KG REDDY
College of Engineering
& Technology
AN AUTONOMOUS INSTITUTION

CELEBRATING 15 YEARS OF BRILLIANCE

Hydraulics & Hydraulic Machinery Lab

LABORATORY MANUAL

Prepared By: Mr. M Vijayakumar, Assistant Professor

Department of Civil Engineering

Institute Vision

To become an institution which is internationally recognized for its holistic approach to engineering, innovative teaching and learning culture, research and entrepreneurial ecosystem, and sustainable social impact in the community.

Institute Mission

- To offer undergraduate and post-graduate programs which are supported through industry relevant curriculum and innovative teaching and learning processes that would help students succeed in their professional careers.
- To provide faculty and students with an ecosystem that fosters innovation, research, entrepreneurship, and international exposure through strategic partnerships with government organizations and collaboration with industries.
- To provide holistic learning environment to students which will contribute to their personal and professional growth and enable them to become leaders in their respective fields.
- To contribute to the development of the region by using our technological expertise to work with nearby communities and support them in their social and economic development

Department Vision

To be recognized for excellence in teaching, innovation, and research aimed towards betterment of society through sustainable infrastructural development.

Department Mission

- To integrate innovative teaching and learning practices that will enable students to build technical competence for working in civil engineering industries.
- To encourage innovation, research, and entrepreneurship among faculty and students that will lead to sustainable development.
- To become self-sustainable through strategic collaborations with industries and nearby communities focused on consultancy services.

Program Educational Objectives

PEO1: Graduates will be able to work in multidisciplinary teams focused on development of infrastructure, design, sustainability, construction management and all the other related fields of Civil Engineering.

PEO2: Graduates will be professionally competent through their ability to use modern civil engineering tools and manage projects in leadership positions.

PEO3: Graduates will transform into change makers who will work towards societal development and advocate for equity, social justice, and sustainable development.

Program Outcomes

PO 1: Engineering Knowledge: Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop to the solution of complex engineering problems.

PO 2: Problem Analysis: Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1, WK2)

PO 3: Design/Development of Solutions: Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for the public health and safety, whole-life cost, net zero carbon, culture, society and environment as required. (WK5)

PO 4: Conduct Investigations of Complex Problems: Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis &interpretation of data to provide valid conclusions. (WK8).

PO 5: Engineering Tool Usage: Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling, recognizing their limitations to solve complex engineering problems. (WK2 & WK6)

PO 6: The Engineer and The World: Analyze and evaluate societal and environmental aspects while solving complex engineering problems for an appeal of sustainability, with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7).

PO 7: Ethics: Apply ethical principles and commit to professional ethics, human values, diversity and inclusion, adhere to national & international laws (WK9)

PO 8: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 9: Communication: Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences

PO 10: Project Management and Finance: Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects and in multidisciplinary environments.

PO 11: Life-Long Learning: Recognize the need for, and have the preparation and ability for i)independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change. (WK8)

iii) critical thinking in the broadest context of technological change. (WK8)

Program Specific Outcomes

PSO1: Graduates will be able to plan, analyze, design safe and sustainable green infrastructure.

PSO2: Graduates will be able to utilize the latest software tools for modeling and simulation in the field of civil engineering.

PSO3: Graduates will be able to work in multidisciplinary teams to design, develop and promote smart construction related.

Hydraulics & Hydraulic Machinery Lab

Course Objectives: The objectives of this course for the student are to:

Course Objectives: The objectives of this course for the student are

1. Apply fluid measurement techniques—including Bernoulli’s principle, discharge devices, and notches—to determine essential hydraulic parameters.
2. Determine flow characteristics such as friction factor, minor losses, and related pipe-flow behavior using experimental data.
3. Compute open-channel flow parameters, including energy loss in hydraulic jumps and flow resistance using Manning’s and Chezy’s constants.
4. Determine the performance characteristics of hydraulic machines by plotting characteristic curves and assessing efficiency under varying operating conditions.
5. Determine the operational behaviour of a centrifugal pump by relating flow rate, head, power consumption, and efficiency.

Course Outcomes: After completion of this course, the students will be able to

CO1: Describe the basic measurement techniques of fluid mechanics and its appropriate application.

CO2: Interpret the results obtained in the laboratory for various experiments.

CO3: Discover the practical working of Hydraulic machines- different types of Turbines, Pumps, and other miscellaneous hydraulics machines.

CO4: Compare the results of analytical models introduced in lecture to the actual behavior of real fluid flows and draw correct and sustainable conclusions.

CO5: Write a technical laboratory report.

Department of Civil Engineering

Hydraulics & Hydraulic Machinery Lab

Course Code: KG25ACE237 **B. Tech. II Year II - Semester**

LIST OF EXPERIMENTS:

1. Verification of Bernoulli's equation.
2. Determination of Coefficient of discharge for a small orifice by a constant head method.
3. Calibration of Venturi meter / Orifice Meter.
4. Calibration of Triangular / Rectangular/Trapezoidal Notch.
5. Determination of Minor losses in pipe flow.
6. Determination of Friction factor of a pipe line.
7. Determination of Energy loss in Hydraulic jump.
8. Determination of Manning's and Chezy's constants for Open channel flow.
9. Impact of jet on vanes.
10. Performance Characteristics of Pelton wheel turbine.
11. Performance Characteristics of Francis turbine.
12. Performance characteristics of Keplan Turbine.
13. Performance Characteristics of a single stage / multi stage Centrifugal Pump.

MANDATORY INSTRUCTIONS

1. Students are advised to come to the laboratory at least 5 minutes before (to the starting time), those who come after 5 minutes will not be allowed into the lab.
2. Plan your task properly much before to the commencement, come prepared to the lab with the synopsis / program / experiment details.
3. Student should enter into the laboratory with:
    a) Laboratory observation notes with all the details (Problem statement, Aim, Procedure,Program, Expected Output, etc.,) filled in for the lab session.
    b) Laboratory Record updated up to the last session experiments and other utensils (if any) needed in thelab.
    c) Proper Dress code and Identity card.
    d) Sign in the laboratory login register, write the TIME-IN, and occupy the computer system allotted to you by the faculty.
4. Execute your task in the laboratory, and record the results / output in the lab observation note book, and get certified by the concerned faculty.
5. All the students should be polite and cooperative with the laboratory staff, must maintain the discipline and decency in the laboratory.
6. Students / Faculty must keep their mobile phones in SWITCHED OFF mode during the lab sessions. Misuse of the equipment, misbehaviors with the staff and systems etc., will attract severe punishment.
7. Students must take the permission of the faculty in case of any urgency to go out; if anybody found loitering outside the lab / class without permission during working hours will be treated seriously and punished appropriately.
8. Always be on the alert for strange sounds. Guard against entangling clothes in moving parts of machinery. In performing the experiments, proceed carefully to minimize any water spills, especially on the electric circuits and wire.
9. Make your workplace clean before leaving the laboratory. Maintain silence, order and discipline inside the lab. Any injury no matter how small must be reported to the instructor immediately.

EXPERIMENT NO: 1

VERIFICATION OF BERNOULLI'S EQUATION

OBJECTIVE:

To understand the Bernoulli's theorem through an experiment.

OUTCOME:

The student will be able to verify the total head of an incompressible liquid is always constant.

SCOPE:

The knowledge of Bernoulli's theorem is used for flow measuring device like Venturimeter, Orificemeter & Pitot tube.

APPARATUS:

Bernoulli's apparatus, Controlling valve at inlet and outlet, Discharge Measuring Tank, Scale, Stopwatch etc.

EXPERIMENTAL SET UP:

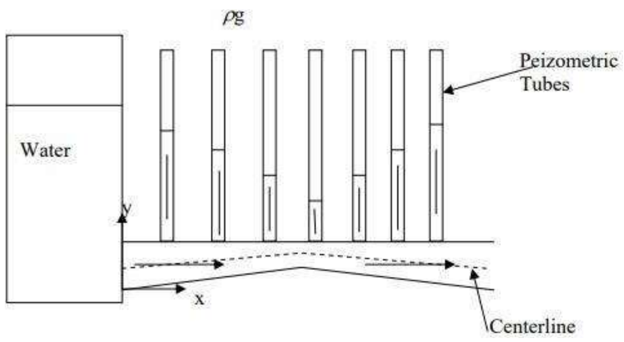


Fig.1 Experimental set up.

PROCEDURE:

1. The apparatus should be accurately leveled by means of screws provided at the base.
2. Connect the water supply to the radial diffuser in the upstream tank.
3. Adjust the level of the discharge pipe by means of the stand and clamp provided to a convenient position.
4. Allow water to flow through the apparatus until all air has been expelled and steady flow conditions are achieved. This can be accomplished by varying the rate of inflow into the apparatus and adjusting the level of the discharge tube.
5. Readings may then be taken from the piezometer tubes and the flow through the apparatus measured.

6. A series of readings can be taken for various through flows.

THEORY:

Bernoulli's principle formulated by Daniel Bernoulli (1700-1780) states that as the speed of a moving fluid increases (liquid or gas), the pressure within the fluid decreases. Although Bernoulli deduced the law, it was Leonhard Euler who derived Bernoulli's equation in its usual form in the year 1752. "Bernoulli's theorem states that, the sum of pressure energy, kinetic energy and potential energy per unit volume of an incompressible, non-viscous fluid in stream line flow remains constant". This statement is called Bernoulli's theorem with reference to section 1 – 1 and 2 – 2 along the length of steady flow in the stream tube. The total energy at section 1 – 1 is equal to the total energy at section 2 – 2 as stated in Bernoulli's theorem.

FORMULA:

$Q_{act} = AH/t$

Coefficient of discharge = $C_d = Q_{act}/Q_{the}$

Coefficient of velocity = C_V = Actual velocity/theoretical velocity

OBSERVATION:

Diameter of the orifice (d) = Area of orifice (a) =

S.No	Constant Head (h) (m)	Time required for 10cm Rise of water (t)(sec)	Actual discharge Qact (m^3/sec)	Theoretical discharge Qthe (m^3/sec)	Coefficient of discharge Cd = Qact/Qthe	Pointer reading (m)		Coeff. of velocity (Cv)	Coeff. of contraction (Cc)
						x	y		
1.									
2.									
3.									

1. **Actual discharge:**
   $Qact = AH/t =$
2. **Theoretical discharge:**
   $Qthe = a \times \sqrt{(2gh)} =$
3. **Coefficient of discharge:**
   $Cd = Qact/Qthe =$
4. **Coeff.of velocity:**
   $Cv = \sqrt{(x^2/4yH)} =$
5. **Coeff.of contraction:**
   $Cc = Cd/Cv =$

GRAPH:

Draw a graph between Qact vs $\sqrt{h}$. Take Qact in Y axis.

RESULT:

The total energy of a streamline, while the particle moves from one point to another. Bernoulli's theorem for an incompressible fluid flow is verified.

PRACTICAL APPLICATIONS

Bernoulli's Energy Equation can be applied in practice for the construction of flow measuring devices such as Venturimeter, flow nozzle, orifice meter and Pitot tube, Furthermore, it can be applied to the problems of flow under a sluice gate, free liquid jet, radial flow and free vortex motion. It can also be applied to real incompressible fluids with good results in situations where frictional effect is very small.

EXPERIMENT VIDEO LINKS

https://www.youtube.com/watch?v=3IKYQ7BYU2g

https://www.youtube.com/watch?v=ev-3wrE8WWQ

EXPERIMENT NO: 2

DETERMINATION OF COEFFICIENT OF DISCHARGE FOR A SMALL ORIFICE BY CONSTANT HEAD METHOD

OBJECTIVE:

To determine the co-efficient of velocity [Cv] co-efficient of contraction [Cc] and co-efficient of discharge [Cd] for circular orifice by constant head method.

