CHAPTER 9: FLUID MECHANICS PRINCIPLES

9.1 Introduction to fluid mechanics

Fluid mechanic principles entails the application of principles of mechanics of fluids and the effects of forces to solve problems relating to changes in pressure, velocity, temperature and density as they affect operation/ functionality of mechanical systems. Fluid mechanic principles are widely applied in various engineering industries e.g. automobile industry in the design and operation of hydraulic systems, tyres and general brake system. This unit of competency covers flow of fluids, effects of forces, fluid dimensional analysis, and operation of fluid systems. The primary training resources in this course include scientific calculators, standalone hydraulic brake system, relevant stationeries, complete pump system, standalone tire suspension units, models of aero foils, boiler system, and steam water line circuit. Upon the completion of this unit, a trainee should be competent to troubleshoot mishaps, calculate the flow rates of fluid in various systems, and calculate effects of forces in mechanical systems. This course prepares a trainee to pursue fluid mechanics as a career in the field of mechanical engineering/manufacturing.

9.2 Performance Standard

The trainee should be able to; identify, formulate, and solve engineering problems including: Measure flow rates and calculate losses in various mechanical systems as per standard principles of operations, measure the effects of various types of forces in fluid systems as per standard principles of operations, perform experiments to demonstrate application of dimensional analysis principles as standard operating parameters, and operate hydraulic mechanical systems as per standard operating procedures.

9.3 Learning Outcome

9.3.1 List of Learning Outcomes

a. Understand the flow of fluids
b. Demonstrate knowledge in viscous flow
c. Perform the dimensional analysis
d. Operate fluid pumps

9.3.1.1 Learning Outcome: No.1 Understand the flow of fluids

Learning Activities

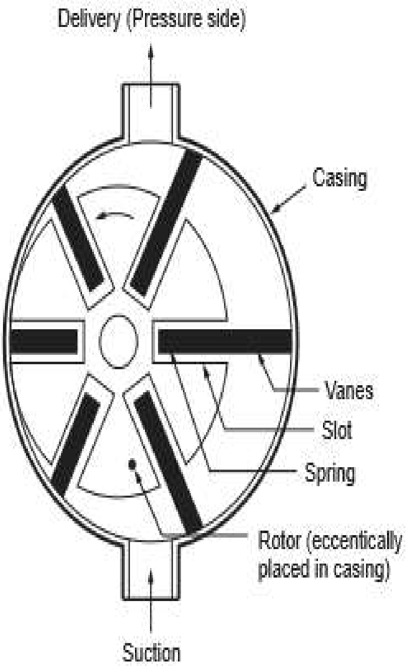
<table>
<tr><th colspan="2">Learning Outcome No 1: Understand the flow of fluids</th></tr>
<tr><th>Learning Activities</th><th>Special Instructions</th></tr>
<tr><td>


Figure 16.6.3 Vane pump
Activity 1: calculate waste/losses of fluid in a leaking pump
Obtain the measuring instruments
Check accuracy and calibrate measuring instruments
Measure flow rates of fluids at different specific points
Perform calculations of the fluid losses
</td><td>Provide manufacturer’s manuals for the specific measuring instrument</td></tr>
</table>

Information Sheet: 9.3.1.1

Introduction

Fluid mechanic is the study of the behavior of liquids and gases, and particularly the forces that they produce. There are five relationships that are most useful in fluid mechanics problems: kinematic, stress, conservation, regulating, and constitutive.

Definition of key terms

A fluid- is a material that continuously deforms under a constant load

Kinematics-is the study of motion without regard to force. This is usually the first step in the analysis or design of a mechanism
Dynamics-is the combination of kinetics and kinematics in fluids
Conservation forces-is a force with the property that the work done in moving a particle between two points is independent of the path it takes. It is dependent only on the position of the object. If a force is conservative, it is possible to assign a numerical value for the potential at any point. When an object moves from one location to another, the force changes the potential energy of the object by an amount that does not depend on the path taken. Gravity and spring forces are examples of conservative forces.
Non-conservative forces transfer energy from the back to the potential energy of the system to regain it during reverse motion. Instead, they transfer the energy from the system in an energy form which cannot be used by the force to transfer it back to the object in motion e.g friction.

PE=mgh
Newton's laws of motion- these are three physical laws that, together, laid the foundation for classical mechanics. They describe the relationship between a body and the forces acting upon it, and its motion in response to those forces. The three laws are summarized as follows:
First law: in an inertial frame of reference, an object either remains at rest or continues to move at constant velocity, unless acted upon by a force.
Second law: in an inertial frame of reference, the vector sum of the forces **F** on an object is equal to the mass m of that object multiplied by the acceleration **a** of the object: **F**=ma. (assumed m is constant)
Third law: when one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction on the first body

Reynolds (Re) number. This dimensionless number characterizes the nature of a fluid flow and relative contribution of inertia and viscous dissipation. In practice, flows with the same Reynolds number will display the same properties. For an object of typical length L moving at typical velocity U, in a fluid of dynamic viscosity µ and density Þ, the Reynolds number is

Re=ULÞ/µ

It also reads Re=UL/v using the kinematic viscosity v=µ/Þ

Bernoulli's principle states that an increase in the speed of a fluid occurs simultaneously with a decrease in pressure or a decrease in fluid's potential energy. This principle can be applied to various types of fluid flow, resulting in various forms of Bernoulli's equation.
Derivations of the Bernoulli's equation
Bernoulli's equation for incompressible fluids ;
can be derived by either integrating Newtonian's second law of motion or by applying the law of conservation of energy between two sections along a streamline, ignoring viscosity, compressibility, and thermal effects.
Derivation through integrating Newton's second law of motion

By first ignoring gravity and considering constrictions and expansions in pipes that are otherwise straight, as seen in Venturi effect.
Let the x axis be directed down the axis of the pipe.
Define a parcel of fluid moving through a pipe with cross-section area A, the length of the parcel is dx, and the volume of the parcel A dv. If mass density is Þ, the mass of the parcel is density multiplied by its volume m=ÞAdx. The change in pressure over distance dx is dp and flow velocity v=dx/dt .the change in pressure over distance dx is dp and flow velocity v=dx/dt

Apply Newton's second law of motion (force = mass × acceleration) and recognizing that the effective force on the parcel of fluid is –Adp. If pressure decreases along /the length of the pipe, dp is negative but the force resulting in flow is positive along the x axis.

m dv/dt=F
ÞA.dv/dt =-Adp
Þdv/dt=-dp/dx

In steady flow the velocity field is constant with respect to time, v=v(x)=v[x(t)], so v itself is not directly a function of time t. it is only when the parcel moves through x that the cross sectional area changes: v depends on t the cross-sectional position x(t)

Dv/dt=dv/dx.dx/dt
=dv/dx.v
$=d/dx(v^2/2)$

With density Þ constant, the equation of motion can be written as

$d/dx\ (Þ.v^2/2+p)=0$

by intergrating with respect to x

V2/2+p/Þ=C

Where C is a constant, referred to as the Bernoulli's constant.

