ANNAI MATHAMMAL SHEELA ENGINEERING COLLEGE, NAMAKKAL

DEPARTMENT OF MECHANICAL ENGINEERING COLLEGE

CE6451 FLUID MECHANICS AND MACHINERY

UNIT I : INTRODUCTION

TWO MARKS

1. Define density or mass density.

   Density of a fluid is defined as the ratio of the mass of a fluid to its volume.

   Density, ρ = mass/volume (Kg/m^3)
   ρ_{water} = 1000 Kg/m^3

2. Define specific weight or weight density.

   Specific weight or weight density of a fluid is defined as the ratio between the weight of a fluid to its volume.

   Specific weight, γ = weight/volume (N/m^3)
   $\gamma = \rho g$
   γ_{water} = 9810 N/m^3

3. Define specific volume.

   Specific volume of a fluid is defined as the volume of fluid occupied by an unit wt or unit mass of a fluid.

   Specific volume vs = volume/ wt = $1/\gamma = 1/\rho g$ ----- for liquids
   Specific volume vs = volume/ mass = $1/\rho$ ----- for gases

4. Define dynamic viscosity.

   Viscosity is defined as the property of fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid.

   $$\zeta = \mu \frac{du}{dy}$$

   μ – dynamic viscosity or viscosity or coefficient of viscosity ($N\text{-}s/m^2$)

   1 $N\text{-}s/m^2$ = 1 Pa-s = 10 Poise

5. Define Kinematic viscosity.

It is defined as the ratio between the dynamic viscosity and density of fluid.

$$\nu = \mu/\rho \qquad (m^2/s)$$

1 m^2/s = 10000 Stokes (or) 1 stoke = 10^{-4} m^2/s

6. Types of fluids.

Ideal fluid, Real fluid, Newtonian fluid, Non-Newtonian fluid, Ideal Plastic fluid.

7. Define Compressibility.

It is defined as the ratio of volumetric strain to compressive stress.

Compressibility, $\beta = (d\,Vol/\,Vol) / dp$ (m^2/N)

8. Define Surface Tension.

Surface tension is defined as the tensile force acting on the surface of the liquid in contact with a gas or on the surface between two immiscible liquids such that the contact surface behaves like a membrane under tension.

Surface Tension, σ = Force/Length (N/m)

σ_{water} = 0.0725 N/m $\sigma_{Mercury}$ = 0.52 N/m

9. Surface tension on liquid droplet, **$\sigma = pd/4$**

Surface tension on a hollow bubble, **$\sigma = pd/8$**

Surface tension on a liquid jet, **$\sigma = pd/2$**

σ – surface tension (N/m)
d – diameter (m)
p – pressure inside (N/m^2)

$p_{total} = p_{inside} + p_{atm}$ $p_{atm} = 101.325 \times 10^3$ N/m^2

10. Define Capillarity.

Capillarity is defined as a phenomenon of rise or fall of a liquid surface in a small tube relative to the adjacent general level of liquid when the tube is held vertically in the liquid. The rise of liquid surface is known as capillary rise while the fall of liquid surface is known as capillary depression.

Capillary Rise or fall, $h = (4\sigma \cos\theta) / \rho g d$

$\theta = 0$ for glass tube and water $\theta = 130^o$ for glass tube and mercury

11. Define Vapour Pressure.

When vaporization takes place, the molecules start accumulating over the free liquid surface exerting pressure on the liquid surface. This pressure is known as Vapour pressure of the liquid.

12. Define Control Volume.

A control volume may be defined as an identified volume fixed in space. The boundaries around the control volume are referred to as control surfaces. An open system is also referred to as a control volume.

13. Write the continuity equation.

The equation based on the principle of conservation of mass is called continuity equation.

$\delta u/\delta x + \delta v/\delta y + \delta w/\delta z = 0$ ----- three dimensional flow
$\delta u/\delta x + \delta v/\delta y = 0$ ----- two dimensional flow
$Q = a_1 v_1 = a_2 v_2$ ----- one dimensional flow

14. List the types of fluid flow.

Steady and unsteady flow
Uniform and non-uniform
flow Laminar and
Turbulent flow
Compressible and incompressible flow
Rotational and ir-rotational flow

15. Define Steady and Unsteady flow.

Steady flow

Fluid flow is said to be steady if at any point in the flowing fluid various characteristics such as velocity, density, pressure,etc do not change with time.

$$\partial V/\partial t = 0 \quad \partial p/\partial t = 0 \quad \partial \rho/\partial t = 0$$

Unsteady flow

Fluid flow is said to be unsteady if at any point flowing fluid any one or all characteristics which describe the behavior of the fluid in motion change with time.

$$\partial V/\partial t \neq 0 \quad \partial p/\partial t \neq 0 \quad \partial \rho/\partial t \neq 0$$

16. Define Uniform and Non-uniform flow.

Uniform flow

When the velocity of flow of fluid does not change both in direction and magnitude from point to point in the flowing fluid for any given instant of time, the flow is said to be uniform.

$$\partial V/\partial s = 0 \quad \partial p/\partial s = 0 \quad \partial \rho/\partial s = 0$$

Non-uniform flow

If the velocity of flow of fluid changes from point to point in the flowing fluid at any instant, the flow is said to be non-uniform flow.

$$\partial V/\partial s \neq 0 \quad \partial p/\partial s \neq 0 \quad \partial \rho/\partial s \neq 0$$

17. Compare Laminar and Turbulent flow.

Laminar and Turbulent flow

A flow is said to be laminar if Reynolds number is less than 2000 for pipe flow. Laminar flow is possible only at low velocities and high viscous fluids. In laminar type of flow, fluid particles move in laminas or layers gliding smoothly over the adjacent layer.