OUTCOME:

The student will be able to find the actual and theoretical discharges and hydraulic coefficients.

SCOPE:

The knowledge of hydraulic coefficients for a small orifice mainly used to find the discharge.

APPARATUS:

An Orifice fitted across a pipeline leading to a collecting tank, Stop Watch

EXPERIMENTAL SETUP:

The orifice meter consists of a throat tiling device (an orifice plate) inserted in the flow. This orifice plate creates a measurable pressure difference between its upstream and downstream sides. This pressure is then related to the flow rate. Like the Venturimeter, the pressure difference varies directly with the flow rate. The co-efficient of discharge is 0.62-0.67 for orifice meter.

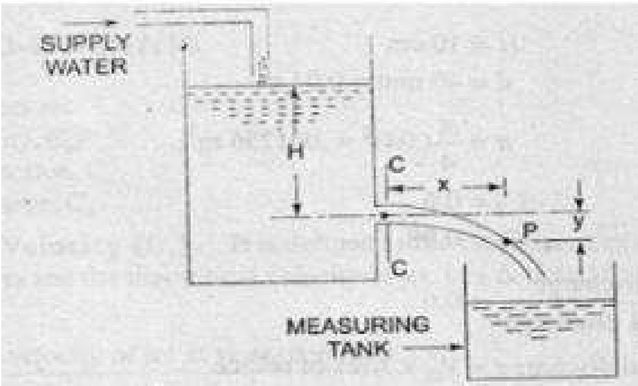


Fig.2 Experimental setup

PROCEDURE:

1. Measure the diameter of the orifice.
2. Supply water to the tank.
3. When the head at the tank (measured by a piezometer attached to the tank) is steady record the reading of the manometer.
4. Measure the x and y co-ordinate of the jet from the vena contracta.

5. Measure the flow rate.
6. Repeat the procedure for different combinations of discharge.

THEORY:

Orifice is a small opening of any cross section such as circular, triangular, rectangular, on a side or on the bottom of the tank, through which a fluid flows. Orifices are used for measuring the rate of flowing fluid. The water is allowed to flow through an orifice fitted to tank and a constant head 'h'. The water is collected in measuring tank for known time ' t '. The height of water in the measuring tank is noted. Then the actual discharge through the orifice was calculated.

FORMULA:

$Q_{act} = AH/t$

Coefficient of discharge = Cd= Q_{act}/Q_{the}

Coefficient of velocity = C_V = Actual velocity/theoretical velocity

OBSERVATION:

Diameter of the orifice (d) = Area of orifice (a) =

S.No	Constant Head (h) (m)	Time required for 10cm Rise of water (t)(sec)	Actual discharge Qact (m^3/sec)	Theoretical discharge Qthe (m^3/sec)	Coefficient of discharge Cd = Qact/Qthe	Pointer reading (m)		Coeff. of velocity (Cv)	Coeff. of contraction (Cc)
						x	y		
1.									
2.									
3.									

1. **Actual discharge:**
   Qact = AH/t =
2. **Theoretical discharge:**
   Qthe = ax$\sqrt{(2gh)}$ =
3. **Coefficient of discharge:**
   Cd = Qact/Qthe =
4. **Coeff.of velocity:**
   Cv = $\sqrt{(x^2/4yH)}$ =
5. **Coeff.of contraction:**
   Cc=Cd/Cv =

GRAPH:

Draw a graph between Qact vs $\sqrt{h}$. Take Qact in Y axis.

RESULT:

The mean values of hydraulic coefficients are as follows:

a) Coefficient of discharge, Cd =

b) Coefficient of velocity, Cv =

c) Coefficient of contraction, Cc =

PRACTICAL APPLICATIONS

The usual purpose of an orifice is the measurement or control of flow from a reservoir. The orifice is frequently encountered in engineering practice operating under a static head where it is usually not used for metering but rather as a special feature in a hydraulic design. Another problem of orifice flow, which frequently arises in engineering practice, is that of discharge from an orifice under falling head, a problem of unsteady flow.

EXPERIMENT VIDEO LINKS

https://www.youtube.com/watch?v=xq_IgKAPt_c

https://www.youtube.com/watch?v=F6NubRmW7tE

EXPERIMENT NO: 3

CALIBRATION OF VENTURIMETER / ORIFICE METER

OBJECTIVE:

To determine the co-efficient of discharge [Cd] for Venturimeter and Orificemeter.

OUTCOME:

The student will be able to find the actual and theoretical discharges and co-efficient of discharges.

SCOPE:

The knowledge in practical application of Bernoulli's theorems through Venturimeter and Orifice meter.

APPARATUS:

Venturimeter/Orifice meter fitted across a pipeline leading to a collecting tank, Stop Watch, U-Tube manometer connected across entry and throat sections etc.

EXPERIMENTAL SETUP:

Venturimeter and Orifice meter are working on the principle on Bernoulli's equation. Venturimeter and Orifice meter is a device used for measuring the rate of fluid flowing through a pipe. Venturimeter consists of three parts 1. Converging cone part, 2. Throat. 3. Diverging cone part. Orifice meter consist of orifice plate with concentric hole at center.

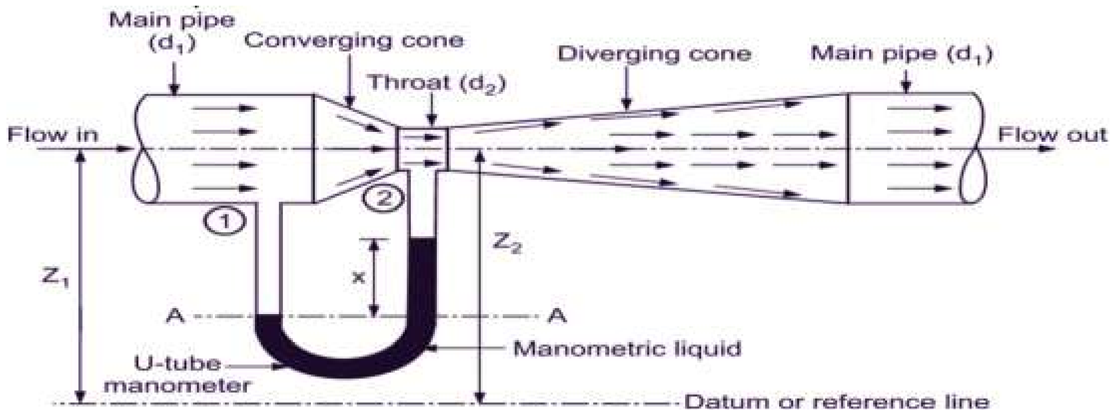


Fig.3.1 Venturimeter

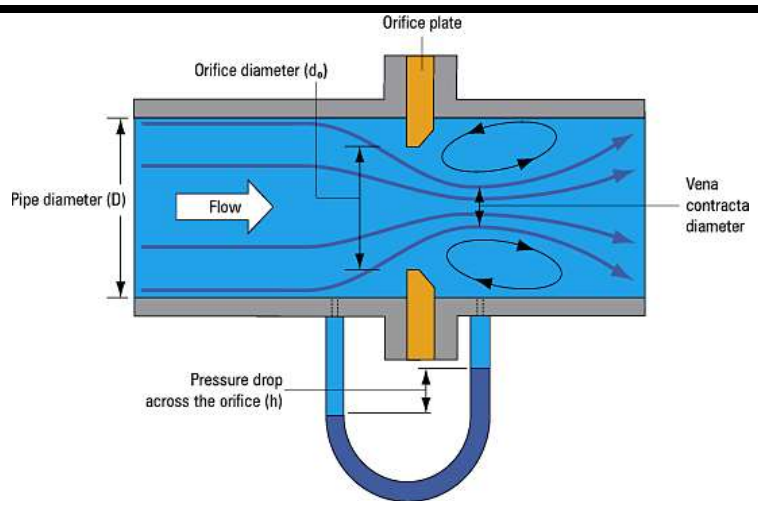


Fig.3.2 Orifice meter

PROCEDURE:

1. Set the manometer pressure to the atmospheric pressure by opening the upper valve.
2. Now start the supply at water controlled by the stop valve.
3. One of the valves of any one of the pipe open and close all other of three.
4. Take the discharge reading for the particular flow.
5. Take the reading for the pressure head on from the u-tube manometer for corresponding reading of discharge.
6. Now take three readings for this pipe and calculate the Cd for that instrument using formula.
7. Now close the valve and open valve of other diameter pipe and take the three reading for this.
8. Similarly take the reading for all other diameter pipe and calculate Cd for each.

THEORY:

Clemens Herschel (1842 – 1930) was an American hydraulic engineer. His career extended from about 1860 to 1930, and he is best known for inventing the Venturimeter, which was the first large-scale, accurate device for measuring water flow. Venturimeter is a device consisting of a short length of gradual convergence and a long length of gradual divergence. Pressure tapping is provided at the location before the convergence commences and another pressure tapping is provided at the throat section of a Venturimeter. The Difference in pressure head between the two tapping is measured by means of a U-tube manometer.

An Orificemeter is used to measure the discharge in a pipe. An Orificemeter in its simplest form consists of a plate having a sharp edged circular hole known as an orifice. The plate is fixed inside the pipe.

Orifice meters need calibration a priori where a known quantity of fluid is passed through the flow meter and the differential pressure across the flow meter related to the actual mass flow rate through a discharge coefficient given as the ratio of actual to theoretical mass flow rate. Two methods of knowing the actual mass flow rate are- measurement of time for collection of a finite volume of fluid and measurement of mass collected in a certain amount of time.

A mercury U-tube manometer is inserted to know the difference of pressure head between the two tapping. Orifice meter works on the same principle as that of Venturimeter i.e. by reducing the area of flow passage a pressure difference is developed between the two sections and the measurement of pressure difference is used to find the discharge.

FORMULA:

Coefficient of discharge = $C_d = Q_{act}/Q_{the}$

$Q_{act} = A.H/t$

$Q_{the} = a_1 a_2 / \sqrt{a_1^2 - a_2^2} * \sqrt{2gh}$ ……. For Venturimeter

$Q_{the} = a_1 a_o / \sqrt{a_1^2 - a_o^2} * \sqrt{2gh}$ ……. For orifice meter

OBSERVATION:

a) Venturimeter

S.No	Manometer reading pressure difference Hm (m)	Head loss h(m)	Time required for 10cm Rise of water (t) (sec)	Actual discharge Qact (m^3/sec)	Theoretical discharge Qthe (m^3/sec)	Coefficient of discharge Cd = Q_{act}/Q_{the}
1.						
2.						
3.						

a) Orifice meter

S.No	Manometer reading pressure difference Hm (m)	Head loss h(m)	Time required for 10cm Rise of water (t) (sec)	Actual discharge Q_{act} (m^3/sec)	Theoretical discharge Q_{the} (m^3/sec)	Coefficient of discharge Cd = Q_{act}/Q_{the}
1.						
2.						
3.						

Diameter of inlet pipe (d1) = Area of inlet pipe (a_1) =

Diameter of throat (d2) = Area of throat (a_2) =

Diameter of orifice (do) = Area of orifice (a_0) =

1. **Head loss (h)**= $(S_m/S_w - 1)Hm$

2. **Actual discharge:**

   $Q_{act} = AH/t$

3. **Theoretical discharge (Venturimeter):**

   $Q_{the} = a1\ a2 / \sqrt{a1^2 - a2^2} * \sqrt{2gh}$

   Theoretical discharge (Orifice meter):

   $Q_{the} = a1\ ao / \sqrt{a1^2 - ao^2} * \sqrt{2gh}$

4. **Coefficient of discharge:**

   $C_d = Q_{act}/Q_{the}$

GRAPH:

Draw a graph between Qact vs √h and Qact vs Qthe. Take Qact in Y axis.

