AALIM MUHAMMED SALEGH COLLEGE OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

ME8694 HYDRAULICS AND PNEUMATICS

YEAR: III **SEMESTER: VI**

ANNA UNIVERSITY QUESTION PAPER SOLVED 2MARKS

UNIT-I

FLUID POWER PRINCIPLES AND HYDRAULIC PUMPS

PART-A

1. Write about positive displacement pumps? (NOV/DEC2011)

Positive displacement pumps have the internal working elements which make a very, close fit together so that there is very little leakage (or) slippage between them. This type of pumps ejects a fixed quantity of liquid into the hydraulic system per revolution of the' pump shaft.

2. Define absolute viscosity and kinematic viscosity. Nov/Dec2011

Absolute Viscosity is the force needed by a fluid to overcome its own internal molecular friction so that it can flow. In the field of fluid mechanics absolute viscosity is also known as dynamic viscosity.

Kinematic viscosity is a measure of a fluid's internal resistance to flow under gravitational forces. It is determined by measuring the time in seconds, required for a fixed volume of fluid to flow a known distance by gravity through a capillary within a calibrated viscometer at a closely controlled temperature.

3. List the primary function of hydraulic fluid. Nov/Dec2012

The major function of a hydraulic fluid is to provide energy transmission through the system which enables work and motion to be accomplished. Hydraulic fluids are also responsible for lubrication, heat transfer and contamination control.

4. List the application of Fluid power in Agriculture and Aviation industries. May/June2013

1. **Agriculture:** Tractors and farm equipments like ploughs, mowers, chemical sprayers, fertilizer spreaders, hay balers
2. **Aviation:** Fluid power equipments like landing wheels on aeroplane and helicopter, aircraft trolleys, aircraft engine test beds.

5. Write the procedure to calculate pressure drop in hydraulic circuits system May/June2013

Pressure drops are also due to valves, expansions, contractions, bends, elbows, tees and pipe fittings. The losses in valves and fittings in hydraulic systems are frequently computed in terms of equivalent length of hydraulic tube. Equivalent lengths can then be substituted in Darcy-Weisbach equation to solve for total pressure loss in the system. The formula for computing equivalent length is

Equivalent length $L_e = KD/f$ K= factor vale of fittings

6. Why screw pumps generate less noise while running? May/June 2013

Conventional, high-pressure gear pumps are noisy because they trap and compress fluid between gear teeth as it rotates. Screw pumps typically run silently with low pulsations, for low to medium, but not high-pressure duty.

7. Differentiate fixed and variable displacement pumps May/June2013

Simple, fixed-displacement pumps are perfect for single jobs that need to be repeated indefinitely over long periods of time, variable-displacement pumps can be used to power a wider variety of tools, but require more expense and more attention.

8. List the basic arrangements in hydrostatic drives. May/June2013

The operating principle of hydrostatic transmissions (HSTs) is simple: A pump, connected to the prime mover, generates flow to drive a hydraulic motor, which is connected to the load. If the displacement of the pump and motor are fixed, the HST simply acts as a gearbox to transmit power from the prime mover to the load. Most HSTs, however, use a variable-displacement pump, motor, or both so that speed, torque, or power can be regulate.

9. What is the importance of Reynolds number? May/June2014

The Reynolds (Re) number is a quantity which engineers use to estimate if a fluid flow is laminar or turbulent. This is important, because increased mixing and shearing occur in turbulent flow. This results in increased viscous losses which affects the efficiency of hydraulic machines.

10. Write the Darcy –Weisbach equation. May/June2014, April /May2015

The energy loss due to friction in a hydraulic system results in a loss of potential energy. This potential energy loss leads to a pressure drop or head loss in the system. Pressure or head loss due to friction in pipes carrying fluids are derived using the Darcy-Weisbach Equation.

$$H_L = f\left(\frac{L}{D}\right)\left(\frac{V^2}{g}\right)$$

H_L – Head Loss

f - Friction Factor

L - Length of pipe

D – Inner Diameter

V – Velocity of Flow

g – Acceleration due to gravity

11. What is a balanced vane pump? May/June2014

In balanced vane pump, there are two inlet and outlet ports which are diametrically opposite to each other. Because the pressure ports are opposite to each other, a complete hydraulic balance is achieved.

12. State any four causes for hydraulic system breakdown. May/June 2012

Hydraulic Fluid Contamination. A leading cause of many hydraulic pump failures is hydraulic fluid contamination

- Heat-Aging
- General Abrasion
- Incorrect Insertion Depth
- Get Help Fast with Air-Way

13 .Write any four application of fluid power system (April/May2015, April/may2008)

Food and Beverage: All types of food processing equipment, wrapping, bottling

Foundry: Full and semi automatic molding machines, tilting of furnaces, die casting machines

Glass Industry: Vacuum suction cups for handling

Material Handling: Jacks, Hoists, Cranes, Forklift, Conveyor system

14. Write about positive displacement pumps? April/May2015

Positive displacement pump (PDP) is a type of pump in which a moving fluid is captured in a cavity and then discharges that fixed amount of fluid. Some of these pumps have expanding cavity at the suction side and a decreasing cavity at the discharge side.

15. What is viscosity index? (April/May2008)

The viscosity index (VI) is an arbitrary, unit less measure of the change of viscosity with temperature, mostly used to characterize the viscosity-temperature behavior of lubricating oils. The lower the VI, the more the viscosity is affected by changes in temperature.

16. Name any four hydraulic fluids that are commonly used. (April/May2008)

1. Mineral hydraulic oil (petroleum base).

2. Phosphate ester based synthetic hydraulic fluids.

3. Vegetable hydraulic oils

4. Water glycol synthetic hydraulic fluids

17. What is pump cavitations? How can you avoid it? (April/May2008)

Cavitation is the formation of bubbles or cavities in liquid, developed in areas of relatively low pressure around an impeller. The imploding or collapsing of these bubbles triggers intense shockwaves inside the pump, causing significant damage to the impeller and/or the pump housing.

1. Lower the temperature.
2. Raise the liquid level in the suction vessel.
3. Change the pump.
4. Reduce motor RPM if possible.
5. Increase the diameter of the eye of the impeller.
6. Use an impeller inducer.
7. Use two lower capacity pumps in parallel

18. What are the advantages of fluid power? (Nov/Dec 2009)

- High horsepower-to-weight ratio you could probably hold a 5-hp hydraulic motor in the palm of your hand, but a 5-hp electric motor might weight 40 lb or more.
- Safety in hazardous environments because they are inherently spark-free and can tolerate high temperatures.
- Force or torque can be held constant — this is unique to fluid power transmission
- High torque at low speed — unlike electric motors, pneumatic and hydraulic motors can produce high torque while operating at low rotational speeds. Some fluid power motors can even maintain torque at zero speed without overheating
- Pressurized fluids can be transmitted over long distances and through complex machine configurations with only a small loss in power
- Multi-functional control — a single hydraulic pump or air compressor can provide power to many cylinders, motors, or other actuators
- Elimination of complicated mechanical trains of gears, chains, belts, cams, and linkages
- Motion can be almost instantly reversed

19. State Pascal's law (Nov/Dec 2009)

Pascal's law states that the pressure of a gas or liquid exerts force equally in all directions against the walls of its container. The force is measured in terms of force per unit area (pounds per square inch—psi). This law is for liquids and gases at rest and neglects the weight of the gas or liquid. It should be noted that the field of fluid power is divided into two parts, pneumatics and hydraulics. These two have many characteristics in common. The difference is that hydraulic systems use liquids and pneumatic systems use gases, usually air. Liquids are only slightly compressible and in hydraulic systems this property can often be neglected. Gases, however, are very

20. Give any two differences between hydraulic and pneumatic power (April/May2010)

1. The working fluid in Pneumatic system is air and in hydraulic it is oil
2. Pneumatic will be used for low pressure requirements, whereas hydraulic is used in case of more pressure requirements.
3. Hydraulic system produces pressure exponentially
4. Application for Pneumatic system is, they are used for automatic closing and opening of bus doors.
5. Application for hydraulic system: they are used in high capacity presses.