Turbulent flow

In Turbulent flow, the flow is possible at both velocities and low viscous fluid. The flow is said to be turbulent if Reynolds number is greater than 4000 for pipe flow. In Turbulent type of flow fluid, particles move in a zig –zag manner.

18. Define Compressible and incompressible flow

Compressible flow

The compressible flow is that type of flow in which the density of the fluid changes from point to point i.e. the density is not constant for the fluid. It is expressed in kg/sec.

$\rho \neq$ constant

Incompressible flow

The incompressible flow is that type of flow in which the density is constant for the fluid flow. Liquids are generally incompressible. It is expressed in m^3/s.

$\rho =$ constant

16 Marks

1. a) What are the different types fluids? Explain each type.
   b) Discuss the thermodynamic properties of fluids
2. a) One litre of crude oil weighs 9.6 N. Calculate its

Specific weight, density and specific weight.

b) The Velocity Distribution for flow over a flat plate is given by

u=(2/3)y-y_2, Where u is the point velocity in meters per second at a distance y metre above the plate. Determine the shear stress at y=0 and y=15 cm. Assume dynamic viscosity as 8.63 poises

3. a) A plate, 0.025 mm distant from a fixed plate, moves at 50 cm/s and requires a force of 1.471 N/ m_2 to maintain this speed. Determine the fluid viscosity between plates in the poise.

b) Determine the intensity of shear of an oil having viscosity =1.2 poise and is used for lubrication in the clearance between a 10 cm diameter shaft and its journal bearing. The clearance is 1.0 mm and Shaft rotates at 200 r.p.m

4. a) Two plates are placed at a distance of 0.15mm apart. The lower plate is fixed while the upper plate having surface area 1.0 m_2 is pulled at 0.3 Nm/s. Find the force and power required to maintain this speed, if the fluid separating them is having viscosity 1.5 poise.

b) An oil film of thickness 1.5 mm is used for lubrication between a square plate of size 0.9m *0.9m and an inclined plane having an angle of inclination

200 . . The weight of square plate is 392.4 N and its slides down the plane with a uniform velocity of 0.2 m/s. find the dynamic viscosity of the oil.

5. a) Assuming the bulk modulus of elasticity of water is 2.07 x10 $_6$ kN/m^2 at standard atmospheric condition determine the increase of pressure necessary to produce one percent reduction in volume at the same temperature. b) Calculate the capillary rise in glass tube pf 3mm diameter when immersed in mercury, take the surface tension and angle of contact of mercury as 0.52 N/m and 130^0 respectively. Also determine the minimum size of the glass tube, if it is immersed in water, given that the surface tension of water is 0.0725 N/m and Capillary rise in tube is not exceed 0.5mm.

UNIT II : FLOW THROUGH CIRCULAR CONDUITS

TWO MARKS

1. Mention the range of Reynold's number for laminar and turbulent flow in a pipe.

If the Reynold,s number is less than 2000, the flow is laminar. But if the Reynold's number is greater than 4000, the flow is turbulent flow.

2. What does Haigen-Poiseulle equation refer to?

The equation refers to the value of loss of head in a pipe of length 'L' due to viscosity in a laminar flow.

3. What is Hagen poiseuille's formula?

$$(P_1-P_2) / \rho g = h_f = 32\,\mu \bar{U} L / \rho g D^2$$

The expression is known as Hagen poiseuille formula.

Where $P_1-P_2 / \rho g$ = Loss of pressure head, $\bar{U}$= Average velocity, μ = Coefficient of viscosity, D = Diameter of pipe, L = Length of pipe

4. Write the expression for shear stress?

Shear stress $\zeta = -(\partial p/\partial x)(r/2)$

$\zeta_{max} = -(\partial p/\partial x)(R/2)$

5. Give the formula for velocity distribution: -

The formula for velocity distribution is given as

$$u = -(¼\,\mu)(\partial p/\partial x)(R^2-r^2)$$

Where R = Radius of the pipe, r = Radius of the fluid element

6. Give the equation for average velocity : -

The equation for average velocity is given as

$$\bar{U} = -(1/8\mu)(\partial p/\partial x) R^2$$

Where R = Radius of the pipe

7. Write the relation between Umax and Ū?

$$\mathbf{U_{max} / \bar{U} = \{ -(\tfrac{1}{4}\mu)(\partial p/\partial x) R^2 \} / \{ -\tfrac{1}{8}\mu (\partial p/\partial x) R^2 \}}$$

$$\mathbf{U_{max} / \bar{U} = 2}$$

8. Give the expression for the coefficient of friction in viscous flow?
Coefficient of friction between pipe and fluid in viscous flow **f =16/ Re**
Where, f = Re = Reynolds number

9. What are the factors to be determined when viscous fluid flows through the circular pipe?
The factors to be determined are:
i Velocity distribution across the section.
ii. Ratio of maximum velocity to the average velocity.
iii.Shear stress distribution.

10. Define kinetic energy correction factor?
Kinetic energy factor is defined as the ratio of the kinetic energy of the flow per sec based on actual velocity across a section to the kinetic energy of the flow per sec based on average velocity across the same section. It is denoted by (α).
K. E factor (α) = K.E per sec based on actual velocity / K.E per sec based on
Average velocity

11. Define momentum correction factor (β):
It is defined as the ratio of momentum of the flow per sec based on actual velocity to the momentum of the flow per sec based on average velocity across the section.
β= Momentum per sec based on actual velocity/Momentum Per sec based on average velocity

12. Define Boundary layer.
When a real fluid flow passed a solid boundary, fluid layer is adhered to the solid boundary. Due to adhesion fluid undergoes retardation thereby developing a small region in the immediate vicinity of the boundary.

13. What is mean by boundary layer growth?
At subsequent points downstream of the leading edge, the boundary layer region increases because the retarded fluid is further retarded. This is referred as growth of boundary layer.