RESULT:

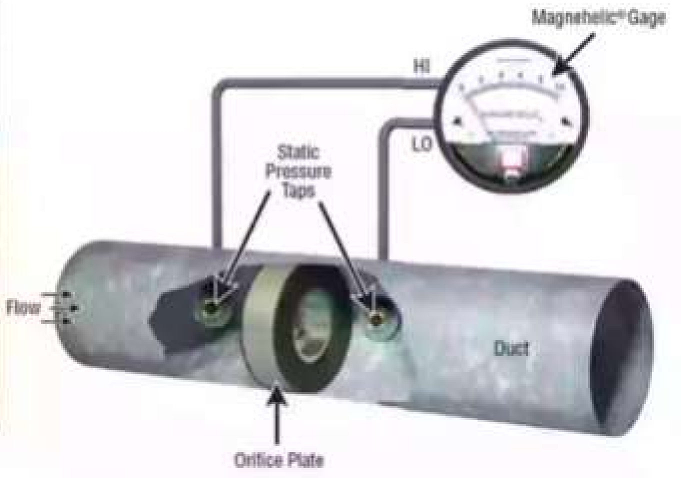
a) Coefficient of discharge (Cd) for Venturimeter =

b) Coefficient of discharge (Cd) for Orifice meter =

PRACTICAL APPLICATIONS

Venturimeter & Orificemeter is a measuring or also considered as a meter device that is usually used in industries to measure the flow of a fluid in the pipe. A Venturimeter may also be used to increase the velocity of any type fluid in a pipe at any particular point. Both Venturimeter & Orifice meter basically works on the principle of Bernoulli's Theorem.

Venturimeter



orifice meter

EXPERIMENT VIDEO LINKS

https://www.youtube.com/watch?v=3wfUev6TQv0

https://www.youtube.com/watch?v=NsW-8FjgjpY

EXPERIMENT NO: 4

CALIBRATION OF TRIANGULAR / RECTANGULAR NOTCH / TRAPEZOIDAL NOTCH

OBJECTIVE:

To determine the co-efficient of discharge [Cd] for Triangular/Rectangular notch/Trapezoidal notch.

OUTCOME:

The student will be able to find the actual and theoretical discharges and co-efficient of discharges.

SCOPE:

The knowledge in practical applications notches through Triangular/Rectangular/Trapezoidal notch experiments.

APPARATUS:

Channel with triangular/rectangular notch, Point gauge, Collecting tank, Stop watch, Scale

EXPERIMENTAL SETUP:

The notch is a thin steel plate which placed across a channel to measure the rate of flow of water. Based on the shape of the crest notches are classified into rectangular notch, triangular notch and trapezoidal notch.

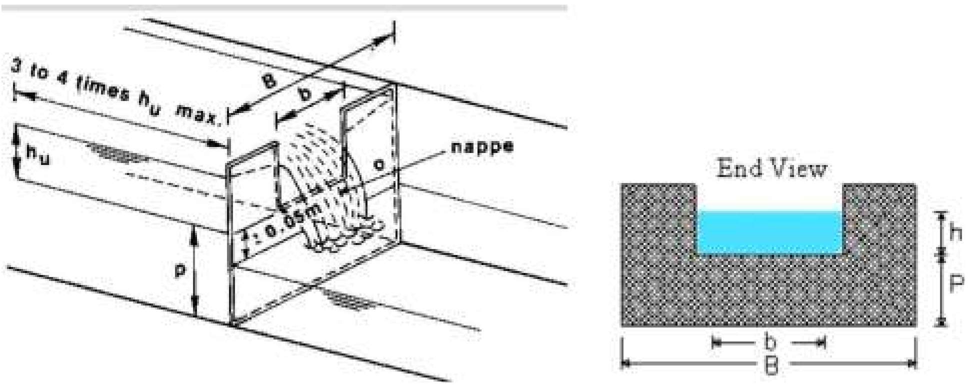


Fig 4.1 Rectangular Notch

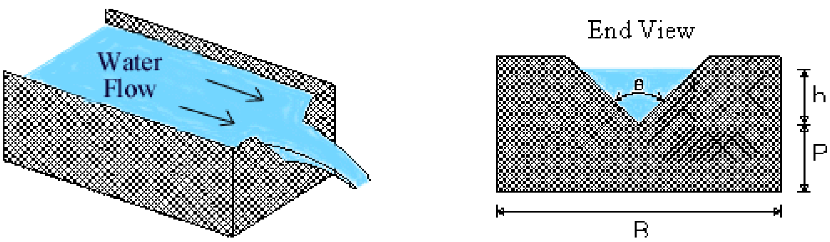


Fig 4.2 Triangular Notch

PROCEDURE:

1. Position the notch plate at the end of approach channel, in a vertical plane, with the sharp edge on the upstream side.
2. Admit water to channel until the water discharges over the notch plate.
3. Close the flow control valve and allow water to stop flowing over weir.
4. Set the point gauge to a datum reading (H1).
5. Position the gauge about half way between the notch plate and stilling baffle.
6. Admit water to the channel and adjust flow control valve to obtain heads (H2).
7. For each flow rate, stabilize conditions, measure and record H.
8. Take readings of volume and time using the volumetric tank to determine the flow rate.

THEORY & FORMULA:

A notch is a device used for measuring the rate of flow of a liquid through a small channel or a tank. It may be defined as an opening in the side of a tank or a small channel in such a way treat the liquid surface edge of the opening.

a) Rectangular notch

Consider a rectangular notch provided in channel or tank carrying water. Let, H = Head of water of still or crest. b = width of notch.

For finding the discharge of water flowing over notch, consider an elementary horizontal strip of water of thickness ‘dh’ and length surface of water.

The area of strip = b x dh

∴ Theoretical discharge Qthe :

$$Q = \int_0^H C_d b.\sqrt{2.g}.\sqrt{h.dh}$$

$$Q = C_d.b.\sqrt{2.g}.\int_0^H \sqrt{h.dh}$$

$$Q = C_d.b.\sqrt{2.g}\,\frac{(H)^{3/2}}{3/2}$$

$$Q_{th} = \frac{2}{3}b\sqrt{2.g}(H)^{3/2}$$

b) Triangular notch

Theoretical discharge for the entire triangular notch may be integration above expression within limit O to H. Then,

$$Q=\int_0^H C_d.\times 2(Hh+H)\tan(\theta/2)dh.\sqrt{2.gh}.$$

Assuming coefficient Cd to be constant for entire notch

$$Q=C_d\times 2(H+h)\tan(\theta/2)\int_0^H\sqrt{h}(dh).$$

$$Q=C_d\times 2(H+h)\tan(\theta/2)\left[\frac{2}{3}H.h^{3/2}-\frac{2}{5}h^{5/2}\right]_0^H$$

$$Q=\frac{8}{15}C_d\left[\tan\left(\frac{\theta}{2}\right)\right]\sqrt{2.g}(H)^{5/2}$$

OBSERVATION:

a) Rectangular notch:

Width of crest in rectangular notch (B) =

OBSERVATION:

a) Rectangular notch:

Width of crest in rectangular notch (B) =

S.No	Difference in water depth (H) (m)	Time required for 10cm Rise of water (t) (sec)	Actual discharge Q_{act} (m^3/sec)	Rectangular notch Theoretical discharge Q_{the} (m^3/sec)	Rectangular notch Coefficient of discharge Cd = Qact/Qthe
1.					
2.					
3.					

b) Triangular notch:

Triangular notch included angle (θ) =

S.No	Difference in water depth (H) (m)	Time required for 10cm Rise of water (sec)	Actual discharge Q_{act} (m^3/sec)	Triangular notch Theoretical discharge Q_{the} (m^3/sec)	Triangular notch Coefficient of discharge Cd = Qact/Qthe
1.					
2.					
3.					

1. Actual discharge:

$$Q = AH/t \qquad (H = 0.1m)$$

2. Theoretical discharge (Rectangular notch):

$$Q_t = \frac{2}{3}\sqrt{2g}\ BH^{3/2}.$$

3. Theoretical discharge (Triangular notch):

$$Q_t = \frac{8}{15}\sqrt{2g}\ \tan\frac{\theta}{2} H^{5/2}$$

4. Coefficient of discharge:

C_d (Rectangular) = Qact/Qthe

C_d (Triangular) = Qact/Qthe

GRAPH:

1. Plot a graph between Qact vs H3/2 and Qact vs Qthe. Take Qact in Y axis for Rectangular notch.
2. Plot a graph between Qact vs H5/2 and Qact vs Qthe. Take Qact in Y axis for Triangular notch.

RESULT:

a) Coefficient of discharge of Rectangular notch =

b) Coefficient of discharge of Triangular notch =

PRACTICAL APPLICATIONS

Notches are generally used to measure flow rate in an open channel flow.In real life applications it is used for seepage measurement of dam in foundation, inspection and top galleries and toe-drains in reservoirs. When small quantity of flow need to be measured the V-notch is preferable because the triangular cross-section of the flow 'nappe' leads to a relatively greater variation in head. V-notch has the advantage that it can function for a very small flows and also measure reasonably larger flows as well.

Rectangular Notch

Triangular Notch

EXPERIMENT VIDEO LINKS

https://www.youtube.com/watch?v=HGQM913rI10

https://www.youtube.com/watch?v=K2NyRPGPS-

https://www.youtube.com/watch?v=YaQkU5FfigM

EXPERIMENT NO: 5

DETERMINATION OF MINOR LOSSES IN PIPE FLOW

(Sudden Expansion & Sudden Contraction)

OBJECTIVE:

To determine the loss of head due to sudden expansion & sudden contraction in the pipe flow.

OUTCOME:

The student will be able to find the minor losses and its effects on the pipe flow.

SCOPE:

The knowledge in various minor losses in the pipe flow is necessary for the design of pipes, calculating velocity and discharge in the pipe flow.

APPARATUS:

Pipe of smaller diameter connected to larger diameter, Pipe of larger diameter connected to smaller diameter inlet, outlet valves, collecting tank, stop watch etc.

EXPERIMENTAL SETUP:

Two pipe of cross-sectional area A1 and A2 flanged together with a constant velocity fluid flowing from smaller diameter pipe. This flow breaks away from edges of narrow edges section, eddies from and resulting turbulence cause dissipation of energy. The initiations and onset of disturbances in turbulence is due to fluid momentum and its area.

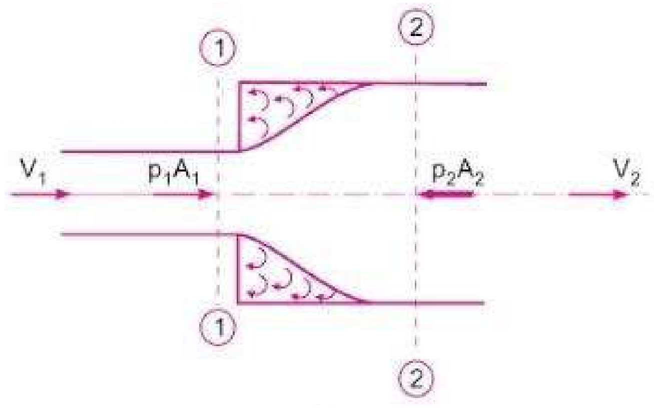


Fig.5.1 Sudden Expansion

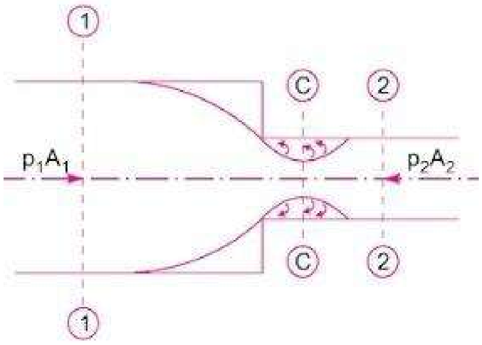


Fig.5.2 Sudden Contraction

PROCEDURE:

1. Measure the diameter of the pipes.
2. Prime the mercury manometer
3. Connect the test section pipe to the main water supply pipe
4. Open flow control valve, priming test section and pipe work.
5. Open clips on water manometer, allowing water to circulate through the system until all the air is expelled.
6. Close pipe clips.
7. Bleed mercury manometers via bleed sewers in conjunction with control valves
8. Close flow control valve.
9. Observe datum level on manometers.
10. To achieve maximum flow fully open flow control valve. Note levels in manometer and measure flow rate. Repeat for different control valve position.