21. Give the expression used to determine friction factor for laminar flow through pipes (April/May2010)

For practical purposes, if the Reynolds number is less than 2000, the flow is laminar. The accepted transition Reynolds number for flow in a circular pipe is $Re_{d,crit}$ = 2300. For laminar flow, the head loss is proportional to velocity rather than velocity squared, thus the friction factor is inversely proportional to velocity**.**

The Darcy friction factor for laminar (slow) flows is a consequence of Poiseuille's law that and it is given by following equations:

$$\text{Circular Pipes: } f = \frac{64}{Re}$$

$$\text{Non-Circular Pipes: } f = \frac{k}{Re},\ 48 \leq k \leq 96$$

Geometry Factor k	
Square	56.91
2:1 Rectangle	62.19
5:1 Rectangle	76.28
Parallel Plates	96.00

22. Sketch the graphical symbol of variable displacement reversible pump and telescopic cylinder (April/May2010)

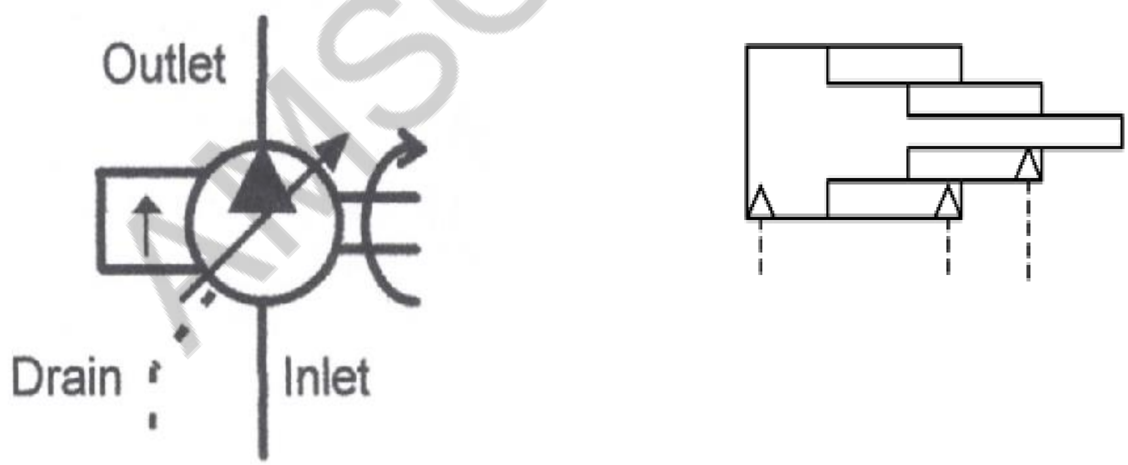
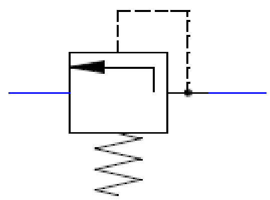


Fig: Variable displacement reversible pump and telescopic cylinder



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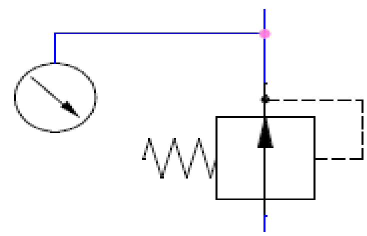

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Fig: Symbol of pneumatic regulator

UNIT-I

PART-B

1. List out the advantages and disadvantages of hydraulic system (April/May2008)

Table 1.4. Advantages of hydraulic power systems

1.	Hydraulic power is easy to generate, transmit, store, regulate and control, maintain and transform.
2.	Hydraulic power systems can generate and transmit large tonnes and forces to any part of a machine. It is also possible to amplify (*i.e.*, multiply) the force and power.
3.	The hydraulic power systems provide reversible, infinitely variable speed and load control.
4.	They can achieve accurate feed back control of load, position, *etc.*
5.	They offer cushioning for shock loads. Hence the noise and vibration produced are minimal.
6.	The wear of the system is reduced due to the self-lubrication action of the transmission medium.
7.	They are mechanically safe, compact and can be easily controlled.
8.	The power-to-weight ratio of a hydraulic power system is comparatively higher than that for electrical and mechanical power systems.
9.	The hydraulic output can be linear and rotational. Use of flexible connection hydraulic system permits generation of complex motion, which is impractical with the kinematic linkages such as gear, belts, cams, *etc.*
10.	The hydraulic power systems offer safe operation for both operator and machine.
11.	Hydraulic elements can be located easily at any place and can be controlled reversely.
12.	This system is a better over-load safe power system. This can be easily achieved by using a pressure relief valve.

2. Disadvantages of Hydraulic Power Systems

Table 1.5 presents some of the major disadvantages of hydraulic systems.

Table 1.5. Drawbacks of hydraulic power systems

1.	Hydraulic fluid leakage poses many problems to the operations as well as operators.
2.	Flammable hydraulic fluids may pose fire hazards thus limiting the upper level of working temperature.
3.	Hydraulic elements require special treatments to protect them against rust, corrosion, dirt, *etc.* Otherwise the contaminated elements may impair the system operation.
4.	Hydraulic fluids may pose problems if it disintegrates due to ageing and chemical deterioration.

2. What is the function of fluid power system in any fluid power system? (April/May2008)

1.7.3.2. Working of the Total Hydraulic System

The total hydraulic system for the task of moving a weight (W) by a distance (D) is shown in Fig.1.1(*b*). The parts enclosed in the dotted-lined box are common to an area of the plant, which may have many linear and rotary hydraulic actuators. In this case, we use only one linear hydraulic actuator.

AC induction motor (M) drives the hydraulic pump (P), so that the fluid is pumped from the tank at the required pressure. The fluid circulated into the system should be clean to reduce the wear of the pump and cylinder; hence a filter is used immediate to the storage tank. Since the pump delivers constant volume of fluid for each revolution of the shaft, the fluid pressure rises indefinitely, until a pipe or pump itself fails. To avoid this, some kind of pressure regulator is used to spill out the excess fluid back to the tank.