14. Classification of boundary layer.

(i) Laminar boundary layer, (ii) Transition zone, (iii) Turbulent boundary layer.

15. Define Laminar boundary layer.

Near the leading edge of the surface of the plate the thickness of boundary layer is small and flow is laminar. This layer of fluid is said to be laminar boundary layer.

The length of the plate from the leading edge, upto which laminar boundary layer exists is called as laminar zone. In this zone the velocity profile is parabolic.

16. Define transition zone.

After laminar zone, the laminar boundary layer becomes unstable and the fluid motion transformed to turbulent boundary layer. This short length over which the changes taking place is called as transition zone.

17. Define Turbulent boundary.

Further downstream of transition zone, the boundary layer is turbulent and continuous to grow in thickness. This layer of boundary is called turbulent boundary layer.

18. Define Laminar sub Layer

In the turbulent boundary layer zone, adjacent to the solid surface of the plate the velocity variation is influenced by viscous effects. Due to very small thickness, the velocity distribution is almost linear. This region is known as laminar sub layer.

19. Define Boundary layer Thickness.

It is defined as the distance from the solid boundary measured in y-direction to the point, where the velocity of fluid is approximately equal to 0.99 times the free stream velocity (U) of the fluid. It is denoted by δ.

20. List the various types of boundary layer thickness.

Displacement thickness(δ*), Momentum thickness(θ), Energy thickness(δ**)

21. Define displacement thickness.

The displacement thickness (δ) is defined as the distance by which the boundary should be displaced to compensate for the reduction in flow rate on account of boundary layer formation.

$$\boldsymbol{\delta^* = \int [\, 1 - (u/U)\,]\, dy}$$

22. Define momentum thickness.

The momentum thickness (θ) is defined as the distance by which the boundary should be displaced to compensate for the reduction in momentum of the flowing fluid on account of boundary layer formation.

$$\theta = \int [\,(u/U) - (u/U)^2\,]\,dy$$

23. Define energy thickness

The energy thickness (δ**) is defined as the distance by which the boundary should be displaced to compensate for the reduction in kinetic energy of the flowing fluid on account of boundary layer formation.

$$\delta^{**} = \int [\,(/U) - (u/U)^3\,]\,dy$$

24. What is meant by energy loss in a pipe?

When the fluid flows through a pipe, it looses some energy or head due to frictional resistance and other reasons. It is called energy loss. The losses are classified as; Major losses and Minor losses

25. Explain the major losses in a pipe.

The major energy losses in a pipe is mainly due to the frictional resistance caused by the shear force between the fluid particles and boundary walls of the pipe and also due to viscosity of the fluid.

26. Explain minor losses in a pipe.

The loss of energy or head due to change of velocity of the flowing fluid in magnitude or direction is called minor losses. It includes: sudden expansion of the pipe, sudden contraction of the pipe, bend in a pipe, pipe fittings and obstruction in the pipe, etc.

16 MARKS

1. a) Explain types of fluid flow.
   b) Explain all dimensional number.

2. Derive continuity equation in three dimension
3. State the Bernoulli's theorem for steady flow of an incompressible fluid. Derive an expression for Bernoulli's equation.

4. Water is flowing through a pipe having diameter 300 mm and 200 mm at the bottom end is 24.525 N/cm^2 and the pressure at the upper end is

   9.81 N/Cm^2 . Determine the difference in datum head if the rate of flow through pipe is 40 lit/s.

5. A pipe line carrying oil of specific gravity 0.87, changes in diameter from 200 mm diameter at a position A to 500 mm diameter at a position B which is 4 meters at a higher level. If the pressure at A and B which

   is 4 m at a higher level. If the pressures at A and B are 9.81 N/Cm^2 and 5.8 86 N/Cm2 respectively and the discharge is 20 litres/s determine the loss of head and direction of flow.

6. The frictional torque T of a disc diameter D rotating at a speed N in a fluid of Viscosity μ and density ρ in a turbulent flow is given by $T=D^5N^2\rho(\mu/D^2N\rho)$. Prove this Buckingham 's Π theorem. 16)

7. A liquid of specific gravity 0.85 is flowing through in an inclined

   venturimeter of 250mm x 115mm size. the difference of pressures between the main and throat is measured by a liquid of specific gravity 0.65 contained in an inverted U-tube which gives a reading of 275mm. If the loss of head between the main and throat is 0.3 times the Kinetic head of the pipe, determine the rate of flow of liquid. 16)

UNIT III : DIMENSIONAL ANALYSIS

1. Define dimensional analysis.

   Dimensional analysis is a mathematical technique which makes use of the study of dimensions as an aid to solution of several engineering problems. It plays an important role in research work.

2. Write the uses of dimension analysis?

   - It helps in testing the dimensional homogeneity of any equation of fluid motion.
   - It helps in deriving equations expressed in terms of non-dimensional parameters.
   - It helps in planning model tests and presenting experimental results in a systematic manner.

3. List the primary and derived quantities.

   Primary or Fundamental quantities: The various physical quantities used to describe a given phenomenon can be described by a set of quantities which are independent of each other. These quantities are known as fundamental quantities or primary quantities. Mass (M), Length (L), Time (T) and Temperature (θ) are the fundamental quantities.

Secondary or Derived quantities: All other quantities such as area, volume, velocity, acceleration, energy, power, etc are termed as derived quantities or secondary quantities because they can be expressed by primary quantities.

4. Write the dimensions for the followings.

Dynamic viscosity (μ) – $ML^{-1}T^{-2}$, Force (F) - MLT^{-2}, Mass density (ρ) – ML^{-3}, Power (P) -$ML^{2}T^{-3}$

5. Define dimensional homogeneity.

An equation is said to be dimensionally homogeneous if the dimensions of the terms on its LHS are same as the dimensions of the terms on its RHS.