Illustrations of Bernoulli's Viscous flow: Newton's law of viscosity. Types of fluids. Effect of temperature on viscosity. Effect of pressure on viscosity. Surface tension and capillaries.

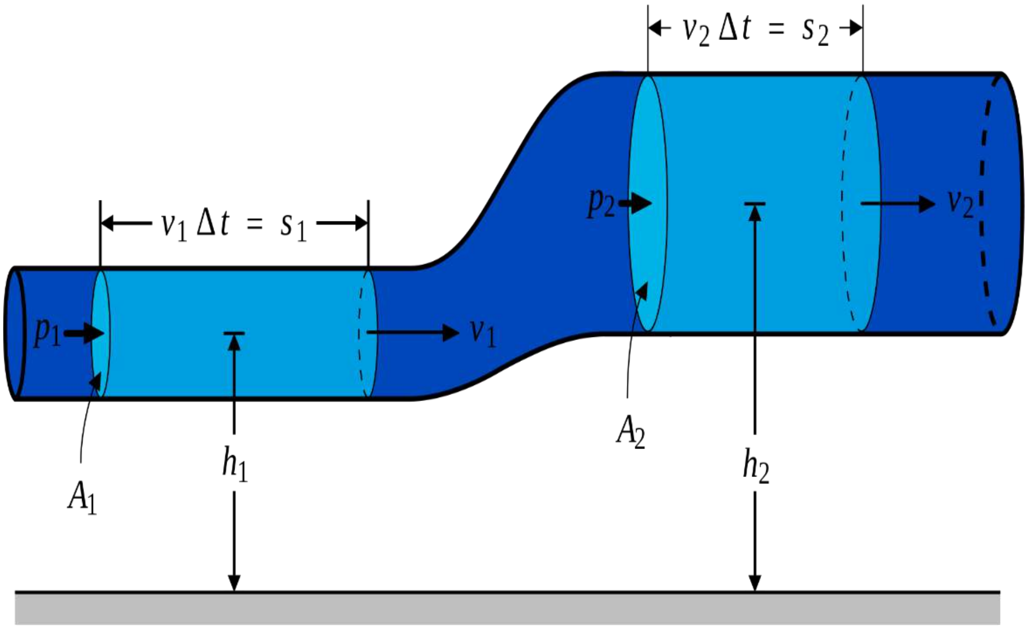


Figure 74: Bernoulli's Principles Source Douglas (2011)
Viscous flow equations. Bernoulli's equation

Dimensional analysis: introduction. Dimensional homogeneity. Fundamental dimensions. Methods of dimensional analysis. Limitations of dimensional analysis. Model analysis. Dimensionless numbers and their significance. Reynolds model law

Operate fluid pumps: classification of pumps. Comparison of rotodynamic and reciprocating pumps. Characteristics of pumps. Description and principle of operation. Flow rate and power. Pumps equations.

For further study refer to fluid mechanics and machinery (second edition) by Kothandaraman C.P or fluid mechanics and hydraulic principle by Rajput Er. R. K

Self-Assessment (assessment questions/evaluation question for the learning

1. In which method of fluid flow analysis do we describe the motion parameters at a point?
   a) Langragian method
   b) Eulerian Method
   c) Control volume analysis
   d) None of the mentioned

2. Which method is most commonly used in fluid mechanics for analysis?
   a) Langragian method
   b) Eulerian Method
   c) Control volume analysis
   d) None of the mentioned

3. In unsteady flow, the flow parameters change with respect to position.
   a) True
   b) False

4. Uniform flow is defined as the type of flow in which acceleration is zero i.e velocity is constant.
   a) True
   b) False

5. In laminar flow fluid particles flow along a streamline.
   a) True
   b) False

6. Eddies formed in the turbulent flow are major cause of the energy loss in the turbulent flow.
   a) True
   b) False

7. For compressible flow specific gravity remains same.
   a) True
   b) False

8. When the flow particles flow in zigzag manner and rotate about their own axis it is what type of flow?
   a) Turbulent flow
   b) errotational flow
   c) Rotational flow
   d) None of the mentioned

9. If the velocity is function of two space coordinates along with time then fluid flow is three dimensional in nature.
   a) True
   b) False

10. What is unit for flow rate for gases?
   a) m3/s
   b) litres/s
   c) cm3/s

d) kgf/s

11. If 5 m3 of certain oil weighs 45 kN calculate the specific weight, specific gravity and mass density of the oil. Mass density=9/0.98, =0.917

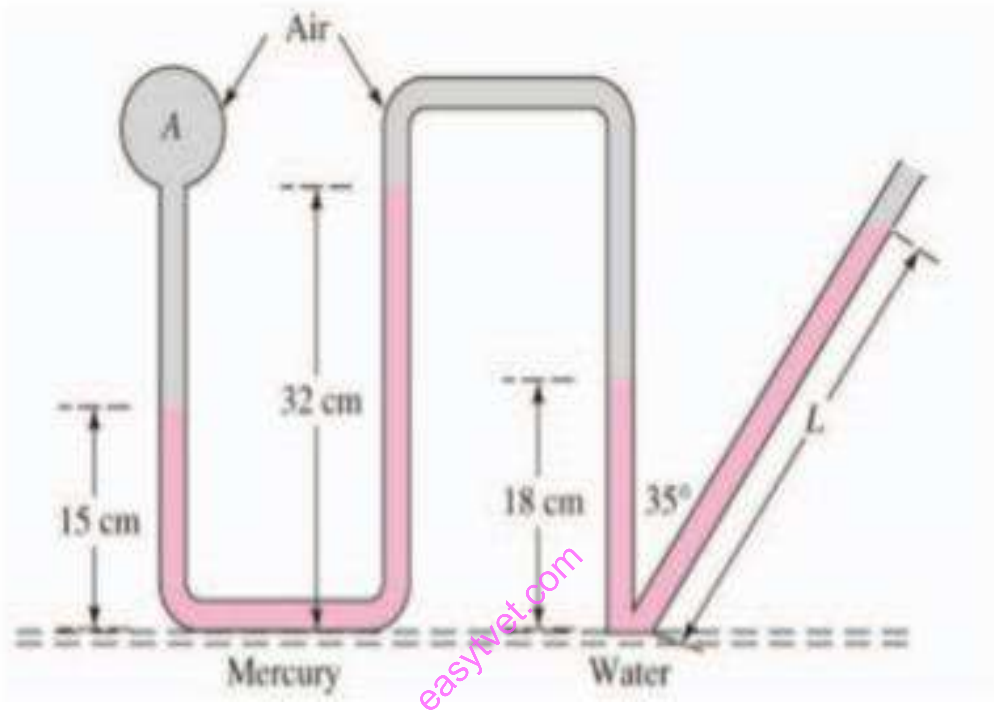


Figure *75:* Hydrostatics. (Douglas. 2000)

12. The system above is open to atmospheric pressure (105 Pa) on its right side. a) If L=120 cm, what is the air pressure in container A? b) Conversely, if pA = 135 kPa, what is the length L? Assume the density of water and mercury are 1,000 kg/m3 and 13,560 kg/m3, respectively.