Cylinder movement is controlled by a 3-position changeover control valve. One side of the valve is connected to a pressurized fluid line and the fluid retrieval line; and other side of the valve is connected to port A and port B of the cylinder. Since the hydraulic circuit is a closed one, the liquid transferred from the storage tank to one side of the piston, and the fluid at the other side of the piston is retrieved back to the tank.

3 What are the required properties of good hydraulic fluid (April/May2008)

(Nov/Dec 2009)

1. Stable viscosity characteristics.
2. Good lubricity.
3. Compatibility with system materials.
4. Stable physical and chemical properties.
5. Good heat dissipation capability.
6. High bulk modulus and degree of incompressibility.
7. Adequate low-temperature properties (such as cloud point, pour point and freezing point).
8. Good flammability characteristics (such as flash and fire points).
9. Low volatility.
10. Good demulsibility.
11. Better fire resistance.
12. Lower foaming† tendency.
13. Nontoxicity.
14. Good oxidation stability.
15. Better rust-and corrosion-preventive qualities.
16. Low density and specific gravity.
17. Low coefficient of expansion.
18. Simple and easy handling.
19. Ready availability.
20. Inexpensive.

4. Short notes on the following (Nov/Dec 2011)

i) Laminar and turbulent flow

As we know, the hydraulic system is concerned with the flow of a liquid through a pipe. e two important types of flow are :

1. Laminar flow, and 2. Turbulent flow.†

.1. Laminar Flow

- ✓ A laminar flow is one in which paths taken by the individual particles do not cross one another and move along well defined paths, as shown in Fig.4.11.
- ✓ The laminar flow is characterized by the fluid flowing in smooth layers of laminae.
- ✓ This type of flow is also known as ***streamline*** or ***viscous flow***, because the particles of fluid moving in an orderly manner and retaining the same relative positions in successive cross-sections.

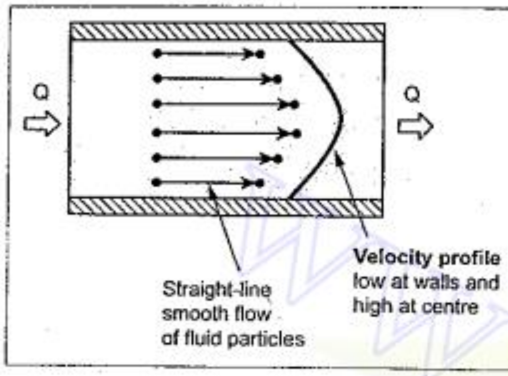


Fig. 4.11. Laminar flow

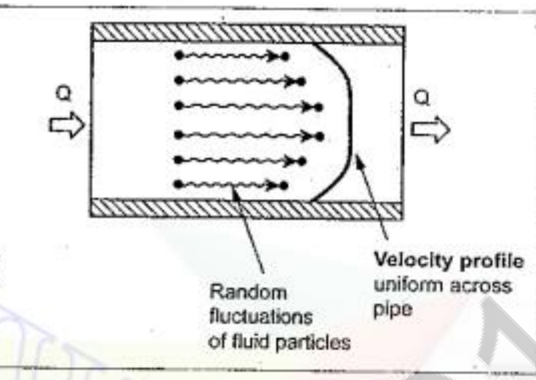


Fig. 4.12. Turbulent flow

- ✓ ***Examples :*** (*i*) Flow of oil in measuring instruments.
  - (*ii*) Flow of blood in veins and arteries.
  - (*iii*) Rise of water in plants through their roots.

.6.2. Turbulent Flow

- ✓ A turbulent flow is that flow in which fluid particles move in a zig-zag way, as shown in Fig.4.12.
- ✓ The turbulent flow is characterized by continuous small fluctuations in the magnitude and direction of the velocity of the fluid particles.
- ✓ ***Causes :*** The turbulence in the fluid may cause :
  - (*i*) More resistance to flow,
  - (*ii*) Greater energy loss, and
  - (*iii*) Increased fluid temperature due to greater energy loss.
- ✓ ***Examples :*** High velocity flow in a pipe of large size. Nearly all fluid flow problems encountered in engineering practice have a turbulent character.

. REYNOLD'S NUMBER

- ✓ Reynolds from his experiments found that the nature of flow in a closed pipe depends upon the following factors :
  - (*i*) Diameter of the pipe (D),
  - (*ii*) Density of the liquid (ρ),
  - (*iii*) Viscosity of the liquid (μ), and
  - (*iv*) Velocity of flow (V).
- ✓ By combining the above variables, Reynolds determined a non-dimensional quantity equal to $\frac{\rho V D}{\mu}$ which is known as ***Reynolds number (Re).***

$$\therefore \quad \text{Reynolds number, } Re = \frac{\rho V D}{\mu} = \frac{V D}{\nu} \quad [\because \nu = \frac{\mu}{\rho}] \qquad \dots (4.16)$$

✓ Laminar and turbulent flows are characterised on the basis of Reynolds number.

1. *If Reynolds number (Re) < 2000, then the flow in pipes is **laminar.***
2. *If Reynolds number (Re) > 4000, then the flow in pipes is **turbulent.***
3. If Reynolds number is between 2000 and 4000, then the flow in pipes is unpredictable.

✓ Since turbulent flow results in greater losses, therefore hydraulic systems should be designed to operate in the laminar flow region.

✓ The turbulent flow can be converted into laminar flow by either reducing the velocity of liquid or by increasing the pipe diameter.

ii) Energy losses in valves and fittings

LOSSES IN VALVES AND FITTINGS

- The loss of head in the various valves and fittings (such as tees, elbows, and bends) is given by the relation :

$$H_L = K\left(\frac{V^2}{2g}\right) \quad \text{... (4.27)}$$

where K = Constant of proportionality called *'the K-factor'*.

- The value of K-factor depends on the type of valves and pipe fittings. Table 4.2 gives typical K-factor values for several common types of valves and fittings.
- If the loss of head H_L is known, it can be expressed into equivalent pressure drop by using the relation,

$$\Delta P = H_L \times w_{oil} \quad \text{... (4.28)}$$

where w_{oil} = Weight density of oil flowing through valves and fittings.

Table 4.2. K-factors of common valves and fittings

Valve or Fitting		K-Factor
Globe valve :	Wide open	10.0
	½ open	12.5
Gate valve :	Wide open	0.19
	¾ open	0.90
	½ open	4.5
	¼ open	24.0
Return bend		2.2
Standard tee		1.8
Standard elbow		0.9
45° Elbow		0.42
90° Elbow		0.75

iii)Darcy equations

4.14. DARCY'S EQUATION

- ✓ The major energy losses i.e., the energy losses due to friction in the pipe can be calculated by using Darcy's equation.
- ✓ The Darcy's equation for the loss of head due to friction in pipes is as follows :

$$\boxed{H_L = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)} \quad \ldots (4.23)$$

where H_L = Loss of head due to friction in pipe in m,

f = Friction factor,

L = Length of pipe in m,

D = Inside diameter of the pipe in m,

V = Average velocity of liquid in m/s, and

g = Acceleration due to gravity in m/s^2.

- ✓ The Darcy's equation holds good for both laminar and turbulent flow provided a proper value of friction factor 'f' is evaluated.

