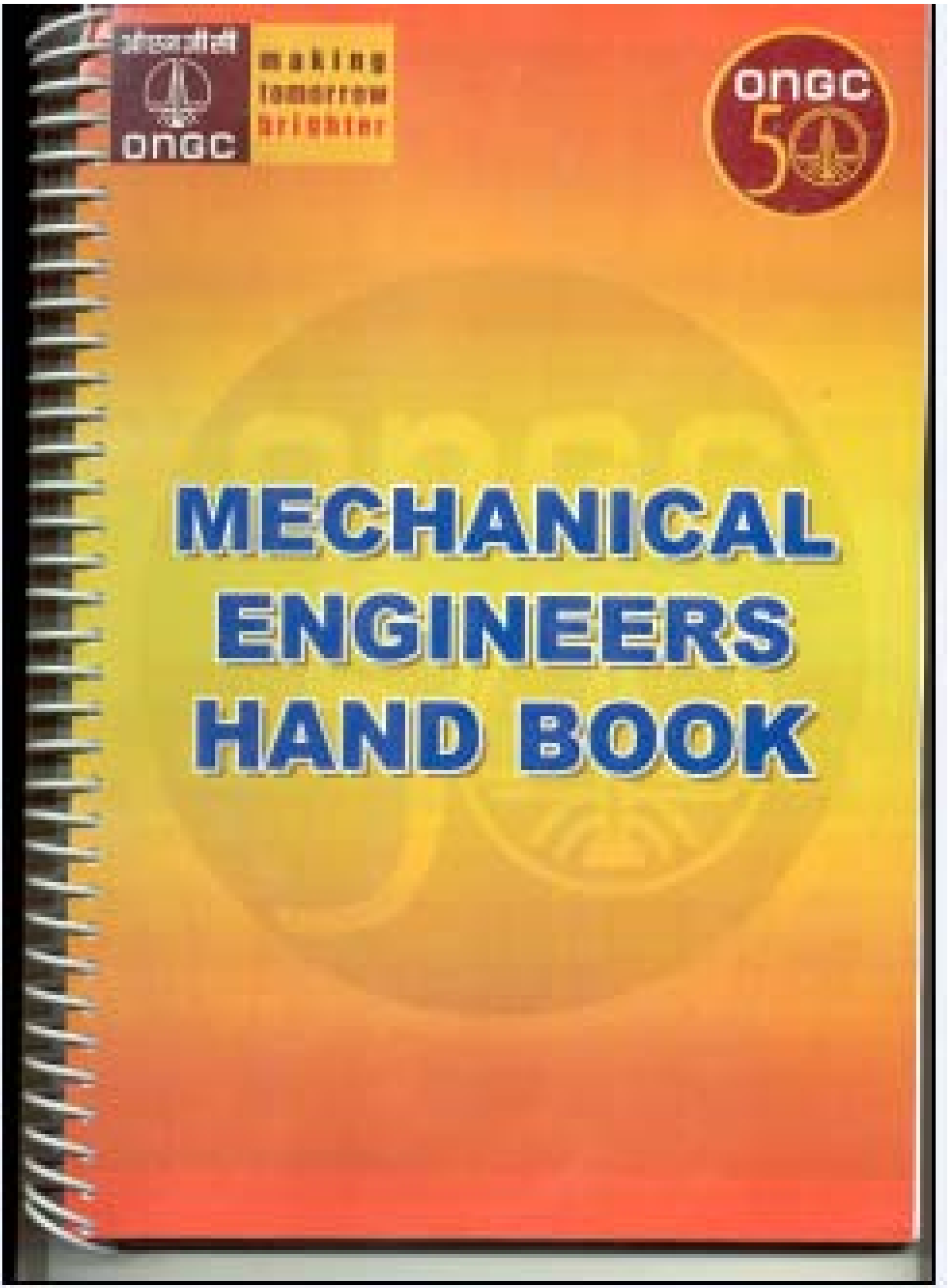

ONGC
making tomorrow brighter
ONGC 50
MECHANICAL ENGINEERS HAND BOOK

Oil and Natural Gas Corporation Limited
Cauvery Asset

FORE WORD

The darkness disappears the moment the lamp is lit. Mind is the seat of thoughts and storehouse of knowledge. Knowledge constitutes skill, key to development and symbol to prosperity. Seamless access to information about knowledge is absolute necessity for a successful organization. There will not be any boundary for the talented people. Outputs with quality efforts deserve rewards. People of high calibre always perform to the best of their ability and reach unmatchable level of performances. This book is a repository of knowledge for the readers. It has possessed variety of technical information. It helps to develop multidimensional skills and quality of the workforce. Knowledge reduces expenses, redundant efforts and guides the people properly to achieve the better result. This book is quite suitable for those who aspire for knowledge. The knowledge revolution will help to enhance human productivity. The topics covered in this book are more informative. It will give clear-cut vision; enhance confidence level and employees potential. Of course this book is an astute analysis of several technical literatures related with Mechanical Engineering Discipline. I appreciate the efforts made by **Shri. K. Chelladurai, SE (MECH)** in bringing out this **"Mechanical Engineers Hand Book"** to the young executives of ONGC for more enlightenment.

I wish him great success

Sd/-
ANIL JOHARI
GGM-Asset Manager

PREFACE

"Pursuit of happiness is one's attitude on life"

The progress towards the ultimate goal of life depends on the knowledge. Knowledge, whose centers are everywhere and their margins are nowhere. The purpose of this book is to provide a comprehensive knowledge and an insight thought into various aspects of engineering and technology. There should not be any boundary for talent people of our organization. A careful thought and attention has been given to this subject for full coverage of technical information required for ONGC. This book is an out come of a hard work, dedication and ceaseless efforts for the past few months. I wish to acknowledge the assistance that I have taken in preparing this book from the large number of textbooks. It will certainly provide required technical input to the mechanical engineers of ONGC. I am of the opinion that the content of this book will make one's learning desire is more enriched and fruitful. It is hoped that the Mechanical Engineers Hand Book will be useful not only to senior executives interested in knowing mechanical engineering subject but also beneficial to all the readers. The author expresses his gratefulness to all those author's, publishers, and manufacturers. This book is an attempt to satisfy the requirement of all ONGC engineers aspiring for self-knowledge. I wish them all the best with my heartiest pleasure.

I am especially thankful to Shri. Anil Johari, GGM-Asset Manager, Shri.A.K. Khanna, DGM (D)-HDS and Shri. T.R. Sivakolundu CE (M) for their encouragement and cooperation in bringing out this book.

Of course, I am grateful to my family for their active cooperation for completion of this book.

Sd/-

K.Chelladurai

SE (MECH), DS

"COUNT WHAT IS KNOWN
EXPOSE WHAT IS NEEDED"

CONTENTS

UNIT OF MEASUREMENTS

FUNDAMENTAL UNITS

Measurement of physical quantities is one of the most important operations in engineering and technology. Every quantity is measured in terms of some arbitrary, but internationally accepted units is called fundamental units. They are:

1. Mass
2. Length
3. Time
4. Temperature
5. Luminous intensity
6. Current

FUNDAMENTAL UNITS

Sl.no.	Physical quantity	C.G.S. unit	S.I. unit	M.K.S. unit	F.P.S. unit
01	Mass	G	Kg	Kg	Lb
02	Length	Cm	M	M	Ft
03	Time	S	S	S	S
04	Temperature	C	K, C	C	F
05	Luminous intensity	Lumen per steyradian	Candela (cd)	Candela (cd)	Candle power
06	Current	A	A	A	A

SYSTEM OF UNITS

In engineering and technology, only four systems of units are commonly used and are universally recognized. They are known as

1. C.G.S. unit---------- Absolute units/physicist units.

2. F.P.S. unit---------- British units

3. M.K.S. unit---------- Gravitational units/engineer's units

4. S.I. unit---------- International system of units (D-unit)

DERIVED UNITS

Some units are expressed in terms of fundamental units known as derived units.

Sl.no.	Physical quantity	C.G.S. unit	S.I. unit	M.K.S. unit	F.P.S. unit
01	Area =side x side or length x width	Cm^2	M^2	M^2	In^2
02	Volume =side x side x side or length x breadth x height	Cm^3	M^3	M^3	M^3
05	Discharge (flow) = Volume of liquid that passes a point in a given time	Ml/s	L/m	L/m	Gpm
06	Velocity = Distance/ unit time	Cm/sec	M/sec	M/sec	Ft/sec
07	Acceleration = Velocity/unit time	Cm/sec^2	M/sec^2	M/sec^2	Ft/sec^2

08	Force = Mass x Acceleration	g x cm/sec^2 =1dyne	Kg x m/sec^2=N = 10^5 dyne	1 kgf =9.81kg m/sec^2 =9.81N= 9.81 x 10^5 dyne	Lb force
09	Work = Force X Distance	Dyne-cm =erg	N-m =Joule	9.81 N-m = 9.81Joule	Ft-lb
10	Power = Work/Unit time	Erg/sec	N-m/sec =Watt	9.81 Watts	Hp
11	Pressure =Force /Unit time	Dyne/cm^2	N/m^2 =1 Pascal 1bar=10^5 Pascal	9.81 Pascal	Psi
12	Specific weight (weight density) = weight of any substance/ it's unit volume	Dyne/cm^3	N/m^3	Kgf/m^3	Lbs/in c^3
13	Density or mass density or specific mass = mass of substance/unit volume	G/m^3	Kg/m^3	Kg/m^3	Lbs/in c^3
14	Specific volume (reciprocal of density) = volume/unit mass	Cm^{3}g	M^3/kg	M^3/kg	Inc^3/lbs
15	Specific gravity = mass of certain volume of the substance/mass of equal volume of water at 4 degree Celsius.	No unit	No unit	No unit	No unit

16	Relative density = density of any substance / density of water at 4 degree Celsius.	No unit	No unit	No unit	No unit
17	Viscosity = ratio of the shearing stress and force between adjacent layers of fluid to rate of change of velocity perpendicular to the direction of motion	G / Cm/sec =poise	Kg/m/s = 10 poise	Kg/m/s =10 poise	Slugs/ foot-sec = 0.002089 poise
18	Kinematics viscosity = absolute viscosity/mass Density	Cm^2sec = stokes	M^2/sec = 10^4 stokes	M^2/sec = 10^4	Sq. ft /sec =0.001076 stokes
19	Specific heat = The heat required by a unit mass of a substance to raise temperature by one degree is called the specific heat of the substance.	J/g°c	J/kg °k	Kcal/kg°c	Btu/lb °k
20	Heat flow rate	J/sec	Watts or j/sec	Kcal/hr	Btu

ATMOSPHERIC PRESSURE:

It is the pressure of the air in our atmosphere due to its weight. It is 29.92 inches of mercury. Vacuum is measured in psi (or) inches of mercury. The drop in atmospheric pressure above an altitude of more than 500 meters above sea level is approximately at a rate of decrease of one meter of water column pressure with every 1000-meter increase in altitude.

Atmospheric pressure = 1 atmos absolute

= 1.01325 bars (SI unit)

= 101325 pascals (SI unit)

= 1.0332 kgf/cm² (MKS unit)

= 760 mm of mercury column or torr

= 10.332 meter of water column (mwc)

= 14.697 lbs per square inch.

1 ata = 1 kgf
= 736 mm Hg

1 bar = 10^5 N/m²
= 760mm Hg

1mm Hg = 1 torr

HEAT

F = (C x 9/5) +32

C = (F- 32) x 5/9

1 kcal/hr = 4186.8 joules

1 btu = 252 calorie

= 0.252 kcal

1HP = 33000ft-lb/min

= 75kgm/sec

= 4500kgm/min

= 746 watts

= 42.4 btu/min

1 btu/min = 0.02358 HP

1 cal/min = 0.00009357 HP

1 kcal /min = 0.09357 HP

1 btu (British thermal unit) is 1 pound of water to rise by 1 foot.

1 calorie is 1 gram of water to raise by 1°c

TIME

A.M. =Ante meridian

P.M. = Post meridian

1 year = 365 days

1 leaf year = 366 days

1 Decade = 10 years

1 Century = 100 years

1 Millennium = 1000 years

SIZE

Visible particle size = 40 micron

Human hair size = 80 micron

1micron = 0.000039 inches

1 micron = 0.000099 cm

1 inch = 25641 micron

1 cm = 10095 micron

1 thou = 1/1000 inch

1kg/cm2 = 14.2234 psi

Man normal hearable noise = 40 db

Govt. permitted noise = 75 db (for industrial machines)

WEIGHT

28.35 g = oz 1 g = 0 .035 oz (OUNCE)

0.454 kg = lb 1 kg = 2.2046 lb

1.016 tonnes = ton 1 tonne = 0.984 ton

1000 Kg = 1 tonne

CAPACITY

28.413 ml = floz 1 ml = 0.035 floz (fluid ounce)

0.568L = pint 1 l = 1.759 pints

1.64 hl = barrel 1 hl = 0.611 barrel

4.546 litres = gallon 1 litre = 0.22 gallon

1 pint = 20 fluid ounce

1 British gallon = 4.546 litres

1 U.S.A gallon= 3.785 litres

1 Barrel (petroleum measure) = 42 U.S.A gallon

Volume

16.39 cm3 = in^3 1 cm^3 = 0.061 in^3

0.765 m^3 = yd^3 1 m^3 = 1.308 yd^3

0.0283 m^3 = ft^3 1 m^3 = 35.315 ft^3

AREA

6.452 cm^2 = in^2 1 cm^2 = 0.155 in^2

0.836m^2 = yd^2 1 m^2 = 1.196 yd^2

0.405 ha = acre 1 ha = 2.4711 acre

LENGTH

0.04 in = mm 1 in = 2.54 cm/25.4mm

3.28 ft = m 1 ft = 0.304 m

0.91 m = yd 1 m = 1.09yd

0.62 mile = km 1 mile = 1.609 km

12 in = 1 foot
3 feet = 1 yard
51/2 yard = 1 rod
4 rods = 1 chain
10 chain = 1 furlong
8 furlong = 1 mile

$$\textit{SPECIFIC WEIGHT} = \frac{\text{Force/ Weight}}{\text{Unit volume}}$$

$\gamma = W/v$

W = weight in kgf

V = volume in m^3

Specific weight of water at 4* Celsius is 1000 kg/m^3

$$\textit{DENSITY/ MASS DENSITY/ SPECIFIC MASS} = \frac{\text{Mass of substance}}{\text{Unit volume}}$$

$\rho = M/v = w/gv = \gamma/g$

DENSITY OF WATER = 1000 kg/m^3 x 1/9.81 m/sec^2

= 101.94$kg.sec/m^4$

$$\textit{SPECIFIC GRAVITY} = \frac{\text{Mass of certain volume of the substance}}{\text{Mass of equal volume of water at 4* Celsius}} \text{(no unit)}$$

$$\textit{RELATIVE DENSITY} = \frac{\text{Density of substance}}{\text{Density of water at 4* Celsius}} \text{ (no unit)}$$

SPECIFIC VOLUME =volume /unit mass =ν = V/m= Reciprocal of the density i.e. = $\nu = 1/\rho$

SPECIFIC HEAT :- The heat required by a unit mass of a substance to raise temperature by one degree is called the specific heat of the substance. It is called the heat capacity of the substance.

MATTER: Anything that occupies space is called matter.

MASS: is the amount of matter contained in a given body and it does not vary with gravitational force.

GRAVITY: is a force, which pulls objects towards the earth gives the object weight.

The value of "g" is 9.81 kg/cm^2

WEIGHT: Defined as the force with which the body is attracted towards the centre of the earth and it vary with gravitational force.

$$W = m \times g$$

FORCE

Force = Push /pull.

= Make the object move /deform.

= Produces/tends to produce or destroys/ tends to destroy motion.

From Newton's second law of motion: applied force "F" is directionally proportional to rate of change of momentum.

Momentum = mass x velocity

Force (F) = (mv-mu)/t

F=m (v-u)/t = m.a where E (v-u)/t =Acceleration
F = m.a = mass x acceleration

Type of force:

a) Gravitational force
b) Electro magnetic force
c) Physical force

INERTIA FORCE:

It is an imaginary force, which when acts upon a body and keeps the body in equilibrium position. It is numerically equal to the accelerating force in magnitude, but opposite in direction.
Inertia force = (-) of accelerating force

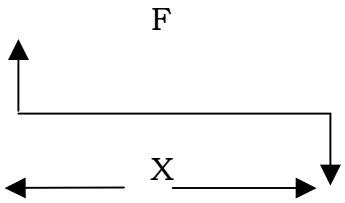
MASS MOMENT OF INERTIA: The mass moment of inertia of a body is the product of its mass and square of its perpendicular distance from a fixed line.

$I = MK^2$

K = Perpendicular distance of the body from a fixed line or radius of gyration

Couple = Two equal and opposite parallel force

Moment of a couple = F x X



TORQUE=COUPLE
F = force
X= distance

MOMENTUM: Quantity of motion possessed by a moving body is called momentum.

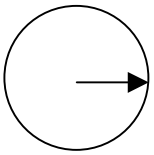
Momentum=mass x velocity

MOMENT OF A FORCE: It is the turning effect produced by a force.

TORQUE: Defined as the product of force and the perpendicular distance of its line
Of action from the given point/axis.

Torque &rate of change of angular momentum.

Torque = force x radial distance



WORK

Work is said to be done only when a force is applied and it produces motion.

The product of force and the component of the displacement in the direction of the force measure work done.
Work is a measure of accomplishment.

Work makes no allowance for the time factor.

Work done by a force = Force x Displacement of a body in the direction of the force

Work done by the couple or torque = Torque x Angular displacement

NOTE: Both force and pressure are primarily measure of effort and work is measure of accomplishment.

POWER

Power = Rate of doing work

Horse powers the standard unit of power measurement.

1HP is that the amount of power necessary to raise 33,000 lbs in one feet in one minute.

MOTION

Motion is a kind of movement caused by force (or) called kinetic energy.

Types of motion

1. Linear motion
2. Circular motion
3. Reciprocating motion
4. Rotary motion

LINEAR MOTION: An object going in a straight line like a rocket shooting through deep space has linear motion.

Ex: linear motion shale shaker

CIRCULAR MOTION: An object going around a central point like a ball swing round on a string has circular motion.

Ex: motors

RECIPROCATING MOTION: An object moving to and fro like a Pendulum has reciprocating motion.

Ex: reciprocating pumps (mud pumps)

ROTARY MOTION: An object that twists around like a wheel or a Screw driver has rotary motion.

Ex: rotary table

FRICTION: A force that resists the movement of one surface against another.

THRUST: When a force is opposed by a spring the reactional force generated in the spring is called thrust.

PRESSURE: The amount of force acting on a certain area.
Force or thrust exerted/unit area.

$$P = F/A$$

MATTER

- ✓ Anything that occupies space is called matter.
- ✓ Matter posses energy.
- ✓ Matter is in three forms:
  - ❖ Solid
  - ❖ Liquid and
  - ❖ Gas

ENERGY

- ❖ Is required to do work.
- ❖ Ability to make things happen.
- ❖ Capacity for producing an effect

Type of energy:

- ✓ Potential energy
- ✓ Kinetic energy
- ✓ Strain energy

Potential energy: It is the energy possessed by a body, for doing work, by virtue of its position.

Potential energy=m x g x h

Ex: Storage of water above the ground level possesses potential energy. (Water in a static condition)

KINETIC ENERGY: It is the energy possessed by a body, for doing work, by virtue of its mass and velocity of motion. (Flowing water from the top of hill or dam i.e. water in motion)

Kinetic energy=$1/2mv^2$

STRAIN ENERGY: It is the potential energy stored by an elastic body when deformed.

Ex: A compressed spring possesses this type of energy.

ENERGY CAN EXIST IN DIFFERENT FORM:

- ✓ Light energy
- ✓ Heat energy
- ✓ Sound energy
- ✓ Electrical energy
- ✓ Hydro power
- ✓ Chemical energy
- ✓ Nuclear energy
- ✓ Geothermal energy
- ✓ Wind energy
- ✓ Solar energy
- ✓ Tidal wave
- ✓ Atomic energy

MACHINE: is a device, which receives energy and transforms it into some useful work.

Machine makes the work easy for us.

Six kinds of machines

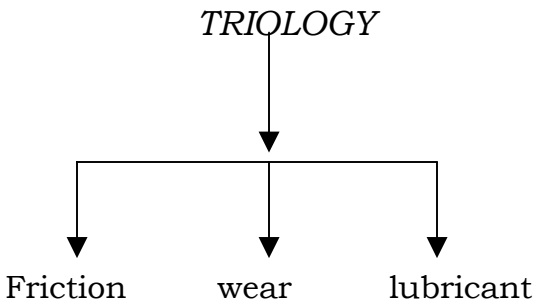
1) Axle
2) Lever
3) Pulley
4) Screw
5) Wedge
6) Wheel

TRIBOLOGY

"THE SCIENCE OF COMBATTING WEAR"

Tribology is a modern science which deals with friction, wear and lubricant. The word tribology derived from the Greek root "tribein," meaning "to rub". Tribology is a multidisciplinary field based on fluid and machine dynamics, metallurgy, physical and surface chemistry, heat transfer, and stress analysis. The reason for multidisciplinary approach is that contact between sliding or rolling surfaces creates highly complex reactions that can only be understood by drawing from a range of disciplines. Tribology offers a systematic, broad based approach to wear control. In this systematic approach, the critical performance factors that may cause wear problems are first measured and evaluated and then reduce the detrimental effects of surface interaction to enhancing service life and reliability of machineries. More complex strategies are to be applied to minimize the causes of wear based on:

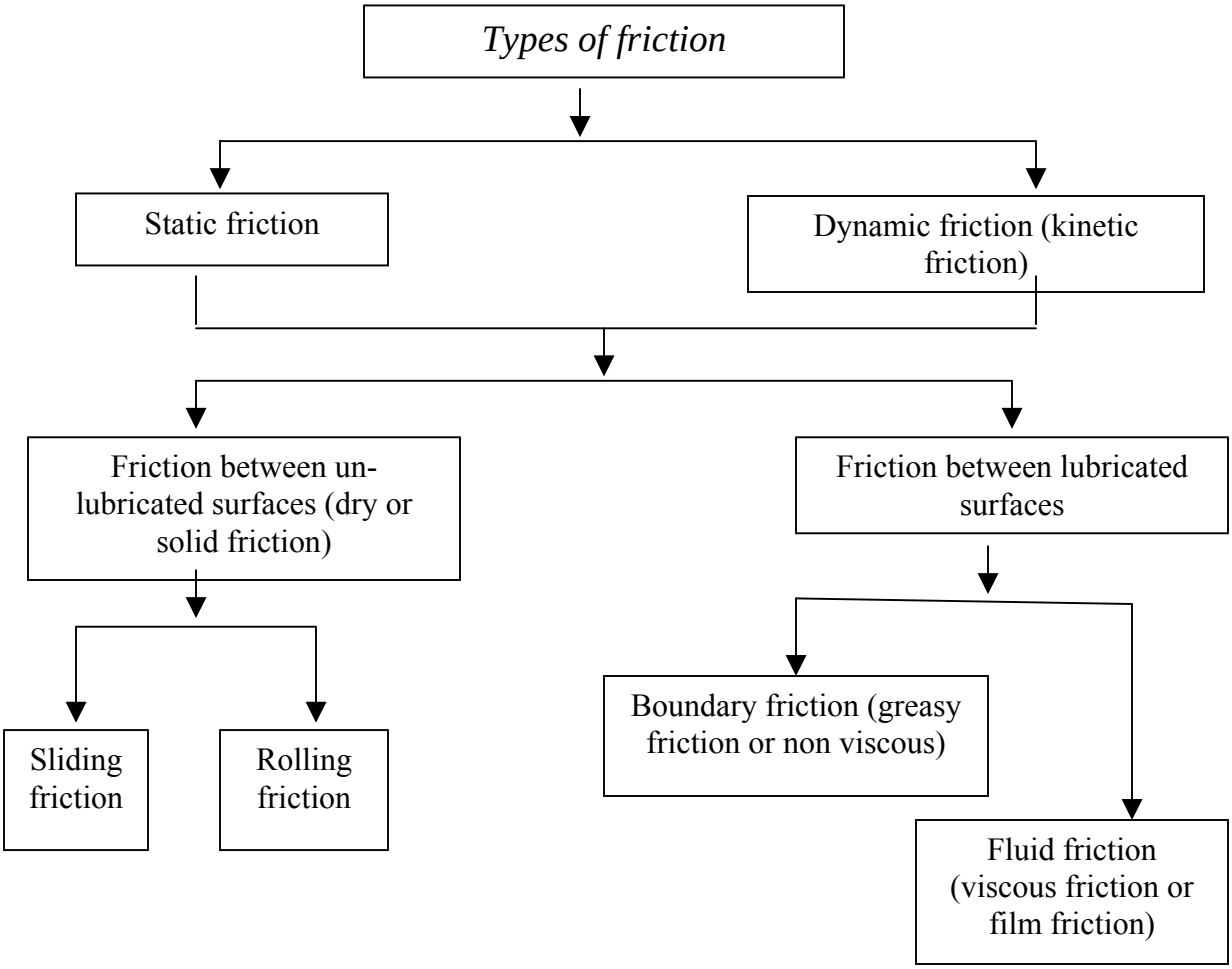
1. Selection of suitable materials that withstand a range of operating conditions and good resistance to external factors.
2. Science of tribology can be applied to enhance understanding of what occurs between contacting surfaces in relative motion.
3. Refinement of designs and geometries that minimize friction and wear, as well as the amount of lubrication needed for components and assemblies
4. Application of tribology to understand in-depth knowledge of the basic mechanisms of lubrication so that all relevant factors can be integrated into the systematic approach.
5. Development of lubricants that perform under certain conditions of temperature, stress, and pressure, and in particular environments for the required service period.
6. Optimize equipment performance through advanced lubrication technology and proper selection of equipment.
7. Ultimately reduce wear and energy consumption.