THEORY:

a) Sudden expansion:

Loss of energy duet to change of velocity of the flowing fluid in magnitude or direction is called as minor loss of energy. Consider a fluid flowing through a pipe line which has sudden enlargement. Consider two section 1 – 1 and 2 – 2 before and after enlargement.

Let,

P1 = Pressure intensity at section 1 – 1. V1 = Velocity of flow at section 1 – 1. A1 = Area of pipe at section 1 – 1.

P2, V2 and A2 = Corresponding values of pressure, velocity & area at section 2 - 2.

Due to sudden change of diameter, the liquid flowing from smaller pipe is not able to fallow abrupt change of boundary and turbulent eddies are formed, since the flow separates from the boundary.

Let,

P1 = Pressure intensity of the liquid eddies on Area A2 – A1, he = Loss of head due to expansion.

Applying Bernoulli's equation at section 1 – 1 and 2 – 2.

$$\frac{p_1}{w} + \frac{v_1^2}{2g} + Z_1 = \frac{p_2}{w} + \frac{v_2^2}{2g} + Z_2$$

But Z1 = Z2

$$h_e = \left(\frac{p_1}{w} - \frac{p_2}{w}\right) + \left(\frac{v_1^2}{2g} - \frac{v_2^2}{2g}\right) \text{ ------- } 1$$

Consider the control volume of liquid between 2 sections.

Fx = P1 A1 + P1 (A2 - A1) P2 A2 = (P1 - P2) A2……………………..2

Momentum of liquid / sec at section 1 –1 = Mass x Velocity

= Q A1 V1·V1

= Q A1 V1·V1

Similarly Momentum of liquid / sec at section 2 – 2 = $\varrho A_2 V_2^2$

∴Change of momentum / Sec $= \varrho A_2 V_2^2 - \varrho A_2 V_2 \times V_1$

$= \varrho A_2 (V_2^2 - V_1 V_2)$--------3.

Net force acting on the control vol. in the direction of flow must be equal to the rate of change of momentum per second. Hence equating equation 2 and 3.

$$(P_1 - P_2) A_2 = \varrho A_2 (V_2^2 - V_1 V_2)$$

On solving we get He = $(V_1 - V_2)^2 / 2g$

Where :

He = Loss of head due to sudden expansion.

V_1 = Velocity of flow at smaller section.

V_2 = Velocity of flow at larger Section.

b) Sudden contraction:

Water is flowing from large diameter pipe to smaller diameter pipe as shown in figure. The loss of head due to sudden contraction is actually due to sudden enlargement from vena-contracta to sec.2.

$$Hc = 0.5 V_2^2 / 2g$$

OBSERVATION:

a) Sudden expansion:

S.No	Difference in manometric reading (m)	Pressure head difference (m)	Time required for 10cm rise of water (t) sec	Actual discharge (Qact) (m^3/sec)	Inlet velocity V_1 (m/sec)	Outlet velocity V_2 (m/sec)	Head loss due to expansion (m) $He = (V_1-V_2)^2/2g$
1.							
2.							
3.							

Diameter of smaller pipe (d1) =

Diameter of larger pipe (d2) =

1. **Pressure head loss (H)** = $(S_m/S_w - 1)Hm$
2. **Actual discharge:**

$$Qact = AH/t$$

3. **Inlet velocity (V_1)** $= 4Q/\pi d_1^2$
4. **Outlet velocity (V_2)** $= 4Q/\pi d_2^2$
5. **Loss of head (He)** $= (V_1-V_2)^2/2g$

b) Sudden contraction:

S.No	Difference in manometric reading (m)	Pressure Head loss (m)	Time required for 10cm rise of water (sec)	Actual discharge (Qact) (m^3/sec)	Outlet velocity V_2 (m/sec)	Head loss due to contraction $Hc = (0.5V_2)^2/2g$
1.						
2.						
3.						

Diameter of larger pipe (d1) =

Diameter of smaller pipe (d2) =

1. **Pressure head loss (H)** = $(S_m/S_w - 1)Hm$
2. **Actual discharge:**

$$Qact = AH/t$$

3. **Inlet velocity (V_1)** $= 4Q/\pi d_1^2 =$
4. **Outlet velocity (V_2)** $= 4Q/\pi d_2^2 =$
5. **Loss of head (Hc)** $= 0.5V_2^2/2g =$

GRAPH:

1. Draw the graph between Qact vs Head loss due to expansion. Take Qact in Y axis
2. Draw the graph between Qact vs Head loss due to contraction. Take Qact in Y axis

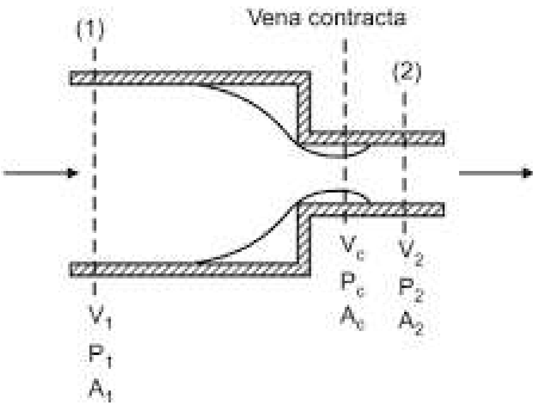
RESULT:

a) Head loss due to sudden expansion (H_e) =

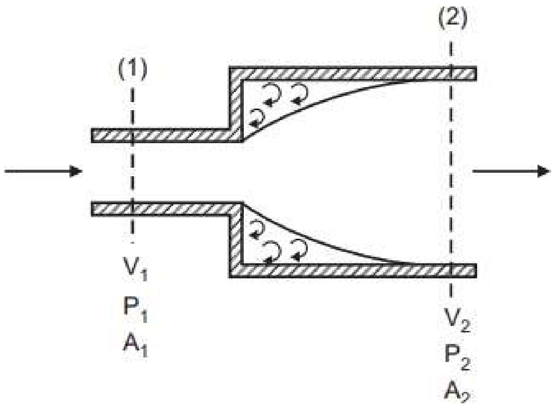
b) Head loss due to sudden contraction (H_c) =

PRACTICAL APPLICATIONS

In practical setting, fluid flows through different pipe fittings such as sudden contraction, sudden enlargement valve, elbow or bend, tee section etc. Sudden changes in the flow path result in secondary flow patterns, denoted as separation region and vena contracta. In the pipe network there may sudden change in pipe diameter, In any change in pipe diameter there is considerable head loss and we need to calculate the loss. From this experiment, we can determine the coefficient to calculate the losses.



Sudden Contraction



Sudden expansion

EXPERIMENT VIDEO LINKS

https://www.youtube.com/watch?v=7tI_1qVOAE4

https://www.youtube.com/watch?v=6z4NZY-iwZQ

EXPERIMENT NO: 6

DETERMINATION OF FRICTION FACTOR OF A PIPE LINE

OBJECTIVE:

To investigate the friction factor (f) for a pipe carrying water.

OUTCOME:

The student will be able to find the major loss due to friction and its effects in a pipe flow.

SCOPE:

The knowledge in major loss in the pipe flow is necessary for the design of pipes, calculating velocity and discharge in a pipe flow.

APPARATUS:

U – tube manometer connected across a pipe line, Stop Watch, Collecting tank.

EXPERIMENTAL SETUP:

The equipment used in the experiment was the fluid flow setup and the materials used were steel tape, stopwatch and thermometer. Water was used as the working fluid. The pump was primed and started in order for the fluid to initiate the flowing along the pipelines. Collecting tank collects the water for calculating volumetric flow rate.

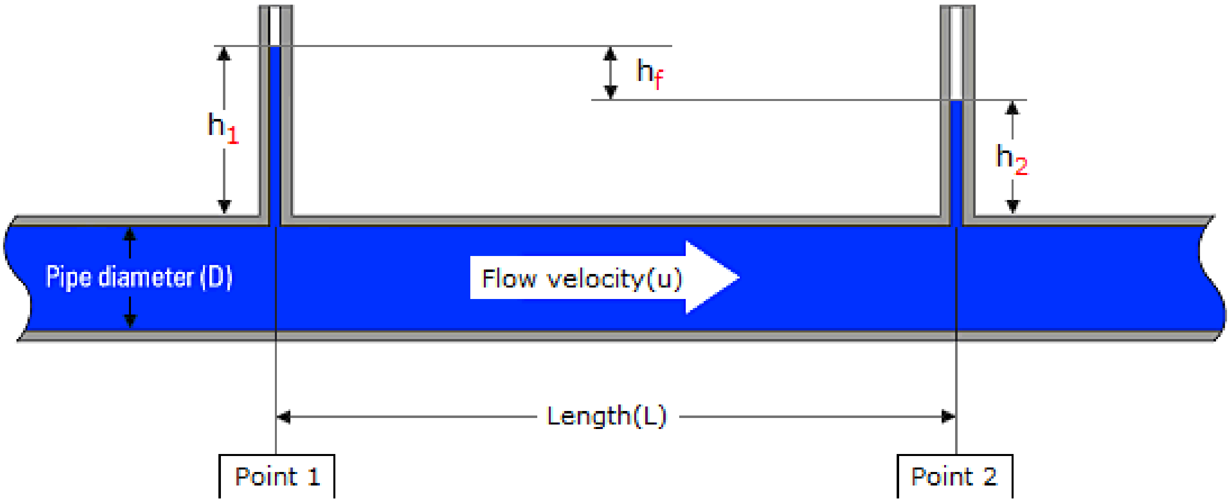


Fig.6 Experimental setup

PROCEDURE:

1. Measure the diameter of the pipe and distance between the two tapings.
2. Prime the mercury manometer.
3. Connect the test section pipe to the main water supply pipe.
4. Open flow control valve, priming test section and pipe work.
5. Open clips on water manometer, allowing water to circulate through the system until all the air is expelled.
6. Close pipe clips.
7. Bleed mercury manometer via bleed screws in conjunction with the control valves.
8. Close flow control valve.
9. Observe datum level on manometer.
10. To achieve maximum flow fully open flow control valve. Note levels in manometer and measure flow rate. Repeat for different control valve position.

THEORY:

In fluid dynamics, the Darcy–Weisbach equation is an empirical equation that relates the head loss, or pressure loss, due to friction along a given length of pipe to the average velocity of the fluid flow for an incompressible fluid. The equation is named after Henry Darcy and Julius Weisbach (1806-1871). A pipe is a closed conduit which is used for carrying fluids under pressure. Pipes are commonly circular section. As the pipes carry fluids under pressure, the pipes always run full.