5. Discuss any four hydraulic principles used in hydraulic system (Nov/Dec 2009)

A simple hydraulic system consists of hydraulic fluid, pistons or rams, cylinders, accumulator or oil reservoir, a complete working mechanism, and safety devices. These systems are capable of remotely controlling a wide variety of equipment by transmitting force, carried by the hydraulic fluid, in a confined medium. Modern developments in hydraulics have involved many fields in engineering and transportation. These systems transfer high forces rapidly and accurately even in small pipes of light weight, small size, any shape, and over a long distance. These systems play a vital role from small car's steering to supersonic aircraft's maneuvering devices. More powerful and accurate systems are also used in maneuvering huge ships.

- Fluid pressure creates force on a piston creates movement against a spring.
- Pressure drop across and orifice creates flow proportional to the orifice size.
- Load pressure changes, affect the control pressure.
- Leakage results from small clearances between the spools and bores.
- Dynamic seals reduce leakage but cause hysteresis.
- Restricting volume changes is used to control timings.

6. Discuss any application of fluid power (Nov/Dec 2009) (Nov/Dec2013)

The applications of hydraulic and pneumatic power systems cannot be simply listed/counted, because new uses of them are being found and adopted every day in all fields. However few of the applications of fluid power are summarised in Table 1.8.

Table 1.8. Applications of fluid power

Sl.No.	Industry/Field	Applications
1.	Manufacturing industry	Hydraulic presses, pneumatic hand tools, hydraulic and pneumatic fixtures, automatic and semi-automatic operating machines such as machines with hydraulic feed, pneumatic drive, automatic indexing machine, hydraulic-driven die-casting machine, hydraulic feed machines, automatic lathe with air-operated equipment, hydraulically operated shaving machines, cutting machines, drilling machines, *etc.*
2.	Automobile industry	Welding equipment using hydraulic controls, hydraulic brakes, automotive transmissions, power steering, power brakes, air conditioning, lubrication, water coolant, and gasoline pumping systems.
3.	Agriculture industry	Hydraulic and pneumatic driven elevator conveyors for use in harvesting of grains; fluid power driven farm equipments.
4.	Naval industry	Fluid power used for cargo handling, winches, propeller pitch control, submarine control systems, operation of shipboard aircraft elevators, and drive systems for radar and sonar.
5.	Aviation and Aerospace industry	Hydraulic-actuated landing gears, cargo doors, gun drives, and flight control devices such as rudders, ailerons, and elerons for aircraft; fluid powered missile launching systems.
6.	Mechatronics field	Fluid logic components, servo-controlled pneumatic actuators in robotics and tactile sensing; Fluid power used for operating various mechatronic elements such as spindle drives, feed drives, automatic tool clamping and work clamping, tool magazines and automatic tool chargers, *etc.*

7. Explain how Bernoulli's equation can be used to determine the pressure drop between two stations in a hydraulic system (Nov/Dec 2009)

✓ Bernoulli equation states as follows :

"In an ideal, incompressible fluid when the flow is steady and continuous, the sum of potential energy, kinetic energy and pressure energy is constant across all cross sections of the pipe."

✓ For the incompressible fluid flowing through a non-uniform pipe shown in Fig.4.15, the Bernoulli's equation can be written as,

$$z_1 + \frac{V_1^2}{2g} + \frac{P_1}{w} = z_2 + \frac{V_2^2}{2g} + \frac{P_2}{w} \quad \text{... (4.21)}$$

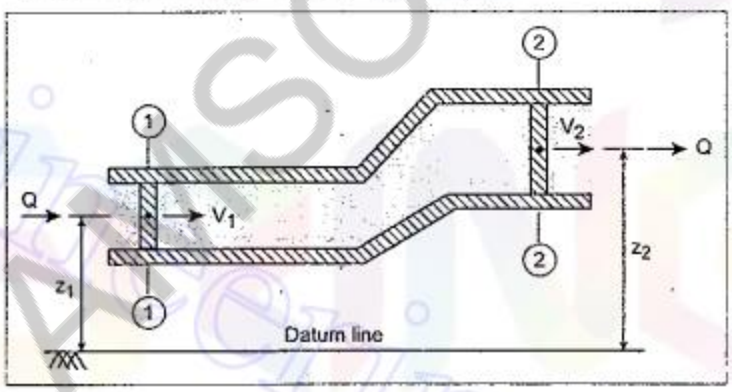


Fig. 4.15. Flow through pipe

8. What types of fluids are available for hydraulic system? (Nov/dec2011) (Nov/Dec2013)

There are two different types fluid systems. They are :

1. Fluid transport systems, and
2. Fluid power systems.

The differences between them are presented in Table 1.1.

Table 1.1. Fluid transport systems Vs Fluid power systems

1.	*Fluid Transport Systems :* ✓ The objective of the fluid transport systems is to transport/deliver fluids from one place to another place to achieve some useful purpose. ✓ *Examples :* Some of the examples of fluid transport systems include : (*i*) Transport of water from water reservoirs (such as wells/rivers) to houses/industries using pipe lines; and (*ii*) Transport of petroleum oil/gas from one country to another through oil/gas pipe lines.
2.	*Fluid Power Systems :* ✓ The fluid power systems are primarily designed to perform work. That is, these systems use pressurized fluids to produce some useful mechanical movements to accomplish the desired work.

Table 1.2. Methods of transmitting power

1.	*Electrical Power Transmission :* ✓ *Concept :* Electrical power is transmitted by imposing an electromagnetic field on a conductor. ✓ *Suitability :* They are suitable for power transmission over long distances. ✓ *Disadvantages :* The limitations of electric power transmission include magnetic saturation (which may limit the torque developed by an electric motor); material limitations (which may affect the speed); and heat dissipation problem.
2.	*Mechanical Power Transmission :* ✓ *Concept :* Mechanical power is transmitted by employing a variety of kinematic mechanisms such as belts, chains, pulleys, sprockets, gear trains, bar linkages, and cams. ✓ *Suitability :* They are suitable for the transmission of motion and force over relatively short distances. ✓ *Disadvantages :* The disadvantages of mechanical power transmission include lubrication problems, limited speed and torque control capabilities, uneven force distribution, and relatively large space requirements.

3. ***Fluid Power Transmission :***

(a) Hydraulic Power Transmission : ✓ *Concept :* Hydraulic power is transmitted by the pressure and flow of liquids. The most common liquids used are petroleum oils.

- ✓ *Suitability :* They are suitable for power transmission over intermediate distances. That is, they can be employed over greater distances than mechanical types but not as far as electrical systems.
- ✓ *Advantages :* Hydraulic systems are mechanically stiff, and can be designed to give fast operation and move very heavy loads.
- ✓ *Disadvantages :* The disadvantages of hydraulic system include hydraulic fluid leakage; impairment of system operation by contamination; and fire hazards with flammable hydraulic fluids.

(b) Pneumatic Power Transmission : ✓ *Concept :* Pneumatic power is transmitted by the pressure and flow of compressed gases. The most commonly used gas is air.