13. Some of you may have noticed that dams are much thicker at their bottom (e.g. see prob. 2). For example, in the Hoover dam example we considered in the class the thickness of the dam at the top is about 45 feet while the thickness at the bottom is about 660 feet. Can you explain why dams are built that way?
14. A 10-kg hollow copper ball, a 10-kg solid copper ball and a 10-kg solid copper cube are submerged in a liquid. Will the buoyancy forces acting on these three bodies be the same or different? Explain and justify your answer quantitatively

15. Conduct an experiment to determine fluid flow
16. Measure Flow rate in pipes
17. Determine Losses in pipes
18. Determine Causes of losses in pipes

19. Apply Flow losses equations in problem solving

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Fluid mechanics principle textbook
- Models and charts
- Stand-alone brake system
- Pumps
- Aero foil

References (APA)

Rajput .RK., 1998, Fluid mechanics and Hydraulic Machinery, by S.Chand and company ltd, Ram Nagar, New Delhi-110055

Graebel, W.P. Advanced Fluid Mechanics, University of Michigan

Buddhi. N. Hewakandamby, 2012, A first course in fluids mechanics for engineers, VENTUS,

Internet www/htts.fluidmechanics.co.ke

Douglas, D. F (1992) Solution of Problems in Fluid Mechanics, Prt 1 The pitman

9.3.1.2 Learning Outcome No.2 Demonstrate knowledge in viscous flow

Learning activities

Learning Outcome No 2: Demonstrate knowledge in viscous flow	
Learning Activities	**Special Instructions**
Measure the viscosity of different liquid Using the following Tools and equipment may include: ruler stopwatch graduated cylinder marble or steel ball calculators Internet access, to research viscosities for one worksheet question thick, somewhat clear household fluids, such as motor oil, corn syrup, pancake syrup, shampoo, liquid soap (perhaps a different fluid for each 1-2 groups), enough of each liquid to fill a graduated cylinder for each group that tests it scale	Provide manufacturer's manuals for the specific measuring instrument -provide viscosity activity worksheet

Information Sheet: 9.3.1.2

Introduction

Viscous flow entails the application of fluid flow principles to solve problems of fluid forces on projectiles. Competencies in viscous flow principles are in great demand in the field of mechanical engineering, military, automobile industries, airplane construction, construction of marine vessels, and in the field medical engineering. to measure and calculate the internal forces in fluid like friction which causes the resistance to flow . This property of fluid is known as viscosity which is primarily due to cohesion and molecular momentum exchange between fluid layers. Viscous flow play a major in industries in the practical processes like polymer processing which determines the success of the operation, production of lubricating fluids, melting of metals, leak testing packages and testing the rate of flow in pipes. This learning outcome covers the Newtonian's law of viscosity, types of fluids and the effects of temperature and pressure on viscosity. The primary training resources in this outcome include scientific calculators, viscous flow air meters, and horse pipe and air compressor machine. Upon the completion of this outcome, the trainee should be competent in understanding how fluids behave under various conditions to help him/her to select the optimal fluids to operate in devices or to design devices that are able to successfully operate in environments that contain fluids and apply the viscous flow equations in problem solving involving leakages in pipes.

These outcome describes how a fluid resists forces. Fluids with low viscosity have a low resistance to flow, and therefore the molecules flow quickly and are easy to move through. Fluids with high viscosity flow more slowly and are harder to move through. One example of a high-viscosity fluid is honey.

When an object free falls through a fluid, at some point the force due to gravity is balanced by the resistance to shear by the fluid. This is called **terminal velocity,** and is the point at which the falling object maintains a constant velocity.

Trainee to watch video; https://www.youtube.com/

Definition of terms

Shear - A type of force that occurs when two objects slide parallel to one another
Terminal velocity - The point at which the force exerted by gravity on a falling object is equaled by a fluid's resistance to that force
Viscosity – is the ability of fluid to resist forces
Further reading; also trainee to define the following terms,
Kinematics, strain, stress, torque, velocity
Reference www.teachingengineering.org/lesson

Illustrations of laminar flow

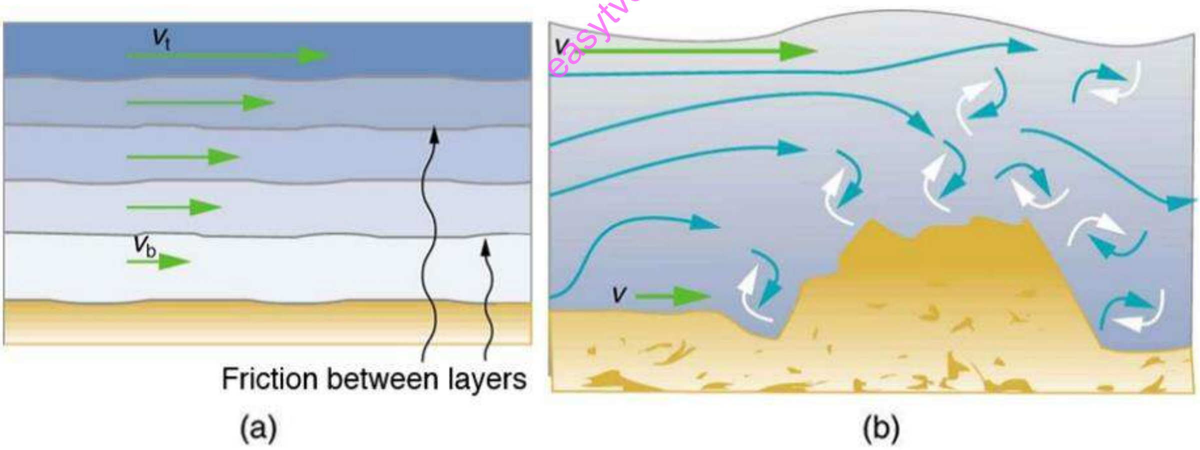


Figure 76: Laminar Flow Source, Rajput (2013)

