring the head of water, ensure that it should be a constant head.
3. Datum of channel should be measured correctly.
4. While measuring the head of water, the point gauge should touch the free water surface.

**APPLICATION :**

The determination of discharge through a channel under the different bed slope, hydraulic radius any under different velocity constant or value, Chezy's Manning's formula is useful. Sometimes, $C = 1/N(R)^{1/6}$ may be used to calculate the Chezy's Constant.

# DEVELOPING THE SPECIFIC ENERGY DIAGRAM FOR A RECTANGULAR CHANNEL

**Aim**

To develop the specific energy diagram for a rectangular channel.

**Apparatus:**

(i) Tilting Flume apparatus
(ii) Venturimeter
(iii) Manometer
(iv) Measuring Scale
(v) Point gauge etc.

**Theory:**

Specific energy may be defined as the energy per unit weight of the following water of the channel measured with respect to the channel bottom taken as datum

i.e. $$E = Y + \frac{V^2}{2g} = Y + \frac{Q^2}{2gA^2}$$

Now free water surface of a channel flow represents the hydraulic gradient and if we consider two sections, then by applying Bernullie's thermo between s/c 11 and s/c 22, We have that the distance (1) apart may be written as –

$$Z_1 + Y_1 + \frac{V_1^2}{2g} = Z_2 + Y_2 + \frac{V_2^2}{2g} + hf$$

Where, hf = head loss between two sections.
The term represents the total energy per unit weight of water at any section.

We may represent the specific energy graphically, in which specific energy is plotted against the depth of flow. The curve so obtained is called as specific energy curve. This curve has two limbs. The lower limb appeases the horizontal axis. The upper limb approaches to the line which passes through the origin and has angle of inclination = $45^0$. At any point on this curve the ordinate represents the specific energy. Which is equal to the sum of the depth of the flow and velocity head.

It can be seen from the curve that there is one point on the curve, which has minimum specific energy. The depth of flow at which the specific energy is minimum, is called critical depth for my YC for my other value of the specific curve, there are two possible depths one greater than the critical depth. The two depths of given figure, the following observation is made:-

i. When depth is very less, the flow has high velocity and hence the flow is super critical, As the depth the specific energy (E) decreases.

ii. The depth corresponding to minimum specific energy is called "Critical Depth" (Yc)

iii. With further increase in the depth, E increase, velocity is low, the flow is subcritical.

iv. For each value of (E), there are two depts. $Y_1$ & $Y_2$ , if $Y_1<Y_2$ then flow is sper critical and d1 or $Y_1 > Y_2$ then flow is super critical. The two depths are called alternate depth of each other.

v. For a rectangular channel, of bed width (B) carrying discharge Q, the discharge per unit width (B) is

$$q = Q/B$$

The critical depth Yc is given by

$$Yc = (q^2/g)^{1/3}$$

vi. The minimum specific energy is given by 3/2 Yc

**Procedure:**

1 First of all set the apparatus without errors

2 Adjust the point gauge to the proper initial position

3 Start flow through rectangular channel

4 Taking the reading from Venturimeter and point gauge reading at the bottom and top of water surface, which is flowing

5 About 4 to 5 readings are taken.

6 Calculate the values of specific energy from the observed readings.

7 Plot the specific energy against depth of flow.

8 Indicate super critical depth, sub critical depth and critical depth region on graph.

**Result:**

From the graph the following conclusion are made:

1 E min =

2 Critical depth Yc =

**PRECAUTION:**

The concept of specific energy is useful in the study of open channel flow and solving many problem on channel flow such G.V.F., R.V.F., solving the problems on Hydraulic Jump and channel transition etc.

**OBSERVATIONS**

(i) Inlet diam. Of Venturimeter = d1 =

(ii) Throat diam. Of venutrimeter = d2 =

(iii) Width of channel = B =

(iv) Length of channel = L =

(v) Coeff. Of discharge for Venturimeter =

(vi) Slope of channel

**OBSERVATION TABLE**

| Slo -pe | Manometer Reading | | Diff. (x) (cm) | Head Diff. H=12.6x (cm) | Diff. (y) (cm) | (Qact) ($cm^3$/sec) $= K\sqrt{\square H}$ | V=Q/A (cm/sec) | $\frac{V^2}{2g}$ (cm) | $E=Y+V^2/2g$ (cm) |
|---|---|---|---|---|---|---|---|---|---|
| | L limb | R limb | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**GRAPH:**

Graph is plot between specific energy and depth.

# STUDY THE HYDRAULIC JUMP

**AIM :** To study the hydraulic jump in horizontal rectangular channel.

**THEORY :**

From the specific energy diagram we know that for a given specific energy E. there are two possibly depth d1 & d2. The depth d1 is less then critical depth. And d2 is greater than the critical depth.

When the depth is less than critical depth, the flow is said to be `shooting flow'. But when the depth is greater than the critical depth, the flow is said to be a streaming flow shooting flow is an unstable type of flow and does not continue on the downstream side. The shooting flow transforms itself, to streaming flow by increasing its depth on downstream side.

The rise in water level, which occurs during the transformation of the unstable shooting flow to stable streaming flow is called Hydraulic jump wave.

Definition of Hydraulic Jump :-

"A hydraulic jump is an occurrence, when super critical flow of high velocity and low depth meet the sub critical flow of high depth & low velocity.
It is the case of unsealed non uniform flow." A hydraulic jump, formed on a horizontal floor of channel I as shown in figure.

**Flow characteristics:-**

(1) Flow before the hydraulic jump is steady, uniform and supercritical having high velocity.

(2) The flow after the jump is steady, uniform and sub critical flow with low velocity.

(3) The flow in hydraulic jump is unsteady, non-uniform and changes its state from supercritical to sul critical. The flow is highly turbulent. Large eddies and sounds are formed, causing loss of energy

(4) The initial depth d1 is less then the final depth $d_2$. These depths are called as conjugate depts.. These are different from alternate depths. At

alternate depth, the specific energy is constant, but at conjugate depth, the specific energy is different.