FRICTION

Friction is a force that resists the movement of one surface against another due to interlocking property of projecting particles of rolling, sliding and roughing elements. It is the root cause of problem for metal wear out.

Friction opposes movement, causes wear and tear and changes useful energy into wasteful heat. Hence friction is considered as enemy of machines. However, friction is favorable in clutch and brake applications, bulldozers, excavators, transport vehicles, grinders etc.



*STATIC FRICTION***:** is the friction experienced by a body at rest.
Ex: Standing car on a road.

DYNAMIC FRICTION: is the friction experienced by a body in motion.
Ex: Moving car on a road.

SLIDING FRICTION

It is the friction experienced by a body when it slides over another body. Generally, sliding friction is high as compare to rolling friction due to large area of contact between sliding elements.
Ex: X-head and guide of mud pump and piston and cylinder of an engine.

ROLLING FRICTION

It is the friction experienced between the surfaces which have balls or rollers interposed between them
Ex: Antifriction bearings

BOUNDARY FRICTION

It is the friction experienced between the rubbing surfaces, when the surfaces have a very thin layer of lubricant. The thickness of this very thin layer is of the molecular dimension. In this type of friction, a thin layer of lubricant forms a bond between the two rubbing surfaces. The lubricant is absorbed on the surfaces and forms a thin film. This thin film of the lubricant results in less friction between them. The boundary friction follows *the laws of solid friction***.**

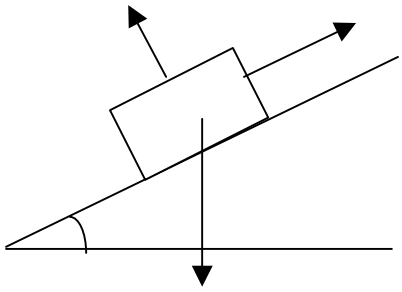
FLUID FRICTION

It is the friction experienced between the surfaces of fluid layers due to viscosity and oiliness of the lubricant. In this case, the actual surfaces do not come in contact and thus do not rub against each other. It is thus obvious that fluid friction is not due to the surfaces in contact; but it is due to the viscosity and oiliness of the lubricant.
Ex: lubricants.

LIMITING FRICTION

When a body just begins to slide over the surface of the other body due to applied force exceeds the frictional force is known as limiting friction.

Coefficient of friction



$$\text{Coefficient of friction} = \frac{\text{Limiting friction}}{\text{Normal reaction}}$$

= shear stress/hardness

W - Weight of a body acting vertically downwards.

Rn - Normal reaction acting at right angles to the plane.

F - Frictional force acting upwards along the plane.

Q - An angle of inclined plane at which a body just begins to slide down the plane, is called the angle of friction.

$$\mu = \tan o = \frac{F}{R_n}$$

LAWS OF STATIC FRICTION

2) The force of friction always acts in a direction, opposite to that in which the body tends to move, if the force of friction would have been absent.
3) The magnitude of the force of friction is exactly equal to the force, which tends the body to move.
4) The magnitude of the limiting friction bears a constant ratio to the normal reaction between the two surfaces.
5) The force of friction is independent of the area of contact between the two surfaces.

LAWS OF KINETIC OR DYNAMIC FRICTION

1) The force of friction always acts in a direction, opposite to that in which the body is moving.

2) The magnitude of the kinetic friction bears a constant ratio to the normal reaction between the two surfaces. Bu the ratio is slightly less than that in case of limiting friction.
3) For moderate speeds, the force of friction remains constant, but it decreases slightly with the increase of speed.

LOSS OF SOLID FRICTION

1) The force of friction is directly proportional to the normal load between the surfaces.
2) The force of friction is independent of the are a of the contact surfaces for a given normal load.
3) The force of friction depends upon the material of which the contact surfaces are made.
4) The force of friction is independent of the velocity of sliding of one body relative to the other body.

LAWS OF FLUID FRICTION

1) The force of friction is almost independent of the load.
2) The force of friction reduces with the increase of temperature of the lubricant.
3) The force of friction is independent of the substances of the bearing surfaces.
4) The force of friction is different for different lubricants.

The force of friction is due to roughness of the contact surfaces of the two bodies which tends to prevent their relative motion. The direction of the force of friction is always opposite to the direction, in which a body tends to move.

WEAR

Wear is caused by mechanical means like friction, abrasion and corrosion. Wear is due to mechanical or chemical reasons are greater at higher temperature. The rate of wear is proportional to the surface areas in contact and the load per unit area. Larger the area, the lower the load per unit area and hence lower the rate of wear.

ADHESIVE WEAR: A new engine which is going to run approaches adhesive wear. The maximum wear is in turn to abrasive wear.

Volume of wear (v) = kAd/4

Where k = probability of wear

A = real area

D = distance traveled

Load $\propto$ contact surface

Speed $\propto$ wear and tear

ABRASIVE WEAR:

It is the surface injury caused by fine metallic particles detached from gear teeth or bearings, abrasive not removed before assembly and or scale from casting or other impurities (in oil) carried in the lubricant. These abrasive wear particles in lubricating fluid attack the mating surfaces by cutting and scratching and produce tiny chips. It is characterized by numerous fine scratches on the surfaces of mating components.

FATIGUE WEAR:

It comes in the form of scaling of minute particles in the surface layers of mating parts. Failure due to fatigue always starts to occur at sharp corners where stress concentrations occur. The root of any surface irregularities acts as a sharp corner and such part fails earlier. Thus in order to increase the life of any part, subjected to repeated reversals of stress, the working and non working surfaces must have good finish.

ERROSIVE WEAR:

Loss of material by contact with fluid that contains particles and relative motion between the surfaces fluid is essential to this process.

DEFORMATING WEAR (DUE TO WRAPING):

It is due to the displacement of metal beyond the contact surfaces resulting in friction accompanying the wear process

CORROSION WEAR:

It is the result of chemical action on metal tooth surfaces by oxidation due to contamination or inferior quality oil or excessive moisture in oil sump. The surfaces get pitted or corroded due to moisture in air, coolants, etc.

Good bearing properties in any part are obtained when the surface has large number of irregularities, i.e. a large number of hills and valleys. The hills in irregular surface reduce the metal to metal contact and the valleys help to retain the film of lubrication.

Wear ruins hundreds of millions of rupees worth of equipment and products every year. To curtail these losses, oil industry like ONGC having wide variety of equipment must use effective techniques resulting from tribology to minimize maintenance costs. Though the tribology techniques should be applied in the equipment design stage itself, still we have better scopes for reducing wear limit in the operation stage by selecting suitable lubricants, lubrication supply method and adapting better maintenance practices and also initiate programme to track wear costs.

LUBRICANTS

TRIBOLOGICAL APPROACH TO LUBRICANT FOR SELECTION AND APPLICATION

Tribology has mainly focused on lubrication, because it is the simplest, understood and most available method, above all least expensive and frequently used commodity in machineries to control the wear. Therefore, it is better to focus this topic mainly on lubricant selection, application and maintenance.

The tribological processes, namely the contact, the friction and the wear processes are, in general, related to direct physical interactions between relatively moving surfaces. All these processes can be influenced or modified by the process of lubrication. The purpose of lubrication is to separate the surfaces moving relative to each other with a film of material which can be sheared with low resistance without causing any damage to the surfaces.

Tribology classified the lubrication system in term of amount of separation between contacting surfaces of machine elements. Machine elements could be bearings, gears, cams, traction drives, differentials and face seals etc. No machine can exist without these elements. Types of lubrication system adapt for the machine elements to achieve acceptable performance levels and service life is:

1. Hydrostatic lubrication method
2. Hydrodynamic lubrication method
3. Elasto hydrodynamic lubrication method
4. Boundary lubrication method
5. Mixed lubrication method

HYDROSTATIC LUBRICATION METHOD:

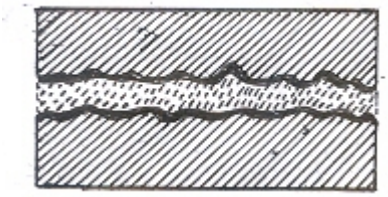
Full film lubrication under very high load, very slow speed conditions is possible with hydrostatic lubrication.

HYDRODYNAMIC LUBRICATION:

Hydrodynamic conditions exist when a viscous oil film (thick of the order of 25μm) completely separates moving surfaces within machine elements as in well operating journal bearings. Under these conditions, direct surface to surface contact does not take place and thus wear does not occur except surface fatigue wear and cavitations wear or fluid erosion. Low friction and infinitely long service life can be obtained under these conditions provided a sufficient supply of

clean lubricant of the right viscosity is continuously maintained. In this system, friction is proportional to viscosity and speed and inversely proportional to load. Hence for element operating with hydrodynamic lubrication, mathematical calculation has been formulated to predict accurately;

1. Fluid film thick
2. Frictional losses
3. Heat generation
4. Safe operating limits of the lubrication system.



Full fluid film lubrication

The surfaces are completely separated by a load carrying oil film. In the full-fluid film region of operation the most important considerations are bearing design and lubricant viscosity. Bearing materials need only provide adequate strength, be non porous, and be able to withstand periodic rubbing contact at start up and shut down.

Conditions necessary to promote full-film or hydrodynamic operation of slider bearings are:

1. Relative surface speed should be greater than 8 mpm and continuous in one direction.
2. Lubricant should have the proper viscosity.
3. Lubricant at the proper flow rate should be continuously supplied to the bearing, and the flow must not be less than a specified minimum rate.
4. The bearing must be properly designed to promote and maintain full-film hydrodynamic lubrication.

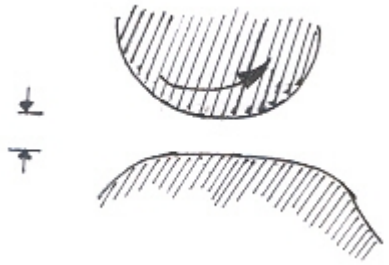
Sliding bearing coefficients of friction for full film lubrication are of the order of 0.005. However, coefficients of friction of 0.001 or less can be obtained in certain application.

Although these ideal conditions may not always be maintained throughout the entire equipment operating cycle, hydrodynamic analysis, nonetheless, can yield workable solutions to a broad group of practical lubrication and wear problems in internal combustion engines, turbines, compressors and transmissions.

ELASTOHYDRODYNAMIC LUBRICATION:

It pertains to sliding surface, but more often involves rolling surfaces separated by an oil film. The mechanisms for oil film formation in EHD lubrication are very much like those in hydrodynamic lubrication; however, in elasto hydrodynamic lubrication, the interface region between the moving parts elastically deforms under the contact pressure. This deformation creates larger oil film areas, and therefore, greater load carrying ability than that predicted by hydrodynamic theory. Elasto hydrodynamic films are very thin and require polished surfaces to prevent asperity contact.
Here, too, mathematical calculation can be applied to predict film thickness, frictional losses, heat generation, and safe operating limits of the lubrication system.

Elasto hydrodynamic lubrication for wear control is typically used in rolling element bearings, gears, cams, and traction drives in such equipment as jet engines, precision gyroscopes for navigation, centrifugal blowers, and transmissions.



Elasto hydrodynamic – where elastic deformation at the contact interface allows greater load carrying ability.

BOUNDARY LUBRICATION:

For slowly moving elements under heavy load, hydrodynamic and elasto hydrodynamic lubricant pressures are often insufficient to separate surfaces completely. In these cases, surfaces can be protected from excessive friction and wear by adsorbed films created by chemical interactions between the surfaces and the lubricant. If this boundary film is sufficiently thick, it will also prevent adhesion due to direct surface to surface contact. In this process known as boundary lubrication-lubricant thickness, friction, and heat generation predictions are empirically based. Boundary lubrication reduces friction and wear in high load, low speed applications and permits startup or shutdown of hydrodynamic bearings when speeds are too slow to generate adequate films. Complete boundary lubrication indicates that the bearing and runner surfaces are

rubbing together in the presence of an extremely thin film of lubricant adhered to both surfaces. Unless the bearing is re-lubricated periodically, the thin film is eventually destroyed and intimate, metal to metal contact results. A cast bronze alloy with a high percentage of lead (15 to 25%) is recommended for complete boundary conditions. Sliding bearings which usually operate in this realm are:

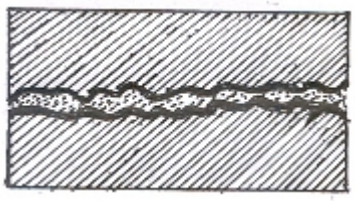
1. Grease lubricated.
2. Periodically re-lubricated by hand oiling or greasing.
3. Used for oscillating-motion applications.
4. Used in very slow speed applications where relative velocity between runner and bearing is less than 3mpm.

Boundary lubrication

The lubrication effect mainly depends on the lubricating properties of the boundary layer

MIXED FILM LUBRICATION:

Apart from hydrodynamic, elasto hydrodynamic and boundary lubrication, another condition, known as “mixed film” lubrication may occur. Mixed film lubrication, as the term implies, is actually a combination of boundary and hydrodynamic or elasto hydrodynamic modes. This intermediate state is attained when the oil film becomes very thin, causing asperities to penetrate the film and contact the opposing surface. i.e. the load is partially supported by a fluid film, and partially by solid contact. Coefficients of friction in this region are normally 0.02 to 0.08.



Mixed lubrication

Both the load carrying oil film and the boundary layer play a major role

This condition is created in hydrodynamic or elasto hydrodynamic bearings when

1. operating speed is too low
2. load is too high
3. lubrication viscosity is too low

Consequently, mixed film lubrication results during:

1. Start up
2. Slow down to stop
3. Overloading
4. Overheating

Operation in this mode typically causes bearings to wear: yet realistically, this state cannot be totally avoided. Consequently, bearing structural design must allow for operation during mixed film as well as during boundary film conditions. In addition to meticulous geometrical design, careful selection of materials and lubricants can also help to compensate for operation in this mode.

USING TRIBOLOGICAL LUBRICATION FOR VARIOUS INDUSTRIAL NEEDS AND PROBLEMS

Lubrication system	Element with operation or design problem	Equipment using these elements	Friction coefficient range	Service life	Operating conditions	Lubricant film types and thicknesses	Fabrication materials	Space requirement	Maintenance and replacement costs	Areas in which advances are being made
Hydrodynamic	Journal bearings Thrust bearings Porous bearings Bushings Gas lubricated bearings	Internal combustion engines Turbines Compressors Transmissions Gyroscopes	0.001 to 0. 005	Hydrodynamic bearings Provide long service life Promote conformability and embedability Typically are not subject to fatigue spalling under monotonic loading	Not used for very low speed or very high speed operation Temperature limitations depend on lubricant capabilities General use falls between 40F to 300F	Hydrodynamic bearings Can potentially use any liquid or gas for lubricant Have film thicknesses ranging between 0.003 and 0.0001	Materials should have resistance to corrosion and good hardness properties for load carrying. Typical materials include composites of tin, copper, Teflon and graphite fibers, lead: low-tin bronze	Relatively smaller sized hydrodynamic bearings are effective in confined spaces. Pressurized lubrication systems require pumps, filters and initial oil volume. Simpler lubrication systems can be used on moderate load and speed bearings.	Maintenance costs are relatively low. Replacement costs result mainly from inadequate system monitoring improper lubricant maintenance and dirt entry into lubricant.	Extended life formulations in lubricants. Improved friction reducing lubricants. Better lubricant additives More refined lubrication systems More accurate lubricant selection Improved bearing materials. Coatings Computer

		spindles		Will fatigue under cyclic loading found in internal combustion engines and crank shaft bearings						modeling for improved designs.
elasto hydrodynamic	Rolling element bearings Ball bearings Gears Cams Traction drives	Jet engines Inertial guidance systems	0.005 to 0.01	EHD bearings Are subject to rolling contact fatigue damage Are often made of steels susceptible to corrosion Are sensitive to dirt contamination	Used in conditions where starting torque low is essential Also in devices where accurate shaft positioning is required. Temperature limitations depend on Lubricant capabilities General use falls between 0F and 600F	EHD bearings Generally use low viscosity liquid lubricants to reduce heating from high shear rates. Have very thin lubricant films – i.e. 0.1 to 1μm(4 to 40 micro-inches) thick.	Bearing steels heat treated to high hardness levels (58 to 64 Rc) are typically Used. Steels used include AISI 52100.M.2 and M.50 tool steel 440C stainless and carburized alloy steels.	For a given load capacity EHD bearings are typically larger than hydrodynamic bearings and thus require more space. Most lubrication methods for EHD bearings require multi component systems.	Maintenance requires very Clean lubricant. Condition of bearings can be monitored automatically by sonic emission techniques. Replacement costs are high for large precision bearings.	Non- liquid Lubricants. Improved bearing performance in Severe temperature environments. Traction drive technology. Computer modeling for Improved design.

Boundary And Mixed film	Automotive hypoid differentials Journal bearings Oscillating bearings(as in airframe landing gear and control surfaces) worm gears face seals	Vane pumps Airframe bearings Off-road construction machinery	0.02 to 0.10	Frictional heat generation represents the Significant life limiting factor. Thermal decomposition of lubricant or bearing material results in ultimate failure.	Used for Unusual operating conditions in components normally designed to be hydro dynamically lubricated. Alleviates friction and wear during stop- start operating modes.e.g. overloads,misalignments, and when lubricant supply is cut off	Boundary lubricated elements. Commonly use additives to oils and greases. These additives can be fatty acids, phosphates, sulfur and chlorine compounds or colloidal suspensions of graphite or MoS2	Materials include Tin-bronzes Copper-lead Teflon-fiber mixtures Carbon-graphite Ultra high molecular weight polyethylene Greases Solid lubricants.	Bearings generally occupy a smaller envelope than hydrodynamic or EHD Bearings. No complex auxiliary lubrication equipment is Needed.	Maintenance costs are very low. Replacement costs are low as long as shaft damage does not occur.	Development of extreme pressure and other specialty additives Improved synthetic lubricants. New self Lubricating materials.

LUBRICANTS

IMPORTANT ROLES OF LUBRICANT IN MACHINE FUNCTION

- Lubricant is lifeline of machine.
- Machine can not perform its function without lubricant
- Lubricant is needed in machinery to eliminate the potential problems created by frictional force and corrosion, which are natural phenomena.
- Machine is to be lubricated with the right lubricants at the right time and at the right location.
- Lubricants must reduce friction, prevent wear, dissipate heat and capable of carrying heavy load to keep the machine operating at top efficiency.
- Lubricants are also expected to retain their physical and performance characteristics over long extended use.
- Lubricants are of superior performance, better productivity, lower maintenance cost and high lubricant economy
- Lubricant may be oil or grease.

CLASSIFICATION OF LUBRICANTS

Lubricants can be broadly classified into:

1. Automotive lubricants.
2. Industrial lubricants.

AUTOMOTIVE LUBRICANTS:

1. Engine oil
2. Transmission oil/ gear oil

Automotive lubricants for these applications are available in different viscosities for wide range of applications and have been assigned different numbers called viscosity grades by the society of automotive engineers (SAE). SAE has established that 12 viscosity grades are suitable for engine lubricating oils. The physical requirements for these viscosity grades are described in SAE J300

which is intended for use by engine manufacturers in determining engine oil viscosity grades suitable for use in their engines.

ENGINE OIL

Engine oils are assigned an SAE grade based on their viscosity at 100°C due to engine normal operating temperature and absence of water particles in that temperature. SAE has established that 12 viscosity grades are suitable for engine lubricating oils.

Base Stock + Additives = Engine Oil

What is lubricant?
Lubricant is a mixture of base stock and chemical additives.

What is base stock?
Base stock is highly solvent mineral oil refined from crude petroleum. It may be mineral oil or synthetic.

What are additives?
Additives are chemicals, which enhance the cleaning and protecting properties of the oil and also extend the lubricating and cooling properties.

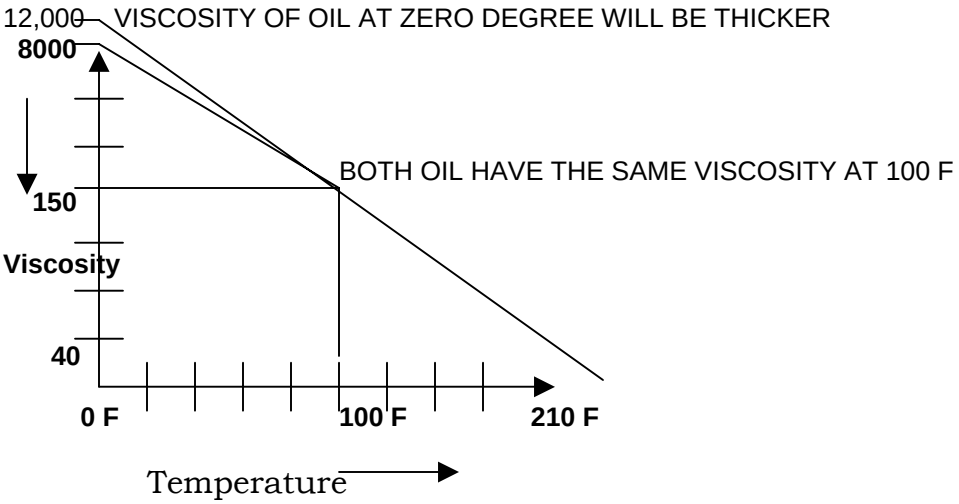
ADDITIVES

sl	Functions of additives	Additive package
01	Lubrication	Viscosity index improver. If the oil is multi- grade, a polymeric viscosity improver is also added.
02	Acid neutralization	Alkaline additives
03	Keep foreign particles in suspension	Dispersants
04	Cleaning of oil	Detergent
05	Anti-wear agent/ oxidation inhibitors	Zinc salt of a sulfur-containing phosphoric acid
06	Foam inhibitors	Silicone polymers or organic polymers to reduce the surface tension of the oil. High viscosity oils tend to be more prone to foaming.
07	Pour point depressants	Lowers the solidification temperature by blocking wax crystal growth in the mineral oil base stock. Additives have pour point depressant properties.