The fluid flowing in a pipe is always subjected to resistance due to shear forces between fluid particles and the boundary walls of the pipe and between the fluid particles themselves resulting from the viscosity of the fluid. The resistance to the flow of fluid is, in general known as frictional resistance. Since certain amount of energy possessed by the flowing fluid will be consumed in overcoming this resistance to the flow, there will always be some loss of energy in the direction of flow, which however depends on the type of flow, W.froude conducted a series of experiments to investigate frictional resistance offered to the flowing water by different surfaces.

As per Darcy Weisbach equation

hf = 4flv2/2gd.

Above equation is used to find loss of head due to friction in pipes. Here is f friction factor. In order to determine the loss of head due to friction correctly, it is essential to estimate the value of the factor f correctly when a fluid flows through a pipe, certain resistance is offered to the flowing fluid, which results in causing a loss of energy. The various energy losses in pipes may be classified as

i) major losses

ii) minor losses

The major loss of energy, as a fluid of flows through a pipe, is caused by friction. It may be computed by Darcy-Weisbach equation. The loss of energy due to friction is classified as a major loss because in the case of long pipelines it is usually much more than the loss of energy incurred by other causes.

FORMULA:

Loss of head due to friction (hf) = 4flv2/2gd Where,

f = friction factor

l = length of the pipe v = velocity in the pipe

d = diameter of the pipe

is Darcy Weisbach equation which is commonly used for computing the

OBSERVATION:

Diameter of the pipe (d) = Area of the pipe =

Length of the pipe (l) =

S.No	Difference in manometric reading (m) (Hm)	Frictional head loss(h_f) (m)	Time required for 10cm rise of water (t) (sec)	Actual discharge (Qact) (m^3/sec)	Velocity in the pipe (m/sec)	Friction factor (f)
1.						
2.						
3.						

1. **Frictional head loss (hf)** $= (S_m/S_w - 1)Hm$
2. **Actual discharge: Q_{act}** $= AH/t$
3. **Velocity (V)** $= 4Q/\pi d^2$
4. **Friction factor (f)** $= \frac{2\, h_f g\, d}{4lV^2} =$

GRAPH:

Draw the graph between hf vs $V^2/2g$ with hf on X-axis.

RESULT:

The friction factor "f" for the pipe is found to be________.

PRACTICAL APPLICATIONS

Flow through a single pipe line, pipes in series and parallel and also in pipe network system, cause head loss due to friction. The head loss from source to the point of interest due to the friction along the pipe also provides the basis of pipe size (diameter) design. This experiment gives an estimate of head loss due to friction in the pipe per unit length of the pipe.

EXPERIMENT VIDEO LINKS

https://www.youtube.com/watch?v=f83D4h2LN4I

https://www.youtube.com/watch?v=tSVwiAc8DWo

EXPERIMENT NO: 7

DETERMINATION OF ENERGY LOSS IN HYDRAULIC JUMP

OBJECTIVE:

To understand the Energy loss in Hydraulic jump through an experiment.

OUTCOME:

The student will be able to verify the total Energy loss in Hydraulic jump.

SCOPE:

The knowledge of Energy loss in Hydraulic jump is used for flow measuring device like at Dams, rivers and other slope areas.

APPARATUS:

Open Channel Flow Setup, Depth Gauges, Stopwatch

EXPERIMENTAL SETUP:

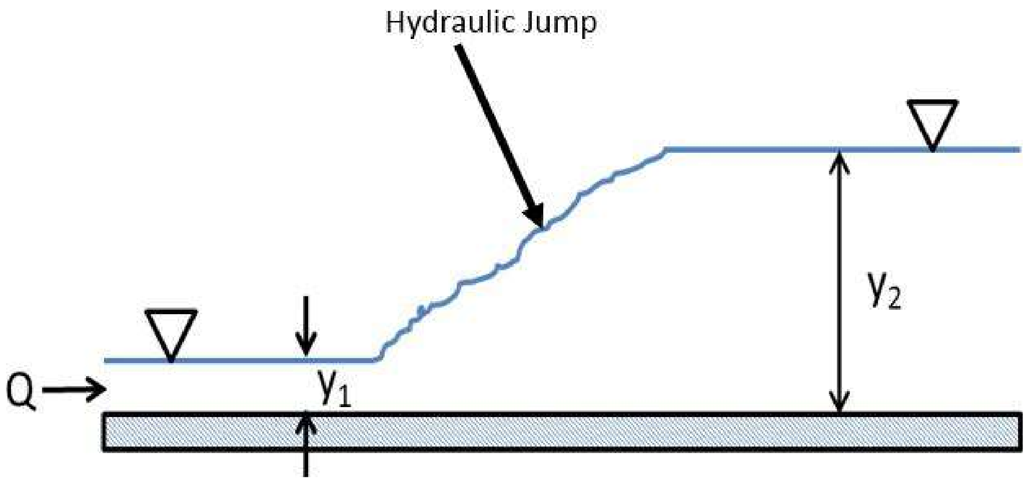


Fig.7 Hydraulic Jump experimental setup

PROCEDURE:

1. Set the channel for a given slope.
2. Close both the inlet and outlet gates.
3. Allow water in the channel.
4. Open the gate II completely.
5. Open the gate I slightly, so that water flows under the gate in supercritical (shooting) condition.

6. Close the gate II gently, so that it causes obstruction to the shooting flow, and a Hydraulic Jump is formed.
7. Regulate the gate II finely that the Hydraulic Jump stays at the middle of the channel.
8. With the help of traveling hook gauge measure the conjugate depths of the flow before and after the Hydraulic Jump, y1 and y2.
9. Note the time taken for 'R' level rise for calculating the actual discharge.

THEORY:

Hydraulic jump forms in an open channel when the unstable super critical flow changes to the stable sub critical flow. This change in the flow condition will cause the flow to cross the critical depth. As the water surface slope becomes infinity at the critical depth, the water surface tends to become vertical which is manifested in the formation of a hydraulic jump. Since the hydraulic jump occurs in an abrupt manner over a relatively short distance. It is classified as rapidly varied flow. The flow in a hydraulic jump is accompanied by the formation of turbulent rollers resulting in a considerable dissipation of energy.

The formation of hydraulic jump also known as standing wave occurs frequently in a canal below a regulating sluice, at the foot of a spillway or at the place where the bottom slope of the channel changes from steep to mild.

FORMULA:

1. Velocity before the jump, $V1 = Q/(W \times y1)$ m/sec
2. Velocity after the jump, $V2 = Q/(W \times y2)$ m/sec
3. Loss of Energy, $EL= (y2-y1)3 / 4y1y2$ m.kg/kg

FORMULA:

1. Velocity before the jump, $V_1 = Q/(W \times y1)$ m/sec
2. Velocity after the jump, $V_2 = Q/(W \times y2)$ m/sec
3. Loss of Energy, $E_L = (y2-y1)^3 / 4y1y2$ m.kg/kg

OBSERVATION:

Depth before jump, y1=

Depth after jump, y2=

Sl. No.	Depth before jump (y1) m	Depth after jump (y2) m	Time taken for 10 cm rise of water in the collecting tank (t) sec
1.			
2.			
3.			

Sl. No	Discharge Q (m^3/sec)	Velocity V_1 (m/sec)	Velocity V_2 (m/sec)	Loss of Energy (E_L)	Average Loss of Energy
1.					
2.					
3.					

GRAPH:

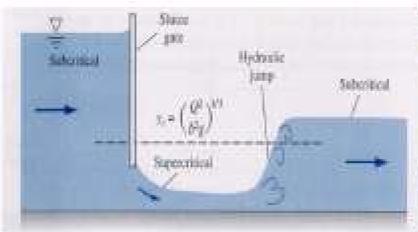
Draw the graph between Qact vs Loss of energy.

RESULT:

Average Loss of Energy due to Hydraulic Jump, EL =

PRACTICAL APPLICATIONS

Usually Hydraulic jump reverses the flow of water. Hydraulic jump usually maintains the in high water level on downstream side. the water level can be used for irrigation purposes. hydraulic jump can be used to remove the air from water supply and sewage lines to prevent the air locking.



EXPERIMENT VIDEO LINKS

https://www.youtube.com/watch?v=5etwhZ0d2GU

EXPERIMENT NO: 8

DETERMINATION OF MANNING'S AND CHEZY'S CONSTANTS FOR OPEN CHANNEL FLOW

OBJECTIVE:

To determine the Chezy's and Manning's constant for an open channel.

OUTCOME:

The student will be able to verify the total head of Chezy's and Manning's constant for an open channel.

SCOPE:

The knowledge of the Chezy's and Manning's constant is used for flow measuring device like Dams, rivers and different water levels.

APPARATUS:

Open Channel Flow Setup, Stop Watch

EXPERIMENTAL SETUP:

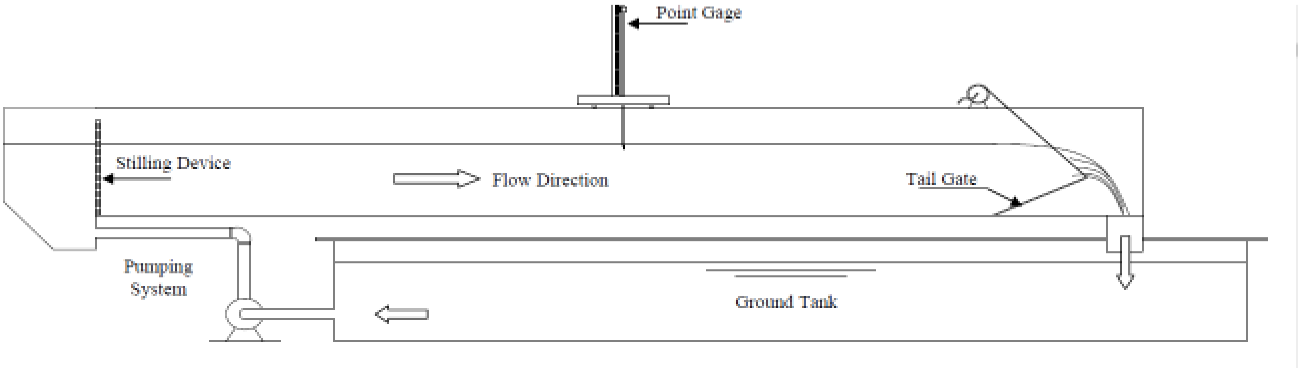


Fig.8 Open channel experimental setup

PROCEDURE:

1. Set the channel for the required slope and allow the water to flow through the channel.
2. Adjust the inlet valve to get the required depth of water in the channel and measure the depth as d cm, using pointer gauge.
3. Adjust the inlet valve opening to get the required depth of water in the channel
4. Note the time 't' to collect water for a rise of 'H' m in the measuring tank.
5. Repeat the experiment for different depths of water for the same bed slope.

THEORY:

Chezy's equation was presented in 1775. It states that velocity in an open channel flow is a function of hydraulic radius and slope of the channel bed. It describes the mean flow velocity of steady, turbulent open channel flow. The formula is named after Antoine de Chezy (1718-1798), the French hydraulics engineer who devised it in 1775. One the most commonly used equations governing Open Channel Flow is known as the Mannings's Equation. It was introduced by the Irish Engineer Robert Manning in 1889 as an alternative to the Chezy Equation. The Manning's equation is an empirical equation that applies to uniform flow in open channels and is a function of the channel velocity, flow area and channel slope.

FORMULA:

Chezy's formula,

$V = C * \sqrt{(mi)}$

Where,

V = Average Velocity (m/s)

C = Chezy's Constant

m = hydraulic mean depth (m) i = bottom slope (m/m)

The Manning's formula is an empirical formula estimating the average velocity of a liquid flowing in an open channel.