(5) The initial velocity V1 is much higher than the final velocity V2.

(6) The initial depth d1 and the final depth d2 are related as below.

$$\frac{d_2}{d_1}=\frac{1}{2}\left[-1x\sqrt{gd_1}\right]\ \frac{d_2}{d_1}=\frac{1}{2}\left[-1x\sqrt{1+8f_1^{\,2}}\right]$$

Where, F1 = V1 / $\sqrt{gd_1}$

This equation can be proved by application of continuity & momentum equation.

(7) Losses of Head : Energy is lost in hydraulic jump by turbulence and sound. The loss of head (HL) is given by –

$$HL=\frac{(d_1+V_1^{\,2})}{2g}\quad \frac{-(\mathrm{d2}+\mathrm{V}_2^{\,2}}{2g}$$

i.e. the difference between specific energies before & after the jump or directly.

$$\frac{H_L=(V_1-V_2)^3}{2g(V1+V2)}$$

(8) Length (Li) :- The length of jump is the distance between the first boil and the last boil. This distance varies substantially even for the same jump. Approximately.

Lj = (4.5 to 6.0) (d2 – d1)

Location of Hydraulic Jump :- The hydraulic jump, being a unsteady flow phenomenon, its location fluctuates continuously. Hence special structural components (like sill, chute blocks, friction blocks) are required to be constructed, to hold a particular location.

The hydraulic jump occurs at the following location :

(i) At the down stream of sluice gate

(ii) At the foot of the spillway

(iii) After the canal fall

(iv) At the junction of steep slope with the milds lope beds.

**Classification of Hydraulic Jump : -**

There are number of types of hydraulic jump. The classification is based on the value of frauds number of initial supercritical flow as given below. (Only in rectangular channel of horizontal bed).

| $F = \frac{V1}{\sqrt{gd1}}$ | **Name of Hydraulic Jump** | **Main characteristics** |
|---|---|---|
| Less than 1.7 | Undular | Wavy Surface |
| 1.7 to 2.5 | Weak | Small eddies, Steady Surface |
| 2.5 to 4.5 | Oscillating | Jet submerges and come to surface alternately |
| 4.5 to 9.0 | Stable | Good Jump |
| More than | | |
| 9.0 | Strong | Large eddies with 85% loss |

(1) The water surface shows undulations and the jump is called as undulation and the jump is called as an Undular jump.

(2) The jump is called as weak jump, as the velocity throughout is fairly uniform and only a small amount of energy is dissipated. In this case a series of small ralless from on the jump surface, but the down steam wear surface remains quite smooth.

(3) In this case the entering jet of water oscillator back & forth from the bottom to the surface and back again.

(4) The jump formed is well stabilized and is called a steady jump. For this jump the energy dissipation is ranges from 40 to 70%.

(5) In this case a rough surface prevails which continues downstream for a long distance. The jump action is quite rough but is effective since the energy dissipation may reach 85%.

**Uses of Hydraulic Jump :-**

The Phenomenon of hydraulic jump has many practical applications as listed below :-

(1) Energy dissipation : The super critical flow that exists before the jump has high velocity and hence more energy. If such high velocity flow is allowed

in canal, the bed and sides of the canal (even if having hard surface) may be scoured. Hence it is essential to convert the flow into sub-critical state by causing the loss of energy. The hydraulic jump is caused to farm at such plates.

(2) Mixing Chemicals :- In water treatment plants chemicals like alum are required to be mixed thoroughly. Such chemicals are introduced in the flow before the jump are get mixed thoroughly due to turbulence in the jump.

(3) Regain Head :- In irrigation canal when measuring flumes are introduced, the depth is reduced. This causes reduction in the commanded area of canal. Since the depth of flow after the jump is more, such loss can be avoided. Hence an adverse slope is provided beyond the throat s/c so that a hydraulic jump is formed & head regained.

(4) It increases the weight on an apron of a hydraulic structure due to increased depth of flow and hence the unlift form are acting on the apron is considerably counterbalanced.

(5) It increases the discharge through a slice by holding back the tail water.

# STUDY AND PERFORMANCE OF FRANCIS TURBINE

**AIM** : To study and perform the Frainsis Turbine and to determine the efficiency.

**APPARATUS:** Lab setup of Fransis, Turbine, Scale, Weights, etc.

**FORMULA:-**

(i) Overall efficiency $\eta_o = \mathrm{P_o P_i}$

(ii) $\mathrm{Pi} = \ell.\mathrm{g\,Q.H}$

(iii) $\mathrm{H} = \mathrm{P} / \omega$

(iv) $\mathrm{Q} = \mathrm{C_d}\,.a_1.a_1\sqrt{2gh} / \sqrt{(a_1)^2 - (a_2)^2}$

(v) $\mathrm{P_o} = 2\mathrm{II(NWL)}$

(vi) $\mathrm{P_u} = \mathrm{P} / \mathrm{H}^{3/2}$

(vii) $\mathrm{N_u} = \mathrm{N} / \sqrt{\mathrm{H}}$

(viii) $\mathrm{Q_u} = \mathrm{Q} / \sqrt{\mathrm{H}}$

Where $P_1$ = input power of turbine

Po = developed power of turbine

N = Speed of turbine

W = Difference in the tension in the two sides of brake drum ($T_1$-$T_2$ ) L = Radius of brake drum

H = Head over the turbine

h = Head difference in manometric liquid

$N_u$,$Q_u$,$P_u$ = Unit speed, Unit discharge and unit power respectively.

**THEORY:**

**Construction and Working: -**

Francis turbine is an inward radial-flow reaction turbine and is used for intermediate head and large discharge. In this turbine water is directed to the wheel through guide passages external to the wheel. Water after flowing radially inside the wheel leaves it in a direction parallel to the axis.