6. Mention the methods available for dimensional analysis.

Rayleigh method, Buckinghum π method

7. State Buckingham's π theorem.

It states that "if there are 'n' variables (both independent & dependent variables) in a physical phenomenon and if these variables contain 'm' functional dimensions and are related by a dimensionally homogeneous equation, then the variables are arranged into n-m dimensionless terms. Each term is called π term".

8. List the repeating variables used in Buckingham π theorem.

Geometrical Properties – l, d, H, h, etc, Flow Properties – v, a, g, ω, Q, etc, Fluid Properties – ρ, μ, γ, etc.

9. Define model and prototype.

The small scale replica of an actual structure or the machine is known as its Model, while the actual structure or machine is called as its Prototype. Mostly models are much smaller than the corresponding prototype.

10. Write the advantages of model analysis.

- Model test are quite economical and convenient.
- Alterations can be continued until most suitable design is obtained.

- Modification of prototype based on the model results.
- The information about the performance of prototype can be obtained well in advance.

11. List the types of similarities or similitude used in model anlaysis.

Geometric similarities, Kinematic similarities, Dynamic similarities

12. Define geometric similarities

It exists between the model and prototype if the ratio of corresponding lengths, dimensions in the model and the prototype are equal. Such a ratio is known as "Scale Ratio".

13. Define kinematic similarities

It exists between the model and prototype if the paths of the homogeneous moving particles are geometrically similar and if the ratio of the flow properties is equal.

14. Define dynamic similarities

It exits between model and the prototype which are geometrically and kinematically similar and if the ratio of all forces acting on the model and prototype are equal.

15. Mention the various forces considered in fluid flow.

Inertia force, Viscous force, Gravity
Pressure force, Surface Tension force, Elasticity force

16. Define model law or similarity law.

The condition for existence of completely dynamic similarity between a model and its prototype are denoted by equation obtained from dimensionless numbers. The laws on which the models are designed for dynamic similarity are called Model laws or Laws of Similarity.

17. List the various model laws applied in model analysis.

Reynold's Model Froude's Model Law,
Euler's Model Law, Weber Model Law, Mach Model Law

18. State Reynold's model law

For the flow, where in addition to inertia force the viscous force is the only other predominant force, the similarity of flow in the model and its prototype can be established, if the Renold's number is same for both the systems. This is known as Reynold's model law. **Re(p) = Re(m)**

19. State Froude's model law

When the forces of gravity can be considered to be the only predominant force which controls the motion in addition to the force of inertia, the dynamic similarities of the flow in any two such systems can be established, if the Froude number for both the system is the same. This is known as Froude Model Law. **Fr(p) = Fr (m)**

20. State Euler's model law

In a fluid system where supplied pressures are the controlling forces in addition to inertia forces and other forces are either entirely absent or in-significant the Euler's number for both the model and prototype which known as Euler Model Law.

21. State Weber's model law

When surface tension effect predominates in addition to inertia force then the dynamic similarity is obtained by equating the Weber's number for both model and its prototype, which is called as Weber Model Law.

22. State Mach's model law

If in any phenomenon only the forces resulting from elastic compression are significant in addition to inertia forces and all other forces may be neglected, then the dynamic similarity between model and its prototype may be achieved by equating the Mach's number for both the systems. This is known Mach Model Law.

23. Classify the hydraulic models.

The hydraulic models are classified as: Undistorted model & Distorted model

24. Define undistorted model

An undistorted model is that which is geometrically similar to its prototype, i.e. the scale ratio for corresponding linear dimensions of the model and its prototype are same.

25. Define distorted model

Distorted models are those in which one or more terms of the model are not identical with their counterparts in the prototype.

26. Define Scale effect

An effect in fluid flow that results from changing the scale, but not the shape, of a body around which the flow passes.

27. List the advantages of distorted model.

- The results in steeper water surface slopes and magnification of wave heights in model can be obtained by providing true vertical structure with accuracy.
- The model size can be reduced to lower down the cast.
- Sufficient tractate force can be developed to produce bed movement with a small model.

28. Write the dimensions for the followings.

Quantitie	Symbol	Uni	Dimension
Area	**A**	**m^2**	**L^2**
Volume	**V**	**m^3**	**L^3**
Angle	**A**	**Deg. Or Rad**	**$M^0L^0T^0$**
Velocity	**v**	**m/s**	**LT^{-1}**
Angular Velocity	**ω**	**Rad/s**	**T^{-1}**
Speed	**N**	**rpm**	**T^{-1}**
Acceleration	**a**	**m/s^2**	**LT^{-2}**
Gravitational Acceleration	**g**	**m/s^2**	**LT^{-2}**
Discharge	**Q**	**m^3/s**	**L^3T^{-1}**
Discharge per meter run	**q**	**m^2/s**	**L^2T^{-1}**
Mass Density	**ρ**	**Kg/m^3**	**ML^3**
Sp. Weight or Unit Weight		**N/m^3**	**$ML^{-2}T^{-2}$**
Dynamic Viscosity	**μ**	**$N\text{-}s/m^2$**	**$ML^{-1}T^{-1}$**
Kinematic viscosity		**m^2/s**	**L^2T^{-1}**
Force or Weight	**F or W**	**N**	**MLT^{-2}**
Pressure or Pressure	**p**	**N/m^2 or Pa**	**$ML^{-1}T^{-2}$**
Modulus of Elasticity	**E**	**N/m^2 or Pa**	**$ML^{-1}T^{-2}$**
Bulk Modulus	**K**	**N/m^2 or Pa**	**$ML^{-1}T^{-2}$**
Workdone or Energy	**W or E**	**N-m**	**ML^2T^{-2}**
Torque	**T**	**N-m**	**ML^2T^{-2}**
Power	**P**	**N-m/s or J/s or**	**ML^2T^{-3}**

16 MARKS

1. a) Derive an expression for the velocity distribution for viscous flow through a circular pipe.

b) A main pipe divides into two parallel pipes, which again forms one pipe. The length and diameter for the first parallel pipe are 2000m and 1m respectively, while the length and diameter of second parallel pipe are 2000 and 0.8 m respectively. Find the rate of flow in each parallel pipe, if total flow in the main is 3 m^3/s. The

coefficient of friction for each parallel pipe
is same and equal to 0.005.