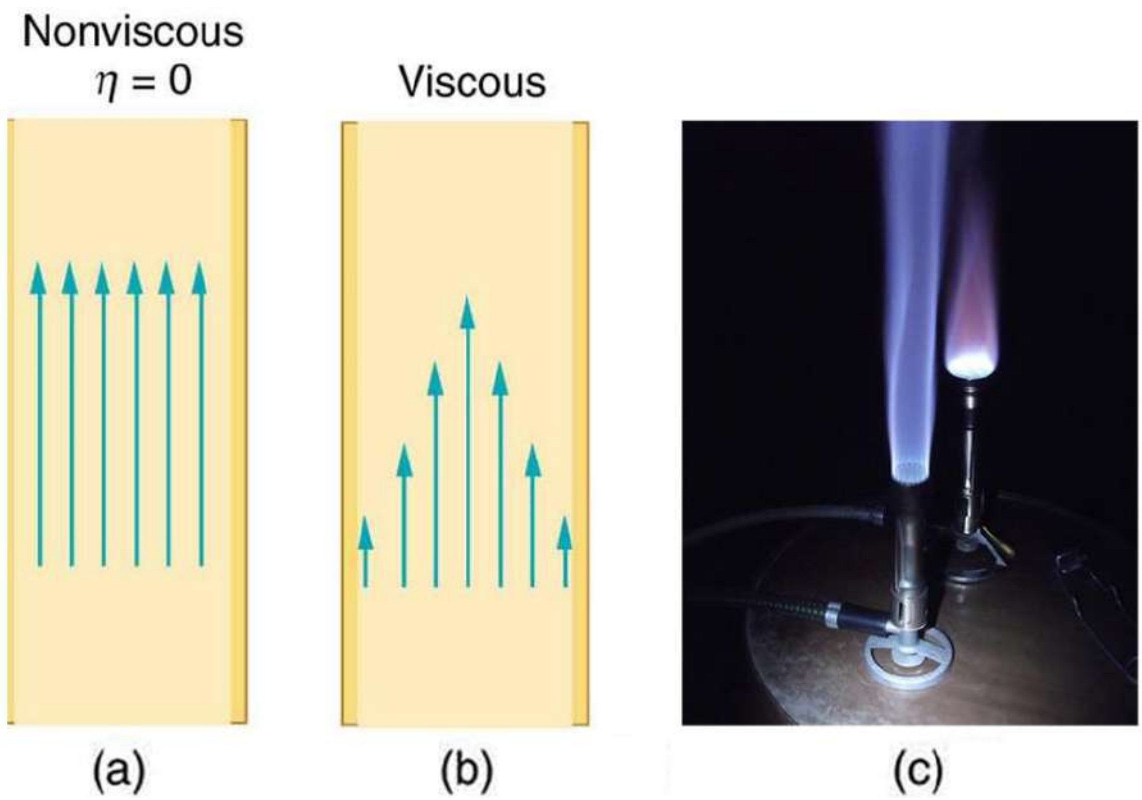


Figure 77: Non-viscous Vs Viscous

Source Douglas (2000)

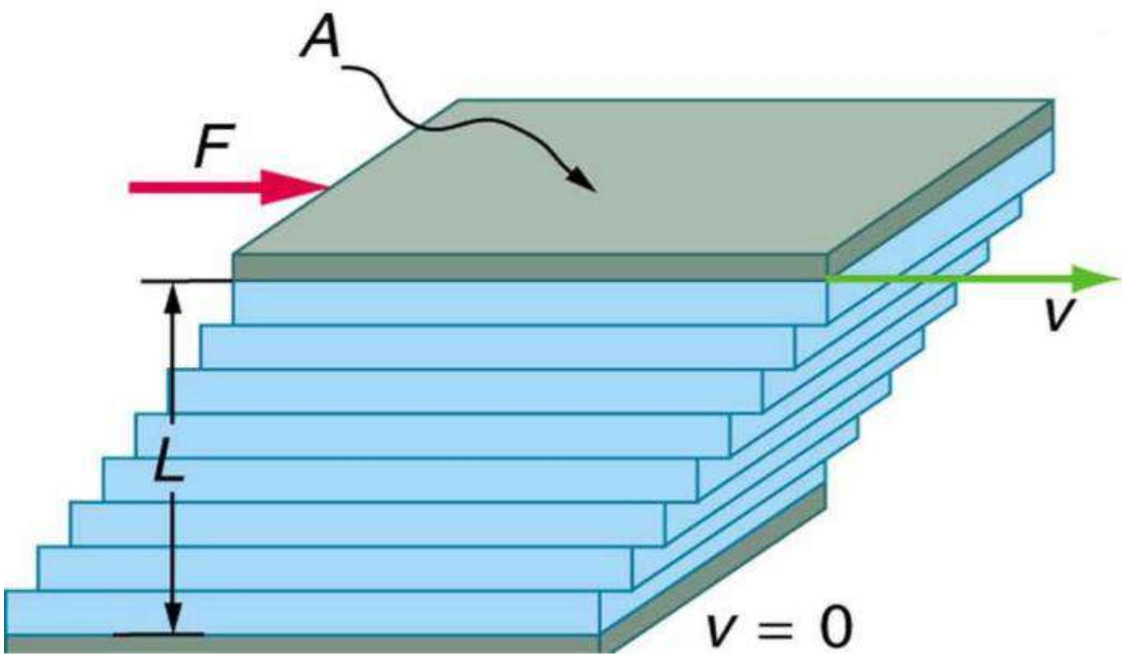


Figure 78: Laminar Flow Adapted from Douglas, 2000

The graphic shows laminar flow of fluid between two plates of area . The bottom plate is fixed. When the top plate is pushed to the right, it drags the fluid along with it.

Procedure

Before the Activity

Gather materials and make copies of the viscosity activity worksheet.

Be sure the ball sinks slowly enough in all of the fluids that a velocity measurement can be obtained. If the ball falls too quickly, it is hard to accurately start and stop the stopwatch.

Divide the class into groups of three students each. Hand out the worksheets.

With the Students

Have each group choose a fluid to measure the viscosity of (or assign each group a fluid).

Have students calculate the density of the fluid.

Weigh the empty graduated cylinder.

Fill the cylinder with fluid, and record the volume.

Weigh the full graduated cylinder. Subtract the mass of the empty graduated cylinder to determine the mass of the fluid.

The density of the fluid is the mass over the volume.

$$\rho_f = \frac{mass\ of\ fluid\ [kg]}{volume\ of\ fluid\ [cm^3]}$$

Note: 1 cm^3=1 ml.

Have students measure the density of the sphere.

Measure the radius of the ball. Record as r [cm].

Calculate the volume of the sphere: $Vol_s = \frac{4}{3}\pi r^3$

Alternatively, place the sphere in a graduated cylinder half filled with water; the displacement of the water is equal to the volume of the sphere.

Weigh the sphere, and calculate the density:

$$\rho_s = \frac{mass\ of\ sphere\ [kg]}{volume\ of\ sphere\ [cm^3]}$$

Have students drop the ball into the fluid, timing the ball as it falls a measured distance.

(Note: Ideally students would wait for the ball to reach a constant velocity, however for this activity we assume the ball reaches terminal velocity very quickly, so that students can measure the time from when the ball enters the fluid until it reaches the cylinder bottom. For less-viscous, "thinner," fluids, this may be very quick).

Calculate the velocity of the ball falling through the fluid.

$$V_s = \frac{distance\ ball\ drops\ [cm]}{length\ of\ time\ for\ ball\ to\ drop\ [s]}$$

Calculate the viscosity of the fluid using the following equation,

$$\mu = \frac{4}{9}\frac{r^2 g(\rho_s - \rho_f)}{V_s}$$

Where g is acceleration due to gravity (981 [cm/s^2]). The answer should be in units of kg/cm s, or mPa-s. For comparison, the viscosity of water is approximately 1 mPa-s.

For accuracy, have students repeat the experiment and calculate an average viscosity.

Have groups share, compare and discuss their results as a class by either writing the results in a table on the board or on a class overhead projector.