The turbine consist of a runner mounted on a vertical shaft resting on a foot step bearing. The runner is supported at the top by a collar bearing. The wicket gate consists of a series of adjustable vanes located around the circumference of the runner. The water after passing through the wicket gate enters the runner and finally gets discharged into the draft tube which delivers water below the tail race. The maximum Portion of a useful work is obtained from the difference of pressure between the inlet and outlet of the vanes. Only small portion of the useful work is received from kinetic energy of water. This turbine can be placed either above or below the tail race.

**OBSERVATIONS:**

(1) Diameter of throat of Venturimeter = 7 cm

Area = $a_2$ = 3.85 x $10^{-3}$ $m^2$

(2) Diameter of inlet of Venturimeter = 10 cm

Area J $a_1$ = 7.854 x $10^{-3}$ $m^2$

(3) Radius of Brake durm L = 0.15m

(4) Constant C = 1500

**OBSERVATION TABLE:-**

| S.No. | Venturineter Readings | | Pressure Difference Kg/$cm^2$ | Head (m) (h) | Pressure at | | Pressure at in m | | Discharge ($m^3$/Sec) (Q) |
|---|---|---|---|---|---|---|---|---|---|
| | $X_1$ Kg/$cm^2$ ($p_1$) | $X_2$ Kg/$cm^2$ ($p_2$) | | | Inlet Kg/$cm^2$ ($p_i$) | Outlet Kg/$cm^2$ ($p_o$) | Inlet (m) ($p_i$) | Outlet (m) ($p_o$) | |
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |

| Spring Balance | | Head (m) (H) | Power at | | Efficiency (n) (%) | $N_u$ | $Q_u$ | $P_u$ |
|---|---|---|---|---|---|---|---|---|
| (Kg) $T_1$ | (Kg) $T_2$ | | Inlet ($P_i$) | Outlet ($p_o$) | | | | |
| | | | | | | | | |
| | | | | | | | | |

**PROCEDURE:-**

(1) Prime the pump with water and start the pump.

(2) Adjust the delivery valve of centrifugal pump to keep head (H) some and speed motor.

(3) Keep the guide vane fully separated.

(4) Note the pressure gauge and suction gauge reading.

(5) Note the reading on the manometer

(6) Measure the speed of turbine by tachometer.

(7) Adjust the load over the brake drum to vary the speed of drum.

(8) Repeat the experiment procedure for several loads and take reading for different values of guide vancs and loads.

**RESULT:-**

The overall average efficiency of Francis turbine is found out to be ----------

**PRECAUTIONS:-**

1) Head over the turbine should be kept constant.

2) All the readings must be taken and recorded accurately

3) Do not close the main pipe quickly as it can burst the pipe line to “Water hammer”.

**Operating Characteristic of a Fransis Turbine:**

The operating characteristic curve of a fransis turbine are obtained by maintaining the constant speed. Constant speed is maintained by varying the discharge (by varying the gate opening) as the head changes. Operating characteristic are also known as constant speed characteristic curve. From the measured discharge, head and power developed efficiency is calculated and graph is plotted between efficiency ($\eta_o$) and staff power (P)

The purpose of providing the casing is, for the even distribution of water around the circumference of turbine runner maintaining an approx. constant velocity for the water so disturbed. In orer to keep velocity ofwater constant throughout path or round the runner. The c/s of casing gradually decreases. The casing is made of cost iron, steel etc. depending upon the pressure to which it is subjected from small casing, water passes through the speed ring and. The speed ring consists of upper and lower end by lowering the head together by a series of fixed vanes called stay vanes.

From stay vanes wear passes through a series of guide vanes provided all around the peripheral of turbine runner. The main purpose f various components is to lead water to runner with min loss in energy. The change in direction of flow of water from radial to axial exit passes through runner produces circumferential force on runner to make runner to rotate and continue to useful output of runner.

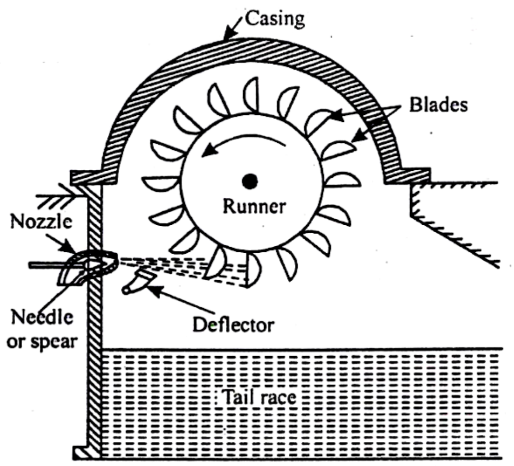
The water after passing through runner flows through a draft tube. A draft tube is a passage of gradually increasing c/s area which connects the runner to the tail race. Draft tube permits the negative suction head to be established at runner exit and converts a large portion of velocity energy rejected from runner to useful energy.

## STUDY AND PERFORMANCE OF PELTON TURBINE

**AIM: -** Determination of performance characteristics of Pelton wheel

**APPARATUS:** - Pelton wheel turbine, spring balance, weight, manometer.

**FIGURE: -**




**PELTON**

**FORMULA: -**

1. Discharge, $Q = 1.84\ Lh^{3/2}$

   Where, L = Length of weir

   h = Head of the weir.

2. Shaft power developed (S.P.)

   $P = (W\text{-}S) \times D/2 \times 2\pi N$

   $= (W\text{-}S)\ \pi DN$ watts

   $$= \frac{(W-S)\pi DN}{60 \times 1000} kW$$

   Where, W = Load applied on the brake drum (N)

   S = Spring balance reading (N)

   D = Mean diameter of the brake drum (m), and

   N = Speed in r. p. m.