2. Two pipes of 15 cm and 30 cm diameters are laid in parallel to pass a total discharge of 100 liters/ second. Each pipe is 250 m long. Determine discharge through each pipe. Now these pipes are connected in series to connect two tanks 500 m apart, to carry same total discharge. Determine water level difference between the tanks. Neglect minor losses in both cases, f=0.02 f_n both pipes.

b) A pipe line carrying oil of specific gravity 0.85, changes in diameter from 350 mm at position 1 to 550 mm diameter to a position 2, which is at 6 m at a higher level. If the pressure at position 1 and 2 are taken as 20 N/cm^2 and 15 N/ cm^2 respectively and discharge through the pipe is 0.2 m^3/s. determine the loss of head.

3. Obtain an expression for Hagen- Poisulle flow. Deduce the condition of maximum velocity.

4. A flat plate 1.5 m X 1.5 m moves at 50 km / h in a stationary air density 1.15 kg/ m^3. If the coefficient of drag and lift are 0.15 and 0.75 respectively, determine (i) the lift force (ii) the drag force (iii) the resultant force and (iv) the power required to set the plate in motion .(1 6)

5. a). The rate of flow of water through a horizontal pipe is 0.3 m^3/s. The diameter of the pipe is suddenly enlarged from 25 cm to 50 cm. The pressure intensity in the smaller pipe is $14 N/m^2$. Determine (i) Loss of head due to sudden enlargement. (ii) Pressure intensity in the large pipe and (iii) Power lost due to enlargement.

b) Water is flowing through a tapering pipe of length 200 m having diameters 500 mm at the upper end and 250 mm at the lower end, the pipe has a slope of 1 in 40. The rate of flow through the pipe is 250 lit/ sec. the pressure at the lower end and the upper end are 20 N/cm^2 and 10 N/cm^2 respectively. Find the loss of head and direction of flow.

UNIT IV : TURBINES

1. What are fluid machines or Hydraulic machines?

The machines which use the liquid or gas for the transfer of energy from fluid to rotor or from rotor to fluid are known as fluid machines.

2. How are fluid machines classified?

Fluid machines are classified into two categories depending upon transfer of energy:

1. Turbines – hydraulic energy is converted to mechanical energy and then electrical energy. 2. Pumps – electrical energy is converted to mechanical energy and then hydraulic energy.

3. What are called turbines?

Hydraulic turbines are the machines which use the energy of water and convert it into mechanical energy. The mechanical energy developed by a turbine is used in running the electrical generator which is directly coupled to the shaft.

4. What is known as Euler's equation for turbo-machines?

The general expression for the work done per second on impeller is

$$\rho Q[V_{w1}u_1 \pm V_{w2}u_2]$$

5. Define Gross Head of a turbine.

The difference between head race level and tail race level is known as Gross Head

6. Define Net head of a turbine.

It is also called effective head and is defined as the head available at the inlet of the turbine. $H = H_g - h_f$

7. What are the efficiencies of a turbine?

Hydraulic efficiency   Mechanical efficiency
Volumetric efficiency   Overall efficiency

8. Define Hydraulic efficiency.

It is defined as the ratio of the power given by water to the runner of a turbine to the power supplied by the water at the inlet of the turbine.

$$\eta_h = \frac{\text{Power delivered to runner (runner power)}}{\text{Power supplied at inlet (waterpower)}}$$

Water power = $\gamma QH = (1/2)\, m v^2$

9. Define Mechanical efficiency.

The ratio of the power available at the shaft of the turbine to the power delivered to the runner is defined as mechanical efficiency.

Power available at the shaft (shaft power)

ηm = --
Power delivered to runner (runner power)

10. Define volumetric efficiency.

The ratio of the volume of the water actually striking the runner to the volume of water supplied to the turbine is defined as volumetric efficiency.

11. Define Overall efficiency.

It is defined as the ratio of the power available at the shaft of the turbine to the power supplied by the water at the inlet of the turbine.

Power available at the shaft (shaft power)
ηo = --- -------------- Power supplied at inlet (water power)

ηo = ηh ηm ηv (or) ηo = ηh ηm

12. What are an impulse turbine and a reaction turbine?

Impulse Turbine:

If at the inlet of the turbine, the energy available is only kinetic energy, the turbine is known as impulse turbine. The pressure at the inlet of the turbine is atmosphere. This turbine is used for high heads. The water strikes the bucket along the tangent of the runner. Ex: Pelton Wheel Turbine.

Reaction Turbine:

If at the inlet of the turbine, the water possesses kinetic energy as well as pressure energy, the turbine is known as reaction turbine. As the water flows through the runner, the water is under pressure and the pressure energy goes on changing into kinetic energy. The runner is completely enclosed in an air-tight casing and the runner and casing is completely full of water. This turbine is used for medium heads. Ex: Francis Turbine.