Content;

Viscous flow: Newton's law of viscosity. Types of fluids. Effect of temperature on viscosity. Effect of pressure on viscosity. Surface tension and capillaries. Viscous flow equations. Bernoulli's equation. Laminar and turbulent flow.

For further study refer to fluid mechanics and machinery **(**second edition) by Kothandaraman C.P or fluid mechanics and hydraulic principle by Rajput Er. R. K

Conclusion

Trainee assignment

Considering the fluids available for activity testing, ask students to estimate which liquid they think will have the highest viscosity. Which will have the lowest? Write their predictions.

Trainer

Have students share and discuss their measured/calculated viscosities with the class. Compare and discuss the class results with the predictions made before beginning the activity.

Check on the safety as per the work place procedure

Self-Assessment

1. Which among the following does not depend on the friction factor?
   a) Pipe diameter
   b) Fluid density
   c) Viscosity
   d) Weight

2. Which among the following is the formula for friction factor (f)?
   a) f = 0.079*Re0.25
   b) f = 0.079/Re0.25
   c) f = 0.079/Re0.5
   d) f = 0.079*Re0.5

3. How do we calculate losses for a larger range of Reynolds number?
   a) Moody chart
   b) Bar chart
   c) Scatter chart
   d) Column histogram

4. Darcy- Weisbach equation gives relation between___________
   a) Pressure and temperature
   b) Mass, volume and pressure
   c) Head loss and pressure loss

d) Pressure loss only

5. Which among the following is formula for friction factor of circular pipes?
   a) 16/Re
   b) 64/Re
   c) Re/16
   d) Re/64

6. Loss of head due to friction is ___________
   a) Directly proportional to hydraulic radius
   b) Inversely proportional to velocity
   c) Inversely proportional to hydraulic radius
   d) Directly proportional to gravitational constant

7. The formula for hydraulic diameter is_______
   a) 4A/P
   b) 4AP
   c) 4AV
   d) 4V

8. What are the reasons for minor head loses in a pipe?
   a) Friction
   b) Heat
   c) Valves and bends
   d) Temperature

9. What happens to the head loss when the flow rate is doubled?
   a) Doubles
   b) Same
   c) Triples
   d) Four times

10. Relative roughness is__________
    a) ϵ/D
    b) ϵ*D
    c) ϵ/Dm
    d) ϵgD

11. A plate 0.05 mm distant from a fixed plate moves at 1.2 m/s and requires a force of 2.2 N/m2 to maintain this speed. Find the viscosity of the fluid between the plates. (Answer 9.16x10-4 poise)

12. Explain viscous flow between parallel surfaces

13. Derive and apply viscous flow equations between parallel surfaces
14. Derive and apply viscous flow equations in circular pipes

Tools, Equipment, Supplies and Materials for the specific learning outcome

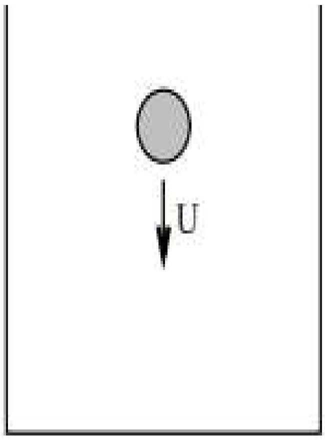
- ruler
- stopwatch
- graduated cylinder
- marble or steel ball
- Internet access, to research viscosities for one worksheet question
- scale

References (APA)

Rajput,.RK. 1998, Fluid mechanics and Hydraulic Machinery, by S.Chand and company ltd, Ram Nagar, New Delhi-110055
Graebel, W.P. Advanced Fluid Mechanics, University of Michigan
Buddhi. N. Hewakandamby, 2012, A first course in fluids mechanics for engineers, VENTUS,
Internet www/htts.fluidmechanics.co.ke
Douglas, D. F (1992) Solution of Problems in Fluid Mechanics, Prt 1 The pitman

9.3.1.3 Learning Outcome No.3 Perform the dimensional analysis

Learning Activities

Learning Outcome No.3: Perform the dimensional analysis	
Learning Activities	**Special Instructions**
sphere falling in a tank containing a liquid  Tools and equipment required Transparent measuring cylinder A sphere Liquid Micrometer screw gauge Activity; Take cylinder of known diameter Pour liquid in it Drop sphere of different radius Note the velocity of sphere	-Provide manufacturer's manuals for the specific measuring instrument

Information Sheet:9.3.1.3

Introduction

Dimensional analysis is a very powerful tool used in fluid mechanics to predict physical parameters that influence the flow in fluid mechanics, heat transfer in thermodynamics, and mechanical operations of machine systems and to design unit operations in engineering processes so as to obtain the relationship between the average transfer rates (mass, heat, momentum) and the applied forces that are used to drive the transport (concentration difference, temperature difference, velocity difference) . It reduces the number of variables in the problem by combining dimensional variables to form non-dimensional parameters so as to obtain a functional relationship among the various variables involved in terms of non-dimensional parameters. This elements covers the dimensional homogeneity, methods of dimensional analysis, limitations of dimensional analysis and forces influencing hydraulic phenomena. The primary resources in this element include measuring tools calibrated according to ISO standards, scientific calculators, SMP tables and portable objects. Upon the completion of this unit, a trainee should be competent to troubleshoot mishaps, calculate the flow rates of fluid in various systems, and calculate effects of forces in hydraulic phenomena. This course prepares a trainee to pursue fluid mechanics as a career in the field of mechanical engineering/manufacturing and chemical engineering

These outcome involves the identification of the transport properties that include fluid velocity, heat flux, mass flux, and the material properties which include viscosity, thermal conductivity, specific heat, density, etc. which are relevant to the problem, and list out all these quantities along with their dimensions.

Definition of terms;

The variable; is any quantity including dimensional and non-dimensional constants in a physical situation under investigation.

Dimensional Homogeneity: If an equation truly expresses a proper relationship among variables in a physical process, then it will be dimensionally homogeneous. The equations are correct for any system of units and consequently each group of terms in the equation must have the same dimensional representation. This is also known as the law of dimensional homogeneity.

Dimensional variables: These are the quantities, which actually vary during a given case and can be plotted against each other.

Dimensional constants: These are normally held constant during a given run. But, they may vary from case to case.

Trainee to find the definition of the following terms;

Pure constants

Pi-terms

Further reading;

Fluid mechanics and machinery **(**second edition) by Kothandaraman C. P. or fluid mechanics and hydraulic principle by Rajput, R. K

Experiment; to find the value of critical velocity in pipes by Reynolds experiment

Apparatus

- -Reynolds apparatus consisting of piping system
- -measuring tank
- -differential manometer
- -stop watch

Procedure

Open the supply valve and allow the water to flow through one pipe of which the diameter is measured/ noted.

Connect the two rubber pipe leads from the manometer to pad-locks on the pipe at certain distance apart (distance actually measured).

Admit water through pipe to the rubber leads and adjust the supply of water by the supply valve till a suitable reading is available on the manometer.