- ✓ *Suitability :* They are suitable for power transmission over intermediate distances.
- ✓ *Advantages :* Pneumatic systems use simple equipment, have small transmission lines, and do not present a fire hazard.
- ✓ *Disadvantages :* The disadvantages of pneumatic system include a high fluid compressibility and a small power-to-size ratio of components.

9. What are the basic components that are required for a hydraulic system? Explain their functions (Nov/dec2011)

1.7. HYDRAULIC POWER SYSTEM

As we know, the hydraulic system uses the pressurized hydraulic liquid as the fluid medium. Also *hydraulic system is always a closed loop system.*

1.7.1. Arrangement

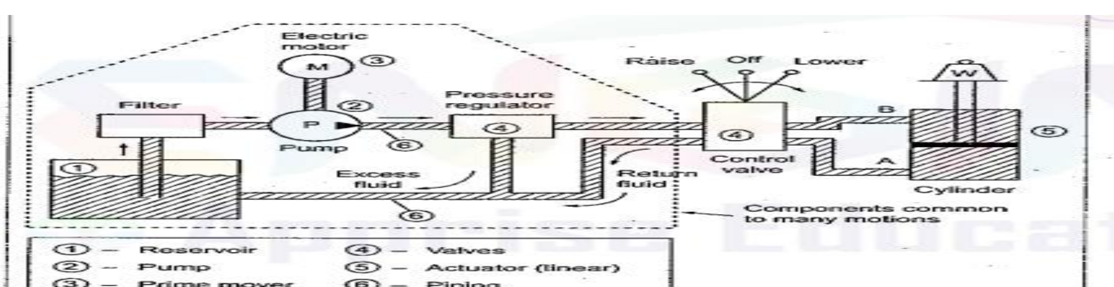
The general arrangement of a basic hydraulic system is shown in Fig.1.1.

1.7.2. Basic Components of a Hydraulic System

A hydraulic system consists of six basic components, as shown in Fig.1.1(*b*). The basic components and their functions are presented in Table 1.9.

Table 1.9. Basic components† of a hydraulic system

1.	*Reservoir (or tank) :* A reservoir is an oil supply tank. It is provided to hold the hydraulic liquid (usually oil).
2.	*Pump :* A pump is used to force the liquid into the system.
3.	*Prime mover :* A prime mover, usually an electric motor, is used to drive the pump.
4.	*Valves :* Valves are fitted in the system to control liquid direction, pressure, and flow rate.
5.	*Actuator :* An actuator is provided to convert the liquid energy into mechanical force or torque to do useful work. The actuator is the actual working element of the system. The actuators can be either cylinders (to provide linear motion) or hydro motors (to provide rotary motion).
6.	*Fluid-transfer piping :* The hydraulic piping is provided to carry the liquid from one place to another.



(b) General arrangement of a hydraulic system

10. Write notes on (May/June 2013)

i. Neutralization number

2.22. NEUTRALIZATION NUMBER

- ✓ The term 'Neutralization number' is used to express an acidity or alkalinity of lubricating liquids and hydraulic fluids.
- ✓ ***Definition :*** The neutralization number is defined as the number of milligrams of potassium hydroxide required to neutralize all the acids present in one gram of the sample.

ii. Frictional losses in laminar and turbulent flow

4.14.1. Frictional Losses in Laminar Flow

For laminar flow, the friction factor '*f*' is function of Reynolds number only and is given by,

$$\boxed{f = \frac{64}{Re}} \qquad \dots (4.24)$$

Substituting equation (4.24) into equation (4.23), we get

$$\boxed{H_L = \frac{64}{Re}\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)} \qquad \dots (4.25)$$

The above equation is known as the ***Hagen-Poiseuille equation,*** which is valid only for laminar flow.

4.14.2. Frictional Losses in Turbulent Flow

- ✓ Unlike for laminar flow, the friction factor '*f*' for turbulent flow is a function of Reynolds number as well as the relative roughness of the pipe.
- ✓ The ***relative roughness*** is defined as the pipe inside surface roughness (ε) divided by the inside diameter of the pipe (D).

$$\therefore \quad \boxed{\text{Relative roughness} = \frac{\varepsilon}{D}} \qquad \dots (4.26)$$

- ✓ In equation (4.26), the 'ε' is called the ***absolute roughness.*** Table 4.1 gives typical values of absolute roughness for various types of pipes. For a given pipe, the appropriate 'ε' value may be selected using the Table 4.1.

Table 4.1. Typical values of absolute roughness

Types of pipe	Absolute roughness ε (mm)
Glass or plastic	Smooth
Drawn tubing	0.0015
Commercial steel or wrought iron	0.046
Asphalted cast iron	0.12
Galvanized iron	0.15
Cast iron	0.26
Riveted steel	1.8

✓ Once we calculate the relative roughness (ε/D) and Reynolds number, we can determine the friction factor for use in Darcy's equation by using the Moody diagram. The Moody diagram is presented in Fig.4.16. The Moody diagram contains many curves. The curves indicate the value of friction factor as a function of Reynolds number and relative roughness.

11. How will you measure the pump performance? Explain each with suitable example (April/May2005) (Nov/Dec2005)

.16. PUMP PERFORMANCE

The performance characteristics of a pump can be represented in terms of overall fficiency. Overall efficiency, in turn, has two components : 'Volumetric efficiency' and nechanical efficiency'. These three efficiencies are presented below.

.16.1. Volumetric Efficiency

✓ ***Definition :*** It is the ratio between the actual flow rate produced by the pump and the theoretical flow rate that the pump should produce.

✓ ***Formula :***

$$\text{Volumetric efficiency} = \frac{\text{Actual flow rate produced by the pump}}{\text{Theoretical flow rate that the pump should produce}} \times 100$$

$$\boxed{\eta_{vol} = \frac{Q_A}{Q_T} \times 100} \quad \dots (5.10)$$

✓ ***Significance :*** *The volumetric efficiency indicates the amount of leakage within the pump.* The lower the internal slip losses, the higher the volumetric efficiency. For zero slip, the volumetric efficiency is 100%.

5.16.2. Mechanical Efficiency

✓ ***Definition :*** It is the ratio between the theoretical power required to operate the pump and the actual power delivered to the pump.

✓ ***Formula :***

$$\text{Mechanical efficiency} = \frac{\text{Theoretical power required to opeate the pump}}{\text{Actual power delivered to pump}} \times 100 \quad \dots (5.11)$$

or

$$\boxed{\eta_{mech} = \left(\frac{P \times Q_T}{T_A \times \omega}\right) \times 100} \quad \dots (5.12)$$

where
P = Pump discharge pressure in N/m^2,
Q_T = Theoretical flow rate of the pump in m^3/s,
T_A = Actual torque delivered to pump in N-m,
ω = Angular speed of the pump in rad/s = $\frac{2\pi N}{60}$, and
N = Speed of the pump in r.p.m.