13. Define Jet Ratio.

It is defined as the ratio of the pitch diameter (D) of the Pelton wheel to the diameter of the jet (d). It is denoted by 'm' and is given as **m = D/d.**

14. Classification of hydraulic turbines:

(a) Based on type of energy available at inlet
Impulse turbine (Pelton wheel)
Reaction turbine (Francis turbine, Kaplan turbine, Propeller turbine)

(b) Based on head available at inlet
High head turbine – [> 250 m] - (Pelton wheel)
Medium head turbine – [60 to 250 m] - (Francis turbine)
Low head turbine – [< 60 m] – (Kaplan turbine, Propeller turbine)

(c) Based on specific speed
High specific speed turbine – (Kaplan turbine, Propeller turbine) Medium specific speed turbine - (Francis turbine)
Low specific speed turbine - (Pelton wheel)

(d) Based on direction of flow through runner
Tangential flow turbine
Radial flow turbine Axial flow turbine
Mixed flow turbine

15. Define Radial flow reaction turbine and their types.

If water flows in the radial direction in the turbine then it is referred as radial flow turbine.

Types

Inward radial flow reaction turbine: If the water flows from outwards to inwards through the runner, the turbine is known as inward radial flow reaction turbine. Here the outer diameter of the runner is inlet diameter whereas the inner diameter of the runner is outlet diameter.

Outward radial flow reaction turbine: If the water flows from inwards to outwards through the runner, the turbine is called as outward radial flow reaction turbine. Here the outer diameter of the runner is outlet diameter whereas the inner diameter of the runner is inlet diameter.

16. What is mean by Draft Tube?

The draft tube is a pipe of gradually increasing area which connects the outlet of the runner to the tail race. One end of the draft tube is connected to the outlet of the runner while the other end is sub-merged below the level of water in the tail race.

17. Why do draft tubes have enlarging passage area in the direction of flow?

The pressure at the exit of the reaction turbine is generally less than atmospheric and this makes the water NOT to discharge directly to the tail race. By the introduction of draft tube, which has enlarged area in the direction of flow, the kinetic head reduces and pressure head increases. There by discharge of water to the tail race safely.

18.Define specific speed of a turbine.

It is defined as the speed of the turbine which is geometrically similar and it will develop unit power when working under unit head.

$$N_S = N\sqrt{P}/(H)^{5/4}$$

19. Define Runaway speed of Turbine.

The max speed reached by the turbine after the removal of the external load is called runaway speed of turbine. The various rotating components of the turbine should be designed to remain safe at the runaway speed.

20. List the characteristic curves of Hydraulic turbine.

Main Characteristic Curves (or) Constant Head Curves
Operating Characteristic Curves (or) Constant Speed
Curves Muschel Curves (or) Constant Efficiency Curves

21. What is roto dynamic pump?

When the increase in pressure is developed by rotating impeller or by action of centrifugal force then the pump is called as roto dynamic pump.

22. Define Centrifugal pump.

Hydraulic pump means it converts mechanical energy into hydraulic energy. If the mechanical energy is converted into pressure energy means of centrifugal force acting on the fluid, the hydraulic machine is called Centrifugal Pump.

23. Define Specific speed of a centrifugal pump.

The specific speed of a centrifugal pump is defined as the speed of a geometrically similar pump which would deliver 1 m^3/s against a head of 1 m.

$$N_S = N\sqrt{Q}/(H)^{3/4} \qquad \text{(OR)} \qquad N_S = N\sqrt{P}/(H)^{5/4}$$

24. Efficiencies of a Centrifugal Pump:

Manometric Efficiency:

The ratio of the manometric head to the head imparted by the impeller to the water is known as manometric efficiency.

$$\eta_{mano} = \frac{\text{Manometric Head}}{\text{Head imparted by impeller to water}} = \frac{g H_m}{V_{w2} u_2}$$

Head imparted by impeller to water = $V_{w2} u_2 / g$

Mechanical Efficiency:

The ratio of the power available at the impeller to the power at the shaft of the centrifugal pump is known as mechanical efficiency.

$$\eta_{mech} = \frac{\text{Power at the impeller}}{\text{Shaft Power}}$$

Power at the impeller = workdone by impeller per sec = $\rho Q V_{w2} u_2$

Overall Efficiency:

The ratio of power output of the pump to the power input to the pump is called as overall efficiency.

$$\eta_o = \frac{\text{Weight of water lifted x } H_m}{\text{Shaft Power}}$$

16 MARKS

1. Obtain en expression for the work done per second by water on the runner of a –pelton wheel. Hence derive an expression for maximum efficiency of the pelton wheel giving the relationship between the jet speed and bucket speed. 16)

2. a) A pelton wheel is having a mean bucket diameter of 1 m and is running at 1000 rpm. The net head on the pelton wheel is 700 m. If the side clearance angle is 15º and discharge through nozzle is 0.1 m^3/s, find (1) power available at nozzle and (2) hydraulic efficiency of the turbine. Take C_v=1 b) A turbine is to operate under a head of 25 m at 200 rpm. The discharge is 9 m^3/s. If the efficiency is 90% determine, Specific speed of the machine, Power generated and type of turbine.

3. A pelton turbine is required to develop 9000 KW when working under a head of 300 m the impeller may rotate at 500 rpm. Assuming a jet ratio of 10 And an overall efficiency of 85% calculate (1) Quantity of water required. (2) Diameter of the wheel (3) Number of jets (4) Number and size of the bucket vanes on the runner.

4.An Outward flow reaction turbine has internal and external diameters of the runner as 0.5 m and 1.0 m respectively. The turbine is running at 250 rpm and rate of flow of water through the turbine is 8 m^3/s. The width of the runner is constant at inlet and out let and is equal to 30 cm. The head on the turbine is 10 m and discharge at outlet6 is radial, determine (1) Vane angle at inlet and outlet. (2) Velocity of flow at inlet and outlet.

5. The Nozzle of a pelton Wheel gives a jet of 9 cm diameter and velocity 75 m/s. Coefficient of velocity is 0.978. The pitch circle diameter is 1.5 m and the deflection angle of the bucket is 170°. The wheel velocity is 0.46 times the jet velocity. Estimate the speed of the pelton wheel turbine in rpm, theoretical power developed and also the efficiency of the turbine.