Read the loss of head on the manometer. Collect the water discharging from the pipe in the measuring tank and note the rise of water level in tank.

Repeat the experiment at different velocities by varying the rate of flow of water in the pipe and tabulate the readings. Use these results to plot a curve (between hf and v). The point where the graph changes from straight line to curve will give the critical velocity.

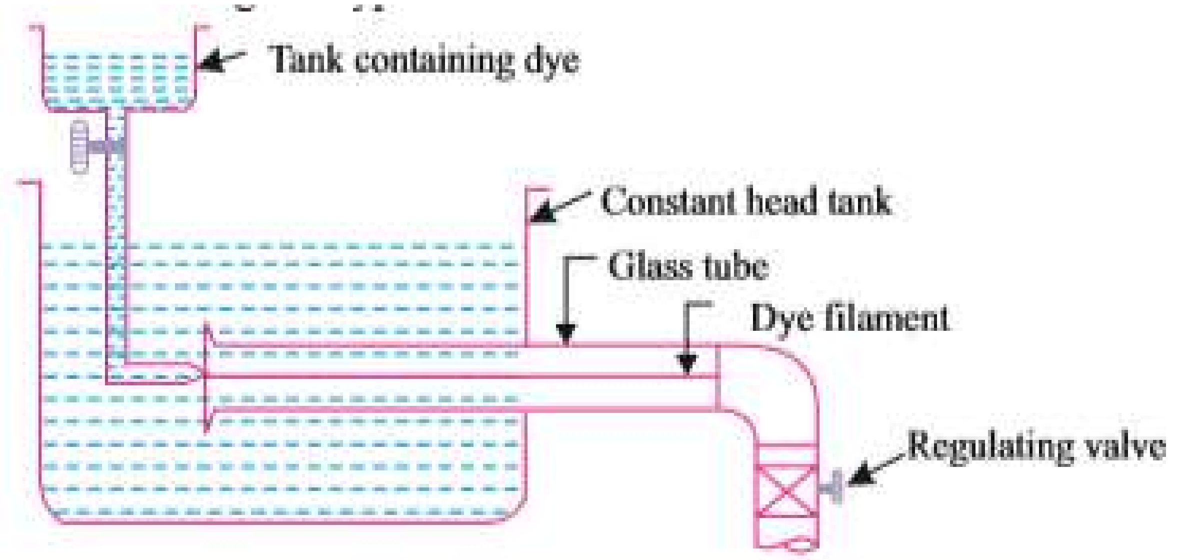


Fig. 9. Reynolds apparatus.

Dimensionless numbers and their significance. Reynolds model law

Figure 79: Reynolds apparatus- (Source, Rajput 1998)

For further study refer to fluid mechanics and machinery (second edition) by Kothandaraman C.P or fluid mechanics and hydraulic principle by Rajput. R. K

Conclusion

Trainee to do the assignment;

The efficiency η of a fan depends on the density ρ, the dynamic viscosity μ of the fluid, the angular velocity ω, diameter D of the rotor and the discharge Q. Express η in terms of dimensionless parameters.

Trainer

To check whether the assignment is done as per the standards

For further reading fluid mechanics and machinery (second edition) by Kothandaraman C.P or fluid mechanics and hydraulic principle by Rajput. R. K

Self-Assessment

1. Ratio of actual velocity to sonic velocity is known as
   a) Mach number
   b) Peclet number
   c) Reynolds number
   d) Grashof number

2. The value of Prandtl number for air is about
   a) 0.1
   b) 0.4
   c) 0.7
   d) 1.1

3. Let us say Mach number (greater than one), the flow is
   a) Sonic
   b) Subsonic
   c) Supersonic
   d) No flow

4. Free convection heat flow does not depend on
   a) Density
   b) Coefficient of viscosity
   c) Gravitational force

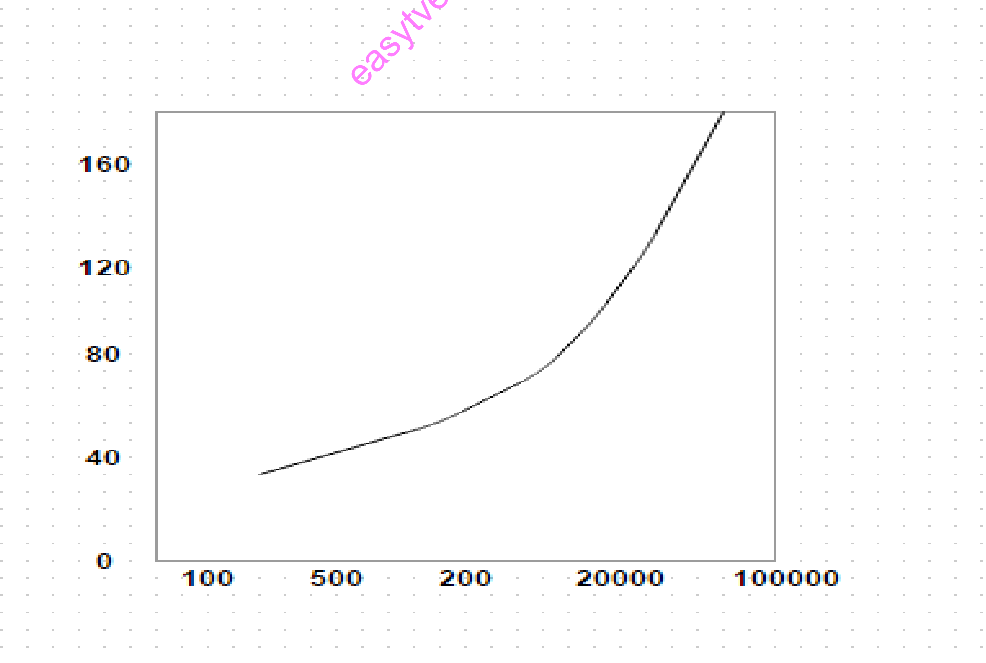
d) Velocity

5. Which dimensionless number has a significant role in forced convection?
   a) Prandtl number
   b) Peclet number
   c) Mach number
   d) Reynolds number

6. The non-dimensional parameter known as Stanton number is used in
   a) Forced convection heat transfer
   b) Condensation heat transfer
   c) Natural convection heat transfer
   d) Unsteady state heat transfer

7. The Prandtl number will be lowest for
   a) Water
   b) Liquid metal
   c) Lube oil
   d) Aqueous solution

8. The dimensionless parameter l 3 p 2 β g d t/μ 2 is referred to as



a) Stanton number
b) Schmidt number
c) Grashof number
d) Peclet number

Figure depicts the variation of which two numbers?

a) Nusselt number and Reynolds number
b) Stanton number and Reynolds number
c) Peclet number and Grashof number
d) Nusselt number and Stanton number

9. Heat is loss from a 100 mm diameter steam pipe placed horizontally in ambient air at 30 degree Celsius. If the Nusselt number is 25 W/m2 K and thermal conductivity of the air is 0.03 W/m K, then heat transfer coefficient will be
a) 7.5 W/m2 K
b) 16.5 W/m2 K
c) 25 W/m2 K
d) 30 W/m2 K

10. The resistance force R of a supersonic plane during flight can be considered as dependent upon the length of the aircraft l, velocity V, air viscosity μ, air density ρ and bulk modulus of air K. Express the functional relationship between these variables and the resisting force.