What is viscosity?

- Viscosity is a measure of the resistance offered to the sliding one layer of the lubricant over an adjacent layer.
- Viscosity determines the ability of oil to support a load on a fluid film, the power consumed in friction and the amount of heat that will be generated.
- It is the most important single property of lubricating oils.
- Viscosity is key indicator of oil serviceability.
- All viscosities are relative to temperature and pressure.
- The unit of viscosity is cST

VISCOSITY INDEX: Viscosity index is a relative measure of viscosity change with temperature change. A fluid that has stable viscosity at temperature extreme has a high viscosity index.



Petroleum oils tend to become thin as temperature increases and thicken as temperature decreases. Viscosity index of oil is a means of expressing this property.

POUR POINT

This is the lowest temperature at which oil will flow under specified conditions. In case of cold starts, we should use oil with a low pour point characteristic. The pour point should be 20 °F less than the lower temperature encountered.

FLASH POINT

This is the temperature at which oil forms an ignitable mixture with the air when heated under specified conditions.

EFFECT OF TOO HIGH & TOO LOW VISCOSITY OIL

HIGH VISCOSITY:

When an oil viscosity increases, it means the oil is getting thicker. The most common cause of oil thickening is oxidation. Oxidation is a natural process and is the principal reason that oil changes are necessary. High operating temperature, overloading, and water /coolant contamination are the examples of conditions that can accelerate oxidation causing oil to thicken prematurely. Contamination with soot or excessive dirt can also cause increased viscosity. High viscosity can cause cavitations problem in pumps. High viscosity can cause overheating, restricted oil flow, and can ultimately lead to catastrophic failure.

The three greatest factors that promote oxidation are

1. Air
2. Heat
3. Contamination

LOW VISCOSITY:

Decreased viscosity (oil thinning) is typically the result of contamination with fuel or different grade oil. Low viscosity can lead to increased friction, overheating, metal-to-metal contact, and ultimately failure. Therefore selection of right viscosity oil is necessary to ensure that:

- The lubricant should provide a film of oil between two moving metal parts.
- The lubricant should also be high enough to prevent metal-to-metal contact and low enough to reduce viscous drag (due to fluid friction).

TOTAL BASE NUMBER
METHOD: ASTM D-4739
INSTRUMENT: Automatic titrator unit –mgkoh/g

SIGNIFICANT OF TOTAL BASE NUMBER:

Total base number is a measurement of an oils reserve alkalinity. Many oils are fortified with alkaline (basic) additives to neutralize acids formed in the combustion chamber.

THE TBN IS HIGHEST WHEN OIL IS NEW AND WILL DECREASE WITH USE.

REASONS FOR FAST DEPLETION OF TBN:

Low TBN typically indicates that oil has reached the end of its useful life. If TBN decreases too quickly it may indicate excessive acid formation due to oil oxidation, overheating, or the use of high sulfur fuel.

TOTAL ACID NUMBER
METHOD: ASTM D-664
INSTRUMENT- Automatic titrator unit mgkoh/g

SIGNIFICANCE OF TOTAL ACID NUMBER:

Total acid number is an indicator of oil serviceability. Oil oxidation causes acid to form. High acid levels can indicate depletion of the oil additives, and can lead to corrosion of the internal components. Acid is also produced in the combustion chamber of engines. The TAN is lowest when oil is new, and increases with use. By monitoring the acid level, the oil can be changed before any damage occurs.

REASONS FOR RAISING TAN VALUE:

High acid levels in oil can be caused by oil oxidation or depletion of the alkaline additive package. Other possible sources include the use of high sulfur fuel, excessive overheating, or extended oil drain.

SPECTROCHEMICAL ANALYSIS FOR WEAR METAL LIMITS
METHOD: Arc emission spectroscopy (AES)
INSTRUMENT: Spectrometer
Unit –ppm

SIGNIFICANCE OF MEASURING CONTAMINATION LEVEL:

By measuring levels of elements associated with wear, contamination, and additives, several determinations can be made concerning the condition of the oil and the unit being sampled. Specific elements tested and typical sources are list below.

Typical Wear Metal Limits

Material used	Hydraulic	Gear box	Diesel Engine	Gas engine	Transmission	Differential
Iron	75	300	150	300	300	1000
Chromium	5	N/a	25	40	10	N/a
Lead	20	N/a	50	N/a	50	N/a
Copper	75	250	50	75	400	250
Tin	10	250	25	40	20	250
Aluminum	25	250	30	40	50	250
Nickel	5	N/a	10	15	20	N/a
Silver	5	N/a	5	5	5	N/a
Silicon	75	250	25	50	50	250

The max. limits given above are indicative. However the recommendations must be sought from manufacturer of engines/equipments

SAE NUMBER:

SUS viscosity measured at SAE lies to temperature. Winder numbers are at a temperature of the 0°F and summer numbers are tested at 21°F.

RELATIVE VISCOSITY (SUS): is determined by timing the flow of a given quantity of the fluid through a standard orifice at a given temperature. Unit is "SAY BOLT UNIVERSAL SECONDS" obviously a thick liquid will flow slowly; the viscosity will be higher than a thinner one. The temperature is usually at 100° F OR 210° F.

ABSOLUTE VISCOSITY (POISE): it is defined, as the force/unit area required moving one parallel surface at a speed of one cm/sec. past another parallel separated by a fluid film of 1 cm thick.

- Force is dynes in metric system
- Area is in sq.cms.

Poise = 1 dyne = Second/sq.cm

KINEMATIC VISCOSITY: is the use of a head of liquid to flow through a capillary tube.

$$\text{Kinematics viscosity} = \frac{\text{Co-efficient of absolute viscosity}}{\text{Mass density of the liquid}}$$

Centi- stoke = centipoises/density

What is high performance lubricant?

An ideal high performance lubricant should meet: -

1. Technological requirements
    - High temperature conditions.
    - Less mechanical/chemical wears of engine components.
    - Less carbon deposits on piston.

2. Social demands
    - Fuel economy
    - Less emissions
    - Environment friendly

Types of lubricant
- Mono-grade
- Multi-grade

ADVANDAGE OF MULTIGRADE OIL
- Exceptional viscosity-temperature characteristics to oil.
- Quick engine start and longer battery life.
- Longer engine life and longer oil drain interval. And hence reduces oil consumption.
- Eliminates seasonal oil changes.
- High degree of engine cleanliness.
- Excellent oxidation stability and added protection against engine deposits, rust, corrosion and wear.
- May give 1-3% fuel efficiency.

*PERFORMANCE FEATURES OF ENGINE OILS***:** is concerned with potential problems and ways to formulate an engine oil to guard against them.

POTENTIAL PROBLEMS:

1. Deposits
2. Rust and corrosion
3. Viscosity stability
4. Wear

DEPOSIT: Generally, deposits originate either from fuel or lubricant

Types of deposits

sl	Deposit	Originates
01	Sludge and varnish deposits	Predominantly fuel derived and occur in gasoline engines
02	Lacquer deposits	Decomposition of lubricant in diesel engines

SLUDGE DEPOSIT: is primarily composed of oil and combustion products of fuel and air mixture which does not drain from surface, but which can be easily removed by wiping with a cloth. In the extreme case, buildup of sludge leads to blockage of lubricant

passages and lubricant starvation. Sludge formation is favoured under low temperature operating conditions when blow-by containing liquid oxidized fuel, inorganic salts, and polymerized organic compounds reacts with oil components to form solids. These deposits build up in stagnant areas such as the valve decks and the timing gear cover.

PREVENTION:
Sludge can be reduced dramatically with engine design changes, which prevent liquid oxidized fuel fractions from entering the crankcase or by using ash less dispersant additives, which suspend potential sludge formation in the lubricant.

*EMULSION SLUDGE***:**

Emulsion sludge is a water and oil emulsion. This deposit occurs on cold engine surfaces such as the oil filler cap and the rocker covers. It disappears at higher engine operating temperatures or with good ventilation. Emulsion sludge is primarily cosmetic and seldom hinders engine performance.

VARNISH DEPOSIT:

During combustion processes, the fuel hydrocarbons react with oxygen and nitrogen oxides in the presence of water to form varnish. These varnish precursors are found in below-by, cure into a resinous coating inside liner and piston and valve stem and lifter leads to piston ring and valve lifter sticking.

PREVENTION:

- It can be reduced by lowered compression ratios.
- It can be reduced by decreased or increased water temperature.
- Dispersants are helpful in preventing them from curing on engine surfaces.

LACQUER DEPOSIT OR SOOT:

- The lubricant degradation products acting as polymeric binder with fuel combustion initiate this product.
- This soot formation increases with increasing level of sulfur in the fuel.
- It is a life limiting deposit of diesel engines because it occurs in the piston ring area and can lead to piston ring sticking and scuffing.

RUST AND CORROSION:

- Water vapor present in the combustion products during cold weather and short trip operation, condenses and accumulates in the crankcase through below-by is promoting rust.

- Halide scavengers from leaded fuel also promoting rust formation.
- Rust can reduce clearance between moving parts and cause sticking in adjusters, the oil pump relief plunger, and valve stem.
- Rust can also abrade moving parts.

CORROSION

- The organic acids and mineral acids formed in the oil due to degrease in TBN leads to lead and copper loss in the bearing alloy.
- Bearing corrosion leads to loss of bearing material and increase clearances.
- It will create pressure loss of engine oil.

WEAR:

- Wear due to lack of lubrication
- Wear due to corrosion

sl	Causes	Affecting components in engines
01	Wear due to lack of lubrication	1.Valve drain components like cam and follower 2.Bearings Reasons: Extreme pressure due to line or point contact.
02	Wear due to corrosion	1. Piston ring 2. Liner bore Reason: Halides scavengers and sulfur present in the fuel can produce corrosive acid. Prevention: In gasoline engines chrome-plated and molybdenum filled piston rings is less sensitive attack than iron rings.

OIL CONSUMPTION:

Sl no	Oil consumption due to corrosion	Prevention
01	High oil temperature and leakage through worn piston rings	Using synthetic base stock instead of mineral oil base stock
02	Valve guides and crankshaft seals	Using high viscosity oil or by adding viscosity improver

03	Ring sticking	Adding cleanliness additives
04	Bore polishing and bore glazing	Adding detergents and anti-wear compounds

FRICTION LOSSES

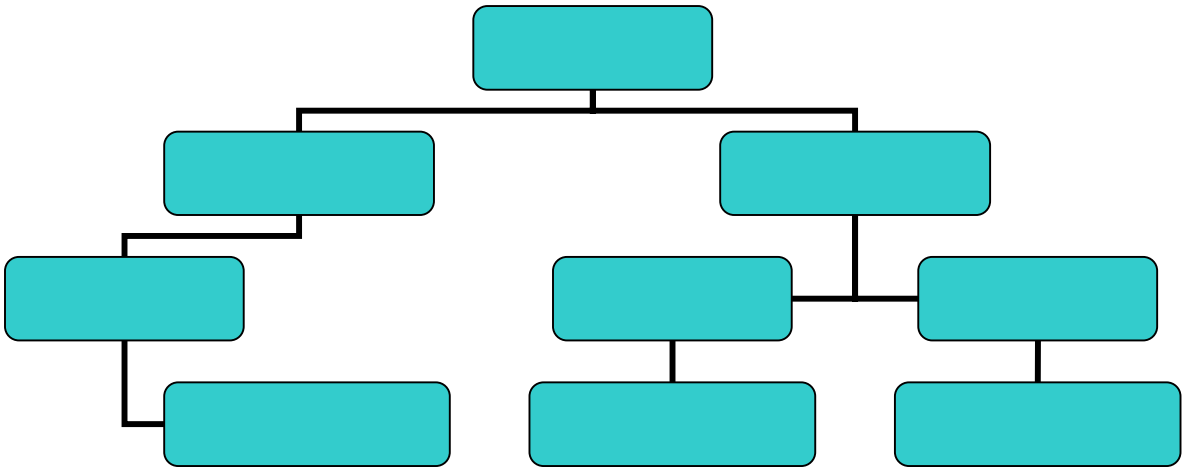
sl	Area of friction loss	In percentage
01	Piston ring and skirt area	3%
02	Bearings, valve train and oil itself due viscosity	4.5%

NOTE: - If the ideal frictionless lubricant eliminated 7.5% frictional loss, brake HP would increase by 30%.

NOTE:

- Oil barrels are watertight and not air tight to allow gases to go out due to high temperature. Hence oil barrels should be kept horizontal to avoid air to contact with oil and prevent formation of oxidation.
- Grease barrels should be kept vertical, otherwise the lubricant oil from the base stock gets squished out and soap alone will be left out in the barrels, which is of no use for lubrication bearings.

LUBRICATION SYSTEM OF I.C.ENGINES



Depending on the type of the engines, methods employed for lubrication may vary considerably.

FUNCTION OF ENGINE OIL

- To provide thin film of oil between moving elements to avoid metal-to-metal contact and reduce friction.
- To reduce heat generated by engine during operation and keep internal components cool.
- To reduce wear out of metallic parts like cylinders, piston rings, valves gears and bearings etc.
- To improve combustion sealing by filling oil in the uneven surfaces and spaces between the cylinder liners and piston rings.
- To provide balance between high and low temperature
- To keep the engine clean from deposits, sludges etc.
- To control corrosion and rusting of various parts of engine
- To provide shock damping and load distribution to engine.
- To eliminate harmful chemicals produced by combustion.

LUBRICATION SYSTEM OF FOUR STROKE ENGINES

Pressure circulating system is most commonly applied for main and big end bearings of four stroke engines with a by-pass to the camshafts and other components. Cylinders are lubricated by oil thrown from the big ends, by direct feed from mechanical lubricators or by a combination of this two. Gudgeon pins are lubricated by means of oil taken from the big ends or by oil throw.

Normally bearing lubrication is not difficult in 4 stroke engines during operation as long as oil reaches the bearings. This is because the rotation of the journal tends mechanically to build up and maintain an oil film between the bearing and journal surfaces.

COMMON CAUSES OF BEARING FAILURE

Bearing failures occur due to restriction in supply of oil as a result of mechanical faults or blocked oil –ways or breakup of the bearing metal under the repeated pounding to which it is subjected by the power strokes. This latter effect is most likely to occur if there is an abnormally high rate of pressure rise caused by faulty ignition, the use of low grade fuel, incorrect timing etc.

The most common problems in bearing lubrication of I.C. engines are that the oil thickens up, thinning out, emulsifies or throws down block deposits.

THINNING:

- Thinning of oil is caused by un-burnt fuel reaching the relatively cool cylinder walls and then finding ways to crank case. This is because long time idle running of engine.

THICKENS UP:

- Oil due to deposition of partially burnt fuel and carbon as a result of imperfect combustion. This will increase viscosity of oil and in time that are deposited as sludge.
- Oxidation due to high operating temperature, overloading, and water /coolant contamination are also thickens up oil.

Emulsion:

- Water present in the oil due to leakage through gasket or condensation of combustion products at low operating temperature. This may lead to sludge through formation of oil-and-water emulsion.

NEED FOR CLOSED CIRCUIT LUBRICATION SYSTEM

As the crank case oil of I.C. engines are exposed to air at moderately high temp during engine operation, it is necessary to keep oil-circulating system in an enclosed circuit. Because heated air has a very definite oxidizing effect on all oils when they are in a fine state of dispersions. The oil should have high resistance to oxidation; otherwise rapid deterioration of the oil may take place with consequent thickening, slugging and production of acids with the widespread use of certain alloy bearing metals, which are more susceptible to corrosion than white metal. So the need for oils having high oxidation stability has increased especially in the case of engines running under heavy-duty conditions.

CYLINDER LUBRICATION OF FOUR STROKE ENGINES

The reciprocating movement of piston, wherein it is momentary stationary at the top and bottom of the stroke and the high temp and pressure condition in the combustion chamber, provides circumstances particularly unfavorable to the maintenance of a continuous oil film between the piston rings and the walls of the cylinder. Cylinder lubrication is therefore a far more difficult problem than that of lubricating the bearings.

*NOTE***:** Sliding friction is high as compare to rolling friction due to large area of contact between two elements (piston & liner)

For cylinder lubrication, the oil must be fluid enough to reach the cylinder walls without delay on starting up from cold and spread over the surfaces rapidly. Thick oils may fail in this respect. Moreover they have a greater tendency to form carbon. The oil must be chemically

stable to avoid the formation of gummy deposits and should burn away without producing carbonaceous deposits once it has reached the combustion chamber.

Many of the operation troubles with the cylinders of internal combustion engines are however connected not with the lubricating oil itself but also with the combustion of the fuel. Thus, in gasoline engines, the formation of carbon and other deposits may often be traced to faults such as incorrect carburetor adjustment and faulty ignition timing.

Diesel engines are inherently sensitive to cylinder operating troubles because the mixing of fuel and air is achieved after the introduction of the fuel into the combustion chamber. Troubles may arise from any of the following causes.

- Faulty fuel injection or incorrect timing of fuel injection valves.
- Inadequate compression pressure.
- Inefficient blowing or scavenging
- Overloading or excessive light-load running
- Abnormally high or low operating temperatures.

Efficient running of the engine is dependent on effective sealing of the combustion chamber:

This in turn depends on the lubricating oil film and the proper functioning of the rings. Deposits of soot and gummy substances interfere with free action of the rings and cause blow-by. This will reduce compression, cause incomplete combustion and over-heating, and permit hot gases, partially burnt fuel and impurities to reach the rings and grooves more easily. These conditions tend to cause stuck rings, increased wear and poor engine performance. Keeping the piston, rings and ring grooves substantially free from lacquer and deposits are an important function of the lubricating oil. To do this properly oil must be able to keep lacquer forming materials in solutions and to prevent agglomeration and deposition of insoluble impurities-such as particles of soot and carbonaceous material-by holding them in suspension in a finely divided state in which they can do no harm. Oils with good properties in this respect can be produced by careful selection of the base stock and use of special refining processes. Additive type oils specially formulated to give unusually strong properties in this direction are generally recommended where conditions conducive to ring sticking are particularly severe. For example: in any modern high- speed diesel engine having high piston and crankcase temperature. Successful operation of certain highly rated engines have in fact, been made possible only by the use of these so-called heavy-duty oils.

It will be seen from these considerations that, to get the maximum life out of good lubricating oil, it is necessary to pay great attention to conditions of combustion and to prevent the entry of impurities.

Now the importance of lubricants has been clearly understood and efforts may be put in for the correct usage of right type and grade of lubricants for smooth trouble free and prolonged running of modern engines with higher output, better performance and more fuel economy.

TWO STROKE PETROL ENGINES

Lubrication of a two-stroke petrol engine is quite different from that of a four-stroke engine as it is not possible to have a separate lubricating oil sump. Hence a petrol mixture always lubricates a two-stroke petrol engine. The lubricating oil is mixed with petrol in suitable proportions as per the manufacturer's recommendation. In the latest generation two-stroke engines, the lubricating oil is directly injected by an accurate metering device from a separate tank into the petrol in quantities dependent on the speed and load of the engine.

When the petroil mixture enters the crankcase, because of the high temperatures prevailing the petrol fraction vaporizes leaving a thin film of lubricant on the crankcase, cylinder walls, crankshaft and bearings.

The primary requirement of two stroke engine oil is its ability to readily mix with petrol and burn without leaving too much of ash. The oil should reduce engine wear, spark plug fouling, combustion chamber deposits, and piston ring sticking; exhaust port blocking and silencer deposits. In addition the oil should have the ability to keep the engine clean at high engine operating temperatures and prevent bearing corrosion at lean oil-fuel ratios.

The particular requirements of two stroke oil include protection against piston/cylinder scuffing, protection against ring sticking and exhaust located carbon formation, protection against deposit induced pre-ignition and good fuel miscibility in the petroil system the oil is mixed with the petrol in the proportion recommended by the manufacturers.

ADVANTAGE OF LATEST GENERATION HIGH PERFORMANCE LUBRICANT

- Reduced spark plug fouling.
- High temperature engine cleanliness.
- Reduced piston ring sticking.

- Reduced exhaust port block.
- Reduction in silencer deposits.

TRANSMISSION:-

Automatic transmissions are complex hydro-mechanical devices, which essentially consist of four elements.

1) Torque converter
2) Clutch packs and break band assembly
3) Epicyclic gear train
4) Hydraulic systems

Further the elements classified into hydraulic transmission components and mechanical transmission components.

Hydraulic transmission:

1) Fluid coupling
2) Torque converters.

Mechanical transmission components are.

1) Planetary or epicyclic gears
2) Clutch packs and breaks band assembly

FLUID COUPLING: Merely transmits the engine torque to the mechanical gearbox.

TORQUE CONVERTER:

Torque converter converts the low torque of the rapidly rotating engine into a high torque in conjunction with the low speed of rotation at the output shaft of the converter.

FUNCTION OF THE TRANSMISSION

1) Provide a method of disconnecting the power train from the engine so that vehicle can be started and stopped with engine running.
2) Provide torque multiplication for conditions where greater driving torque is required at the wheels than is available from the engine
3) Provide a method for reversing the drive.

TRANSMISSION FLUID

Transmission fluid contains as many as fifteen types of additives to provide:

- Friction properties
- Seal compatibility
- Corrosion protection
- Improved oxidation stability
- Specific gravity
- Anti-wear performance

- Viscosity-temperature properties
- Anti-foam characteristic

FRICTION PROPERTIES:

The friction properties of transmission fluids are to complement the friction properties of the clutch plates. Which are made of special paper or cellulose fibers and resins, asbestos, graphite or ceramics, sintered bronze or semi metallic to provide optimum wear resistance, coefficient of friction and durability. Paper friction materials are porous, which facilitates their cooling by the oil that is observed.

Transmission fluids have high static coefficient of friction will give a high coefficient of friction as the sliding speed approaches zero. Friction modifier can reduce to low static coefficient of friction to eliminate stick-slip phenomena that occur in low sliding speed for smooth shifting of clutch or gear.

Fluids with improper frictional properties can result in clutch plate or brake band wear and excessive heat buildup of the clutch plate surfaces during engagement.

1) SPECFIC GRAVITY:

Oil is energy transfer medium in the torque converter. Oil should be having high specific gravity to increase mass for energy transfer because kinetic energy is the product of mass and velocity of oil.

Kinetic energy = mass of oil x velocity of oil

= 1/2mv2

VISCOSITY-TEMPERATURE CHARACTERISTIC:

Transmission fluids are expected to operate over a wide temp range of minus 40c to plus 175c so oil circulation is necessary to transfer energy. And oil should have low viscosity to flow with a minimum of drag to reduce power loss and heat generation and increase mechanical efficiency.

VISCOSITY:

As the oil is circulated in the torque converter continuously and as it transfers energy, it must be of sufficiently low viscosity to flow with a minimum of drag. Viscous drag absorbs power, causes heat and lowers the mechanical efficiency of the converter.

LOW-TEMPERATURE PROPERTIES:

The oil must possess good cold temperature properties –low pour point and low viscosity so that it will circulate at the lowest start-up temp. At the highest operating temp the oil must retain sufficient viscosity to lubricate the bearings in the converter.

COMPATIBITY:

The oil must have no adverse effect on oil seal or o- ring material.

OXIDATION AND THERMAL STABILITY:

- Oil must stand up to intense heating conditions without serious degradation.
- The service life of oil is reduced by oxidation. Because, petroleum products are readily susceptible to oxidation since oxygen combines with carbon and hydrogen.