3. Water power (W.P.) = $\frac{wQH}{1000} kW$

   Where, w = Specific weight of water (= 9810 N/m3)

   Q = Discharge in $m^3$ /s (as calculated at 1), and

   H = Head (of water) acting on Pelton wheel

4. Overall efficiency, $\eta$ o` = $\frac{S.P.}{W.P.}$

**THEORY: -**

This is the only impulse type of hydrodynamic turbine now in common use. It is well suited for operating under high heads. Figure shows the elements of a typical pelton wheel installation. The runner consists of a circular disc with a number of buckets evenly spaced round its periphery. The bucket has a shape of double hemispherical cup. Each bucket is divided into two symmetrical parts by a 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 centers of buckets called pitch circle. The jet of water impinges on the splitter which divides the jet into two equal positions, each of which after flowing round the smooth inner surface of the bucket leaves it at its outer edge. The buckets are so shaped that angle at the outlet tip varies from 10º to 20º so that the jet of water gets deflected through 160º to 170º. The advantages of having a double cup shaped bucket is that axial thrust neutralize each other, being equal and opposite and hence the bearing supports the wheel shaft are not subjected to any axial or end thrust. Further at the lower tip of the bucket, a notch is cut which prevents the jet striking the preceding bucket being intercepted by the next bucket very soon, and it also avoids the deflection of water toward the centre of the wheel as the bucket firsts meets the jet. For low heads the buckets are made of cast iron, but for higher heads they are made of cast steel, bronze or stainless steel. In order to control the quantity of water striking the runner, the nozzle fitted or needle having a penstock, provided with a spear or needle having a streamlined head which is fixed to the end of a rod .The spear may be operated into either by a wheel in case of very small units or automatically by a governor in case of almost all the bigger units. When shaft of pelton wheel is horizontal then not more than two jets are used. But if the wheel is mounted on a vertical shaft then larger number of jet is possible.

**PROCEDURE: -**

1. Note down the internal diameter of initial pipe and throat.
2. Keeps the gate opening at 20 % initially?
3. The setup is then started and the initial weight is kept zero kg.
4. The corresponding values of spring balance weight, speed in rpm, manometric head and present gauge reading were noted down.
5. Increase the weight successively at 1, 2, 3 and 4 kgs and take the corresponding all the above mentioned reading.
6. Stop the set up and keep opening at 40 %.
7. Repeat step no. 3, 4, 5.
8. Repeat the same procedure for gate opening at 50 %.

**OBSERVATIONS: -**

1. Diameter of pipe =
2. Diameter of throat of venturimeter =
3. Perpendicular distance d =

**OBSERVATION TABLE: -**

| Pressure gauge reading | Speed(rpm) N | Break weight | Spring balance reading | Manometer reading | | | Net eight= (W1-W2) |
|---|---|---|---|---|---|---|---|
| | | | | $h_1$ | $h_2$ | $h_3$ | |
| FOR GATE OPENING 20% | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| FOR GATE OPENING 30% | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| FOR GATE OPENING 40% | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**CALCULATION: -**

| Head (H) | Torque (T) | Discharge (Q) | Input (KW) power | Output power (KW) | Efficiency (ή) | Unit speed (N) | Unit Discharge (Qu) | Unit power (Pu) | H (m) |
|---|---|---|---|---|---|---|---|---|---|
| For 20% gate openings | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| For 30%gate openings | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| For 40% gate openings | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**RESULT: -**

The working of pelton wheel turbine has been studied. The average efficiency of the turbine for different gate openings is found to be: -

1. For 20 % gate opening =
2. For 30 % gate opening =
3. For 40 % gate opening =

## RECIPROCATING PUMP

**AIM :**

To understand the general behaviour of reciprocating pump and

1. To determine coefficient of discharge
2. To calculate the percentage of slip.
3. To compute the overall efficiency of pump.

**APPARATUS :**

Reciprocating pump setup, various component parts, suction pipe, delivery pipe, cylinder piston, crank, pressure gauge etc.

**THEORY :**

"Reciprocating pump" may be defined as a positive displacement pump in which liquid is Sucked and it is then pumped or displaced due to the trust exerted on it by a moving member, which results in the lifting of the liquid to the required height. These pumps have usually one or more chambers which are alternately filled with the liquid to be pumped.

**Component Parts :**

Reciprocating pump consist of the following parts.

(2) Piston

(3) Closed fitting cylinder

(4) Suction pipe

(5) Delivery pipe

(6) Non return or one way valve/delivery valve

(7) A crank for transmitting circular motion of the motor into longitudinal motion of the piston.

(8) Air vessel

**Working :**

The cylinder of the pump is attached to a suction pipe and a delivery pipe, both fitted with non return valve. The non return valve admits liquid in one direction only. The suction valve sucks the liquid inside and the delivery valve discharges the liquid.

The suction and delivery is achieved by the help of a moving piston or plunger, moving to and from a cylinder. The motion of a piston is divided from the circular motion of a motor. The circular motion is transmitted into longitudinal motion (to and from motion) of the piston with the help of a crank attached to the cylinder. When the crank rotates from $\theta = 0$ to $180^0$ the moves from extreme left to extreme right position within the cylinder ie outward movement. During the outward movement of the piston or plunger a partial vacuum is created in the cylinder, when the atmospheric pressure acting on the surface of the liquid in the sump forces the liquid up the suction pipe and fills the cylinder by forcing open the suction valve.

Thus when a crank rotates from $0^0$ to $180^0$ the liquid is sucked from below sump called suction stroke. Thus at the end of the suction stroke the piston or plunger is at its entrance right position i.e. $\theta = 180^0$ (outer dead centre) now as the cylinder is filled with liquid the suction valve is closed by the weight of the fluid in the cylinder. Again when the crank rotates from $\theta$ $180^0$ to $360^0$ the piston or plunger rotates from its exreme right position to the left. The inward movementof the piston or plunger causes the pressure of the liquid in the cylinder to rise above atmospheric pressure. Due to the pressure, suction valve is completely closed and delivery valve is opened. The liquid is forced up at the delivery pipe and raised to the required height. Since during operation, liquid is actually delivered to the required height, it is called delivery stroke. At the end of the delivery stroke, the piston or plunger is at the extreme left, so that it has completed from one full revolution.