Mechanical efficiency can also be calculated in terms of torques as follows :

$$\eta_{mech} = \frac{\text{Theoretical torque required to operate pump}}{\text{Actual torque delivered to pump}} \times 100 \quad \dots (5.13)$$

$$\boxed{\eta_{mech} = \frac{T_T}{T_A} \times 100}$$

Here $$T_T\,(N.m) = \frac{V_D\,(m^3) \times P\,(Pa)}{2\pi} \quad \text{... (5.14)}$$

and $$T_A = \frac{\text{Actual power delivered to pump (watts)}}{\left(\frac{2\pi N}{60}\right)} \quad \text{... (5.15)}$$

- ✓ ***Significance :*** The mechanical efficiency indicates the amount of energy lost due to friction in bearings and other mating parts, and energy lost due to fluid turbulence. In other words, *the mechanical efficiency indicates the amount of energy losses that occur due to reasons other than leakages.*
- ✓ Since the amount of power required to overcome friction rises with increased liquid viscosity, mechanical efficiency decreases as liquid viscosity decreases.
- ✓ Power losses in timing gears, bearings and seals reduce mechanical efficiency.

5.16.3. Overall Efficiency

- ✓ ***Definition :*** It is the ratio between the actual power delivered by pump and the actual power delivered to pump.
- ✓ ***Formula :***

$$\text{Overall efficiency} = \frac{\text{Actual power delivered by pump}}{\text{Actual power delivered to pump}} \times 100 \quad \text{... (5.16)}$$

Mathematically, the overall efficiency can also be written as

$$\eta_0 = \text{Volumetric efficiency} \times \text{Mechanical efficiency}$$

or $$\eta_0 = \eta_{vol} \times \eta_{mech} \quad \text{... (5.17)}$$

Substituting equations (5.10), (5.12), and (5.17), we get

$$\eta_0 = \left(\frac{P \cdot Q_A}{T_A \cdot \omega}\right) \times 100 \quad \text{... (5.18)}$$

✓ ***Significance :*** *The overall efficiency indicates the amount of energy losses by all means.*

ii)

A pump has a displacement volume of 98.4 cm³. It delivers 0.00152 m³/s of oil at 1000 rpm and 70 bars. If the prime mover input torque is 124.3 N-m (1) What is the overall efficiency of the pump ? (2) What is the theoretical torque required to operate the pump ? **(8)**

Given Data : $V_D = 98.4\ cm^3 = 98.4 \times 10^{-6}\ m^3$; $Q_A = 0.00152\ m^3/s$; $N = 1000$ rpm; $P = 70\ bar = 70 \times 10^5\ N/m^2$; $T_A = 124.3$ N-m.

☺ ***Solution :*** $\omega = 2\pi N/60 = 2\pi\,(1000)/60 = 104.72$ rad/s.

(1) To find overall efficiency of the pump (η_o) :

We know that,

$$\eta_o = \frac{P \times Q_A}{T_A \cdot \omega} \times 100$$

$$= \frac{(70 \times 10^5)\,(0.00152)}{124.3 \times 104.72} \times 100 = \mathbf{81.74\%} \quad \textbf{Ans.}$$

(2) To find the theoretical torque required to operate the pump (T_T) :

We know that,

$$T_T = \frac{V_D \times P}{2\pi}$$

$$= \frac{(98.4 \times 10^{-6})\,(70 \times 10^5)}{2\pi} = \mathbf{109.62\ N\text{-}m} \quad \textbf{Ans.}$$

12. How do you classify pumps? Explain with suitable sketch the working of vane pump(Nov/Dec2005)

With reference to the fluid power applications, pumps can be broadly classified into : (*i*) Positive displacement pumps, and (*ii*) Non-positive displacement pumps. They are further classified into many types, as shown in Fig.5.2.

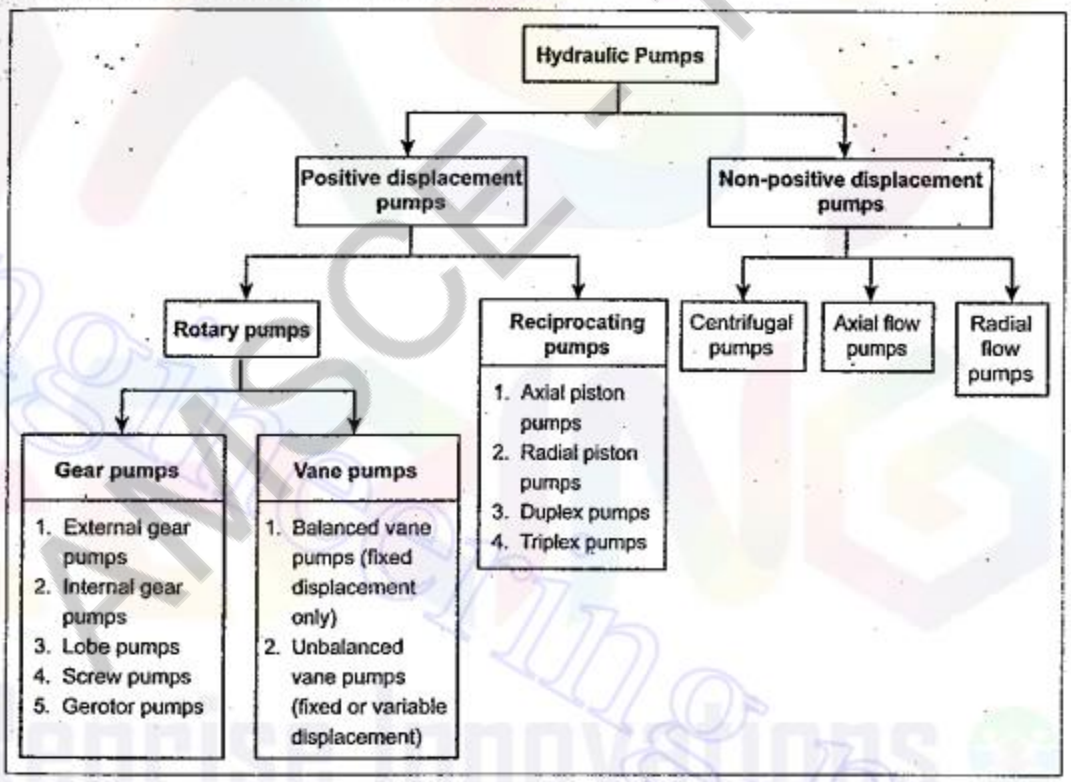


Fig. 5.2. Classification scheme of pumps

5.10.1. Introduction

The major problem in gear pumps is that the significant amount of leakage occurs between the small gaps of teeth, and also between teeth and pump housing. The vane pumps reduce this leakage by using spring-or hydraulic-loaded vanes.