- Mostly oxidation products are soluble in the oil and additional reaction takes place to form gum, sludge, and varnish. The first stage products are acid in nature and can cause corrosion in the entire system and in addition viscosity increases. The insoluble gums, sludge and varnish plug orifices, increase wear and cause valves to stick.

FOAMING:

The oil must have good anti-foaming properties. A mixture of air and oil has a very low specific gravity and will not transfer sufficient kinetic energy for the converter to work.

IF THE SAME OIL FOR BOTH TRANSMISSION AND GEAR:

If the same oil from the torque converter is also used in the gearbox, additional properties may be needed.

LOAD CARRYING PROPERTIES:

EP or load carrying properties is required in the oil for lubrication of bearings and gears under are temperature conditions.

VISCOSITY:

The oil must retain sufficient viscosity at the maximum operating temperatures to protect the gearbox operating in the hydraulic system.

DISPERENCY:

The oil must not cause glazing of the clutch plates by degradation products and so cause a lowering of the coefficient of friction. This property is connected with the high –temperature oxidation stability of the oil. Dispersant additives are to minimize glazing or coating of the clutch plates.

MANY AUTOMATIC:

Many automatic gearboxes have completely automatic gear changing. The speed at which the gear change occurs is oil pressure generated by the gearbox-operating pump. The viscosity of the oil falling off when the oil is hot and the viscosity low to minimize these temp effects it is usually to gear oils for these applications with potent viscosity improver additives to give exceptionally high viscosity indices can affect this pressure.

FUNCTION OF TRANSMISSION FLUID:

- To act as a power transfer media.
- As a hydraulic medium for delicate control mechanism
- As a lubricant for gears clutch plates, and bearing.
- As a heat transfer medium.

TYPES OF TRANSMISSION FLUID:

- Fluids for automatic transmissions of passenger cars.
- Fluids for transmissions system of off highway equipment
- Fluids for railroad hydraulic transmissions
- Fluids for tractor transmission

INDUSTRIAL LUBRICANTS

Industrial lubricants include hydraulic fluids, turbine oils, industrial gear oils, metal working fluids etc. In general, specifications for these products are set by original equipment manufacturers. However, an international organization for standardization (ISO) has finalized18 viscosity grades ranging from 2 cSt to 1500 cSt, which has been accepted and used worldwide.

GEAR LUBRICATION

The essential factor in the lubrication of gearing, as compare with other mechanisms, is the maintenance of a fluid film between the surfaces of components with relative motion, and mutual loading. By separating the surfaces in this way, there is a reduction in the degree of contact between the asperities on the mating parts. Inadequate separation leads to welding of the areas of contact followed by tearing /scuffing of the metal surfaces and the virtual destruction of the gears.

The degree of contact of the mating surface is governed by the loading, surface finish and viscosity of lubricant.

Gearing will most often operate between boundary and hydrodynamic lubrication. At one extreme condition, the load is supported almost entirely by metal-to-metal contact, with the minimum of pressure in the

intermittent oil film under this condition of boundary lubrication wear and scuffing may be so severe that the surfaces of the gear teeth are irreparably damaged. At the other end of the scale, full hydrodynamic lubrication will support the load entirely on the oil film, and contact of the separation will be virtually non-existent.

An intermediate zone exists between boundary and hydrodynamics lubrication is called elasto- hydrodynamics lubrication. Under this zone, the surfaces of the materials in contact deform elastically under pressure and hence the load is spread over a greater area, which reduces pressure on particular point/ area and enhances availability of lubrication. Thus the viscosity of the lubricant increases dramatically at high pressure thereby increasing the load- carrying ability in the contact zone.

The required minimum film thickness will be governed by the surface roughness of the conjoined surfaces. The film thickness should exceed the combined heights of the asperities on mating teeth. The actual thickness of the film generated will depend on the relative velocity of these surfaces, their dimensions and viscosity of the oil under this condition. Therefore, a lubricant is selected with a viscosity that will permit the necessary film thickness to give a predominantly hydrodynamic mode of lubrication.

Industrial gears may be either of the enclosed or of the open type. The enclosed type may be lubricated by splash, in which case the oil level In the gear box is maintained so that the teeth of the bottom wheel just dips into the oil. Alternatively a pressure circulating system may be used in which oil is sprayed on the teeth close to the point of engagement and is re-circulated either directly from the bottom of the gear case or by way of a separate oil tank. Splash lubrication is suitable where pitch line speeds are low, up to 5m/sec for spur, helical and bevel gears and up to 4m/sec for worm gears. With splash lubricated gears it is most important that the oil level should not be too high, otherwise excessive churning of oil will occur with consequent rise in oil temperature and power loss. The depth to which the bottom wheel should dip into the oil when stationary is generally between 2 cms to 4 cms depending upon the size of the gear. Usually twice the tooth depth is sufficient for splash lubrication to minimize excessive churning. Where high-powered gear sets running at high speeds are used pressure-circulating systems with oil coolers are preferred to reduce churning.

In the case of open gears the lubricant is generally applied to the teeth by hand/brush, alternatively dip shallow pool; automatic drip or spray methods (continuous or intermittent) can also be used.

The main functions of a gear lubricant are to reduce friction and wear by providing a lubricating film between working surfaces of meshing teeth and, in case of enclosed gears, to carry away the heat developed during tooth contact or meshing of gears.

To perform these functions properly, in cases where the conditions of tooth engagement are not abnormally severe and where straight mineral oils are suitable, the lubricant must be viscous enough to maintain the film and yet sufficiently free flowing to give adequate heat dissipation. These conflicting requirements are best met by oil as thin as is consistent with proper lubrication of the teeth. It must be borne in mind that in most cases oil is used not only for the gear teeth but also for the gear wheel and pinion bearings and that the bearings will tend to over heat with too thick oil.

Wherever the conditions of tooth engagement is severe, example in the hypoid gears, the lubricant is unable by virtue of its viscosity alone to provide a film that can entirely prevent metal-to-contact between the teeth. In such cases it is necessary to employ extreme pressure (e.p) lubricants. These lubricants contain chemical substances which at the relatively higher surface temperatures developed at the points of metallic contact react with the metal of the gear teeth at these points to form solid or semi solid films possessing anti welding properties

The use of greases in enclosed gears should be avoided all but exceptional cases, because of their tendency to channel and leave the teeth dry, also because of the possibility of their separating out and forming deposits in consequence of conditions existing in the gearbox. In addition, fluid friction tends to be higher with grease than with an oil of suitable viscosity and heat dissipation with the former is very low because of its sluggishness. However it may be necessary to use grease for some enclosed medium and low-speed gears where the box is not oil-tight. For enclosed gears the lubricant is required to perform satisfactorily over long periods and high quality oils of good stability towards oxidation are therefore required. This is particularly so where conditions are such that aeration of the oil is pronounced for example, in high-speed gears or where operating temperatures are high.

SELECTION OF OIL FOR SPUR, HELICAL AND BEVEL GEARS:-

In these gears the choice of oil depends mainly on the tooth loading and the pitch line speed. In general it can be said that higher the tensile strength of the gear material, higher will be the tooth loading and greater the required oil viscosity. It is also generally true that higher the pitch line speed, lower will be the tooth loading and less is the required oil

viscosity. It is therefore practicable to use oils of low viscosity for high-speed gears, which is desirable from the point of view of cooling and frictional losses also. Fluid friction and the heat produced by it, increase as gear speed and oil viscosity increase Lower viscosity oils are also preferable because they give better separation of water and other insoluble contaminants and have less tendency to foam.

Straight mineral oils are suitable for most gears of this type. In the case of turbine gears and similar high-speed units employing a pressure circulating system, the use of turbine oil with high resistance to oxidation is generally advisable. In certain medium and low speed applications, e.g. steel mill gears, where tooth loading may be abnormally high or where shock loads occur, straight mineral oils may allow a higher rate of wear than usual and fail to prevent some deterioration in the condition of the contact surfaces of the teeth. In such circumstances oils containing additives, which confer additional load carrying, and anti wear properties, without having true EP properties, may be used with advantage. As rule EP lubricants are not required for gears of this type, though they may be recommended for some designs, e.g. spiral bevel units, where conditions of tooth engagement are liable to be severe.

HYPOID GEARS:-

These are designed to transmit high power in proportion to their size. High degree of sliding, introduced due to offset of the axis, along the line of contact between meshing teeth, coupled with the heavy loading generally associated with this type of gear makes lubrication conditions particularly severe and places an extreme requirement on the gear oil.

Straight mineral oils, or oils conditioning relatively inactive additives of the anti wear type are inadequate and will generally allow severe scuffing to take place as these gears operate under boundary or mixed film conditions essentially all the time. Hence lubricants containing active extreme pressure additives are invariably recommended for these gears.

WORM GEARS:-

These are usually splash lubricated. As these do not usually exceed a pitch line velocity of 4 m/sec, but if they do so, spray lubrication is essential. Owing to almost pure sliding between the teeth, worm gears generally run at a higher temperature than other types.

As worm gear efficiency depends upon the operating temperature, increase in temperature is a limiting factor for the power transmitting capacity of a worm gear unit. It is necessary to reduce tooth friction as much as possible by the use of comparatively heavy oils of carefully selected type. However, in order to limit the temperature rise due to churning, the viscosity selected should be lowered with increasing speed of the gears. Normally straight mineral oils are preferred but, under very high loading conditions, compounded oils may be advantageous notwithstanding their inferior chemical stability.

OPEN GEARS:-

These are generally spur or bevel gear and the lubricant is applied manually to the gear teeth.

A special type of lubricant with good adhesive properties is required to prevent its being flung off the teeth or being squeezed out.

Heavy, adhesive type residual oils and greases meet these requirements. Heavy straight mineral residual oils need to be heated or thinned with solvent before they can be applied to the gears. The solvent evaporates after application, leaving the teeth coated. The high viscosity of the oil alone gives good protection to the gears. For improved load carrying capacity, oils containing EP additives are also recommended. Sometimes straight mineral oils are also compounded with fatty material to give improved film strength and to provide adequate lubrication where water is present.

OPERATING TROUBLES:

Two sources of trouble directly related to lubrication in gear systems are high temperature and wear.

Excessive wear of teeth can result from misalignment or incorrect machining of the teeth; it may also result from the use of an oil of too low viscosity, which would not provide an adequate film of lubricant between the two contacting surfaces. In addition, oil starvation, or the presence of abrasive impurities in the oil can cause high gear wear. High temperature may be due to any of the following causes.

- Use of an oil of too high viscosity.
- Excessive churning of the oil because of the level being too high (this applies to splash-lubricated types)
- Insufficient supply of oil to the teeth (where a force –feed circulating system is employed) is usually due to choking of oil pipes or oil strainer, causing high metallic frictional heat.
- Inefficiency of the cooling system, if one is provided.

Cleanliness is an all-important factor if efficient and trouble free lubrication of gears is to be achieved. Special attention should be given to the thorough cleaning of any gear system before initial operation. Therefore, the oil should be purified regularly and renewed when necessary.

INTERFERENCE: It is caused by extremely heavy contact between tip edge of one tooth and fillet surface of a mating tooth. Such interference may cause localize abrasion or gouging.

GREASE

DROP POINT (temperature**)**
It is the point at which grease become liquid.

Liquid lubricant + thickener +additives =grease

Classification of grease based on thickener

	thickener	Water resistance	Drop point(temperature)
01	Calcium base (lime)	Good	175
02	Sodium base (soda)	poor	250
03	Lithium base	Extremely good	300

Calcium base----water resistance
Sodium base ----to take heavy loads
Lithium base----multi purpose

CALCIUM BASE GREASE

- Water resistant.
- Adhesive grease.
- Suitable for moderate operating temperature.
- Suitable for excessive moisture.
- Excellent mechanical and thermal stability.
- Good antirust and excellent resistance properties
- Recommended for use in ball and roller bearing.

USES

- Chassis lubrication of automotive vehicles, including commercial vehicles, tractors and
- Heavy duty equipment.
- Wheel bearing
- Water pumps operating at moderate temperature.
- Plain bearing operating under moderate temperature and light load conditions.
- Suitable for plain bearings operating in wet conditions

SODIUM BASE GREASE

1. High melting point characteristic.
2. Poor water resistance quality.

USES

1. Suitable for ball and roller bearings of wheels and electrical equipment.

LITHIUM BASE GREASE

- Multifunctional
- High temperature.
- High drop point
- Good thermal and structural stability.
- High degree of resistance to oxidation.
- Provides protection against rusting and corrosion.
- Excellent shear stability
- High load carrying capacity.
- Suitable for shock loads at temperatures up to about 130*c.
- Recommended for heavy duty roller and plain bearings.

USES

- Automotive vehicles for all grease lubricated parts

DIFFERENCE BETWEEN OIL AND GREASE LUBRICATION

sl	Oil lubricant	Grease lubricant
1	Oil is generally considered to be more effective lubricant and is to be preferred if the sealing arrangements are adequate, especially where the operating temperature or surface speed of the balls or rollers is high.	It is usual to employ grease as a lubricant where temperatures and speeds are not excessive and the sealing arrangements do not offer satisfactory lubrication by oils.
2	Oil doesn't have self sealing properties and hence protecting the bearing against the entry of contaminants is less.	Grease possesses excellent self sealing properties and protects the bearing against the entry of contaminants
3	Viscosity of oil at low or moderate rates of shear lower than grease and so the bearing reaches hydrodynamic or full film stage less than grease.	Viscosity of grease at low or moderate rates of shear remains much higher than lubricating oil in general and so the bearing reaches hydrodynamic or full film stage more rapidly than with oil

4	Suitable for high speed application due to more effective cooling system	At high speed , frictional losses are high and more frictional heat is also generated due to limitation in cooling system
5	The method used to apply the oil depends mainly on the running speed of the bearing.	The method used to apply the grease is governed by the design of the bearings and by conditions of operation.

BEARING LUBRICATION

The most common application of a lubricant is to bearings which are endless uses in machineries.

TYPES OF BEARINGS

1. plain bearings/journal and bush bearings
2. rolling bearings/anti friction bearings

OIL LUBRICATION OF PLAIN OR JOURNAL AND BUSH BEARINGS

When a journal rotates in a plain bearing which is receiving oil in adequate quantity, a fluid film of oil is built up by virtue of the viscosity of the oil as a result of rotation of the journal in the bearing. Under suitable conditions this oil film prevents metallic contact between the journal and the bearing. While frictional resistance to the movement of the journal depends mainly on the speed of rotation of the journal and viscosity of the oil under the conditions existing in the film. Friction may be reduced by using oils of progressively lower viscosities. But in every case, depending on speed and load, there is a lower limit of viscosity below which a fluid film is not fully maintained and metal-to-metal contact is likely to occur. In practice, therefore, it is usual to employ oils of sufficient viscosity to provide a safety margin. The effect of operating temperature on viscosity must not be overlooked.

To ensure fluid film lubrication, the bearing must at all times be flooded with oil. So the oil must be supplied to the bearing at a rate equal to that at which it escapes. The rate of escape depends on the viscosity of the oil(less viscous oils escape more rapidly) and on such factors as bearing clearances and the mechanical condition of the bearing. Speaking generally, the greater the load, the lower the speed; or the larger the clearances the more viscous the lubricant must be. Conversely, lighter loads, higher speeds and smaller clearances necessitate oils of relatively low viscosity. Viscosity requirement also varies directly with surface specifications and bearing mean pressures. Selection of right kind of viscosity oil is to give most effective lubrication under all possible conditions.

The viscosity required for any given set of conditions depends on size, speed, load and temperature of the bearing.

Over lubrication should be avoided.

Oil level should not be above the centre of the bottom rolling element when the bearing is not rotation.

Suitable method is used to apply the oil depends mainly on the running speed of the bearing to avoid overheating problem due to churning of oil.

sl	Method of oil lubrication	Speed of machine
01	Oil bath and splash systems	Low and medium speed
02	Circulating systems	Medium speed
03	Spray or mist	High speed

Cleanliness in handling and applying the lubricant is most important to reduce wear, and every precaution should be taken to prevent impurities and moisture getting into bearings. Correct alignment is also a matter of obvious importance in preventing overheating and wear.

ANTIFRICTION BEARING

1. Ball bearing
2. Roller bearing
3. Needle bearing
4. Tapered roller bearing

The main duties of ball and roller bearing lubricants are:

- To reduce friction between the rolling elements and the separator or cage, and between the rolling elements and the races at any point where true rolling is absent.
- To reduce friction between the ends of rollers and the guiding surfaces which form part of the inner or outer race.
- To assist in dissipating heat generated within the bearing.
- To protect the highly polished working surfaces of the bearing from corrosion and rusting.
- To assist in sealing the bearing against the entry of contaminants such as dust and moisture.

The methods used to apply grease are governed by the design of the bearings and by conditions of operation.

sl	Method of grease lubrication	Periodicity of greasing
01	Grease packing	Applicable where periodic addition of fresh grease is not required.
02	Compression cup or pressure gun application	Employed where the addition of fresh grease is periodically necessary.
03	Centralized pressure systems	For severe service where the rate of consumption makes it necessary to add fresh grease at frequent and regular intervals.

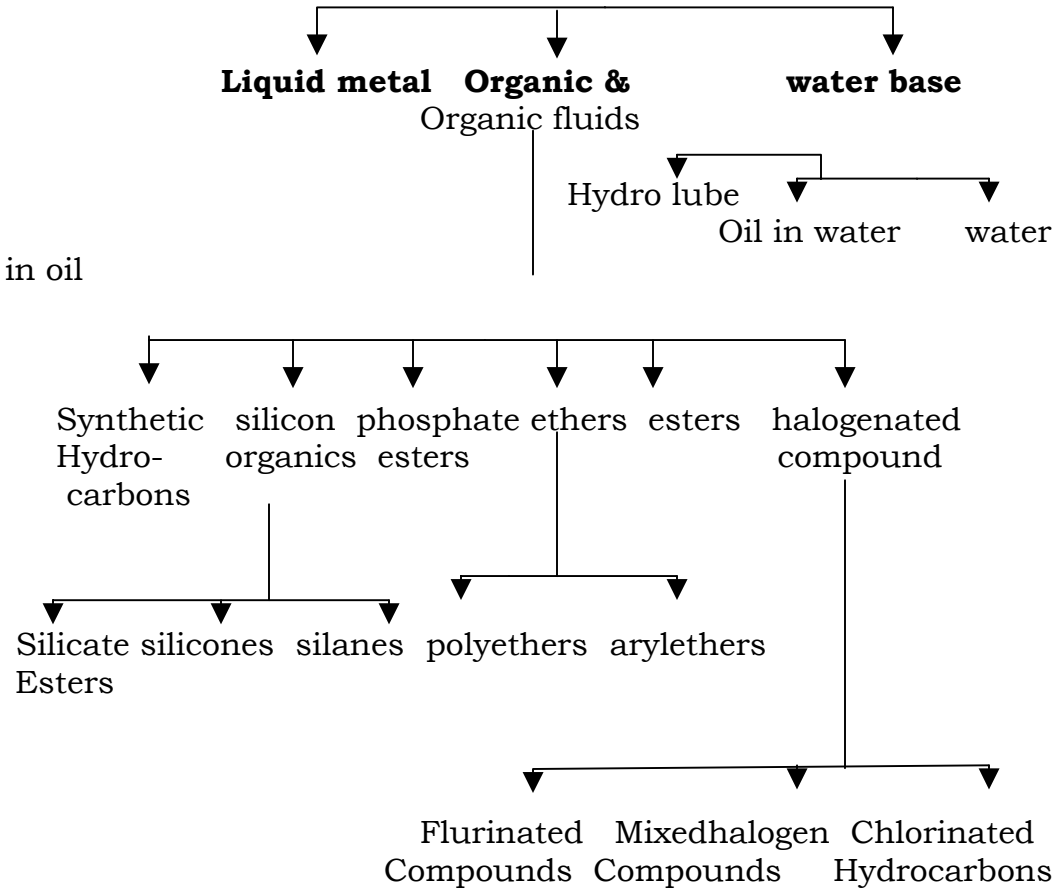
POWER HYDRAULIC

INTRODUCTION:

The fluid power system using oil as the medium for developing transmitting, controlling and utilizing power is commonly referred as fluid power system. It is widely used in every branch of modern industry and at home as well. The reason for this widespread use is that a fluid is one of the most versatile means of transmitting power and modifying motions. In the hydraulic power system, fluid is not a source of power, but it is a power-transmitting medium. The main power source of hydraulic system is prime movers such as electric motor, engine, etc.

Most commonly petroleum based oil is used in a hydraulic system.

HYDRAULIC FLUID



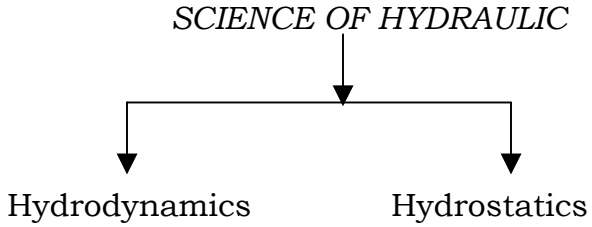
ADVANTAGES OF USING HYDRAULIC FLUID:

Hydraulic power systems have proved to be very effective in a number of applications in the fields of industry, automotive, marine and aerospace because of the following advantages.

- Fluid is infinitely flexible to operate.
- It can readily change its shape.
- It can be divided into parts to do work in different locations.
- It can move rapidly in one place and slowly in another.
- It can transmit a force in any (or) all directions.
- No other medium combines the same degree of positive ness, accuracy and flexibility of control, with the ability to transmit a maximum of power in a minimum of bulk and weight.
- Self-lubricities of internal components of the systems.
- Precise control over the movement of work, almost instantaneous
- Stopping and reversal of motion.
- Infinitely variable control of speed and virtual absence of backlash.
- Stopless variable speed drive apart from linear/rotary motions.
- Since fluids are practically incompressible, mechanical forces may be transmitted, multiplied or controlled by means of hydraulic fluids under pressure.
- Oil is incompressible liquid and it therefore will transmit power instantaneously in a hydraulic system.13)
- Above all the system is simple, compact, economy and safety.

DISADVANTAGE:

- ✓ Efficiency is 50%
- ✓ Preservation of oil is essential
- ✓ Oil is costly
- ✓ Oil subject to oxidation hydraulic oil should work within $70^{o}c$ beyond $70^{o}c$ the oxidation rate increase and reduce oil life half.



*HYDRODYNAMIC*S: Deals with power transmitted by liquid in motion.
Ex: Water stored in a Dam rotates turbine.

HYDROSTATICS: Deals with power transmitted by confined liquids under pressure. The liquid in the hydrostatic system moves (or) flows but energy is transmitted primarily because the liquid is pressurized.

BASIC PRINCIPLES OF HYDRAULIC:

- Liquids have no shape of their own.
- Liquids are practically incompressible.
- Liquids transmit applied pressure in all directions.
- Liquids provide greater increase in work force.

PRIMARY FUNCTIONS OF HYDRAULIC OIL:

- Power transmission
- Lubricants
- Sealing
- Cooling
- Maintain pressure

POWER TRANSMISSION:

Power transmission required that the fluid should flow easily through lines and components. Resistance to flow causes considerable loss of power. The fluid must be incompressible so that the action is instantaneous.

LUBRICATION:

Hydraulic fluid provides the internal lubrication for the pump components and other wearing parts as they slide against each other. For long components life, the oil must have good anti-wear characteristics.

SEALING:

The hydraulic oil acts as a seal against pressure inside the hydraulic components. In spool valves, the oil acts as a seal and there is no leakage from high-pressure passages to low-pressure passages. The close mechanical fit and the viscosity determines leakage ratio.