6. a) A turbine is to operate a head of a 25 m at 200 rpm; the available discharge is 9 m^3/s assuming an efficiency of 90%. Determine (1) Specific speed (2) Power generated (3) Performance under a head of 20 m (4) The type of turbine

b) A vertical reaction turbine under 6m head at 400 rpm the area and diameter of runner at inlet are 0.7 m^2 and 1m respective the absolute and relative velocities of fluid entering are 1 5° and 60° to the tangential direction. Calculate hydraulic efficiency.

7. A Francis turbine has an inlet diameter of 2.0 m and an outlet diameter of 1 .2m. The width of the blades is constant at 0.2 m. The runner rotates at a speed of 250 rpm with a discharge of 8 m^3/s .The vanes are radial at the inlet and the discharge is radially outwards at the outlet. Calculate the angle of guide vane at inlet and blade angle at the outlet.

8. A Kaplan turbine develops 20000KW at a head of 35 m and at rotational speed of 420 rpm. The outer diameter of the blades is 2.5 m and the hub diameter is 0.85m. If the overall efficiency is 85% and the hydraulic efficiency is 88%. Calculate the discharge, the inlet flow angle and the blade angle at the inlet.

<u>UNIT V : PUMPS</u>

1) What is a reciprocating pump?

Reciprocating pump is a positive displacement pump. This means the liquid is first sucked into the cylinder and then displaced or pushed by the thrust of a piston.

2) What is single acting pump and double acting pump?

If the water is in contact with one side of the piston the pump then it is known as single acting reciprocating pump. For one complete revolution one suction stroke and one delivery stroke occurs.

If the water is in contact with both sides of the piston the pump then it is called double acting reciprocating pump. For one complete revolution two suction strokes and two delivery strokes occurs.

3) What is Discharge through a Reciprocating Pump?

For Single acting Reciprocating Pump: Discharge (Q_T)=ALN/60

For Double acting Reciprocating Pump: Q_T =2ALN/60

A=Area of the Cyclinder (m^2), L=Length of Stroke (m), N=Speed of Crank (rpm)

4) What is the Workdone by Reciprocating Pump per sec?

For Single acting Reciprocating Pump: Workdone = $\rho gALN(h_s+h_d)/60$

For Double acting Reciprocating Pump: Work done= $2\rho gALN(h_s+h_d)/60$

Where, ρ=Density of Water (kg/m^3), A=Area of the Cylinder (m^2), L= Stroke Length (m), N=Speed (rpm), hs, hd=Suction and Delivery head (m).

5) Define slip and % slip.

The difference between the theoretical discharge (Q_T) and actual discharge (Q_{act}) is known as slip of the pump.

Slip = $Q_T - Q_{act}$

% Slip = $[(Q_T - Q_{act})/Q_T] \times 100$

If Q_{act} is more than the Q_T then slip will be –ive.
If Q_{act} lesser than Q_T then the slip will be +ive.

6) Define coefficient of discharge of reciprocating pump?

It is defined as the ratio of actual discharge to theoretical discharge of reciprocating pump. C_d=Qa/Qth. If C_d > 1 then –ive slip occurs and if C_d < 1 then +ive slip occurs.

7) Write the expression for pressure head due to acceleration in suction and delivery pipes.

Pressure head due to acceleration in suction pipe, $h_{as} = (l_s/g)(A/a_s)\,\omega^2 r \cos\omega t$

Where, l_s - length of suction pipe; A – area of piston cylinder,
a_s – area of suction pipe; ω – angular velocity; r – radius of crank.

Pressure head due to acceleration in delivery pipe, $h_{ad} = (l_d/g)(A/a_d)\,\omega^2 r \cos\omega t$

Where, l_d - length of delivery pipe; A – area of piston cylinder,
a_d – area of delivery pipe; ω – angular velocity; r – radius of crank.

Max pressure head due to acceleration, $h_a = (l/g)(A/a)\,\omega^2 r$

13) What is an air vessel?

An air vessel is a closed chamber containing compressed air in the top portion and liquid at the bottom of the chamber. At the base of the chamber there is an opening through which the liquid may flow into the vessel or out from the vessel. When the liquid enters the air vessel, the air gets compressed further and when the liquid flows out of the vessel, the air will expand into the chamber.

14) What is the purpose of an air vessel fitted in the pump?

To obtain a continuous supply of liquid at a uniform rate.
To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipes, and
To run the pump at a high speed with out separation.

15) What is the work saved by fitting an air vessel in a single acting, double acting pump?

Work saved by fitting air vessels in a single acting pump is 84.87%, In a double acting pump the work saved is 39.2%.

16) Define Cavitation.

If the pressure in the cylinder is below the vapour pressure, the dissolved gases will be liberated from the liquid and air bubbles are formed. This process is termed as Cavitation.

17) Define separation pressure and separation pressure head.

Due to Cavitation process the continuous flow of fluid will get affected and separation takes place. The pressure at which separation takes place is known as separation pressure and the head corresponding to separation pressure is called separation pressure head.

For water the limiting value of separation pressure head is,

$$\mathbf{h_{sep} = -7.8\ m\ (Gauge\ pressure)}$$
$$\mathbf{h_{sep} = 10.3 - 7.8 = 2.5\ m\ (Absolute\ pressure)}$$

18) How will you obtain the maximum speed during suction stroke?

The absolute pressure head will be minimum at the beginning of suction stroke. Thus, in the cylinder the separation taking place at the beginning of suction stroke only. In this case, the absolute pressure head will be equal to the separation pressure.

$$\mathbf{h_{sep} = H_{atm} - (h_s + h_{as})} \quad [or] \quad \mathbf{h_{as} = H_{atm} - h_s - h_{sep}}$$

Equating both the angular velocity(ω) and Speed (N) are obtained. This N is the maximum speed of the pump during the suction stroke without separation.