11. Explain the concept Dimensional analysis
12. Describe the principle of dimensional homogeneity
13. State the Fundamental dimensions
14. Define dimensional units
15. Identify Physical quantities
16. Apply Dimensional analysis is in problem solving

Tools, Equipment, Supplies and Materials for the specific learning outcome

- measuring tools calibrated according to ISO standards,
- scientific calculators,
- SMP tables and
- portable objects
- Internet
- Reynolds apparatus

References (APA)

Er.RK.Rajput, 1998, Fluid mechanics and Hydraulic Machinery, by S.Chand and company ltd, Ram Nagar, New Delhi-110055

W.P. Graebel, Professor Emeritus, Advanced Fluid Mechanics, University of Michigan

Buddhi. N. Hewakandamby, 2012, A first course in fluids mechanics for engineers, VENTUS,

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Douglas, D. F (1992) Solution of Problems in Fluid Mechanics, Prt 1 The pitman

9.3.1.4 Learning Outcome No 4: Operate fluid pumps

Learning Activities

Learning Outcome No. 4: Operate fluid pumps	
Learning Activities	**Special Instructions**
Experiment; to obtain the performance of a reciprocating pump Apparatus: A single-acting reciprocating pump with all the necessary Components A vacuum gauge and pressure gauge A discharge measurement unit Activity; Place the pump above the liquid Pull the plunger in an outward motion to decrease pressure in the chamber Push back plunger, -it will increase the pressure chamber and the inward pressure of the plunger will then open the discharge valve and release the fluid into the delivery pipe at a high velocity	Provide manufacturer's manuals for the specific measuring instrument -prime the pump to remove the air completely before starting up the pump -after each change in the valve opening let the flow stabilize before taking readings

Information Sheet: 9.3.1.4

Introduction

A pump is a device that provides energy to a fluid in a fluid system by converting the mechanical energy so as to increase the pressure energy or kinetic energy, or both of the fluid. The pump is widely used employed for various tasks which include pumping of oil, lifting of heavy loads, lifting viscous fluids in(paper pulp, muddy and sewage water, oil, sugar and molasses), lubricating the machine parts, exhaustion of latrines, pumping of water from underground sources which is clean and removing water from flooded area to safe life. This elements of competency covers the classification of pumps, comparison of rotor dynamic and reciprocating pumps, characteristics of pumps, description and principle of operation. The primary training resources in this course include scientific calculators, standalone hydraulic brake system, relevant stationeries, complete pump system, pointer gauge, hydraulic wave and hele-shaw apparatus. Upon the completion of this element, a trainee should be competent to troubleshoot mishaps, calculate the flow rates of fluid in various systems, and calculate effects of forces in mechanical systems. This course prepares a trainee to pursue fluid mechanics as a career in the field of mechanical engineering.

Pump is a contrivance which provides energy to a fluid in a fluid system by converting the mechanical energy to increase the pressure energy of the fluid in a system. In pumps flow takes place from the low pressure towards the higher pressure unlike in turbines where flow takes place from the higher pressure side to the low pressure side. Pumps are classified into two broad categories based on the transfer of mechanical energy.

Definition of terms

Head (h) [H] – Head is the expression of the energy content of a liquid in reference to an arbitrary datum. It is expressed in units of energy per unit weight of liquid. The measuring unit for head is meters (feet) of liquid.

Total head (H) [H_{tx}]– This is the measure of energy increase, per unit weight of liquid, imparted to the liquid by the pump, and is the difference between total discharge head and total suction head. This is the head normally specified for pumping applications because the complete characteristics of a system determine the total head required.

Rate of flow [Q] – The rate of flow of a pump is the total volume throughput per unit of time at suction conditions. The term capacity is also used.

Best Efficiency Point (BEP) – The rate of flow and total head at which the pump efficiency is maximum at a given speed and impeller diameter.

Displacement (D) – For a positive displacement pump it is the theoretical volume per revolution of the pump shaft.

Trainee to find what meant by the following terms;

Net Positive Suction Head Available
Net Positive Suction Head Required Net Positive Suction Head
Suction specific speed
Impeller

Further reading; for further study refer to fluid mechanics and machinery (second edition) by Kothandaraman C.P or fluid mechanics and hydraulic principle by Rajput Er. R. K

Illustration

Component Parts of A Centrifugal Pump

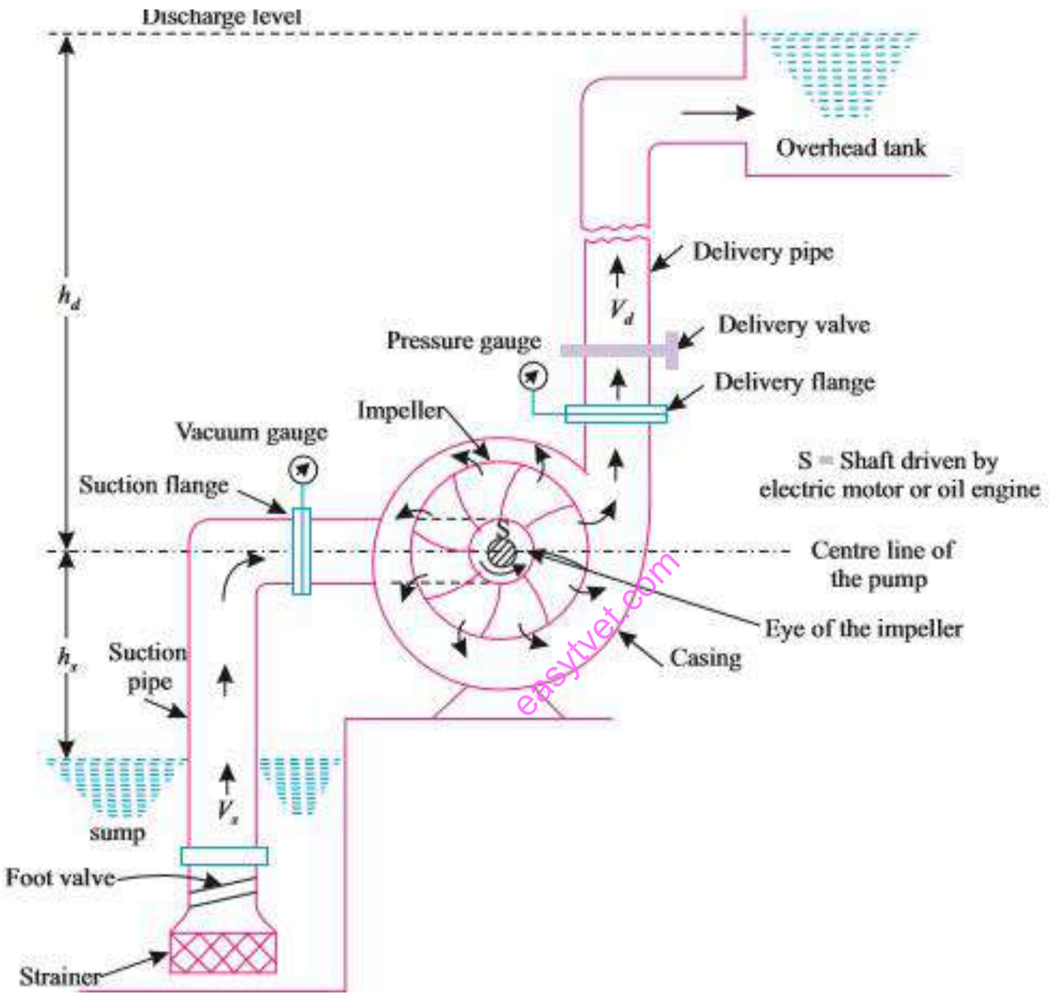

Figure 80: Centrifugal pump. Source: Rajput (1998)