Gauckler-Manning formula,

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

$= (1/N)\, m^{2/3}\, i^{1/2}$

Where,

V = Average Velocity (m/s)

R = the hydraulic radius = depth (m) N = Manning's constant

S = Slope of the hydraulic gradient line (m/m)

Manning derived the following relation between Manning's Constant and Chezy's Constant,

$C = 1 /N x\, m^{1/6}$

OBSERVATION:

1. Length of channel, L = m
2. Width of the channel, W = m
3. Area of the collecting tank, A = m2

S. No.	Bed Slope (i)	Depth of water in the channel (d) (m)	Time taken for 10 cm rise of water (t)	Discharge (Qact) (m^3/sec)
1.				
2.				
3.				

S. No.	Bed Slope (i)	Hydraulic Mean depth (m)	Discharge (Qact) m^3/s	Velocity (V) m/s	Chezy's Constant	Manning's Constant
1.						
2.						
3.						

1. Slope of the channel, i = vertical shift of channel from pointer (y /L)
2. Hydraulic mean radius, m = Area/Wetted perimeter = wd /(w+2d)
3. Actual Discharge, (Q) = AH/t
4. Velocity, V = Q / (wxd)
5. Chezy's constant, C = V /√(mi)
6. Manning's constant, N = 1/C x m 1/6

RESULT:

1. Average Chezy's constant for the given channel, C =
2. Average Manning's constant for the given channel, N =

PRACTICAL APPLICATIONS

The Chezy's and Manning formula are empirical formulas estimating the average velocity of a liquid flowing in a conduit that does not completely enclose the liquid, i.e., open channel flow. However, this equation is also used for calculation of flow variables in case of flow in partially full conduits, as they also possess a free surface like that of open channel flow. All flow in so-called open channels is driven by gravity. The most common application is used in cannel and culvert, dams and also common forestry/rangeland/agriculture to estimate flood travel time in land-use management.

Rectangular channel

Trapezoidal channel

EXPERIMENT VIDEO LINKS

https://www.youtube.com/watch?v=MIULW-w3pPo

EXPERIMENT NO: 9

IMPACT OF JET ON VANES

OBJECTIVE:

To determine the coefficient of impact when jet strikes a) Flat Vane b) Curved Vane with 1350 angle of deflection.

OUTCOME:

The student will be able to verify average coefficient of impact on flat vane and curved vane from the experiment.

SCOPE:

The knowledge of impact of jet on vanes is used for flow measuring device like Flat Vane, Turbine vanes and other plates.

APPARATUS:

Jet and Vane Setup, Flat and Curved Vanes, Digital Weighing Balance, Stop watch

EXPERIMENTAL SETUP:

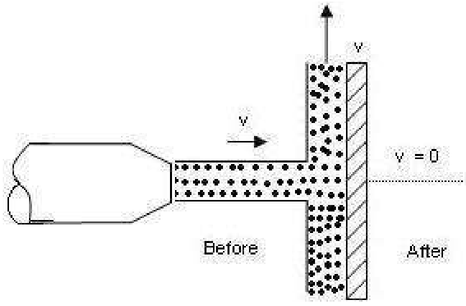


Fig 9.1 Jet striking flat stationary plate

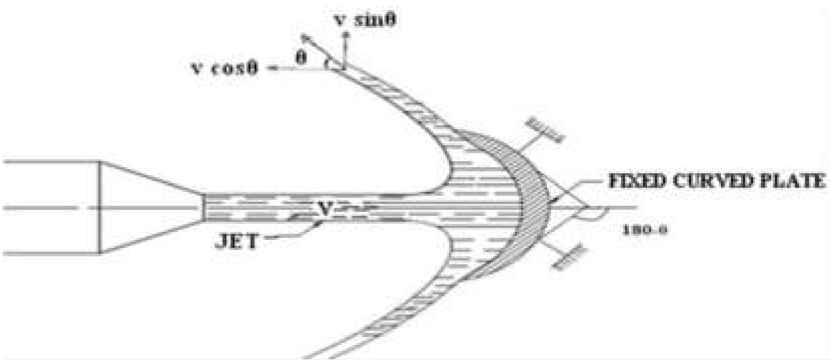


Fig 9.2 Jet striking curved stationary vane

PROCEDURE:

1. Fix up the required vane to the setup and balance the lever.

2. Start the water supply and adjust the water flow to allow the jet create an impact on the fixed vane such that lever will be lifted up.
3. Note the lifting or impact weight on the vane using digital weighing balance as a positive value.
4. Measure the time required (T) for 10cm rise of water level in the collecting tank by closing its valve.
5. The experiment is repeated for a minimum of 3 times for different input discharges.
6. Tabulate the observations as shown in Tabular Column and calculate the average Ci value by substituting the values of Fa and Ft obtained.

THEORY:

A fluid jet is a stream of fluid issuing from a nozzle with a high velocity and hence a high kinetic energy. When a jet strikes a plate or vane, it exerts a force on it due to change in momentum as shown in figures 9.1 and 9.2. This force can be evaluated by using impulse momentumprinciple.

The following cases of impact of jet will be considered:

1. When jet strikes stationary flat plate
2. When jet strikes moving flat plate
3. When jet strikes stationary inclined plate
4. When jet strikes moving inclined plate
5. When jet strikes stationary curved vane
6. When jet strikes moving curved vane

OBSERVATIONS:

1. Diameter of the nozzle (d) =
2. Area of orifice (a) = π/4 * d2 =

Sl. No.	Actual Force (Fa) kg	Time taken for 10 cm rise (H) of water in the collecting tank (t) sec
1.		
2.		
3.		

Sl. No.	Discharge Q (m^3/sec)	Velocity V (m/sec)	Theoretical Force Ft (kg)	Actual Force Fa (kg)	Coefficient of Impact Ci	Average Coefficient of Impact
1.						
2.						
3.						

1. Actual discharge, $Q = \frac{AH}{t}$
2. Velocity of Water, $V = Q/a$
3. Actual force, F_a =
4. Theoretical Force, $F_t = \rho a V$
5. Coefficient of Impact, $C_i = F_a/F_t$

GRAPH:

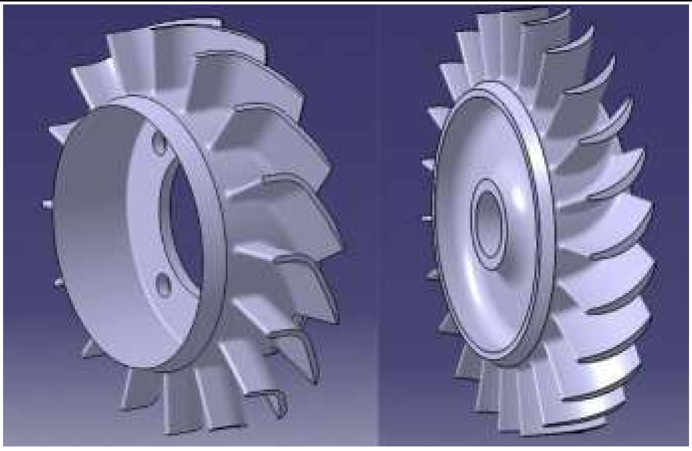
Plot the graph between Fa (on X-axis) and V2 (on Y-axis)

RESULT:

1. Average Coefficient of Impact on flat Vane from the experiment, Ci =
2. Coefficient of Impact on Flat Vane from the graph, Ci =

PRACTICAL APPLICATIONS

Engineers and designers use the momentum equation to accurately calculate the force that moving fluid may exert on a solid body. For example, in hydropower plants, turbines are utilized to generate electricity. Turbines rotate due to force exerted by one or more water jets that are directed tangentially onto the turbine’s vanes or buckets. The impact of the water on the vanes generates a torque on the wheel, causing it to rotate and to generate electricity.



EXPERIMENT VIDEO LINKS

1. https://www.youtube.com/watch?v=52aGAp7qZdU

EXPERIMENT NO: 10

PERFORMANCE CHARACTERISTICS OF PELTON WHEEL TURBINE

OBJECTIVE:

To conduct performance test on Pelton Wheel turbine and to draw characteristic curves.

OUTCOME:

The student will be able to verify the efficiency of Pelton Wheel Turbine from the experiment.

SCOPE:

The knowledge on working principle & efficiency of Pelton Wheel Turbine used in hydro electric power plants.

APPARATUS:

Pelton Wheel turbine test rig, weights, tachometer

EXPERIMENTAL SETUP:

The turbine capable of working under the high potential head of water is the Pelton Wheel Turbine which works on the head greater than 300 m. The runner consists of a circular disc with a suitable number of double semi-ellipsoidal cups known as buckets which are evenly spaced around its Periphery. One or more nozzles are mounted so that, each directs a jet along the tangent to the circle through the centres of the buckets called the Pitch Circle. A casing is provided only to prevent the splashing of water and for discharging the water to the tailrace.

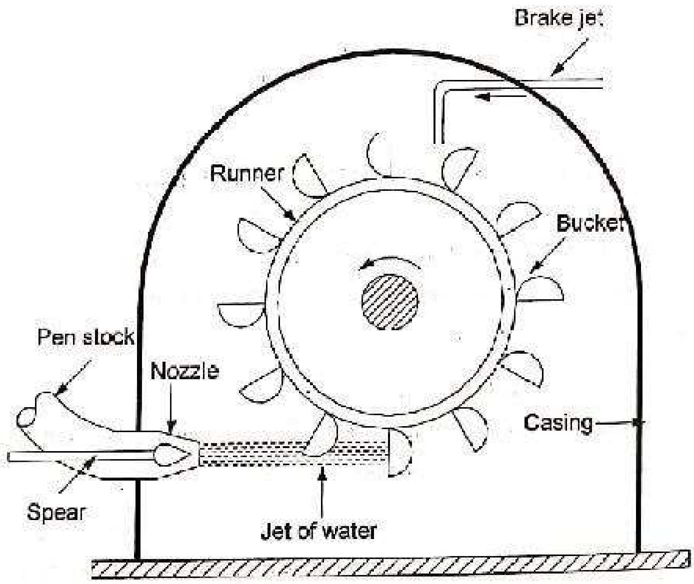


Fig.10 Pelton wheel turbine experimental setup

PROCEDURE:

1. Close the inlet valve and prime the pump.

2. Keep the nozzle at full opening.
3. Start the pump, gradually open the gate valve while monitoring the inlet pressure to the turbine, and set it to the desired value.
4. Add minimum load to the weight hanger of the break drum say 1 kg.
5. Measure the turbine speed in rpm with tachometer.
6. Note the pressure gauge reading at the turbine inlet.
7. Note down the Venturimeter pressure gauge readings P1 and P2.
8. Repeat the experiment by increasing weights on the hanger.

THEORY:

The Pelton wheel or Pelton Turbine is an impulse-type water turbine invented by American inventor Lester Allan Pelton (1829-1908) in the 1870s. The Pelton wheel extracts energy from the impulse of moving water, as opposed to water's dead weight like the traditional overshot water wheel. Pelton wheel is an impulse turbine, which is used to utilize high heads for conversion of hydraulic energy into mechanical energy which in turn can be transformed into electrical energy by coupling shafts of turbine and generator. All the available head is converted into velocity energy by means of spear and nozzle arrangement. The water leaves the nozzle in jet formation. The jet of water then strikes the buckets of the Pelton wheel runner. The buckets are in the shape of double semi-ellipsoidal cups, joined at the middle portion by a vertical splitter. The jet strikes the sharp edged splitter of the buckets with least resistance and shock. Then the jet slides along the path of the cup, and the jet is deflected through more than 160° to 170°. The dynamic force of the jet on the buckets causes the wheel to rotate and hence the shaft also is rotated.