19) How will you obtain the maximum speed during delivery stroke?

The absolute pressure head will be minimum at the end of delivery stroke. Thus, in the cylinder the separation taking place at the end of delivery stroke only. In this case, the absolute pressure head will be equal to the separation pressure.

8) Write the expression for head due to friction in suction and delivery pipes.

Head loss due to friction in suction pipe is, $h_{fs} = (4fl_s/2gd_s)\ [(A/a_s)\ \omega^2 r \sin\omega t]^2$

Where, f – coefficient of friction; l_s - length of suction pipe; A – area of piston cylinder, a_s – area of suction pipe; d_s – diameter of suction pipe; ω – Angular velocity; r – radius of crank.

Head loss due to friction in delivery pipe is, $h_{fs} = (4fl_s/2gd_s)\ [(A/a_s)\ \omega^2 r \sin\omega t]^2$

Where, f – coefficient of friction; l_s - length of delivery pipe; a_s – area of delivery pipe; d_s – diameter of delivery pipe;

9) Define indicator diagram?

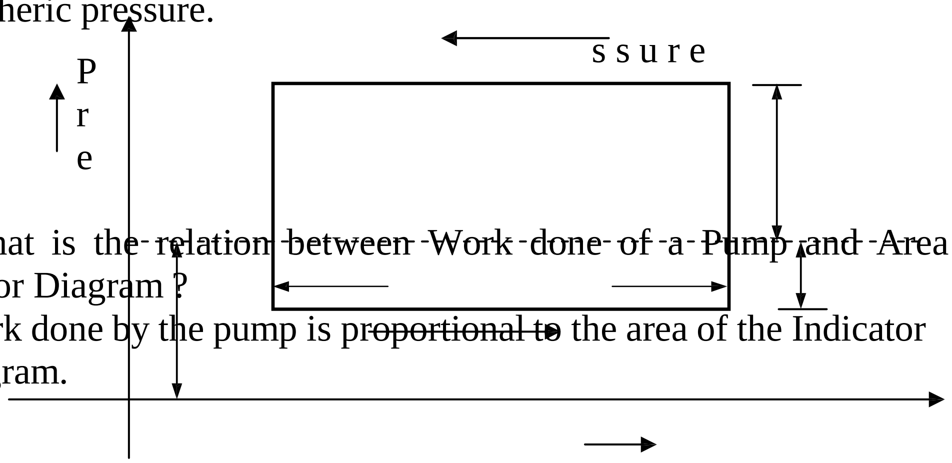
The indicator diagram for a reciprocating pump is defined as the graph drawn between the pressure head in the cylinder and the distance traveled by the piston for one complete revolution of the crank.

10) Define ideal indicator diagram?

It is defined as the graph between pressure head in the cylinder and stroke length of the crank under ideal condition is known as ideal indicator diagram.

During the suction stroke, the pressure in the cylinder is below atmospheric pressure.

During the delivery stroke, the pressure in the cylinder is above atmospheric pressure.



11) What is the relation between Work done of a Pump and Area of Indicator Diagram ?

Work done by the pump is proportional to the area of the Indicator diagram.

12) What is the Work done by the Pump per sec due to acceleration and friction in the suction and delivery Pipes?

For single acting : Workdone/sec =
$\rho gALN(h_s+h_d+0.67h_{fs}+0.67h_{fd})/60$
For Double acting : Workdone/sec =
$2\rho gALN(h_s+h_d+0.67h_{fs}+0.67h_{fd})/60$

Where, h_{fs}, h_{fd} =loss of head due to friction in suction and delivery pipes.

$h_{sep} = H_{atm} + h_s - h_{ad}$ [or] $h_{ad} = H_{atm} + h_d - h_{sep}$

But maximum pressure head due to acceleration in delivery pipe is ,

$$h_{ad} = (l_d/g)\,(A/a_d)\,\omega^2 r$$

Equating both the angular velocity (ω) and Speed (N) are obtained. This N is the maximum spped of the pump during the delivery stroke without separation.

20) What is mean by Maximum speed of a Reciprocating Pump?

The maximum speed at which no separation flow is taking place in the cylinder is called maximum speed of a reciprocating pump. It will be the least value of speeds obtained from maximum speed during suction stroke and maximum speed during delivery stroke.

21) Write the workdone saved by fitting the air vessel in reciprocating pump.

By fitting the air vessel the head loss due to friction in suction and delivery pipe is reduced. This reduction in the head loss saves a certain amount of energy. Therefore, the workdone saved is given by,

Workdone saved by Fitting airvessel = {workdone against friction without airvessel} − {workdone against friction with airvessel}

16 MARKS

1. Write short notes on the following (1) Cavitations in hydraulic machines their causes, effects and remedies. (2) Type of rotary pumps.

2. Draw a neat sketch of centrifugal pump and explain the working principle of the centrifugal pump.

3. Draw a neat sketch of Reciprocating pump and explain the working principle of single acing and double acting Reciprocating pump.

4. A radial flow impeller has a diameter 25 cm and width 7.5 cm at exit. It delivers 120 liters of water per second against a head of

   24 m at 1440 rpm. Assuming the vanes block the flow area by 5% and hydraulic efficiency of 0.8, estimate the vane angle at exit. Also calculate the torque exerted on the driving shaft if the mechanical efficiency is 95%.

5.The diameter and stroke of a single acting reciprocating pump are 200 mm and 400 mm respectively, the pump runs at 60 rpm and lifts 12 liters of water per second through a height of 25 m. The delivery pipe is 20m long and 150mm in diameter. Find (i) Theoretical power required to run the pump. (ii) Percentage of slip. (iii) Acceleration head at the beginning and middle of the delivery stroke.

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