COOLING:

Circulation of oil through lines and around the walls of reservoir gives up heat that is generated in the system.

OTHER REQUIRED QUALITIES OF HYDRAULIC FLUID:

- ✓ Prevent rust.
- ✓ Prevent formation of sludge, gum and varnish.
- ✓ Depress foaming.
- ✓ Maintain its own stability and reduce fuel replacement.
- ✓ Stability over a wide range of temperature.
- ✓ Prevents corrosion and pitting.
- ✓ Separates oil and water.
- ✓ Compatibility with seals and gaskets.
- ✓ Incompressible.

- ✓ Be sufficiently fluid to permit the efficient transmission of power.
- ✓ Allow minimum leakage for good volumetric efficiency.
- ✓ Correct viscosity for good mechanical efficiency.
- ✓ Resistance to mechanical shear.
- ✓ Low specific gravity.
- ✓ Adequate fire resistance.
- ✓ Low vapour pressure.
- ✓ Low coefficient of thermal expansion.

HYDRAULIC FLUID PROPERTIES

- ✓ Viscosity
- ✓ Lubricating ability
- ✓ Catalysts
- ✓ Demulsibility
- ✓ Pour point
- ✓ Oxidation resistance
- ✓ Rust prevention
- ✓ Use of additives

VISCOSITY:

- It is the measure of the fluids resistance to flow (or) an inverse measure of fluidity.
- If fluid flows easily, its viscosity is low (oil is thin)
- A fluid flowing with difficulty has a light viscosity (oil is thick)

HYDRAULIC SYSTEM: high viscosity is desirable for sealing between mating surfaces. But high viscosity increases friction resulting in

- ✓ High resistance to flow
- ✓ Power loss due to friction
- ✓ High temperature
- ✓ Increased pressure drop
- ✓ Sluggish operation
- ✓ Difficulty in separating air from oil in reservoir
- ✓ Cavitations problem in pumps

VISCOSITY TOO LOW:

- Increased internal leakage
- Increased Excessive wear (or) seizure.
- Pump efficiency drops
- Temperature due to leakage losses.

LUBRICATING ABILITY:

Hydraulic system moving parts should have enough clearance to run together on a film of fluid. This is known as full

film lubrication. As long as the fluid has adequate viscosity the minute imperfections of the surfaces do not touch.

But at high speed, pressures and low clearances cause this film of liquid to be squeezed very thin and a condition known as boundary lubrication occurs. Here there may be metal-to-metal contact and a chemical lubricating ability is needed.

OXIDATION RESISTANCE:

The service life of a fluid is reduced by oxidation. i.e, the chemical union with oxygen, petroleum products are readily susceptible to oxidation since oxygen combines with carbon and hydrogen.

Mostly oxidation products are soluble in the oil and an additional reaction takes places to form gum, sludge, and varnish. The first stage products are acid in nature and can cause corrosion in the entire system and in addition viscosity increases. The insoluble gums, sludge and varnish plug orifices, increase wear and cause valves to stick.

CATALYSTS:

Heat, pressure, contaminants water, metal surfaces and agitation all accelerate oxidation, below 135 F oil oxides very slowly. But the rate is double for every 10F increase in temperature.

ADDITIVES:

Oil refineries incorporate additives to stop or to reduce the effects of oxidation. But these additives must be compatible with the base fluid and with each other.

RUST PREVENTION:

Chemical reaction between a metal and a chemical is corrosion. Rust is the chemical union of iron and oxygen. It is difficult to keep air and atmosphere borne moisture out of hydraulic system. Both corrosion and rust contaminate the system and promote wear. Incorporating additives that plate the metal surface can inhabit it.

DEMULSIBITY:

The ability to separate out water is known as demulsibility. Too much water in oil will promote collection of contaminates and can cause sticky valves and accelerated wear.

REJECTION LIMIT OF HYDRAULIC OIL

1. Water content---------change oil if water exceeds 0.2%
2. Viscosity----------10% change maximum
3. Sediment a)----------0.1% if abrasive
   b) ----------0.5% if non abrasive

PRINCIPLES OF FLUID FUNCTION:

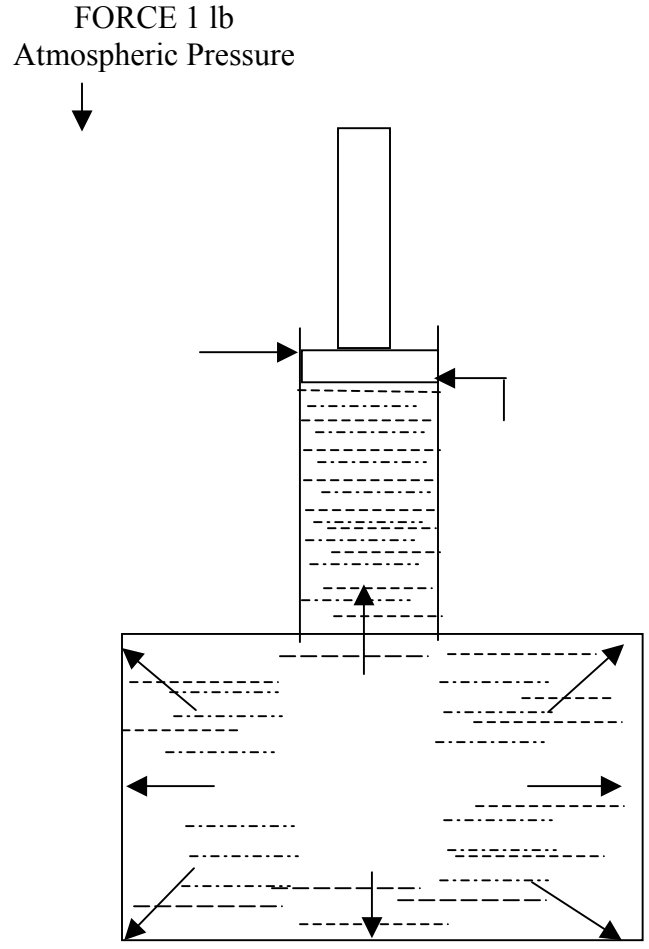
PASCAL'S LAW:

Pressure on a confined fluid is transmitted undiminished in every direction and acts with equal force on equal areas and at right angles to the container walls.

Pressure at any one point in static liquid is the same in every direction and exerts equal force on equal areas. Pascal's law neglects the factor of friction, because it deals with static fluids only.

Illustrating Pascal's law which states that pressure at any point in static liquid is the some in every direction and exerts equal force on equal areas.

Pascal's law neglects the factor of friction, because it deals with static fluids.

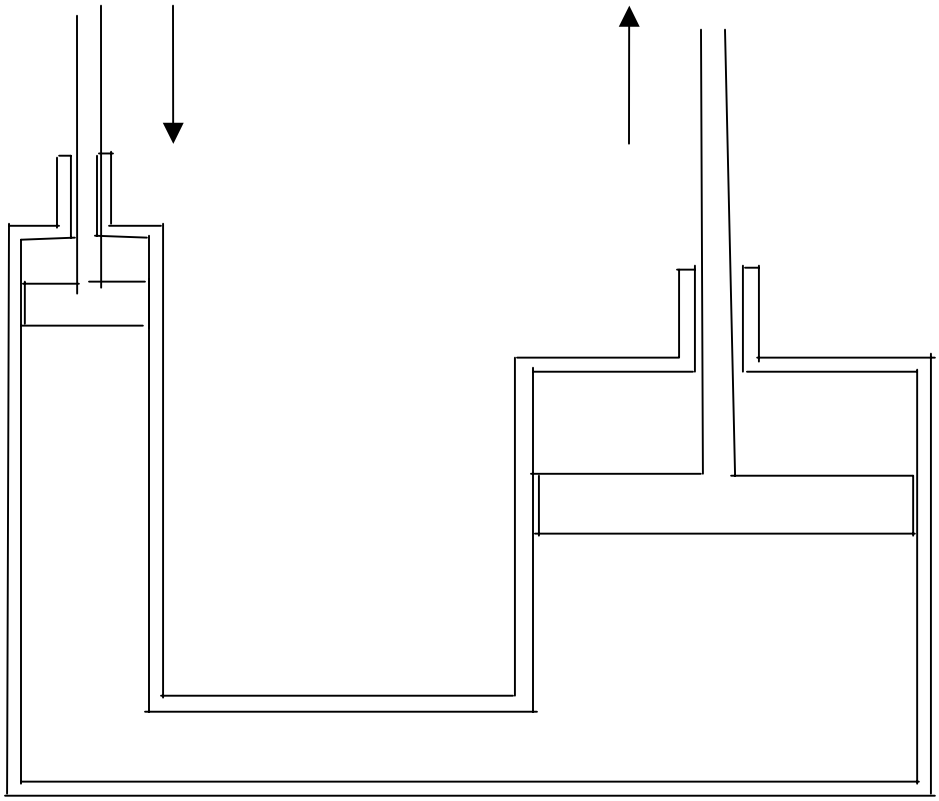


FORCE, PRESSURE AND AREA RELATIONS

Force is directly proportional to the pressure of fluid and area of piston.

100 lbs

1000 lbs



Force = P x A
= Pressure in psi x area in Sq.inch

PRESSURE = Force / Area = 100/1 = 1000/10

Applying 100 lbs of force to the left hand piston causes the right hand piston to rise with a force of 1000 lbs., since the area of the right hand piston is ten times that of the other. The distance traveled by the left hand piston, however, is ten times farther than that for the right hand piston.i.e.Force gained is lost in distance moved or speed.

Small force on a small area would create a proportionately larger force on a larger area; the only limit is the area to which the pressure is exerted. Only the liquid displaced by the small piston making the distance each piston moved inversely proportional to the area move the large piston.

HYDRUALIC CIRCUITS:-

There are four basic components required regardless of the application.

- A tank to hold fluid (reservoir)
- A pump to force the fluid through system
- Valves to control fluid pressure and flow
- An actuator to convert the energy of fluid movement into mechanical force to do the work.(a cylinder for linear or motor for rotary motion)

RESERVOIR:

A well-designed hydraulic reservoir will assists in the separation of air and contaminants from the fluid and helps dissipate heat generated within the system. It consists of

- Main tank with easily removable covers for cleaning purpose.
- Sight glass to check oil level.
- Drain plug to drain oil.
- Filler hole with wire mesh to top up fresh oil.
- Suction strainer between tank and pump to avoid foreign particle entering to suction port of the pump.
- Return line filter to prevent the particle into the tank.
- Breather with air filters to maintain atmospheric pressure to help in suction lift of the pump. The breather assembly used to vent the reservoir contains a filter to purify the air. It permits rapid discharge of displaced air from the reservoir.
- Baffle plate –2/3 height of oil level to separate pump inlet from return line. So as to ensure circuitous route:
    - To prevent local turbulence
    - Allows foreign material to settle

- Entrapped air is getting separated
- Increase heat dissipation.

STRAINERS, FILTERS & MAGNETIC PLUGS:

To assure long life and trouble free performance of hydraulic components, the hydraulic fluid must be kept clean. Filters, strainers and magnetic plugs can be used to remove foreign particles from the hydraulic fluid and are effective safeguards against contamination.

MAGNETIC PLUG:

*A*re useful for removing iron or steel particles from the fluid and are located in the reservoir to trap these particles.

USES OF STRAINER:

Strainer is a coarse filter. It offers less resistance to flow and is used in pump inlet lines where pressure drop must be kept to a inimum. Strainer consists of a fine mesh wire screen, or a screening element made of specially processed wire of varying thickness wrapped around a metal frame.

FILTER:

Filter is a device whose primary function is the retention by a porous media of insoluble contaminants from a fluid. They are able remove the particle as small as 2 microns.

FILTER MATERIAL: Filters are made of various materials

- Mechanical - wire mesh
- Absorbent –porous Micronics element
- Adsorbents – charcoal + earth (it is to be used in hydraulic oil)

NOTE: Fuller's earth or activated clay should not be used with additive-type hydraulic fluids because such elements remove the additives as well as the impurities.

The fluid's viscosity and the allowable pressure drop determine the amount of flow a clean filter can handle.

TYPES OF FILTER:

- ❖ Full flows type.
- ❖ Proportional type.

FULL FLOW TYPE:

*A*ll of the fluid entering the unit passes through the filtering element. Although the filtering element provides a more positive filtering action, it offers greater resistance to flow when it becomes

dirty. For this reason, a full-flow filter usually includes a valve to bypass the element automatically when it cannot handle all the flow through the unit.

PROPORTIONAL TYPE:

*O*nly a portion of the fluid passes through the element. Although only a portion of the fluid is filtered at any given time, continuous re-circulation of fluid through the system eventually causes all the fluid to pass through the filter cartridge.

BYPASS FILTER:

Arrangement can be connected into a hydraulic so that only a portion of the system fluid is filtered and returned to the reservoir.

HEAT EXCHANGER:

*T*he purpose of heat exchanger is to cool the oil in summer (or) to heat the oil in winter.

Two types of heat exchanger:

- Air cooler (blower)
- Water cooler (it can be used as cooler or heater by circulating cold or hot water)

FACTORS INFLUENCING THE FRICTION:-

When a fluid flows in a hydraulic circuit, friction results and heat is produced. Thus some of heat energy being transferred is lost in the form of heat energy.

Four main causes of excessive friction in hydraulic lines are.

- Excessive length of pipelines.
- Excessive number of sharp bends and fittings.
- Excessive fluid velocity caused by under sized pipe line.(friction is proportional to velocity)
- Excessive viscosity of fluid.

USEFUL INFORMATIOM ABOUT HYDRAULICS

- ❖ Oil is the most commonly used hydraulic fluid because it serves as a lubricant for hydraulic components and is practically incompressible.
- ❖ The weight of oil varies considerably with change in viscosity. However, 55 to 58 lbs/cu.ft. Covers the viscosity range of common hydraulic fluids.
- ❖ Pressure at the bottom of a 1' column of oil will be approximately 0.4 psi. to find the approximate pressure at the bottom of any oil column, multiply the height in feet by 0.4

- There must be a pressure drop (pressure difference) across an orifice (or) restriction to cause flow through it. Conversely, if there is no flow, there will be no pressure drop.
- A fluid is pushed into a pump. Atmospheric pressure supplies this push (in a unsuper charged pump) at 14.7 psi at sea level.
- Force exerted by a cylinder is dependent on the pressure applied and piston area.
- Speed of a cylinder is dependent on its piston area and the rate of fluid flow into it.
- Flow velocity through a pipe varies inversely to the square of the inside diameter. Doubling the i.d. increases the area four times.
- To find the area of a pipe need to handle a given flow the formula is used.
- Area = gpm x 0.3208 / velocity (ft/sec)
- To find the horsepower required to move a given volume as a known pressure, the formula is used.

$$POWER = \frac{\text{Force (F) x Distance (D)}}{\text{Time (T)}}$$

1HP = 33000ft-lb/min

= 746 watts

= 42.4 btu/min

Horse power = gpm x pressure in kgf/cm^2

HP = gpm x psi x 0 .000583

(Or)

$$HP = \frac{\text{Pressure (psi) x Flow rate (gpm)}}{1714}$$

(Or)