A brake pulley or brake drum is fitted to the shaft. A rope is wound round the pulley with one end of the rope connected to spring balance at top and the other lower end of the rope to a weight hanger for placing loads. Tachometer is used to record shaft speeds. The Pelton Wheel is supplied with water under high pressure by centrifugal pump. The water is conveyed through Venturimeter to the Pelton wheel. The Venturimeter with manometer connection is used to determine the discharge of the water in the pipe. The nozzle opening can be decreased by operating the spear wheel at the entrance side of the turbine. Pelton wheel turbines are best suited at high heads and specific speed range varies from 10 to 100.

FORMULA:

FORMULA:

Input Power, IP = ρxQxH kW

Turbine Output, OP = $\frac{2\Pi NT}{60000}$ kW

Efficiency, η = Output/Input x100 %

OBSERVATION:

Effective Break Drum diameter =

Constant 'K' Value = 3.183 x 10^{-3}

Weight of rope and hanger =

Specific Weight of Water, ρ = 9.81 kN/m^3

S. No.	Inlet Pressure P (kg/cm^2)	Venturimeter Pressure Gauge Readings		Speed of the turbine N (rpm)	Weight on hanger W1 (kg)	Spring Balance Reading W2 (kg)
		P1 (kg/cm^2)	P2 (kg/cm^2)			
1.						
2.						
3.						
4.						
5.						

S. No.	Venturimeter head h (m)	Net Load N (kg)	Discharge Q (m^3/s)	Input Power I/P	Output Power O/P	Efficiency η (%)
1.						
2.						
3.						
4.						
5.						

1. Input Total Head, H = Pressure Gauge Reading (P) in kg/cm2 x10 m
2. Venturimeter Head, h = (P1 – P2)x10 m
3. Theoretical discharge Q = K$\sqrt{h}$
4. Input Power IP = ρxQxH kW
5. Torque (T) = ((W1 + Weight of rope and hanger) – W2)x D/2 x 9.81 N
6. Turbine Output, OP = 2ΠNT/60000 kW
7. Efficiency, η = OP/IP x100

GRAPH:

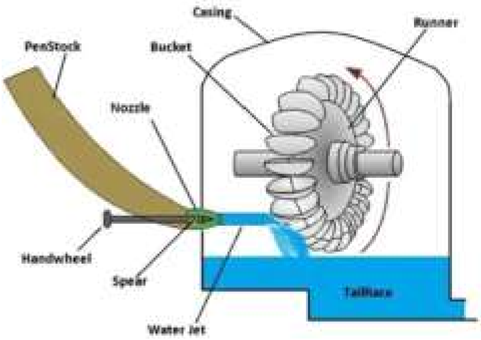
1. Plot a graph between Qact vs Input power and Output power
2. Plot a graph between Qact vs Efficiency

RESULT:

The efficiency of Pelton Wheel Turbine, Ƞ =

PRACTICAL APPLICATIONS

Pelton turbine is used in the hydroelectric power plant where the water available at high head i.e. 150 m to 2000 m or even more. In hydroelectric power plant, it is used to drive the generator attached to it and the generator generates the mechanical energy of the turbine into electrical energy. Pelton wheels are the preferred turbine for hydro-power, when the available water source has relatively high hydraulic head at low flow rates. For maximum power and efficiency, the wheel and turbine system is designed such that the water jet velocity is twice the velocity of the rotating buckets.



EXPERIMENT VIDEO LINKS

https://www.youtube.com/watch?v=R171zuPqa3w

EXPERIMENT NO: 11

PERFORMANCE CHARACTERISTICS OF FRANCIS TURBINE

OBJECTIVE:

To conduct performance test on Francis turbine and to draw characteristic curves.

OUTCOME:

The student will be able to verify the efficiency of Francis Turbine from the experiment.

SCOPE:

The knowledge on working principle & efficiency of Francis Turbine used in hydro electric power plants.

APPARATUS:

Francis turbine test rig, weights, tachometer

EXPERIMENTAL SETUP:

Francis turbine blades are designed in such a way that one portion of the blade design creates the pressure difference between the opposite faces of the blade when water flows through it, and the remaining portion's blade design use the impulse force of water hitting it and this combined action of pressure difference and impulse force generates enough power to get turbine moving at a required speed. Thus there would be a decrease in both kinetic energy and potential energy of water at exit, then what it has when it enters the turbine.

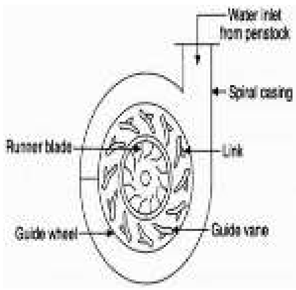


Fig.11 Francis Turbine

PROCEDURE:

1. Close the inlet valve and prime the pump.
2. Start the pump, gradually open the gate valve while monitoring the inlet pressure to the turbine, and set it to the desired value.
3. Add minimum load to the weight hanger of the break drum say 1kg.
4. Measure the turbine speed in rpm with tachometer.
5. Note the pressure gauge reading at the turbine inlet.

6. Note down the Venturimeter pressure gauge readings P1 and P2.
7. Repeat the experiment by increasing weights on the hanger.

THEORY:

James Bicheno Francis (1815 – 1892) was a British-American civil engineer, who invented the Francis turbine. Francis turbine is a reaction type hydraulic turbine, used in dams and reservoir of medium height to convert hydraulic energy into mechanical and electrical energy. Francis turbine is radial inward flow reaction turbine. This has the advantage of centrifugal forces acting against the flow, thus reducing the tendency of the turbine to over speed. Francis turbines are best suited for medium heads. The specific speed ranges from 25 to 300.

Water under the pressure from the pump enters the guide vanes into the runner while passing through the spiral casing and guide vanes; a portion of pressure energy is converted into velocity energy. Water thus enters the runner at high velocity and as it passes through the runner vanes, the remaining pressure energy converted into kinetic energy. Due to the curvature of the vanes, the kinetic energy is transformed into mechanical energy. The water head is converted into mechanical energy and hence the runner rotates. A tachometer is used to measure the speed of rotor.

FORMULA:

1. Input Power, IP = $\rho x Q x H$ kW
2. Turbine Output, OP= $\frac{2\Pi NT}{60000}$ kW
3. Efficiency, η = OP/IP x100

OBSERVATION:

Effective Break Drum diameter =

Constant 'K' Value = 1.4863×10^{-2}

Weight of rope and hanger =

Specific Weight of Water, $\rho = 9.81$ kN/m^3

Sl. No.	Inlet Pressure P (kg/cm^2)	Venturimeter Pressure Gauge Readings		Speed of the turbine N (rpm)	Weight on hanger W1(kg)	Spring Balance Reading W2(kg)
		P1 (kg/cm^2)	P2 (kg/cm^2)			
1.						
2.						
3.						
4.						
5.						

Sl. No.	Venturimeter head h(m)	Net Load N (kg)	Discharge Q (m^3/s)	Input Power I/P	Output Power O/P	Efficiency η (%)
1.						
2.						
3.						
4.						
5.						

1. Input Total Head, H = Pressure Gauge Reading (P) in kg/cm^2x10 m
2. Venturimeter Head, h = (P1 – P2)x10 m
3. Theoretical discharge $Q = K\sqrt{h}$
4. Input Power IP = ρxQxH kW
5. Torque (T) = ((W1 + Weight of rope and hanger) – W2)x D/2 x 9.81 N
6. Turbine Output, $OP = \frac{2\Pi NT}{60000}$ kW
7. Efficiency, η = OP/IP x100

GRAPH:

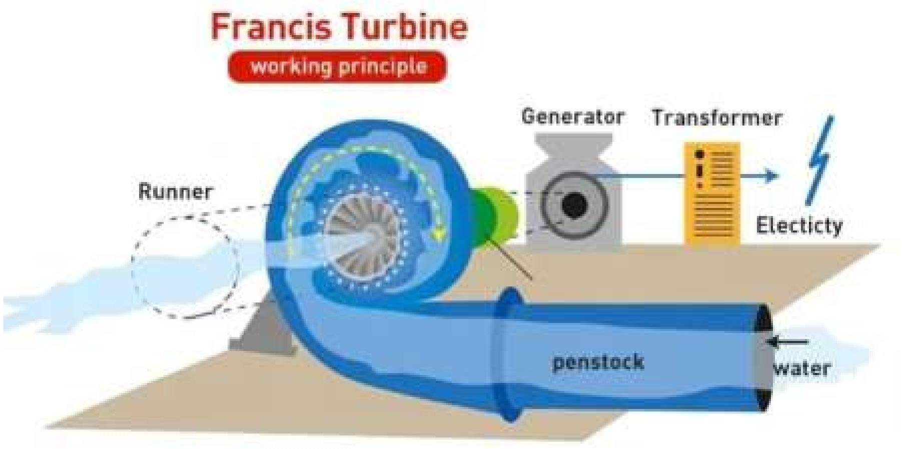
1. Plot a graph between Qact vs Input power and Output power
2. Plot a graph between Qact vs Efficiency

RESULT:

The efficiency of Francis Turbine, η =

PRACTICAL APPLICATIONS

Francis turbine is the most widely used turbine in hydro-power plants to generate electricity. Mixed flow turbine is also used in irrigation water pumping sets to pump water from ground for irrigation. It is efficient over a wide range of water head and flow rate. Francis turbine covers a wide range of heads, from 20 to 700 m, and its output varies from a few kilowatts to 200 megawatts. This possibility, in addition to its high efficiency, has made the Francis turbine the most widely used turbine in the world.



EXPERIMENT VIDEO LINKS

https://www.youtube.com/watch?v=r4EBCorqKNI

https://www.youtube.com/watch?v=R171zuPqa3w

EXPERIMENT NO: 12

PERFORMANCE CHARACTERISTICS OF KAPLAN TURBINE

OBJECTIVE:

To conduct performance test on Kaplan turbine and to draw characteristic curves.

OUTCOME:

The student will be able to verify the efficiency of Kaplan turbine from the experiment.

SCOPE:

The knowledge on working principle & efficiency of Kaplan turbine used in hydro electric power plants.

APPARATUS:

Kaplan turbine test rig, tachometer.

EXPERIMENTAL SETUP:

Kaplan Turbine works on the principle of axial flow reaction. In axial flow turbines, the water flows through the runner along the direction parallel to the axis of rotation of the runner. The water at the inlet of the turbine possesses both kinetic energy as well as pressure energy for effective rotation the blades in a hydro-power station.

Fig 12.1. Longitudinal Section View of Kaplan Turbine Fig 12.2. Top Sectional View of Runner Casing

PROCEDURE:

1. Close the inlet valve and prime the pump.
2. Start the pump, gradually open the gate valve while monitoring the inlet pressure to the turbine, and set it to the desired value.
3. Increase the primary load on the break drum say 1 kg, thus secondary load gets increased.
4. Measure the turbine rpm using tachometer.
5. Note the pressure gauge reading at the turbine inlet.
6. Note down the Orifice meter pressure gauge readings P1 and P2.
7. Repeat the experiment by increasing weights on the hanger.

THEORY:

This Kaplan turbine is one of the first three machines to be put into service in the United States. Named for its Austrian inventor, Viktor Kaplan (1876-1934), the turbine was an outstanding innovation, operating with a high, nearly constant efficiency over a wide load range. The Kaplan turbine is an inward flow reaction turbine, which means that the working fluid changes pressure as it moves through the turbine and gives up its energy. The design combines radial and axial features.