Impeller. It is a wheel (or rotor) with a series of backward curved vanes/ blades mounted on a shaft which is usually coupled to an electric motor.

Casing. It is an airtight chamber surrounding the pump impeller. It contains suction and discharge arrangements, supporting for bearings, and facilitates to house the rotor assembly. It has provision to fix stuffing box and house packing materials which prevent external leakage.

The essential purposes of the casing are:

To guide water to and from the impeller, and

To partially convert the kinetic energy into pressure energy.

Suction pipe- pipe which connects the Centre/eye of the impeller to sump from which liquid is to be lifted. It is provided with a strainer at its lower end to prevent the entry of solid particles, debris etc. into the pup. The lower end of the pipe is also fitted with a non-return foot valve which does not permit the liquid to drain out of the suction pipe when pump is not working and also helps in priming.

Delivery pipe -pipe which is connected at the lower end to the outlet of the pump. It delivers the liquid to the required height. It is provided with a regulating valve to regulate the supply of water.

Working principle of a centrifugal pump

The delivery valve is closed and the pump is primed that is, suction pipe, casing and portion of the delivery pipe up to the delivery valve are completely filled with the liquid (to be pumped) so that no air pocket is left.

Keeping the delivery valve still closed the electric motor is started to rotate the impeller. The rotation of the impeller causes strong suction or vacuum just at the eye of the casing.

The speed of the impeller is gradually increased till the impeller rotates at its normal speed and develops normal energy required for pumping the liquid.

After the impeller attains the normal speed the delivery valve is opened when the liquid is continuously sucked (from sump well) up the suction pipe, it passes through the eye of casing and enters the impeller at its centre or it enters the impeller vanes at their inlet tips. This liquid is impelled out by the rotating vanes and it comes out at the outlet tips of the vanes into the casing. Due to impeller action the pressure head as well as velocity heads of the liquid are increased (some of this velocity heads is converted into pressure head in the casing and in the diffuser blades/vanes if they are also provided

From casing, the liquid passes into pipe and is lifted to the required height (and discharged from the outlet or upper end of the delivery pipe).

So long as motion is given to the impeller and there is supply of liquid to be lifted the process of lifting the liquid to the required height remains continuous.

When pump is to be stopped the delivery valve should be first closed, otherwise there may be some backflow from the reservoir.

Operate fluid pumps: classification of pumps. Comparison of rotor dynamic and reciprocating pumps. Characteristics of pumps. Description and principle of operation. Flow rate and power. Pumps equations.

For further study refer to

Kothandaraman, C. P. & Rajput. R. K Fluid mechanics and machinery (second edition) fluid mechanics hydraulic principle

Trainee assignment;

A centrifugal pump running at 750 r.p.m. discharges water at 0.1 m3/s against a head of 10 m at its best efficiency. A second pump of the same homologous series, when working at 500 r.p.m., is to deliver water at 0.05 m3/s at its best efficiency. What will be the design head of the second pump and what is the scale ratio between the first and the second? (Ans 3.67m, 1.32)

Kothandaraman, C. P. & Rajput. R. K Fluid mechanics and machinery (second edition) fluid mechanics hydraulic principle

Self-Assessment

1. A reciprocating pump is a class of _________
   a) Negative displacement
   b) Positive displacement
   c) Zero displacement
   d) Infinite displacement

2. The simplest application of the reciprocating pump is___________
   a) Piston pump
   b) Plunger
   c) Diaphragm pump
   d) Bicycle pump

3. Power operated deep well reciprocating pump is divided into__________
   a) Single and double acting
   b) Single and multi-stage
   c) Piston and plunger

d) Conductive and nonconductive

4. Which among the following is not an example of a reciprocating pump?
   a) Hand pump
   b) Wind mill
   c) Axial piston pump
   d) Turbine blades

5. Pump converts mechanical energy into _________
   a) Pressure energy only
   b) Kinetic energy only
   c) Pressure and kinetic energy
   d) Potential energy

6. Which among the following is not a positive displacement pump?
   a) Centrifugal
   b) Reciprocating
   c) Rotary
   d) Ionization pump

7. How do we measure the flow rate of liquid?
   a) Coriolis method
   b) Dead weight method

8. Which among the following is called as the velocity pump?
   a) Centrifugal
   b) Reciprocating
   c) Rotary
   d) Ionization pump

9. Discharge capacity of a reciprocating pump is lower than that of reciprocating pump.
   a) True
   b) False

10. Which among the following is a high-pressure pump?
   a) Centrifugal
   b) Reciprocating
   c) Rotary
   d) Ionization pump

11. Describe the principle of operation of pumps
12. Derive reciprocating pump equation
13. Derive centrifugal pump equation
14. Apply Pump equations in problem solving

15. A centrifugal pump, in which water enters radially, delivers water to a height of 165 mm. The impeller has a diameter of 360 mm and width 180 mm at inlet and the corresponding dimensions at the outlet are 720 mm and 90 mm respectively; its rotational speed is 1200 r.p.m. The blades are curved backward at 30° to the tangent at exit and the discharge is 0.389 m3/s. Determine:

i. Theoretical head developed,
ii. Manometric efficiency Pressure rise across the impeller assuming losses equal to 12 percent of velocity head at exit,
iii. Pressure rise and the loss of head in the volute casing,
iv. The vane angle at inlet, and
v. Power required to drive the pump assuming an overall efficiency of 70%. What would be corresponding mechanical efficiency?

(ans 193.4m, 85.3%, 1.91m/s, 93.02m, 17.63, 4.80, 899.5kW, 82%)

Tools, Equipment, Supplies and Materials for the specific learning outcome

- A current meter
- Pointer gauge
- Hydraulic wave
- Hele-shaw
- pump

References (APA)

Rajput, Er. R. K. 1998, Fluid mechanics and Hydraulic Machinery, by S.Chand and company ltd, Ram Nagar, New Delhi-110055
Graebel, W.P. Advanced Fluid Mechanics, University of Michigan
Hewakandamby, B. N. 2012, A first course in fluids mechanics for engineers, VENTUS,
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