$HP=GPM \times KG/CM^2 \times 0.001777$

Cylinder area = Force/pressure

$$\text{Velocity} = \frac{Q}{\text{-----}} \text{ x19.25 ft/min}$$

A

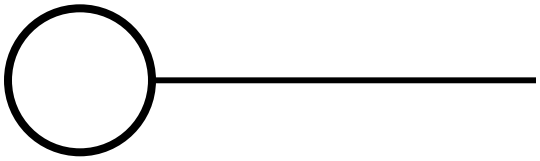
Where Q = gallon/min, A = inch^2

TORQUE: is defined as rotary force.
TORQUE = force x radial distance

RELATION BETWEEN HP, TORQUE AND SPEED

$$HP = \frac{\text{Torque (ft-lb) x Speed (RPM)}}{5252}$$

HYDRAULIC SYMBOLS

PRESSURE SOURCE 

WORKING LINE

PILOT (OR) CONTROL LINE

EXHAUST LINE

FLEXIBLE PIPELINE 

TYPES OF VALVE ACTUATION

1. MANUAL CONTROL

GENERAL 

PUSH BUTTON 

LEVER 

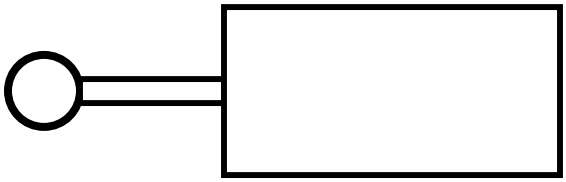
FEDAL 

2. MECHANICAL CONTROL

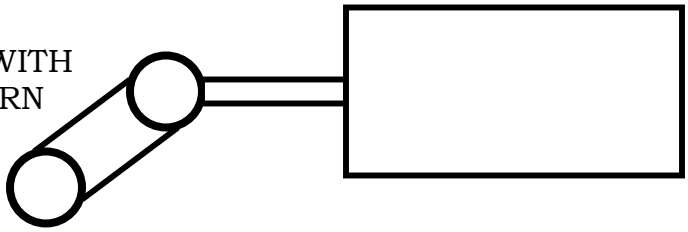
PLUNGER

SPRING

ROLLER



ROLLER LEVER WITH
IDLE RETURN



3. ELECTRIC CONTROL

SOLENOID WITH ONE
EFFECTIVE COIL

4. PNEUMATIC CONTROL

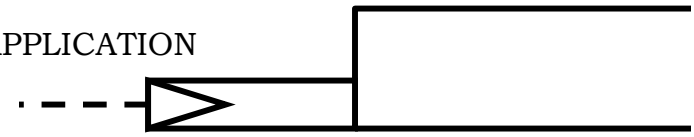
DIRECT BY APPLICATION

OF PRESSURE

DIFFERENTIAL PRESSURE
ACTUATION

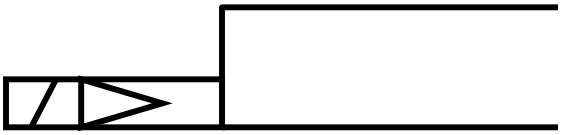
SPRING CENTERED

INDIRECT BY APPLICATION OF PRESSURE

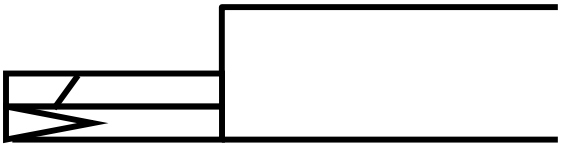


5. <u>COMBINED CONTROLS</u>

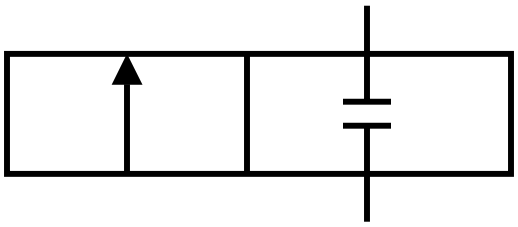
SOLENOID AND PILOT VALVE



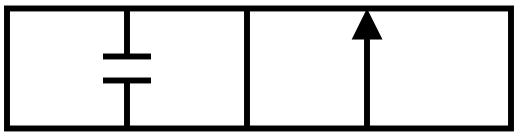
SOLENOID (OR) PILOT VALVE



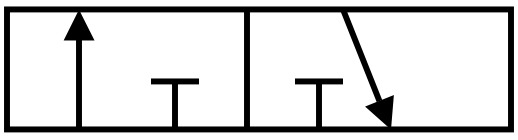
2/2 WAY VALVE CLOSED



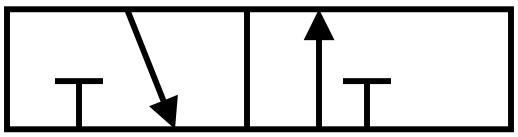
2/2 WAY VALVE OPEN



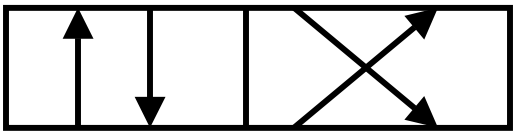
3/2 WAY VALVE CLOSED



3/2 WAY VALVE OPEN



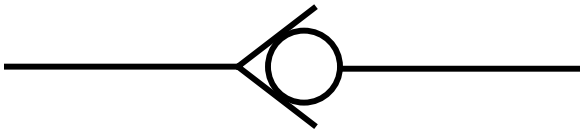
4/2 WAY VALVE



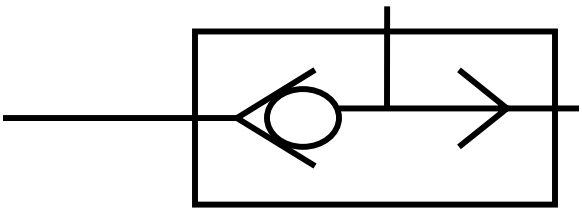
NON – RETURN VALVES

CHECK VALVE WITH SPRING

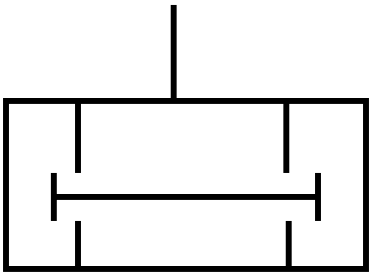
CHECK VALVE



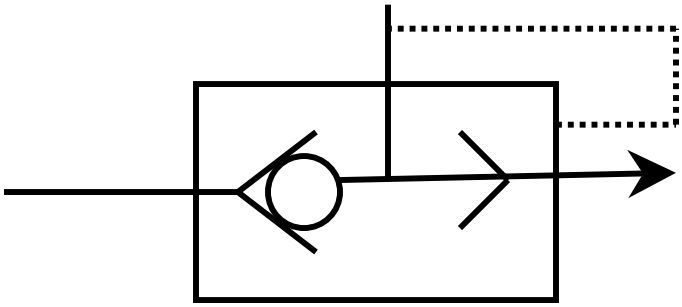
SHUTTLE VALVE



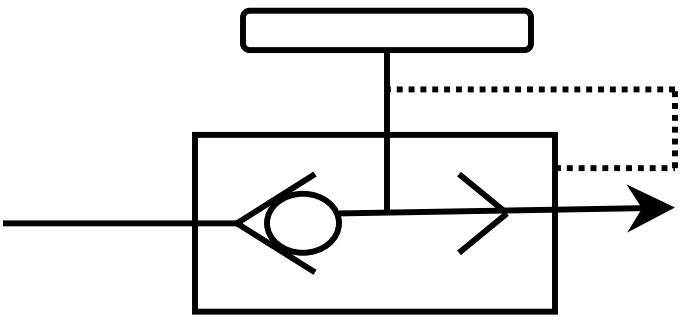
TWO PRESSURE VALVE



QUICK EXHAUST VALVE

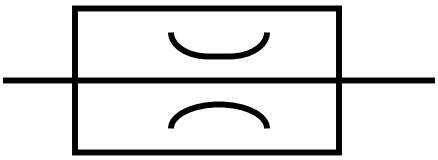


IMPULSE EJECTOR

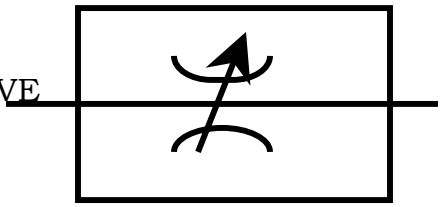


FLOW CONTROL VALVES

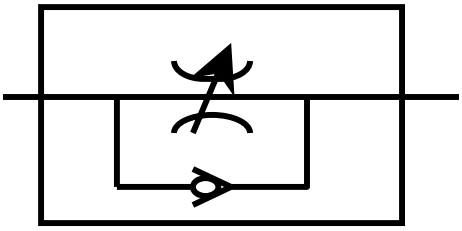
❖ RESTRICTOR VALVE



❖ ADJUSTABLE RESTRICTOR VALVE
THROTTLE VALVE

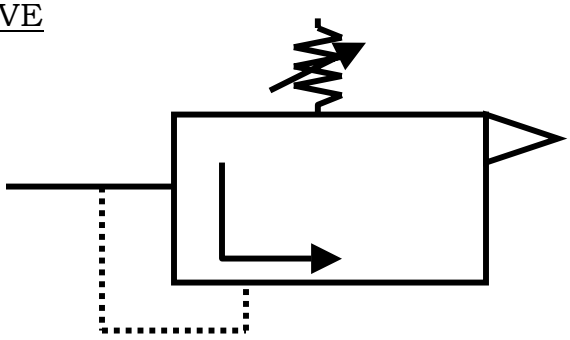


❖ ONE WAY FLOW CONTROL
VALVE THROTTLE RELIEF VALVE

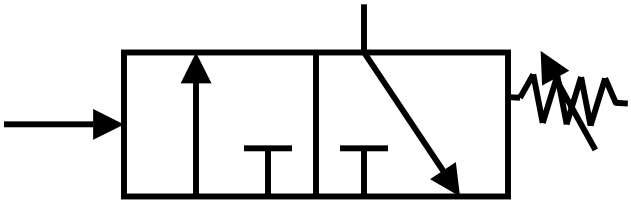


PRESSURE CONTROL VALVE

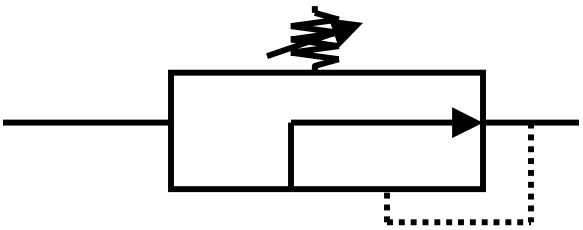
PRESSURE LIMITING
VALVE



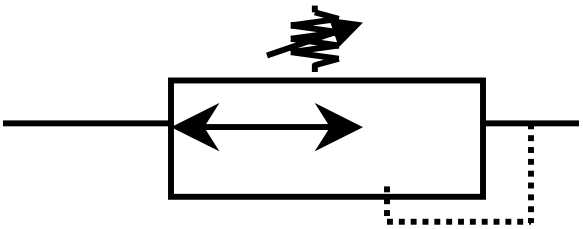
SEQUENCE VALVE



PRESSURE REGULATOR
WITHOUT RELIEF PORT

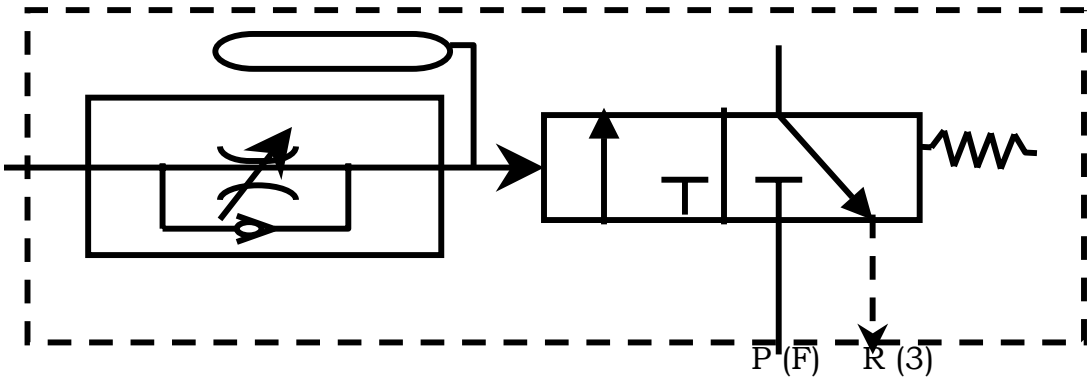


PRESSURE REGULATOR
WITH RELIEF PORT

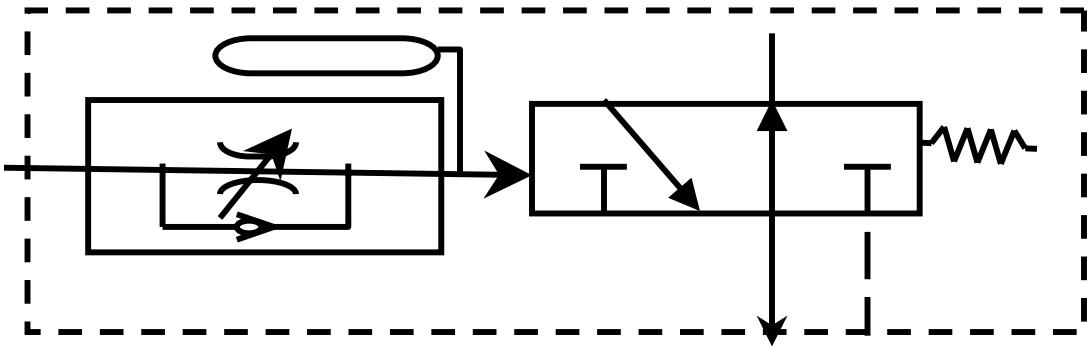


TIME DELAY VALVE

3/2 TIME DELAY VALVE (NC)



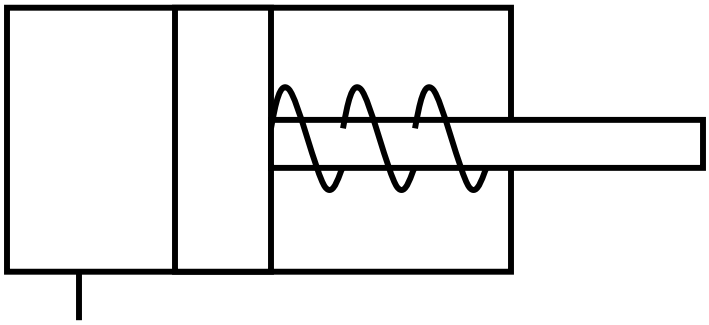
3/2 TIME DELAY VALVE (NO)



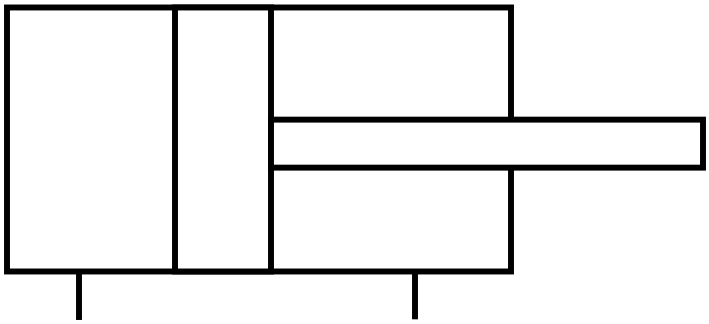
P (F) R (3)

PNEUMATIC CYLINDER

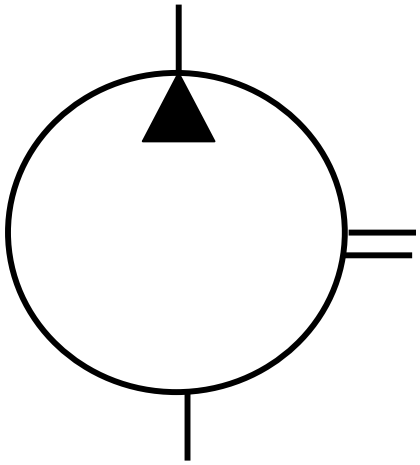
SINGLE – ACTING CYLINDER RETURN MOVEMENT BY SPRING



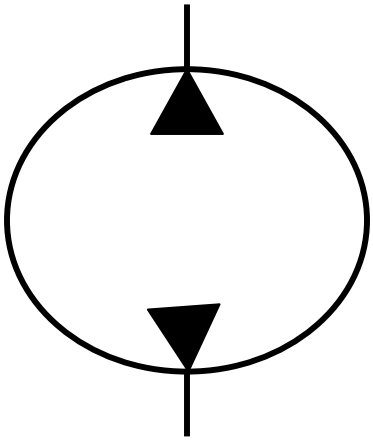
DOUBLE – ACTING CYLINDER



FIXED CAPACITY PUMP

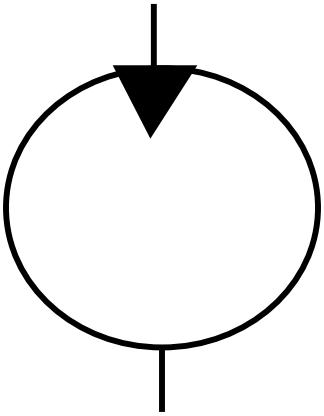


WITH ONE DIRECTION OF FLOW

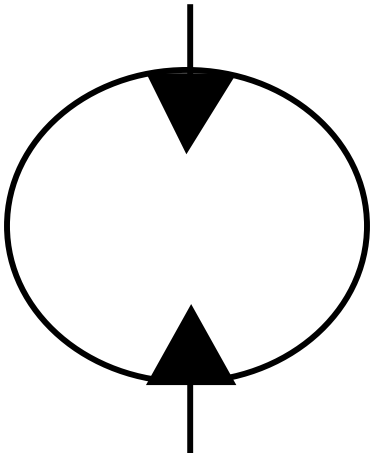


WITH TWO DIRECTIONS OF FLOW

FIXED CAPACITY MOTOR

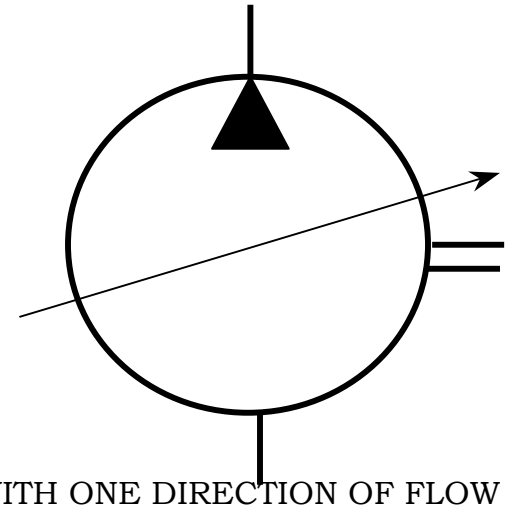


WITH ONE DIRECTION OF FLOW

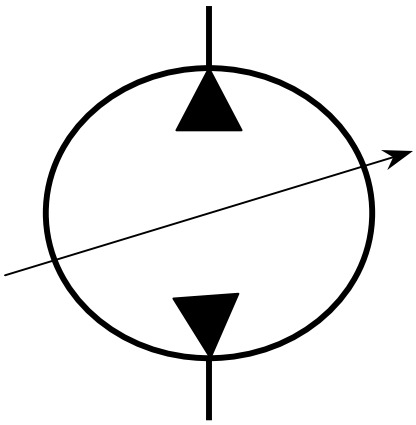


WITH TWO DIRECTIONS OF FLOW

VARIABLE CAPACITY PUMP

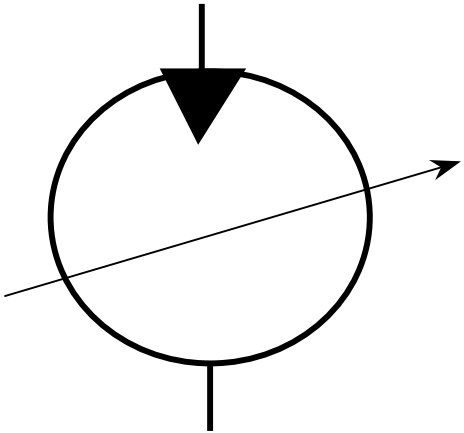


WITH ONE DIRECTION OF FLOW

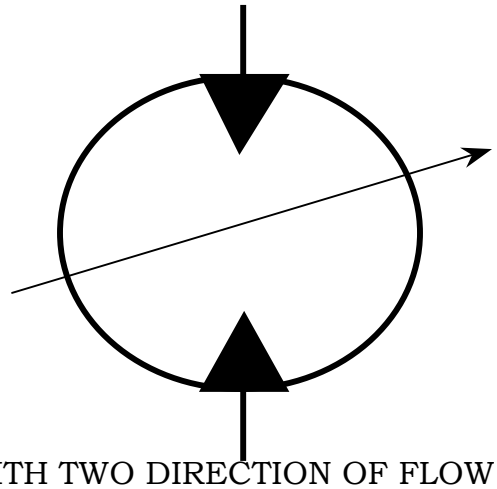


WITH TWO DIRECTIONS OF FLOW

VARIABLE CAPACITY MOTOR



WITH ONE DIRECTION OF FLOW



WITH TWO DIRECTION OF FLOW

HYDRAULIC PUMPS

INDRODUCTION:

Pump is purely a mechanical device, which raises the energy level of various fluids by converting the kinetic energy imparted by its prime mover into hydraulic energy. The mechanical action of an impeller creates a partial vacuum at the suction port of the pump. The atmospheric pressure then due to differential pressure pushes the fluid from the reservoir into the suction port of the pump. It then delivers this fluid to the outlet, forcing the fluid into the hydraulic system. As the fluid flows into the system, it encounters resistance to flow and that creates pressure. Resistance is created by workload and by instant resistance of valves and other restrictions in the line. Pump does not develop pressure, but merely produces flow. Pressure is generated only when a cylinder, motor, valve or restriction tends to resist fluid flow. Pump set the fluid in motion and provides flexible means of transmission of force.

IMPORTANT POINTS TO REMEMBER:

- Actually fluid is not lifted, but forced by atmosphere pressure due to void created at pump inlet.
- Pump dealing with air vapours and gases are called blowers in small sizes and compressors in bigger sizes.
- Oil vaporizes in a vacuum and gas bubbles carried and damaging the pump's lifts.
- At high vacuum and high-speed releases air dissolved in the oil leading to cavitations.
- Air leakage due to loose fittings causes erratic actuation.

CAVITATIONS:

Cavitations are a localized gaseous condition within a liquid stream, which occurs where the pressure is reduced to the vapour pressure.

PUMP RATINGS:

Pump rating is normally determined by their maximum operating pressure and their output in GPM and LPM at a given drive speed.

PRESSURE RATING OF THE PUMP:

Pumps are based on reasonable service life expectancy under specified operating conditions. Operation at higher pressures may shorten the life of pump.

VOLUMETRIC EFFICIENCY:

Theoretically a pump delivers fluid equal to its displacement per revolution or cycle. But due to its internal leakage or slippage the output is less. As pressure increases the leakage from outlet back into inlet also increases and thereby reducing volumetric efficiency.

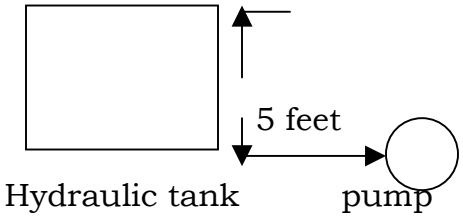
$$\text{Volumetric efficiency} = \frac{\text{Actual output}}{\text{Theoretical output}}$$

PRESSURE IN A COLUMN OF FLUID:

- Weight of volume of liquid varies as per viscosity.
- Most hydraulic oils vary in weight from 55-to 58-lbs/cu ft.
- One-foot column of oil will create a pressure of 0.4 psi
- One-foot column of water will create a pressure of 0.43 psi

1. If the pump inlet is a below the oil level in reservoir a positive pressure is available to push the oil into the pump.

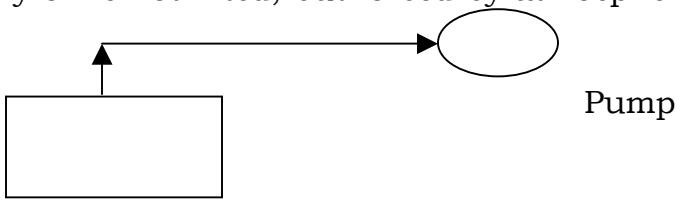
Example:



- The pressure exerted by a fluid increases with depth.
- So, 5 feet height of oil column pressure = 0.40 x 5 = 2 psi.
- This positive head of 5 feet oil column having pressure of 2psi automatically pushes the oil into pump inlet.

2. If the pump inlet is above fluid level in reservoir a vacuum equivalent to 0.4 psi per foot is needed to lift oil to inlet of the pump. Actually oil is not lifted, but forced by atmosphere pressure i.e. 2.5 psi.

Example:



- Most of the pumps create vacuum of 5 inch of mercury column at the pump inlet. Which is equal to 12.2 psi (absolute).
- The normal atmospheric pressure is 14.7 psi.
- Therefore the pressure difference at the inlet port of pump is = atmospheric pressure - pump vacuum pressure. I.e. (14.7 psi --- 12.2 psi = 2.5 psi)
- This excess pressure of 2.5 psi acts on the surface of reservoir oil and force them into the suction port of the pump.

DEFINED PRESSURE:

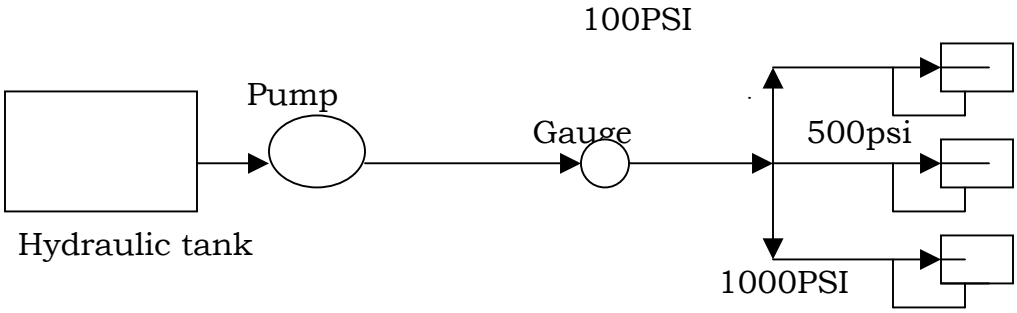
Pressure is responsible for pushing/exerting a force (or) torque. Pressure tendency is to expand/resistance to compression.

HOW PRESSURE IS CREATED:

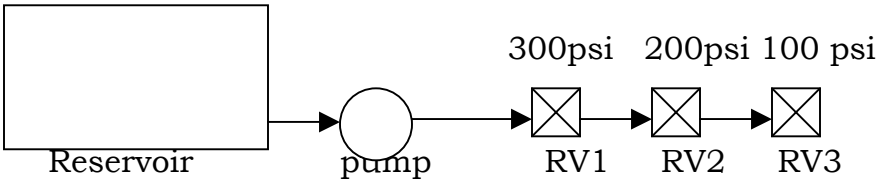
- Pressure created by squeezing (or) pushing in a confined fluid only if there is a resistance to flow.
- Pressure results whenever flow of a fluid is resisted.
- Resistance may come from

1. A load on an actuator cylinder.
2. A restriction in the pipe.

Liquids will always take a path of least resistance. Hence in the parallel paths of hydraulic circuit, the low-pressure relief valve opens first. If the low-pressure relief valve is blocked and failed to open the next nearest high-pressure relief valve open and vice versa.



When resistances to flow are connected in series the pressure adds up.



Since the relief valves are to open as indicated, the pump pressure is the sum of individual pressures. I.e. 100+200+300 =600psi

VELOCITY: is the average speed of a liquid past a given point.
Ft/sec (or) m/sec

FLOW: Flow is a movement of liquid caused by the difference in pressure between two points. Flow is produced by an action of pump. Flow is responsible for making something to move for causing motion.

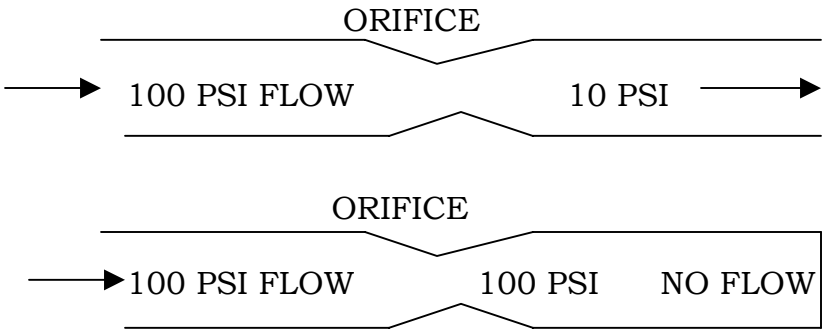
FLOW RATE: is a measure of the volume of liquid that passes a point in a given time (gpm)

LAMINAR FLOW: When a fluid moves in a pipe they will move in straight paths. This is called laminar flow and occurs at low velocity in straight piping; with laminar flow friction is minimized.

TURBULENT FLOW: Turbulent flow is one in which particles do not move parallel to flow direction. Turbulent flow is caused due to abrupt changes in direction or cross section or by too high velocity. This results in high friction.

Similarly if pump is connected to two actuators, the actuator, which needs lowest pressure, will move first.

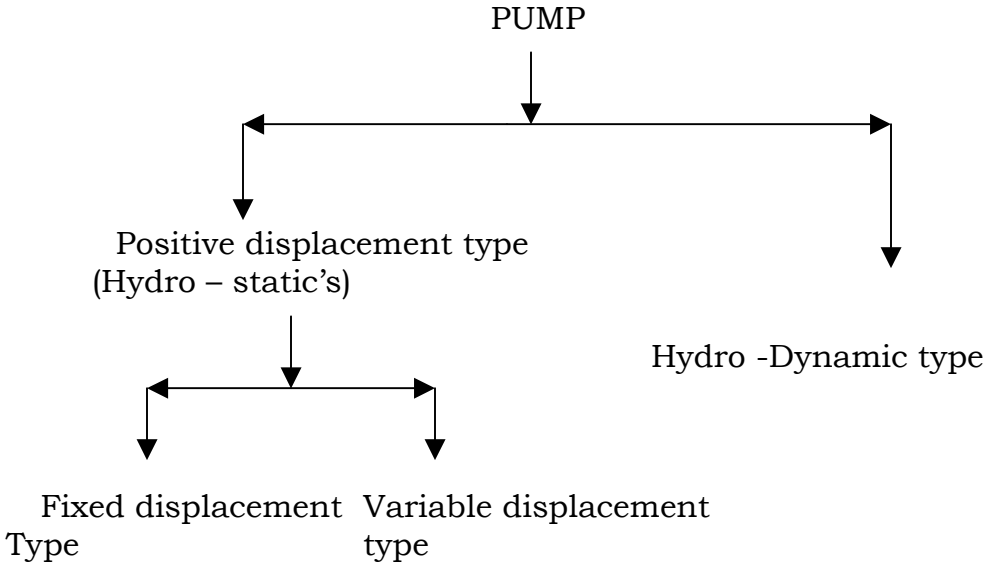
ORIFICE: An orifice is a restricted passage used to control flow on creates a pressure difference. If there is no flow, there is no difference in pressure across the orifice.



PUMP'S CONDITION: is determined not only by pressure, but it is necessary to measure the flow at a given pressure.

Return line oil volume is considerably greater than that delivered by the pump.

Pump inlet and return lines must be below fluid level to avoid foaming.
All pumps used in power hydraulic systems are of the positive displacement type.



All pumps used in power hydraulic systems are of the positive displacement type.

Most hydraulic pumps in use today are rotary type. They are:

- Gear pump
- Vane pump
- Piston pump

POSITIVE DISPLACEMENT TYPE:

A positive displacement pump produces a pulsating flow. But since it provides a positive internal seal against leakage its output is relatively unaffected by variations in system pressure.

Regardless of pressure and changes in efficiency the output is constant, outlet is positively dealed from inlet pump creates FLOW and pressure is caused due to restrictions or resistance to flow.