The inlet is a scroll-shaped tube that wraps around the turbine's wicket gate. Water is directed tangentially, through the wicket gate, and spirals on to a propeller shaped runner, causing it to spin. Between the scroll casing and the runner, the water turns through right angle into the axial direction and passes through the runner and thus rotating the runner shaft. The runner has four blades which can be turned about their own axis so that the angle of inclination may be adjusted while the turbine is in motion. When runner blade angles are varied, high efficiency can be maintained over wide range of operating conditions. In other words even at part loads, when a low discharge is flowing through the runner, a high efficiency can be attained in case of Kaplan turbine, whereas this provision does not exist in Francis & Propeller turbines where, the runner blade angles are fixed and integral with hub.

The outlet is a specially shaped draft tube that helps decelerate the water and recover kinetic energy. The turbine does not need to be at the lowest point of water flow, as long as the draft tube remains full of water. A higher turbine location, however, increases the suction that is imparted on the turbine blades by the draft tube. The resulting pressure drop may lead to cavitations.

FORMULA:

Input Power IP = ρxQxH kW

2ΠNT

Turbine Output, OP = kW

60000

Efficiency, η = OP/IP x100

OBSERVATION:

Sl.

No. Inlet Pressure P

(kg/cm2) Orifice meter Pressure Gauge Readings Speed of the turbine N (rpm)

Primary Load W1 (kg) Secondary Load

W2 (kg)

P1 (kg/cm2) P2 (kg/cm2)

1.

2.

3.

4.

5.

Sl.

No. Orificemeter head

h (m)

Net Load W (N) Discharge Q (m3/s) Input Power I/P Output Power O/P Efficiency

η (%)

1.

2.

3.

4.

5.

2. Input Total Head, H = Pressure Gauge Reading (P) in kg/cm2x10 m

3. Orifice meter head, h = (P1 – P2)x10m

4. Theoretical discharge Q = a1ao√(2gh)/√(a12-ao2) m3/sec

5. Input Power IP = ρxQxH kW

6. Torque = (W1+Weight of rope and hanger – W2)x D/2 x 9.81 N

7. Turbine Output, OP = 2ΠNT kW

60000

8. Efficiency, η = OP/IP x100

GRAPH:

1. Plot a graph between Qact vs Input power and Output power
2. Plot a graph between Qact vs Efficiency

RESULT:

The efficiency of Kaplan Turbine, η =

PRACTICAL APPLICATIONS

Kaplan turbines are widely used throughout the world for electric power production. They cover the lowest head hydro sites and are especially suited for high flow conditions. Inexpensive micro turbines are manufactured for individual power production with as little as two feet of head. Large Kaplan turbines are individually designed for each site to operate at the highest possible efficiency, typically over 90%. They are very expensive to design, manufacture and install but operate for decades.

EXPERIMENT VIDEO LINKS

https://www.youtube.com/watch?v=KUnEGPRxCb4

https://www.youtube.com/watch?v=P6PZw68eBjY

https://www.youtube.com/watch?v=r4EBCorqKNI

EXPERIMENT NO: 13

PERFORMANCE CHARACTERISTICS OF A SINGLE / MULTI STAGE CENTRIFUGAL PUMP

OBJECTIVE:

To find the efficiency and draw the performance characteristics of Single / Multi Stage Centrifugal pump.

OUTCOME:

The student will be able to verify the efficiency of the single /Multi stage centrifugal pump.

SCOPE:

The knowledge of Single /Multi stage centrifugal pump is used for flow measuring device like agriculture, irrigation and other residential areas.

APPARATUS:

Single and Multistage Centrifugal Pump Test Rig, Stop watch

EXPERIMENTAL SETUP:

The primary difference between single-stage and multistage centrifugal pumps lies in the number of stages (also referred to as impellers) they have. As the name implies, single-stage pumps have only one impeller, whereas multistage pumps have at least two.

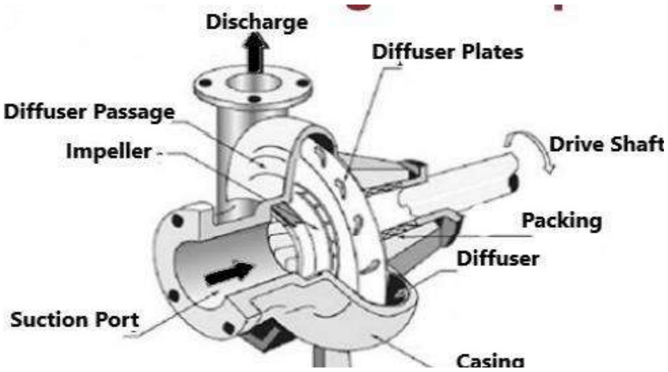


Fig.13 Centrifugal Pump

PROCEDURE:

1. Prime the pump, close the delivery valve and switch on the unit.
2. Set the speed of the pump to a certain desired rated RPM, open the delivery valve and maintain the required delivery head.

Note: a) The pressure gauge reading G

b) The Vacuum gauge reading V

c) Time taken for 5 pulses in the energy meter by means of stopwatch.

3. Close the drain valve and note down the time taken for 10 cm rise of the water level in the collecting tank.

4. Take atleast 4 to 5 sets of readings varying the head from maximum at shutoff to minimum where valve is fully open.

THEORY:

The invention of centrifugal pumps was done by Denis Papin a Physicist in 1689. The centrifugal pump is one of the most used pump in the world currently due to the following reasons.

- Cheap to construct
- Strong
- Delivers fluids faster than other pumps
- Simple

The pump which raises water from lower level to higher level by the action centrifugal force is known as centrifugal pump. . A centrifugal pump consists of essentially an impeller rotating inside the casing. The impeller has a number of curved vanes. Due to the centrifugal head imposed by the rotation of impeller, the fluid enters axially through the middle portion of the pump call the eye, after which it encounters the rotating blades. It acquires tangential and radial velocity by the momentum transfer with impeller blades and acquires additional radial velocity by centrifugal force. Thus water is lifted to higher locations with the acquired energy.

OBSERVATION:

S. No.	Pressure gauge reading (G) kg/cm^2	Vacuum gauge reading (V) mm of Hg	Time required for 5 pulses of energy meter (t) sec	Time required for 10 cm rise of water level (t) sec
1.				
2.				
3.				
4.				
5.				

1) Actual Discharge (Qact) = AH/t Where, A= Area of tank

h= Rise of water level considered

t= Time required for rise

2) Pressure Head, G = Pressure Gauge reading x 10 Vacuum Head, V= (mm of Hg x13.6)/1000

Datum Head, X = 0m

Total Head (H) = G+V+X

3) Output power of pump (B.P) =W*Qact*H

Where, W= Equivalent weight of water (9.81 kN/m3) Qact = Actual Discharge

H = Total head

4) Input power = X x 3600 x 0.6 / C x T kW

Where, X = No.of revolutions of energy meter disc (say 5 Rev) T = Time for energy meter revolutions disc in sec

C = Energy meter constant

5) Efficiency = OP/IP x 100

a) Multi stage centrifugal pump:

a) Multi stage centrifugal pump:

S. No.	Pressure gauge reading (G) kg/cm^2	Vacuum gauge reading (V) mm of Hg	Time required for 5 pulses of energy meter (t) sec	Time required for 10 cm rise of water level (t) sec
1.				
2.				
3.				
4.				
5.				

S. No.	Actual Discharge (Qact)m^3/sec	Total head (H) meters of water	Output power of pump (O.P) kW	Input power of pump (I.P) kW	Efficiency of the pump (η) %
1.					
2.					
3.					
4.					
5.					

1) Actual Discharge (Qact) = AH/t Where, A= Area of tank

h= Rise of water level considered

t= Time required for rise

2) Pressure Head, G = Pressure Gauge reading x 10 Vacuum Head, V= (mm of Hg x13.6)/1000

Datum Head, X = 0m

Total Head (H) = G+V+X

3) Output power of pump (B.P) =W*Qact*H

Where, W= Equivalent weight of water (9.81 kN/m3) Qact = Actual Discharge

H = Total head

4) Input power = X x 3600 x 0.6 / C x T kW

Where, X = No.of revolutions of energy meter disc (say 5 Rev) T = Time for energy meter revolutions disc in sec

C = Energy meter constant

2) Efficiency = OP/IP x 100

GRAPH:

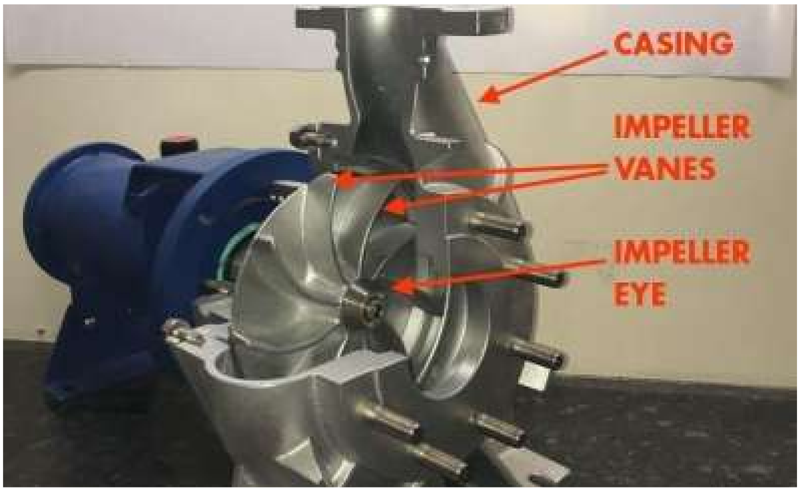
1. Plot a graph between Qact vs Input power and Output power
2. Plot a graph between Qact vs Efficiency

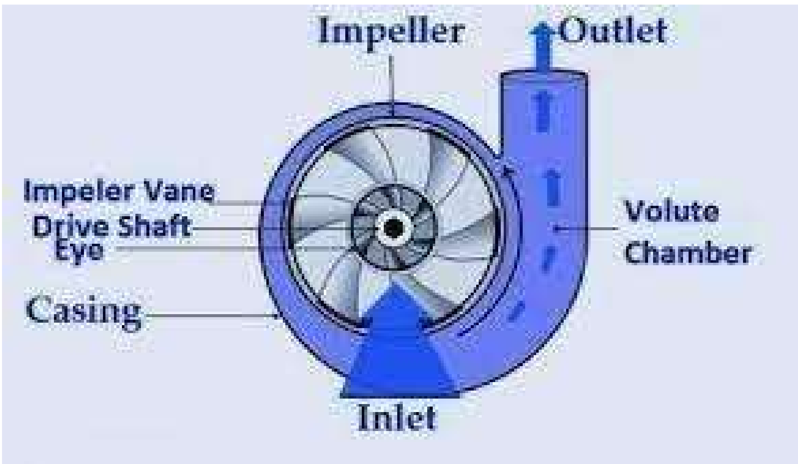
RESULT:

1. The efficiency of the single- stage centrifugal pump is =
2. The efficiency of the multi- stage centrifugal pump is =

PRACTICAL APPLICATIONS

A centrifugal pump containing two or more impellers is called a multistage centrifugal pump. For higher pressures at the outlet, impellers can be connected in series. For higher flow output, impellers can be connected in parallel. A common application of the multistage centrifugal pump is the boiler feed water pump. Centrifugal pumps are the most popular choice for fluid movement makes them a strong contender for many applications and as mentioned previously; they are used across numerous industries. Supplying water, boosting pressure, pumping water for domestic requirements, assisting fire protection systems, hot water circulation, sewage drainage and regulating boiler water are among the most common applications. Outlined below are some of the major sectors that make use of these pumps.





EXPERIMENT VIDEO LINKS

https://www.youtube.com/watch?v=6iENU-Pp3Q0

https://www.youtube.com/watch?v=8rhSzpSh2LE

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