5.10.2. Types of Vane Pumps

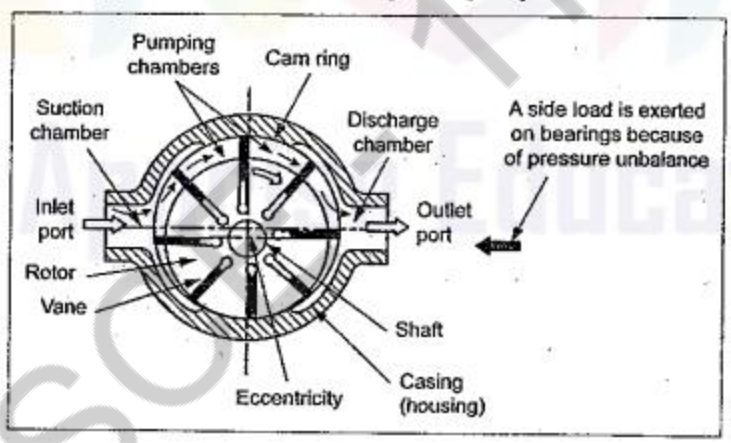
The two important types of vane pumps are :

1. Unbalanced vane pumps, and
   (*a*) Fixed-displacement unbalanced pumps, and
   (*b*) Variable-displacement unbalanced pumps.
2. Balanced vane pumps.

5.11. UNBALANCED VANE PUMP

5.11.1. Construction and Operation

Fig.5.9 illustrates a typical unbalanced sliding-vane pump.



In this pump, the rotor is mounted off-center. At regular intervals around the curved surface of the rotor are rectangular vanes that are free to move in a radial slot. As the rotor revolves, the vanes are thrown outwards by centrifugal force to form a seal against the fixed casing. The eccentricity of the revolving rotor produces a partial vacuum at the suction side of the pump, causing an inflow of liquid. This is carried to other side of the pump in the space between the rotor and the fixed casing.

Generally, pumping rates of these rotary pumps are varied by changing the speed of the rotor. However in unbalanced vane pumps, the pumping rate can also be varied by changing the degree of eccentricity of the rotor, since this determines the amount of liquid carried through per cycle.

5.12. BALANCED VANE PUMP

5.12.1. Construction and Operation

Unlike in unbalanced vane pump, the balanced vane pump has two intake and two outlet ports which are diametrically opposite to each other. Also a balanced vane pump has an elliptical housing instead of a circular cam ring. This configuration creates two diametrically-opposed volumes. The two high-pressure zones balance the forces on the rotor shaft and hence a complete hydraulic balance is achieved.

Fig.5.10 illustrates the operation of a balanced vane pump. Except the above said differences, the construction and basic working principle are similar to the unbalanced vane pumps.

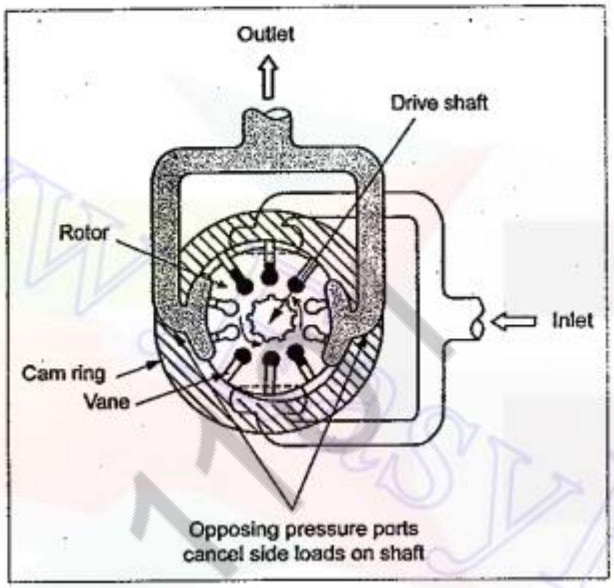


Fig. 5.10. Balanced vane pump operation

13 .Explain the working principles of external gear pump and determine its performance measure (Nov/Dec2006)

5.5. EXTERNAL GEAR PUMPS

5.5.1. Construction

External gear pumps have two mating gears (driver and follower) that are turned in a closely fitted casing, as shown in Fig.5.3. Each gear is mounted on a shaft which is supported on bearings in the end covers. In these, the driver shaft is coupled to the prime mover (electric motor, gasoline engine, *etc.*). Two parts—inlet and delivery parts—are provided directly on the opposite sides of the mesh point of the gears. The larger and straight ports are preferred for better performance. The driving shaft is usually connected to the upper gear of the pump. The rotation of the driver gear causes the follower gear to turn.

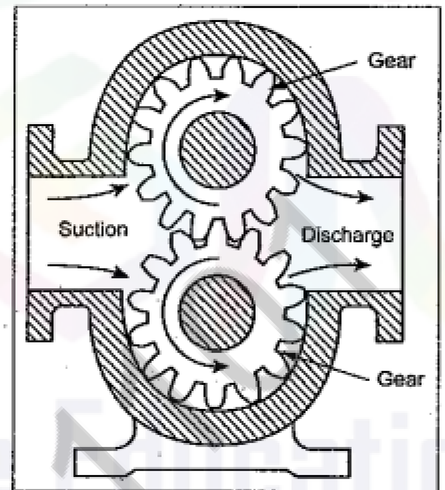


Fig. 5.3. External gear pump

5.5.2. Operation

The self-explanatory Fig.5.4 explains the operation of the external gear pump in steps.

When the pump starts rotating, the rotation of gears forces air out of the casing and into the discharge pipe [Fig.5.4(*a*)]. This removal of air from the pump casing produces a partial vacuum on the suction side of the pump. Fluid from an external reservoir is forced by the atmospheric pressure into the pump inlet. Here the fluid is trapped between the teeth of the upper and lower gears and the pump casing [Fig.5.4(*b*)]. Continued rotation of the gears forces the fluid out of the pump discharge [Fig.5.4(*c*)].

A vacuum is formed in the cavity between the teeth as they un-mesh, causing more fluid to be drawn into the pump. Pressure rise in the pump is produced by the squeezing action on the fluid as it is expelled from between the meshing gear teeth and the casing.

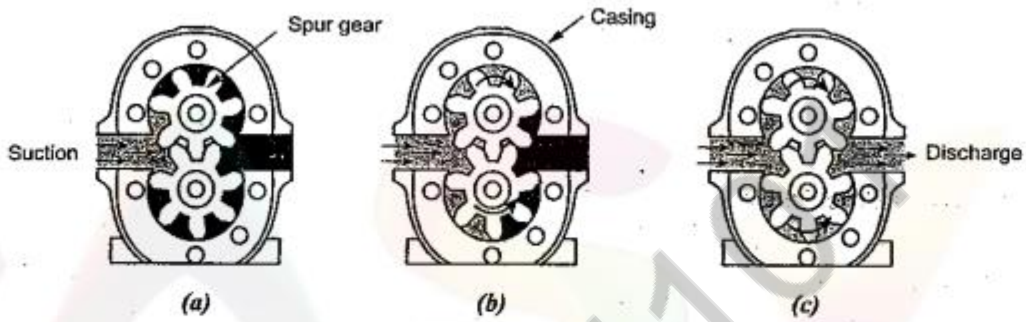


Fig. 5.4. Operation of external gear pumps : (a) Vacuum draws fluid into pump. (b) Teeth carry fluid through pump. (c) Fluid is discharged under pressure

5.5.3. Analysis of Volumetric Displacement and Theoretical Flow Rate

The volumetric displacement and theoretical flow rate of a gear pump can be determined as follows :

Let D_i = Inside diameter of gear teeth in m,

D_o = Outside diameter of gear teeth in m,

L = Width of gear teeth in m,

N = Speed of pump in rpm,

V_D = Volumetric displacement of the pump in m^3/rev, and

Q_T = Theoretical pump flow rate in m^3/sec.