FIXED DISPLACEMENT PUMP: Only changing the pump speed can vary volumetric output. Suitable valve controls the amount of flow going to various portions of the circuit.

VARIABLE- DISPLACEMENT PUMP:

Displacement can be varied through the use of an integral controlling device. Which adjusts the physical relationship of the pump-operating parts.

GEAR PUMP:

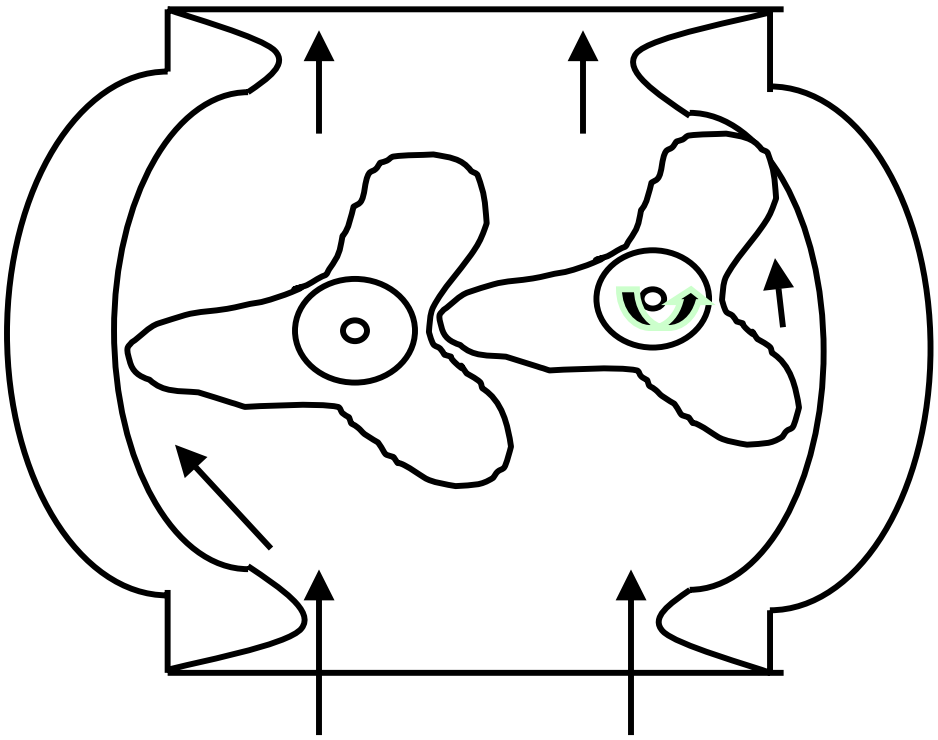
It is the simplest type of fixed displacement pump. The pump consists of a drive gear (1) and a driven gear (2) enclosed in a closely fitted housing. The gears rotate in opposite directions and mesh at a point in the housing between the inlet and outlet ports. As the teeth of the two gears separate, fluid is drawn into the inlet chamber A. The fluid is trapped between the gear teeth and housing and carried through two separate paths around to outlet chamber B. As the teeth re-mesh, fluid is forced through the outlet port. Close fit of the gear teeth within the housing is required to provide a seal between the inlet and outlet sides, minimizing internal leakage.

ADVANTAGE:

- Low cost relative to power output
- Fairly durable and dirt tolerant
- High operating speed.
- Simplicity of design
- Easy to maintain.

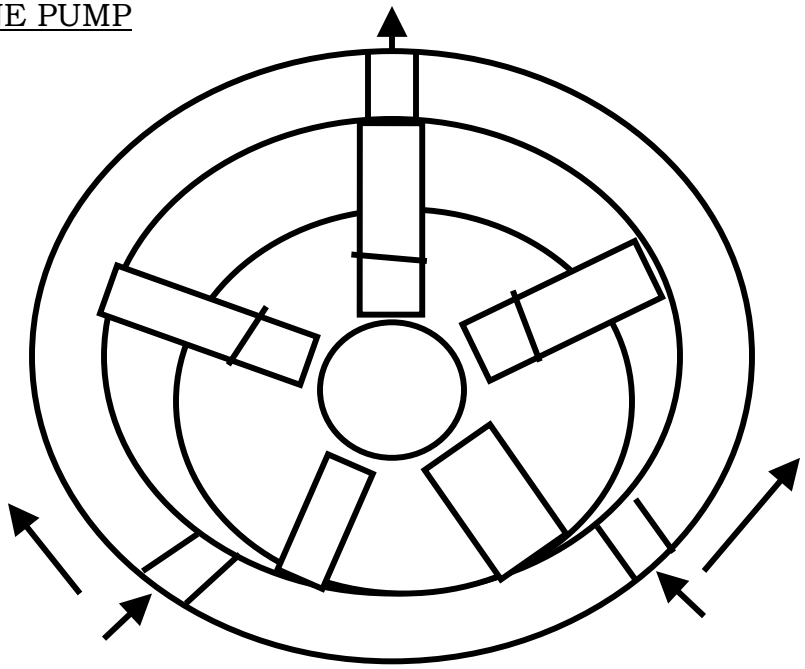
LOBE PUMP

OUT LET



INLET

VANE PUMP



VANE PUMP:

It is a simple vane pump. A cylindrical rotor with moveable vanes in radial slots rotates in a circular housing. As the rotor turns, centrifugal force drives the vanes outward so that they are always in contact with the inner surface of the housing. This action promotes both life long life and efficiency since the vanes move out automatically to compensate for vane tip wear.

The vanes divide the area between the rotor and housing into a series of chambers, which vary in size according to their position around the housing. Pump inlet is located at a point where the chambers are expanding in size. The partial vacuum caused by this expansion draws fluid into the pump. It is then carried to the outlet side of the pump, where the chambers contact and force the fluid through the outlet port.

The pump shown is referred to as "unbalanced" because high pressure is generated on only one side of the rotor and shaft. A vane pump of the "balanced" design has an elliptical housing which forms two separate pumping chambers on opposite sides of the rotor so that the side loads cancel out, increasing bearing life, and permitting higher operating pressures.

ADVANTAGES OF VANE PUMPS:

- Low cost with respect to output.
- Low noise level
- Long service life
- Ability to handle dirt
- It can be variable displacement
- Better efficiency
- Easy to maintain

PISTON PUMPS: There are two basic types of rotary piston pumps—the axial piston and the radial piston.

AXIAL PISTON PUMP:

The rotating cylinder block contains pistons, which are free to move in and out of their bores. A typical pump has nine cylinder bores and pistons. The drive shaft is located at an angle to the cylinder block. Rotation of the drive shaft causes rotation of the pistons and the cylinder block at the same speed.

As each piston moves in and out within its bore, the length of travel depends on the angle at which the cylinder block is tilted. As each piston moves outward, fluid is drawn in through the valve plate. On the return stroke, fluid is forced out through the valve plate under pressure.

RADIAL PISTON PUMP:

It consists of a stationary pintle (pin or bolt), which ports inlet and outlet flow, a cylinder block, which revolves around the pintle and houses the pistons, and rotor, which controls piston stroke. The rotor centerline is offset from the cylinder block centerline. As the drive shaft rotates the cylinder block, centrifugal force or super charge pressure drives the pistons outward so that they press against the rotor, which is free to rotate. Since the rotor centerline is offset from the cylinder block centerline, the pistons move in during one half of a cylinder block revolution and out during the other half.

The pintle includes inlet and outlet ports, which connect with the open ends of the cylinder bores. During rotation, the pistons draw fluid into the cylinder bores as they pass the inlet side of the pintle and force this fluid out of the bores as they pass the outlet side of the pintle.

Pump output is determined by the amount of offset between rotor and cylinder block centerline. When the rotor offset is zero (in the variable displacement version) the, pistons do not reciprocate and there is no output flow.

ADVANTAGE:

- High working pressure
- Reversible flow and variable displacement type.
- High volumetric efficiency
- Can be made to have variable displacements.

HYDRAULIC ACTUATORS:

Perform the opposite function of hydraulic pumps in that they convert hydraulic energy back to mechanical energy to perform useful work.

TYPE:

- Linear actuator
- Rotary actuator

LINEAR ACTUATOR: The simplest linear actuator is the single-acting cylinder or ram.

ROTARY ACTUATOR (or) HYDRAULIC MOTOR

Motor is a rotary hydraulic actuator. They very closely resemble pumps in construction. The motor Instead of pushing the fluid into the system as the pump does, as output members in a hyd.system; they are pushed by the liquid and develop torque and continuous rotating motion. As inlet and outlet ports are pressurized, they are externally drained.

FORCE IS PROPORTIONAL TO PRESSURE AND AREA

$P = F/A$ Where

P = Pressure in psi
F = Force in pounds
A = Area of piston ($\Pi \times d^2/4$)
Where $\Pi = 22/7$)

Pressure gauge indicates only gauge pressure. It ignores the atmospheric pressure.

Absolute pressure = gauge pressure + 14.7 psi (atmospheric pressure)

SPEED OF ACTUATOR: Speed depends on size and rate of oil flow.

$$\text{Speed} = \frac{\text{Volume/time}}{\text{Area}}$$

$$F = P \times A$$

$$A = \frac{\text{Volume/time}}{\text{Speed}}$$

We can conclude from the above formulas is that the force or torque of an actuator is directly proportional to pressure and independent of flow. Speed or rate of travel will depend upon amount of fluid flow without regard to pressure. Speed control usually is accomplished by controlling the flow rate of oil into the motor/actuator the operating pressure of motor would vary with the workload.

VELOCITY, PIPE SIZE RELATION:

Velocity varies inversely as the square of inside diameter. Friction is proportional to velocity. For turbulent flow varies as square of velocity.

If the cylinder volume, diameter of pipe and stroke, length are known then $V = K D^2 E$

Where V (velocity), D = mm, E = mm

$K = 7.854 \times 10^{-7}$

MOTOR RATING:

They are rated as per size, displacement, torque and max. Pressure limitation.

DISPLACEMENT:

It is the amount of fluid the motor will accept in turning one revolution (cu.inch/revoln) capacity of one chamber and no. Of chambers will be total cap.

TORQUE:

Are the force components of motors out ports. It is the turning or twisting effort motion is not required to have torque, but motion will result if the torque is sufficient to overcome friction and resistance of load. Torque is in lb-inches.

PRESSURE:

Required depends on torque load and displacement. A large displacement motor will develop a given torque in pound inches per 100 psi pressure.

$$\text{Torque rate (lb in / 100psi)} = \frac{\text{Torque load (lb in)}}{\text{Operating press x 0.01}}$$

$$\text{Torque} = \frac{\text{Pressure (psi) x displacement (cu. In /rev)}}{2\ M}$$

No	Change	Speed	Effect on operation press	Output force
01	Increase pressure setting	No effect	No effect	Increases
02	Decrease press setting	No effect	No effect	Decreases
03	Increase GPM	Increases	No effect	No effect
04	Decrease GPM	Decreases	No effect	No effect
05	Increase cylinder dia	Decreases	Decreases	Increases
06	Decrease cylinder dia	Increases	Increases	Decreases

ACCUMULATOR:

Unlike gases, the fluids cannot be compressed and stored for usage at a different place and time. An accumulator provides a means of storing these incompressible fluids under pressure. There are three types of accumulators:

- Weight loaded accumulator
- Spring loaded accumulator
- Gas charged accumulator

GAS CHARGED ACCUMULATOR:

*T*he most widely used in which the chamber is pre-charged with inert gas usually dry nitrogen, oxygen should never be used because its tendency to burn or explode under compression with oil. Pre-charge pressures vary with each application and depend upon the working pressure range and volume of fluid required within that range. It should be never less than ¼ and preferably 1/3 of maximum working pressure.

In many hydraulic systems a large volume of oil is required to do the work but the work is done intermittently in the machine cycle. Instead of using a very high volume pump intermittently, such system stores fluid from a small volume pump in an accumulator and discharges it during the ‘ shot’ portion of cycle.

Another application is where it is required to maintain pressure for extended periods of time instead of running the pump constantly at the relief valve setting. It is used to charge the accumulator. The pump can then be unloaded freely tank while the accumulator maintains pressure. Accumulators are also installed in a system to absorb shock or pressure, urges due to sudden stopping or reversal of flow.

CAUTION:

The accumulator must be blocked out of the circuit or completely discharged before attempting to disconnect any hydraulic lines. Never disassemble an accumulator without releasing the precharge whether it is gas, weights springs.

HYDRAULIC CONTROL VALVES:-

Valves are elements used in hydraulic circuits to control, direct and regulate the fluid flow and pressure required for actuators to perform their function.

TYPES OF VALVES:

- Directional control
- Pressure control

- Flow control
- Check valves

DIRECTIONAL CONTROL VALVES:

It consists of a body with internal flow – path that are connected and disconnected by a movable part inside the valve and this results in direction control of the fluid. It will have minimum two positions i.e. neutral or working.

D.C. VALVES GIVE " ON – OFF" FUNCTION ONLY *D.C. VALVES CAN BE EITHER –"N.O". (Or) "N.C".*

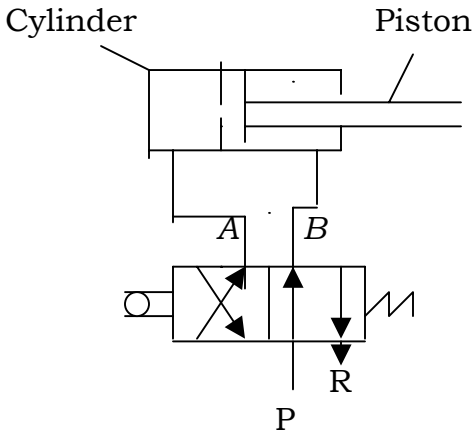
P = Pump port (pressure port in which oil comes from running pump)

A = Outlet port of one side of cylinder

B = Outlet port second side of cylinder

T = Tank port

R = Exhaust port



4/2 – way valve (4 – ports and 2 - position)

PRESSURE CONTROL VALVES: The function of pressure control valve is to control the pressure of the fluid system.

SEQUENCE VALVE:

A sequence valve is used to cause actions to take place in a definite order and to maintain a pre- determined minimum pressure in the primary line while the secondary operation occurs. Fluid flows freely through the primary passage to operate the first phase until the pressure setting of the valve is reached. As the spool lifts flow is diverted to the secondary port to operate second phase. A typical operation is clamping from the prime port and feeding a drill head from the secondary after the work piece is firmly clamped.

To maintain pressure in the primary system, the valve is internally operated. The drain connection must be external since the second port is under pressure when the valve sequence if this pressure is allowed in the drain passage, it would add to spring force and operate the valve.

UNLOADING VALVE:

It unloads a pump when the flow from the pump is not required in the system. The purpose is to save H.P. The H.P. wasted not only increases the power cost but also heats. The hyd. Fluid, which increases maintenance, cost.

The principle of operation is that a pilot pressure cause the piston to move against spring tension and the inlet is opened to exhaust which directs the fluid back to the tank. They are built in size and pressures similar to pressure relief valve.

FLOW CONTROL VALVE:

Volume or flow control valves are used to regulate speed. The speed depends on the amount of oil pumped into it per unit of time. It is possible to regulate flow with a variable displacement pump.

METHOD: there are 3 methods to control actuator speed.

- Meter-in method
- Meter –out method
- Bleed off method

METER-IN METHOD:

The flow control valve is placed in between pump and actuator. This controls the amount of fluid going into the actuator to pick up speed as per requirement. Excess fluid is diverted to tank. It is very accurate method. A meter-in circuit is recommended for applications where the load always opposes the cylinder travel, as for table feeds on grinding, welding, and milling machines.

METER-OUT:

It is used where the load might tend to run-away the flow control is located where it will restrict exhaust flow from the actuator to regulate speed in both directions the valve is installed in the tank line from the directional valve. A by-pass checks valve is required for a rapid return stroke. It is used in those applications where the load has a tendency to run away i.e., drilling, reaming and boring machines.

BLEED-OO-METHOD:

The flow control is bleed off the supply line from the pump and determines the actuator speed by metering a portion of the pump delivery to tank. Advantage is that pump operates at the pressure required by work since excess fluid returns to the tank through the flow control valve instead of relief valve. This method is less accurate because the measured flow is to tank rather than into the cylinder.
A bleed- off circuit can be used for reciprocating motions, such as on grinding and honing machines. Where loads remain relatively constant and feed rates do not require extreme accuracy.

*CHECK VALV*E:

It consists of a valve body with inlet and outlet ports and a movable member, which is compressed by spring pressure. The movable member can be a flapper or plunger but often it is a ball or popped fluid passes through a check valve in one direction only i.e., it permits free flow in one direction and blocks the flow in the other direction. It is used as a by-pass valve and also for isolating sections of a system or a system component.

RELIEF VAVLES:

The pressure at which the valve first begins to pass fluid is called the cracking pressure. As flow through the valve increases, the ball is pushed farther and farther off the seat. Because of the spring rate, full flow pressure is higher than cracking pressure. This condition is referred to as pressure override. The relatively high-pressure override of simple relief valves limits their use in many applications.

PRESSURE REDUCING VALVE:

A pressure-reducing valve is used to limit the pressure in one part of a circuit to valve below the operating pressure required in the main circuit. A relief valve used for this purpose would prevent further pressure build up in the entire system.

Its operation differs from that of relief valve in that it is normally open. Pressure sensed from its port tends to close it as the valve setting is reached.

Pressure above and below the valve spool is equalized through passage Y, and the valve is held open by force of light spring B. Here, too, pressure above the valve spool is limited by a poppet and spring. Pressure at the outlet in excess of poppet setting forces spool A. upward, restricting flow through

DYNAMIC PUMP:

Produces a continuous flow. However because of its design there is no positive internal seal against leakage and its output varies considerably as pressure varies.

BERNAULLI'S THEOREM:

This theorem is based on the law that energy can neither be created nor destroyed, but simply interchanges its form.
Total energy of any fluid in a system remains constant.
Sum of pressure energy and kinetic energy at various points in a system must be constant if the flow rate is constant

ENERGY AND HEAD

Energy contained in any fluid per unit weight is expressed in terms of head or energy.

Potential energy = m.g.h

$$\text{Potential head (static head)} = \frac{\text{potential energy}}{\text{unit weight}} = \frac{m.g.h}{m.g} = h$$

Kinetic energy = $\frac{1}{2}\, m.v^2$

$$\text{Kinetic head} = \frac{\text{Kinetic energy}}{\text{Unit weight}} = \frac{\frac{1}{2}\, m.v2}{m.g} = \frac{V^2}{2g}$$

$$\textit{PRESSURE ENERGY} = \frac{\text{Pressure energy}}{\text{Unit weight}} = \frac{pv}{m.g} = p/\gamma$$

TOTAL HEAD = POTENTIAL HEAD + KINETIC HEAD + PRESSURE HEAD

OR

STATIC HEAD + VELOCITY HEAD + PRESSURE HEAD

THEMODYNAMICS

Thermodynamics is the science that deals with relation between heat, work and properties of systems. It is also deals with study of energy transformations within systems and transfers of energy across the boundaries of the systems. Even though mechanical, electrical and chemical energies fall within the purview of this science, energy due to rise in temperature alone is considered in the thermodynamic.

Anything that occupies space is called matter. Collection of matter is called system. The space and matter external to a thermodynamic system is called the surroundings. System and surroundings put together is called universe.

SPECIFIC VOLUME: It is defined as the volume per unit mass and may be expressed in m^3/kg.

$\nu=Vm$ where V is volume and m is mass

$\nu=1/\rho$ where ρ is density of substance.

HEAT: is a form of energy, while temperature is a measure of how much heat energy a substance or object contains. Heat can move around and between objects in three ways.

1. Conduction
2. Convection
3. Radiation

CONDUCTION:

Heat energy passes between two objects when there are in physical contact with each other. It happens without movement of atoms.

Ex: All metals

CONVECTION:

Heat energy passes through liquid and gas in the form of convection current. Here the individual molecules of liquid and gas move and take the heat with them.

Ex: Water and air

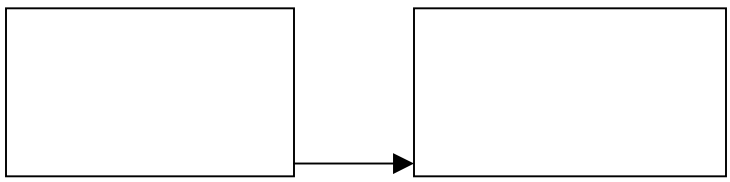
RADIATION:

Heat energy can pass through vacuum. Heat energy from the sun travels through radiation in the form of electromagnetic waves.

NOTE: Conduction and convection both need matter to transfer heat. Radiation does not require matter/medium.

When two systems are originally at different temperatures brought into contact such that the mass flow across the boundary does not take place, but energy transfer can take place. Heat will transfer from system at higher temperature to system at lower temperature by virtue of temperature difference. It is the energy in transition and is not property.

System at higher temp system at lower temp



SPECIFIC HEAT: The heat required by a unit mass of a substance to raise temperature by one degree is called the specific heat of the substance. It is called the heat capacity of the substance.

ENERGY: is "capacity for producing an effect".

Energy can be classified as:

- Stored energy.
- Energy in transition.

1. STORED ENERGY: is the energy that contained within the system boundary.
Ex: potential energy, kinetic energy and internal energy.

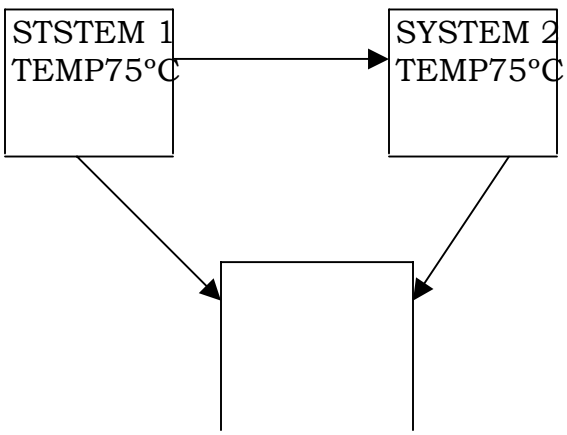
2. *ENERGY IN TRANSITION*: Energy that crosses the system boundary is called energy in transition.
Ex: heat, work and electrical energy.

WORK:
It is defined as the rate of doing work (the energy in transition).

PERFECT/IDEAL GAS:
A perfect gas strictly obeys all the gas laws under all conditions of pressure and temperature. In this sense no gas, which exists in nature, is perfect. But this definition applied fairly well in some gases within the range of pressure and temperature met with in applied thermodynamics.
Ex: Air and Nitrogen.

LAWS

ZEROTH LAW OF THERMODYNAMICS: If two systems are both in thermal equilibrium with a third system they are in thermal equilibrium with each other.



SYSTEM 3
TEMP75°C

Temperature of system1 = system 2 = system 3

LAWS I

BOYLE'S LAW: The volume of a given mass of perfect gas varies inversely as the absolute pressure when temperature is constant.

- Let p be the absolute pressure of the gas.
- ν be the specific volume of the gas at pressure p.
- T be the absolute temperature of the gas.

$\nu \alpha 1/p$ when T is constant
$p\nu$ = constant = C

LAWS II

CHARLES' LAW: The volume of a given mass of a gas varies directly as its absolute temperature, if the pressure remains unchanged.

- Let p be the absolute pressure of the gas.
- ν Be the specific volume of the gas.
- T be the absolute temperature of the gas.

$\nu \alpha T$ when p is constant
ν / T = constant

LAW III

AVOGADRO'S LAW OR AVOGADRO'S HYPOTHESIS: states that the molecular weights of all the perfect gases occupy the same volume under the same conditions of pressure and temperature.