**Types of Reciprocating pump :-**

Classification on the (basis of contact of piston with the liquid surface)

1) Single acting pump :- Liquid contact on one side of piston or plunger
2) Double acting pump :- Liquid on contact on both side of the piston or plunger and has two suction and two delivery pipe.

**Classification on the basis of number of cylinder :**

1. Single acting pump with single cylinder
2. Double cylinder pump
3. Triple cylinder pump
4. Duplex double acting pump
5. quintuple pump

Work done by reciprocating pump in lifting any liquid to a certain height depends upon the rate at which the various moving parts of the pump works in conjunction. The flow rate in delivery tube at any instant varies considerably, having a valve of zero during the whole of the suction stroke and rising to a maximum during the delivery stroke. In other words supplying of liquid by a single cutting pump will be quite intermittent. But in case of all the pumps the velocity of flow in both the suction and delivery pipe varies with the crank position. The non-intermitted flow may controlled by using on apparatus called air vessel.

Air Vessels: - Air Vessel is a closed chamber containing the compressed air in the upper part and the liquid being.

# TO STUDY AND PERFORM THE CENTRIFUGAL PUMP

**AIM**

To study and perform the Centrifugal pump experiment and to determine its efficiency.

**APPARATUS :**

Laboratory setup of Centrifugal pump (Constant head), Scale, stopwatch etc.

**FORMULA :**

$$(II)\ \text{Output} = \frac{\text{Yw.Q.H.}}{75}$$

$$(III)\ \text{Input} = \frac{1000 * 3600}{K/t 74.6 * c}$$

Where

| | | |
|---|---|---|
| Yw | - | Density of water |
| H | - | Total Head |
| Q | - | discharge |
| C | - | A Constant of meter = 150 |

**Theory :**

"A pump may be defined as a mechanical device which converts mechanical energy supplied to it into hydraulic energy and transfer it to the liquid flowing through the pipe line and increasing the energy of flowing liquid.

**PRINCIPLE :**

The basic principle on which the centrifugal pump works is that the in coming liquid particles are forced to move the the direction of rotation of the impeller, thus superimposing a centrifugal force on the particles. This causes in particles to be thrown on the casing and pressure is built up. When sufficient pressure is built up, the particles are force doubt through the delivery pipe.

Centrifugal pump is a roodynamic pump which uses dynamic power to lift water from a lower level to higher level. Since in a pump in the lifting of liquid Is due to centrifugal action, these pumps are called centrifugal pumps.

**Construction:**

A Centrifugal pump comprises of an impeller (rotor), rotating inside a casing (a volute shape thin box). The casing has an opening (Called eye) to admit the liquid from the suction pipe. This impeller has four to eight blades or vanes of certain shapes, mounted on an axle or shaft. This shaft is rotated by a motor (electric or any other) the shape of the casing is adjusted in such a way that the gap between the impeller and the casing in minimum (A) and continuously increases towards the outlet at (B). By the application of continuity equation the area of flow being max. at (B), the velocity must be minimum. By the Bernaullie’s theorm if velocity reduced, the pressure must increase. Thus the velocity or kinetic head is converted into pressure head. At the inlet, the particles near the eye, are forced away by the impeller and a vacuum is caused. Further area at “A” beingless, velocity 6 is more and hence pressure must reduce. Both these together cause vacuum, near the inlet, inside the casing, which at the outside pressure is atmospheric i.e. higher. This causes the liquid to rise in the suction pipe and enter into the casing.

Components of Centrifugal pump :- The main parts of the pump is impeller. Impeller is a rotor on which a service of cruved backward vanes are mounted. There are three types of impeller which are used in centrifugal pump.

(1) Closed impeller

(2) Open impeller

(3) Semi open impeller

Impeller is mounted on a shaft, which is coupled to an external source of energy (usually an electric motor) which imparts the required energy to the impeller thereby making it to rotate.

(1) If the vanes have the base plate and crown plate then the impeller is known as closed impeller. This type of impeller is suitable for lifting the liquid which are pure and free from debris.

(2) An open impeller have no base plate and crown plate. These impellers are suitable for rumpling liquids containing suspended solid matters such as paper pulp, sewage and water containing sand or grit.

(3) For semi open impeller, the vanes have only base plate and no crown plate. Such type of impeller is suitable for pumping the liquids, which are changed with some debris.

**Casing :-** It is an air tight chamber which surrounds the impeller. It is similar to the casing of a reaction turbine.

Casing may be of following type :-

(1) Volute casing

(2) Diffuser casing

Layout and Accessories of Centrifugal Pump :-

The main accessories are

(i) Foot valve with strainer

(ii) Suction pipe with fittings

(iii) Delivery pipe with delivery valve.

(i) Foot valve with strainer is titted at the lower end of suction pipe and it is submerged under water upto 40 to 60 cm. Depth because when water surface in the well is lowered, the foot valve may suck the air and depriming of the pump takes place.

The upper end of the suction pipe is connected at inlet (also callas eye) or centre of the pump. The strainer avoids entry of leaves, wooden pieces papers and other rubbish into the suction pipe. The liquid passes through the foat valve and then enters the suction pipe. The foot valve is a non return valve which opens only in upward direction and prevents the entry of liquid back to the sump.

(ii) Suction pipe is a pipe, which is connected at its upper end to the inlet of the pump or to the centre of the impeller which is commonly known as the eye. The lower end of the suction pipe dips into liquid in a suction tank or a sump from which the liquid is pumped or lifted up. The lower end of the suction pipe is fitted with a foot valve and strainer. The liquid first enters the strainer which is provided in order to keep the debris away. The fittings like bends, coupling etc. are kept air tight.