If addendum and dedendum of a gear is known, then inside diameter of gear teeth can be calculated by

$$D_i = D_o - 2\,(\text{Addendum} + \text{Dedendum})$$

The volumetric displacement, from the geometry of the gear teeth, is given by,

$$\boxed{V_D = \frac{\pi}{4}\,(D_o^2 - D_i^2)\,L} \quad \ldots (5.1)$$

Then the theoretical flow rate can be calculated as

$$\boxed{Q_T = \frac{V_D \times N}{60}} \quad \ldots (5.2)$$

From equation (5.2), it is evident that the pump flow rate depends on :

(*i*) Size of the gear, and (*ii*) Speed of the pump.

Note If the gear is specified by its module and number of teeth, then the theoretical discharge can be found by using the following empirical relation :

$$Q_T = 2\pi L m^2 N \left[z + \left(1 + \frac{\pi^2 \cos \alpha}{12} \right) \right] \text{ m}^3/\text{min} \quad \ldots (5.3)$$

where
L = Width of gear teeth in m,
m = Module of gear in m,
N = Pump speed in rpm, and
z = Number of gear teeth.

Volumetric efficiency

$$\therefore \quad \text{Volumetric efficiency, } \eta_{vol} = \frac{Q_A}{Q_T} \times 100 \quad \ldots (5.4)$$

where Q_A and Q_T are actual and theoretical flow rate of the pump respectively.

Since the internal leakage increases with the increase in discharge pressure, the volumetric efficiency will be lower for the high discharge pressure.

From equation (5.2), it is evident that the pump flow rate depends on :

(*i*) Size of the gear, and (*ii*) Speed of the pump.

Note If the gear is specified by its module and number of teeth, then the theoretical discharge can be found by using the following empirical relation :

$$Q_T = 2\pi L m^2 N \left[z + \left(1 + \frac{\pi^2 \cos \alpha}{12} \right) \right] \text{ m}^3/\text{min} \quad \ldots (5.3)$$

where
L = Width of gear teeth in m,
m = Module of gear in m,
N = Pump speed in rpm, and
z = Number of gear teeth.

5.5.4. Volumetric Efficiency

Obviously there will be a small radial clearance between the gear teeth and the casing so as to achieve the gears rotation. As a result, some of the fluid may leak inside the system without discharging at the outlet port. This internal leakage, also known as ***'pump slippage'***, results in lesser flow rate (Q_A) than the theoretical flow rate (Q_T). This is represented by the volumetric efficiency.

$$\therefore \quad \text{Volumetric efficiency, } \eta_{vol} = \frac{Q_A}{Q_T} \times 100 \quad \ldots (5.4)$$

where Q_A and Q_T are actual and theoretical flow rate of the pump respectively.

Since the internal leakage increases with the increase in discharge pressure, the volumetric efficiency will be lower for the high discharge pressure.

ii) Write short notes on variable displacement pump

2. Variable Displacement Pumps : In variable displacement pumps, the displacement can be varied by changing the physical relationships of various pump elements. This change in pump displacement produces a change in output of fluid flow even though pump speed remains constant.

✓ ***Examples :*** Some of the positive displacement pumps are gear, vane, piston, and screw pumps.

14. With a neat sketch explain the construction ,working , advantages , application and limitation of non pressure compensated reciprocating vane pump (Nov/Dec2006) (Refer Q.No.12)

Table 5.5. Advantages and disadvantages of vane pumps

Advantages	Disadvantages
✓ Vane pumps are self-priming, robust, and give constant delivery for a set rotor speed.	✓ Vane pumps cannot be operated against a closed discharge without damage to the pump. Hence relief valves are required.
✓ They produce uniform discharge with negligible pulsations.	✓ They cannot handle abrasive liquids.
✓ Their vanes are self-compensating for wear and also vanes can be easily replaced.	✓ They require seals.
✓ These pumps do not require check valves.	✓ Foreign bodies can damage the pump.
✓ They can pump in either direction.	
✓ They require little space.	
✓ They are light in weight.	
✓ They can handle liquids containing vapours and gases.	
✓ Volumetric and overall efficiencies are relatively high.	
✓ Only small changes in capacity occur with variations in viscosity and discharge pressure.	

15. Explain the working and construction of gear pump (Nov/Dec2007) Refer Q.No:13

5.6. INTERNAL GEAR PUMP

5.6.1. Introduction

The operation of internal gear pumps is very much similar to external gear pumps, but they are very efficient and produce less noise. The gears rotate in the same direction, with the inner gear rotating at a higher speed. Generally the internal gear pumps are used for low output applications at pressures below 70 bar. This pump is also known as ***crescent seal pumps.***

5.6.2. Construction

Internal gear pump consists of an internal spur gear, a outside ring gear, a crescent shaped spacer, and an external housing, as shown in Fig.5.5. The internal spur gear drives the outside ring gear which is set off-center (*i.e.*, both gears are eccentric to each other). The inner and outer gears are separated by a crescent shaped spacer, which is a stationary part of the housing around which oil is carried. The inlet and outlet ports are located in the end plates between where the gear teeth mesh and un-mesh at the two ends of the crescent shaped spacer.

5.6.3. Operation

The operation of the internal gear pumps is similar to external gear pumps. Oil is transferred from the inlet to the outlet port. The internal gear drives the external gear and affects a fluid tight seal at the place where the teeth start meshing. Rotation causes the teeth to un-mesh near the inlet port, the cavity volume increases and the suction occurs. The oil is trapped between the internal and external gear teeth on both sides of the crescent shaped spacer and is carried from the inlet to the outlet cavity of the pump, as shown in Fig.5.5. Meshing of the gear teeth reduces the volume in the high pressure cavity near the outlet port and exits from the outlet port.

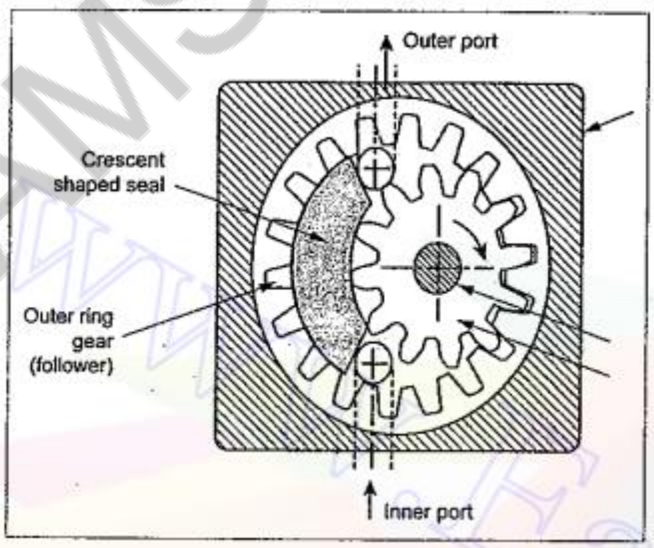


Fig. 5.5. Operation of an internal gear pump