(iii) It is pipe which is connected at its lowr end to the outlet of the pump and it delivers the liquid to the required height. Just near the outlet of the pump of the delivery pipe a delivery valve is invariably provided. A delivery valve is a regulating valve which is of sluice type and is required to be provided. A delivery valve is a regulating valve, which is of sluice type and is required to be provided in order to control the flow form the pump into delivery pipe.

**Types of centrifugal pump :**

According to the type of casing provided, centrifugal pump may be classified into following two classes.

(i) Volute pump

(ii) Diffuser or turtine pump

**(i) Volute Pump** :- In volute pump the impeller is surrounded by a spiral shaped casing, which is known as volute chamber. The volute chamber is designed in such away so that it is gradually enlarged so that the velocity is gradually reduced from the velocity of the liquid leaving the impeller to that in the delivery pipe.

Later development has brought in a new type of volute chamber, fitted with an inner vortex chamber, which significantly prevents the losses of energy due to formation of eddies. The vortex chamber acts as a diffuser and converts kinetic. Energy into pressure energy.

**(ii) Diffuser Or turbine pump :** In this type of pump, the impeller is surrounded by a series of guide vanes mounted on a ring called as the diffuser ring. The diffuser ring and guide vanes are fixed in a position. The adjacent guide vanes provide gradually enlarged passages for flow of liquid. The liquid after leaving the impeller passes through these passages of increasing area, where in the velocity of flow decreases and the pressure increase. The guide vanes are so designed that the liquid emerging from the impeller enters these passages without shock. This condition may however be achieved by making the largest to the guide vane at the inlet top to coincide with the direction of the absolute velocity of the pump liquid leaving the impeller.

**Working of Centrifugal Pump :-**

The working of a Centrifugal pump, is in three distinct stages as priming, starting and stopping.

**(A) Priming :-**

Priming of a pump means removal of all the air (or gas) from inside the casing of the pump and the suction pipe. This is necessary because the suction depends upon the difference between the atmospheric pressure on the free surface in sump (outside the suction pipe) and the vacuum near the eye of the impeller and if air remains present inside the casing or the suction pipe, vacuum is not developed and the pump can not work. Priming is achieved by filling the water is casing or (cylinder) through the priming inlet. The stop cock on the funnel stem and the air vent are opened and water poured into the funnel. The air inside escapes through the air vent with hissing sou,d when the casing is completely filled in hissing sound stops and water will not enter the casing but spill over the funnel edge. At this stage, the stem valve is closed. (air vent valve remain open) self priming pumps do not required priming.

**(B) Starting :-**

To start a pump, first check that the non return valve on delivery pipe is closed condition and primary is done. Start the electric motor according to the directives given in the manual. If the starter is level, pull it down and after a few 3 to 5 sec. again push it up. Modern starters have "Red" and "Green" Rush switches. First push the red switch and then green one. Other motor requires a intital torque to the provided by hand winding a string and pulling it with force or by rotating a handle. This will cause the pump impeller to rotate developing centrifugal force. As the pressure developes, water will come out from the air vent as high velocity jet and with a little experience, it is possible to reckon when the pressure is sufficiently developed. At this stage the delivery valve is opened and the air rent cock is closed.

**(C) Stopping :**

To stop the pump, the delivery vale is partly closed, motor switched of and valve fully closed immediately.

Work done by the impeller of Centrifugal pump on liquid :-

Let V be the absolute velocity of the liquid

U be the peripheral or tangential velocity of liquid

Vr is the relative velocity of the liquid

Vf is the velocity of flow of liquid

Vw is the velocity of whirl of liquid at the entrance of impeller.

Where as V1, U1, Vf1 Vwl represent the counterpart of the inlet velocities at exit point of the impeller

φ = Impeller vane entrance angle

φ = Impeller vane angle at outlet.

α = Angle between the direction of absolute velocity of liquid at entry point and peripheral velocity.

β = Angle between in absolute velocity of leaving liquid and peripheral velocity of the impeller at exit point.

$\sqrt{2gHm)}$ Work done is given by $= \frac{w}{g}(Vw1V1 - Vwu) - -A$

When α = 900 because liquid enters the impeller radically, we have Vw = 0

Work done = $\frac{w}{g}(Vw1V1)$

Further from the outlet velocity triangle of figure

Vu1 = (U1 – Vf1Cotα)

As in case of turbines u1 and v1 can be expressed speed ratio Ku and flow ratio –

U 1 = (Ku $\sqrt{2gHm)}$ and

$Vf1 = - - \sqrt{2gHm)}$

… Work done per second per unit weight of liquid.

$$W.D. = \left\{ \frac{V1^2 - V^2}{2g} \frac{U1^2 - U^2}{2g} + \frac{Vr^2 - Vp1^2}{2g} \right\} - - 1$$

Above expression is the fundamental equation of centrifugal pump.

**Head of a pump:-**

Head of a pump may be expressed in following ways:-

i) Static Head

ii) Manometric Head

iii) Total head or Gross head or Effective Head

**i) Static Head:-** The sum of suction head and delivery head is known as static head. This is represented as $H_{stat}$

$H_{stat} = H_s + H_d$

$H_s$ = Suction Head (Vertical head along the centre line upto the pump from water surface of the sump from where water is raised.)

$H_d$ = Delivery Head (it is the vertical height of the centre line of the pump from the pump shaft to the upper surface of the water in reservoir where the water is delivered.)

**ii) Manometric Head**:- The head against which a centrifugal pump works is known was manometric head, provided that there are no energy loss in the impeller and the casing of pump.

H mano. = Head imparted by impeller to the liquid – loss of heat in the pump i.e. (impeller & casing)

$$= \frac{VW_2U_2}{g} - (hLi + hfc)$$

If the loss of heat in the pump is Zero,

$$H_{manno} = \frac{VW2U2}{g}$$

Now, $H_{mano}$ may be expressed in other form

$$H_{mano} = H_{static} + \text{Lossin pipe} + \frac{Vd^2}{2g} = h_s + h_d + (hf_s + hf_d) + \frac{Vd^2}{2g}$$

In the form of Bernaullie's Equation,

$$H_{mano} = \left(\frac{P_2}{W} + \frac{V_2}{2g} + Z_z\right) - \left(\frac{P_1}{W} + \frac{V_1}{2g} + Z_1\right)$$

$\frac{P_2}{W} =$ Pressure head at outlet of pump.

$\frac{V_2{}^2}{2g} =$ Velocity head at outlet of pump.

$Z_2$ = Vertical height of the pump outlet from datum line.

P1/W, V12/2g Z1, are the pressure, velocity and datum.

**Head at inlet of pump.**

Total, gross or effective head = static head + all the head losses occurring in flow before and through the impeller.

Effeciency of Centrifugal pump & Losses :- Efficiency of Centrifugal pump are :

(i) Manometric Efficiency ($\eta_{mano}$)

(ii) Volumetric Efficiency ($\eta_v$)

(iii) Mechanical Efficiency ($\eta_m$)

(iv) Overall Efficiency ($\eta_o$)

**(I) Manometric Efficiency** ($\eta_{mano}$) L-

$$\eta o = \frac{\text{Power out of the pump}}{\text{Power input to the pump shaft}}$$

$$= \frac{\text{WQH mano}}{P}$$

$$\text{Manometric Efficiency} = \frac{\text{Manometric Head}}{\text{Head imparted by impeller to liquid}}$$

($\eta_{mano}$)

$$\eta \text{mano} = \frac{H_{mano}}{\frac{Vw_2 V_2}{g}} = \frac{g.H_{mano}}{Vw_2 V_2}$$

**(ii)** **Volumetric Efficiency** = The ratio of quality of liquid discharges per second from pump to the quantity passing per second through the impeller is known as volumetric efficiency.

$$\eta v = \frac{Q}{Q+q}$$

Q = Actual discharge/Sec.

Qf = Leakage of liquid/Sec.

**(iii)Mechanical Efficiency :-** The ratio of power delivered by the impeller to the liquid to the power input to the pump is called as mechanical efficiency.

$$\eta m = \frac{\text{Power delivered by impeller to the liquid}}{\text{Power input to the pump shaft (P)}}$$

$$\eta m = \frac{W(Q+q)\ (Vw_2\ U_2 / q)}{P}$$

**Overall efficiency :-** The ratio of power output of the pump to the power input of the pump.

$$\eta o = \frac{\text{Power out of the pump}}{\text{Power input to the pump shaft}}$$

$$= \frac{\text{WQH mano}}{P}$$

Also $\eta o$ = η mano *ηv* ηm

$$= \frac{\text{WQH mano}}{P}$$

**Losses in Centrifugal Pump :-**

Losses in centrifugal pump are of the following types :

(1) Hydraulic losses in the pump :-

(a) Snock or eddy losses at the entrance to and the exit form impeller

(b) Losses due to friction in the impeller.

(c) Friction and eddies losses in the guide Vance's (or diffuser) and casing

**(2) Other hydraulic losses :**

(a) Friction and other minor losses in the suction pipe

(b) Friction and other minor losses in the delivery pipe

**(3) Mechanical Losses :**

(a) Losses due to friction of the disc between the impeller and the liquid which fills the clearance space between the impeller and casing

(b) Friction and other minor losses in the delivery pipe.

**(4) Mechanical Losses :**

(a) Losses due to friction of the disc between the impeller and the liquid, which fills the clearance space between the impeller and casing.

(b) Losses pertaining to friction of the main bearing and glands.

**(5) Leakage Losses** : Losses due to leakage of liquid is known as leakage losses. The various losse sin a centrifugal pump affect efficiency of pump.

**PROCEDURE :-**

(i) The pump is initially printed i.e. the suction pipe, casing of the pump and portion of the delivery pipe up to the delivery value is completely filled with liquid to be pumped.

(ii) With the delivery valve closed, the impeller is made to rotate.

(iii) A forced vortex is developed which imparts a centrifugal head to the liquid.

(iv) Simultaneously, the angular momentum is changed resulting in an increase of liquid pressure.

(v) When the delivery valve is opened, the liquid is forced to flow in an outward radial direction thereby leaving the vanes of the impeller at the outer circumference with high velocity and pressure.

(vi) Overall efficiency of pump is given by

$$\eta = \frac{\text{Output Power}}{\text{Input Power}}$$

**Result :**

Overall average efficiency ( $\eta$ ) of the constant head centrifugal pump is found out to be 24.69% Conclusion : From the above result it is concluded that the efficiency of pump is reduced due to various losses in the operation of the pump such as mechanical losses, hydraulic losses, leakage losses and other minor head losses. So from the above result it is found that output power is not equal to the imput power.

**Precaution :-**

(1) before starting the pump, priming should be done.

(2) During primising operation, air vent valve must be opened to escape the entrapped air.

(3) Delivery valve must be opened thoroughly before starting of pump.

(4) Make sure that all the valves and fittings are in firm and closed position and properly tight.

**Application:-**

The centrifugal pumps are widely used for different jobs in civil Engineering works such as

(i) Water supply for any purpose

(ii) Sewage, Sewerage, dewatering of foundation trenches

(iii) Tube wells and in curing operation.

**OBSERVATION :-**

(i) Area of collecting tank = L x B

(ii) Diameter of inlet pipe = di =

(iii) Diameter of delivery pipe = do =

(iv) Datum head at inlet = Zi =

(v) Datum head at exit = Zo =

(vi) No. of energy meter revolution :

**OBSERVATION TABLE**

| S N | Delivery head (Po) N/cm2 | Suction head (Ps) (m) | Time for 10cm rise (t) | Time for 10 no. of rev. (T) | Q cm3/sec. | Vi cm/sec | Vo Cm/sec | H (m) | Pim watts | Pim watts | Pim watts | η % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | |
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**SAMPLE CALCULATION :**

(i) $Q = A \times H/t$

(ii) $Vi = 4Q / \pi di2$

(iii) $Vo = 4Q/ \pi do2$

# STUDY AND PERFORMANCE OF VARIBLE SPEED CENTRIFUGAL PUMP

**AIM :** To study and perform the variable speed centrifugal pump experiment and to determine its efficiency.

**APPARATUS :** Laboratory setup of Centrifugal pump (Variable head), Scale, stopwatch etc.

**FORMULA :**

I Discharge q = A.H/t

II Inlet Velocity of flow Vi = $4Q / \pi di2$

III Outlet velocity of flow $V0 = 4Q / \pi do2$

IV Pressure head difference h = (Po / p.g. + Vo2/2g+Zo)-(pi/pg+Vi2/2g+Zi)

V Power input to electric motor Pim = 3600 * 1000 * n/ MT

VI Power input to the pump Pip = $\eta$mo * Pim

VII Power output to the pump Pop = p.g. Q.h.

VIII Average efficiency $\eta$o = Pop/Pip * 100

Where, n = No. of energy meter revolution in 1 KV – hr

Pi and Po = Pressure gauge reading at inlet and outlet of pipe S/c

T = time required to complete the 10 No. revolution.

**THEORY :** The basic principle onwhich may centrifugal pump works is that, the incoming fluid particles an found to move in the direction of rotation of the impeller, thus superimposing a centrifugal force on the particles. Thus causes the particles to be thrown on the casing and pressure is built up.

So in variable speed centrifugal pump, the only difference is that, instead of using constant speed, who can modify the rotating speed of motor by applying break to the rotation. Thereby, we can adjust the discharging head of the pump by making the different speeds of motor.

The other features like construction, component parts, layout and accessories etc. are common. The working of pump involves different procedures like priming, starting and stopping etc. are also common which are explained in previous practical.

In variable speed centrifugal pump the constant of pump (M) is changing every time for each two revolution of speed breaks.

| No. of Rotation of break | Value of M |
|---|---|
| 2 | 1050 |
| 4 | 1150 |
| 6 | 1250 |
| 8 | 1350 |

**PROCEDURE**

I The pump is initially primed i.e. the suction pipe, casing of the pump and the portion of the deliver. Pipe upto the delivery valve is completely filled with liquid to bepumped.

II With delivery value closed, the impeller is made to rotate.

III A forced vortex is developed which imparts a centrifugal head to the liquid.

IV Simultaneously, the angular momentum is charged resulting in an increase of liqud pressure.

V When delivery value is opened, the liquid is forced to flow in an outward radial direction therby leaving the vanes of a impeller at the outer circumference with high velocity and pressure.

VI Overall efficiency of pump is given by –

$\eta$ = Output power/ Input Power

**OBSERVATION :**

(i) Area of collecting tank = L x B

(ii) Diameter of inlet pipe = di = 7.00 cm

(iii) Diameter of delivery pipe = do = 5.8 cm

(iv) Datum head of inlet = Zi = 0

(v) Datum head of outlet Zo = 52 cm

**OBSERVATION TABLE :**

**SAMPLE CALCULATION :**

(i) Q = A x H/t

(ii) Inlet Velocity = vi = 4 Q / $\pi$ di2

(iii) Outlet velocity = Vo = 4Q / do

**RESULT :** Overall average efficiency (η) of the variable speed centrifugal pump is found out to be ----

**CONCLUSION :-** From the above result it is concluded that the efficiency of pump reduces due to various losses in the opration of the pump, such as mechanical losses, hydraulic losses, leakage losses an other minor head losses. So from the above result it is found that output power is not equal in input power.

**PRECAUTION :**

1 Before starting the pump, priming should be done.

2 During priming operation, air vent valve must be opend to escape the entrapped air.

3 Delivery value must be opened thoroughly before starting the pump.

4 Make sure that all the valves and fittings are in form and closed position and property tight.

## ANALYSIS OF DESIGN PROBLEM ON PIPE NETWORK

**AIM: -** To analysis the design problem on pipe network.

## THEORY:

When a group of interconnected pipes forming several loops or circuits then it is called as network of pipes. Such networks of pipes are commonly used for municipal water distribution system in cities. The main problem in a pipe network is to determine the distribution of flow through the various pipes of the network such that all the conditions of flow are satisfied and all the circuits are then balanced. The conditions to be satisfied in any network of pipes are as follow:

According to the principle of continuity the flow into each junction must be equal to the outflow of the junction.

In each loop, the loss of head due to flow in clockwise direction must be equal to the loss of head in anticlockwise direction.

The Darcy-Weisbach equation must be satisfied i.e. $h_f \alpha Q^n$

N = exponent having values 1.75 to 2.00

i.e. hf for each loop = 0

## PROCEDURE:

1 Assume most suitable distribution of flow that satisfies continuity at each junction i.e.-inflow outflow

2 With assumed value of Q. Complete the head loss for each pipe using equation

$Hf = KQ^n$ K = const

3 Consider different loops and compute the net head loss around each circuit considering head loss in clockwise direction is (+ve) and anticlockwise direction is (-ve)

4 For correct distribution of flow, the net head loss around the circuit should be equal to zero so that circuit is balanced.

5 When the head loss is not equal to Zero (0), then assumed discharge are corrected by introducing to correction factor Δ Q given by =

$$\eta_o = P_o P_i \qquad \Delta Q = \frac{-\Sigma KQ^n}{\Sigma K.n.Q^{n-1}}$$