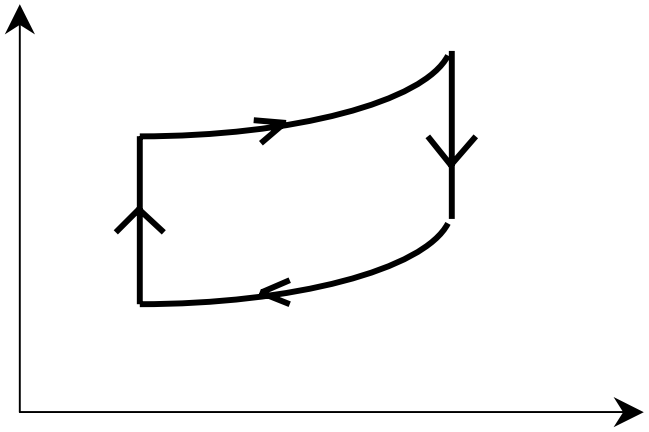
Characteristic equation of gas:

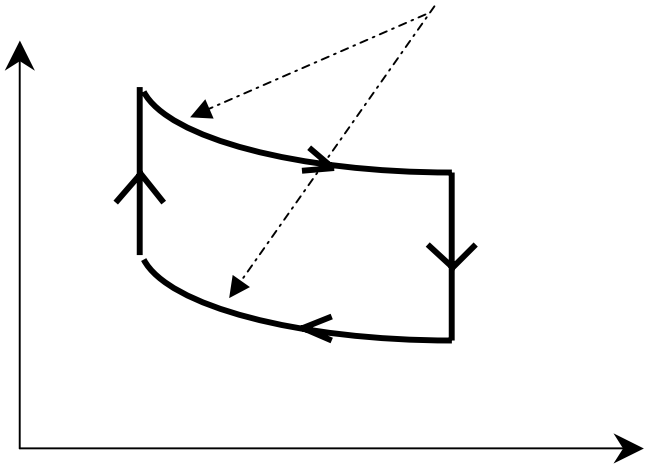
$\nu \alpha 1/p$ when T is constant ---------- (Boyle's law)
$\nu \alpha T$ when p is constant ---------- (charle's law)
$\nu \alpha T/p$ when T and p both vary
$p\nu = RT$ for unit mass
$V = mRT/p$, m is the mass and R is constant depending upon the temperature scale and properties of gas.

PV = Mrt

- Work is done on the system by compression process in a piston and cylinder arrangement
- Work is done by the system by the expansion of gases in a piston and cylinder arrangement
- Process takes place within the system but energy transfer across the system boundary.

OTTO CYCLE / CONSTANT VOLUME CYCLE

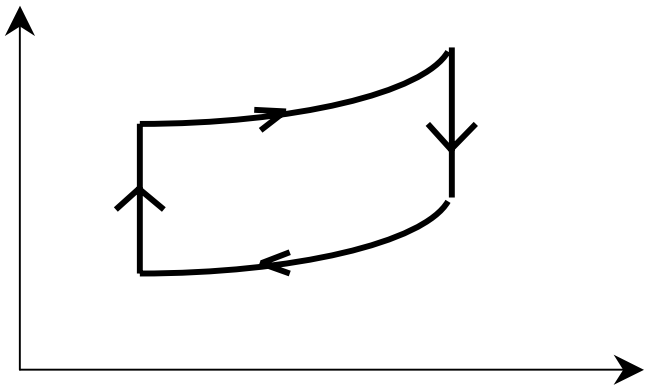


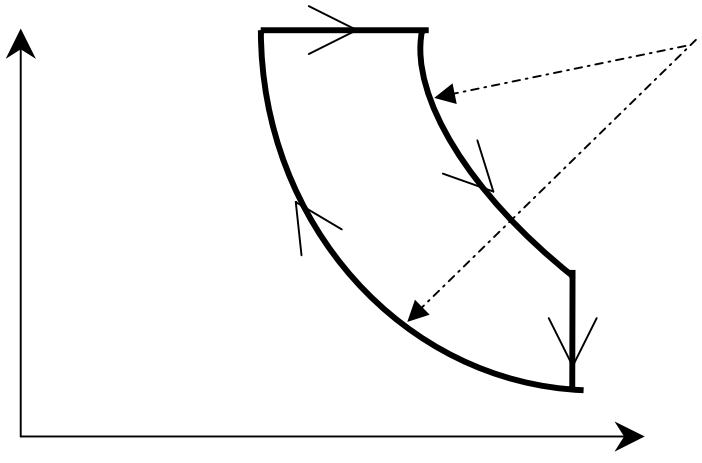


1-2 Reversible adiabatic compression (isentropic)
2-3 Constant volume (heat addition)
3-4 Reversible adiabatic expansion (isentropic)
4-1 Constant volume (heat rejection)

- All the processes occur in the cylinder with constant mass.
- Heat addition at constant volume.
- Thermal efficiency increases with higher compression ratio.

DIESEL CYCLE / CONSTANT PRESSURE CYCLE





This cycle is differs from Otto cycle in one aspect that the heat is added at constant pressure instead of constant volume. Thus it comprises of two isentropic processes one constant pressure, heat addition process and constant volume, heat rejection process.

1-2 Reversible adiabatic (isentropic)
2-3 Constant pressure (heat addition)
3-4 Reversible adiabatic (isentropic) expansion
4-1 Constant volume (heat rejection)

FIRST LAW OF THEMODYNAMIC Work and heat are mutually convertible.

OTTO CYCLE / CONSTANT VOLUME PROCESS

1. Displacement work is eliminated.
2. Work done by the system is zero.
3. Work is done on the system by paddle.
4. Heat is added.
5. Increase internal energy due to rise in temperature.
6. Heat addition at constant volume

PV = RT when V is constant $P \propto T$
Pressure increases with increase in temperature.

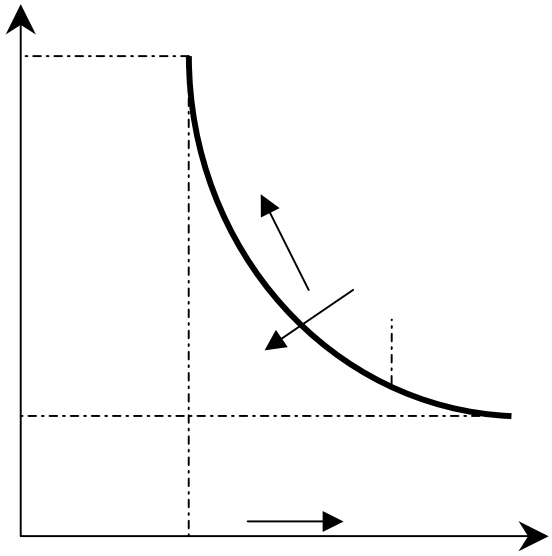
During constant volume process, heat transfer is equal to change in internal energy of the system. Addition of heat to the system by paddle increases internal energy. Rejection of heat from the system decreases internal energy.

Specific heat of fluid at constant volume is the rate of change of internal energy with respect to absolute temperature.

ADIABATIC:

If a process occurs in such a way that there is no heat transfer between the surroundings and the system but the boundary of the system moves giving displacement work, the process is said to be adiabatic. Such a process is possible if the system is thermally insulated from the surroundings.

PV DIAGRAM



1-2 Reversible adiabatic compression (isentropic)
2-3 Constant volume (heat addition, pressure increase with increase in temperature)
3-4 Reversible adiabatic expansion (isentropic)
4-1 Constant volume (heat rejection, pressure decrease with decrease in temperature)

- All the processes occur in the cylinder with constant mass.
- Thermal efficiency increases with higher compression ratio.
- Work output is directly proportional to the pressure ratio or the heat added.
- The compression ratio increase leads to increase of mean effective pressure as well as thermal efficiency.

DIESEL CYCLE / CONSTANT PRESSURE CYCLE

As per Charles's law $V \propto T$ when P is constant. Volume increases with increase of temperature.

This cycle differs from the otto cycle in one respect. The heat is added at constant pressure instead of at constant volume. Thus it comprises of two isentropic processes, one

constant pressure heat addition processes and one constant volume heat rejection process. Other processes do not involve in any heat transfer.

The given compression ratio, the otto cycle is more efficient. The system is subjected to constant hydrostatic pressure at the boundaries. Fluid contained in the cylinder and piston with weight placed on the fluid. By the expansion of the fluid due to addition of heat the piston rises and thus changes the system boundary and displacement work is done by the system against a constant force.

Specific heat at constant pressure is the rate of change of specific enthalpy with respect to absolute temperature.

1-2 reversible adiabatic (isentropic)
2-3 constant pressure (heat addition)
3-4 reversible adiabatic (isentropic) expansion
4-1 constant volume (heat rejection)

ENGINES

CLASSIFICATION OF ENGINES

BASED ON COMBUSTION PROCESS:

1. Internal combustion engine.
2. External combustion engine

INTERNAL COMBUSTION ENGINES:

It is a heat engine in which the chemical energy is released inside the engine cylinder during combustion of fuel (Fuel burn inside the engine).

Example: petrol and diesel engines.

EXTERNAL COMBUSTION ENGINES:

The energy is developed out side the engine during combustion of fuel and then transmits the energy in the form of stream to run the engine (Fuel burn outside the engine).

Example: locomotive steam engines (railway engine)

CLASSIFICATION OF I.C.ENGINES

I. *BASED ON WORKING CYCLE*:

1. Two stroke engine
2. Four stroke engine

I I *TWO STROKE ENGINE*:

Usually motorcycles/scooters are run on the principle of the two-stroke engine. On a few occasions they are also run using a four-stroke engine. The fuel used is mainly petrol. In this engine, there are two strokes in one cycle of operation. There is one power stroke for every one revolution of the crankshaft/flywheel.

I I I. FOUR STROKE ENGINE:

1. Suction stroke
2. Compression stroke
3. Power stroke and
4. Exhaust stroke

Majority of engines operate on the four-stroke cycle.

IV. BASED ON THERMODYNAMIC CYCLE:

- Otto cycle engine
- 2. Diesel cycle engine
- Dual cycle engine (dual combustion engine)

V. BASED ON SPEED:

1. Low speed engine _ up to 500 r.p.m
2. Medium speed engine – up to 1000 r.p.m
3. High speed engine – above 1000 r.p.m

VI. BASED ON METHOD OF COOLING:

1. Air cooled
2. Water cooled

VII.BASED ON FIELD OF SPECIALISATION:

1. Stationary engine - Ex. Engines in drilling rigs & installations.
2. Marine engine - Ex. Marine application
3. Automobile engine - Ex. Bus, car, lorry etc.
4. Motor cycle engine - Ex. Two wheel scooter bike etc.
5. Aero engine - Ex. Air craft engine
6. Locomotive engine - Ex. Railway engine

VIII. BASED ON TYPE OF IGNITION:
1. Compression ignition
2. Spark ignition

COMPRESSION IGNITION ENGINE:
All diesel engines are compression ignition engines.

SPARK IGNITION ENGINE:
All petrol engines are spark ignition engines.

FOUR STROKE CYCLE I.C.ENGINE:

WORKING MECHANISM OF I.C. ENGINES:

The cylinder is inside the cylinder block. The piston is inside the cylinder. The connecting rod links the piston with the crankshaft. The piston rotates the crankshaft through the connecting rod. The crankshaft revolves due to the up and down movement of the piston. The crankshaft drives the camshaft. The gear of the crankshaft meshes with the gear of the camshaft. The camshaft operates the valve by means of the cam, tappet, push rod and rocker arm. The flywheel stores up the energy produced on the power stroke. It releases the energy again during the idle stroke. This is the simple mechanism of four-stroke cycle diesel engine. The internal systems, work principle etc are elaborately explained in this topic to understand about four stroke cycle diesel engines.

STROKE:

A piston moves from the top limit to the bottom limit of the cylinder. The top limit is called the TDC. The bottom limit is called BDC. The movement of a piston from the TDC to BDC is called the stroke/stroke length of the piston.

SUCTION STROKE:

In the suction stroke, the intake valve remains fully open during the entire stroke; the exhaust valve closes a few degrees after top center (i.e. after exhaust stroke). The purpose of delay in closing of exhaust valve at the beginning of suction stroke is to push the exhaust gas away from the cylinder to accommodate fresh air during suction stroke.

Now the piston moves downward from top center to bottom center. The downward movement of the piston causes a partial vacuum in the area above the piston crown. Air rushes in through the open intake valve, at a speed of approximately 60 miles/hour and fills up the area above the piston.

COMPRESSION STROKE:

The piston moves from bottom center to top center, the intake valve closes a few degrees after bottom center. The purpose of intake valve remain open at the beginning of compression stroke is to allow more volume of air inside the cylinder for better combustion (Particularly in the high speed engine).

Now both the intake and exhaust valves are remain fully closed during the entire stroke, as the piston moves up, inter molecular activity causes the temperature of the air to increase rapidly, a few degrees before top center, when the temperature of the air reaches 540C^{o}, high pressure fuel in atomized form is sprayed by the fuel injection nozzles into the combustion chamber, the air and fuel combine thoroughly and the fuel starts burning to produce power.

POWER STROKE:

In this stroke, the intake valve is remaining closed and the exhaust valve is also closed. The force of the burning gas can be as high as 14-tons/square inch, and this high-pressure gas exerts a force on the piston and causes the piston to move downwards from top center to bottom center. A few degrees before bottom center (before end of power stroke), the exhaust valve open and allow the exhaust gas to rush out of the combustion chamber.

EXHAUST STROKE:

In the exhaust stroke, the piston moves from bottom center to top center, the exhaust valve remains fully open during the entire stroke, the upward movement of the piston forces the exhaust gas out of the combustion chamber, a few degrees before top center the intake valve opens (before end of exhaust stroke) and both intake and exhaust valves remain open for some time, this is known as the valve overlap period, valve overlap ensures scavenging of all exhaust gases by the incoming air stream.

The flywheel makes half revolution during each stroke (180^{o}) i.e. suction, compression, power and exhaust. The crankshaft has to complete two revolutions (720$^{o)}$ per power stroke. The crank angle is 360$^{o.}$ The camshaft has to complete one revolution per power stroke (i.e. half the speed of crankshaft 360^{o})

WORKING PARTS OF AN ENGINE:

1. Cylinder block
2. Cylinder
3. Crankcase
4. Cylinder head
5. Piston

6. Connecting rod
7. Crank shaft
8. Cam shaft
9. Valve and valve mechanism

CYLINDER BLOCK:

The cylinder block is usually in one piece. It is cast in a single block. It has cylinders for the pistons, ports for the valves and passes for the cooling water to flow. Oil passages are provided for lubrication. There are tunnels in the cylinder block for push rods. The cylinder block carries the crankshaft and the camshaft.

CYLINDER:

The heart of the engine is cylinder where the fuel is burnt and the power is produced. The inside diameter of the cylinder is called the bore. This cylinder may be removable liner to avoid damages to main block due to wear/worn-out. The inner surface of the liner is honed to make micro channels for flow of lubricant.

TYPE OF CYLINDER LINERS:

1 .Dry liner
2. Wet liner

Cylinder liner is made up of nickel chromium alloys.

DRY LINER:

A dry liner is one, which is in contact with metal block over its whole length or nearly its whole length. Water jackets are provided in the cylinder block.

WET LINER:

Wet liner is one, which is supported by the block over narrow belts only and is surrounded by cooling water between these belts.

CRANKCASE:

The crankcase is the base of the engine. It supports the crankshaft in bearings. The camshaft is also held by the crankcase in bearings. This crankcase is fitted with brackets. These brackets support the engine on the frame.

CYLINDER HEAD:

The cylinder head closes one end of the cylinder block. It has passages for the circulation of cooling water. It supports the valves, springs and the rocker gear. The head contains the combustion chamber. It also possesses the inlet and exhaust ports.

PISTON:

The piston closes the other end of the working space of the cylinder. It moves up and down inside the cylinder that transmits to the crankshaft the power developed by the burning of the fuel. The distance that the piston travels from one end of the cylinder to the other is called the stroke. The piston is made in one piece from aluminum alloys because they are light in weight (half that of cast iron), their co-efficient of heat expansion is twice as that of cast iron and heat conductivity is five times as that of cast iron.

The mixture of fuel and air burns suddenly. The top portion of the piston gets maximum heat. The temperature varies from 270 ^{O}C at centre of piston head to 170 ^{O}C at bottom skirt of the piston. As the piston absorbs the heat, the diameter of the piston will be increased slightly. The water in the water jacket absorbs the heat of the piston. It cools the top portion of the piston. As the heat gets reduced, the diameter of the piston also starts shrinking. For this purpose, a small gap should be provided between the piston and the cylinder wall. The piston should have proper fitness to move in the cylinder along with gap.

The fresh mixture of fuel and air and exhaust gas are able to pass through the gap past the piston. They then flow from the combustion chamber to the crankcase. This leakage should be prevented. Piston rings are introduced to prevent the leakage. Suitable grooves are provided on the piston to fit in the piston rings.

PISTON RINGS:

There are two types of piston rings. One type is called compression ring and the other type is called oil ring.

COMPRESSION RING:

This is made of cast iron. The diameter of a compression ring is slightly greater than diameter of the cylinder bore. At first the rings are installed in the grooves of the piston. The piston is then inserted into the cylinder. The rings are compressed, and their joints nearly closed. The rings press tightly against the cylinder wall. Therefore, the fresh mixture and exhaust gas cannot pass through the piston clearance. There are two or more compression rings, depending on the piston design.

OIL RING:

As the piston moves up and down, it rubs against the cylinder wall. This rubbing causes scratches on the piston and cylinder wall. To prevent this rubbing action oil is splashed from an oil pan on to the cylinder wall when the piston moves up. When the piston moves down, the oil rings scrape the oil from the cylinder wall. Thus, the oil falls into the oil pan. There are holes and slots in the oil rings. These enable the

scraped oil to drip down easily. There are either one or more oil rings, depending upon the design of the piston.

CONNECTING ROD:

The connecting rod transmits power from the piston to the crankshaft. The top end of the connecting rod is called the small end. The bottom end is called the big end. The small end moves up and down with the piston. The big end rotates with the crankshaft. In this type there is a gudgeon pin, which connects the piston and the small end of the connecting rod. The gudgeon pin is also called the piston pin. This is fitted to the small end of the connecting rod inside the piston. Circlips are fitted into recesses in the piston. They prevent the gudgeon pin from touching the cylinder wall. The small end bearing for the gudgeon pin is a bronze bushing. This is pressed into the connecting rod.

CRANKSHAFT:

The forging of steel makes the crankshaft. The main parts of the crankshaft are journals, crankpins, webs or cranks. The journals rotate in the main bearings. The crankpins rotate in the big end bearings of the connecting rods. The webs join the journals to the crankpins. They serve as balance weight/counter weight to support dynamic balance.

The flywheel is fitted to the rear end of the crankshaft. It stores up a part of the energy produced by the power stroke it releases this energy during the idle strokes. Thus the flywheel due to its momentum helps in the smooth running of the crankshaft/engine. The flywheel is fitted with a starter ring gear. A pinion on the starter motor engages this ring gear. A damper, driving pulley, small sprocket and fan pulley are fitted to the front end of the crankshaft. The damper controls torsional vibration. The fan pulley is connected to the pulley of the crankshaft by a belt (driving pulley). The crankshaft rotates the fan pulley by means of this belt. The fan rotates and cools the water. Holes are provided in the crankshaft from the main bearing journals to the crankpins for the lubricating oil to pass through.

CAMSHAFT:

The camshaft is made either of forged steel or of cast iron. The shaft is hardened to resist wear. An eccentric forms a part of the camshaft. It operates the petrol or diesel pump. The pinion rotates the oil pump and the distributor. A gear is fitted to one end of the camshaft. This engages with the gear of the crankshaft. For correct operation the camshaft should rotate once for every two revolution of the crankshaft.

VALVE AND VALVE MECHANISM:

Every cylinder has an inlet and exhaust valve. The valve is of poppet type. The face of this valve is ground at an angle of 30^o or 45^o.

The crankshaft drives the camshaft. The camshaft is connected to the crankshaft by a set of gears. The camshaft rotates at half the engine speed. The cam lifts the push rod, the pusher rod in turn lift the rocker arm and the rocker arm press the valve stem against spring. By this, valve spring is compressed and the valve opens.

As the camshaft rotates further, the tappet moves up and spring get released. Now valve is closed by the valve spring. The valve moves up and down in the valve-stem guide. The valve spring is held by means of a spring retainer.

VALVE- TAPPET CLEARANCE:

A small clearance is provided between the tappet and the valve stem. This is called the tappet clearance. When the engine is hot, the valve expands. The clearance allows the expansion of the valve. The engine manufacturers give the valve of the tappet clearance. The tappet clearance should be adjusted according to their specifications. A larger clearance produces metallic sound/ noise.

OVERHEAD VALVE:

When the camshaft rotates, the cam projection lifts the tappet. This tappet operates the push rod. The push rod causes one end of the rocker arm to rotate about a shaft. The other end of the rocker arm pushes down the valve stem. Due to this action, the valve is opened. As the camshaft rotates further, the tappet moves down. The valve now gets closed by the valve spring. A tappet clearance is provided between the rocker arm and the bottom of the valve stem. This clearance can be adjusted by means of an adjusting screw.

VALVE TIMING:

The valves of an engine should open and close at the correct time to maintain firing order as per design of the engine. There is a special method to enable the valve to open and close in time. This method is called valve timing.

One revolution of the crankshaft is equal to 360^o. This angle is called the crank angle. Four stroke cycle engines have to complete two revolutions (720^o) per power stroke and at the same time camshaft have to complete one revolution i.e. half the speed of crankshaft.

The inlet valve opens at a crank angle of 5^o before the TDC. The suction stroke is completed when the piston from the TDC moves down

to the BDC. The piston moves up a little distance on the compression stroke. The inlet valve closes at a crank angle of 45^o after the BDC.

The compression stroke is completed once the piston reaches the TDC. Just at a crank angle 6^o before the TDC, the injector injects the diesel into the cylinder. The mixture now burns. As the piston is moving down towards the BDC, the exhaust valve opens at a crank angle of 40^o before the BDC. The power stroke is over once the piston reaches the BDC. Then it moves up to the TDC on the exhaust stroke. During this period the exhaust valve is kept open. Thus the exhaust stroke is completed once the piston reaches the TDC. The piston begins to move down from the TDC to the BDC on the suction stroke. During this time the exhaust valve closes at a crank angle of 6^o after the TDC. The inlet valve and exhaust valve are both kept open for a period of 15^o crank angle at the end of exhaust stroke.

The manufacturer of every engine supplies the details of the degrees of the valve timing. The two valves should be adjusted accordingly. Only then can the engine run smoothly and efficiently.

GOVERNOR:

The function of a governor is to regulate the mean speed of an engine when there is variation in the load.

FLYWHEEL:

Flywheel is a device to control the variations in speed during each cycle of an engine. It stores energy during power strokes and release energy during other strokes

INLET VALVE DESIGN FOR OPTIMUM VOLUMETRIC EFFICIENCY

Bore of the cylinder will determine the volume of air available for combustion.

- Volumetric efficiency = $\dfrac{\text{Actual volume}}{\text{Theoretical volume}}$

- IHP------ Power produces inside the cylinder.
- ------ Indicated horsepower.

- BHP---- Crankshaft HP/Flywheel HP/Out put HP of the engine.
- ----- Brake horsepower.

- FHP----- Negative HP generates inside engine body due to movement of components and frictions.

- ----- Frictional horsepower.
- IHP = BHP + FHP
- η_{mech} = BHP/IHP = 1 if FHP is zero.
- FHP increases with increase in RPM of the engine.
- Mechanical efficiency is high if FHP minimum.
- IHP $\propto$ Air capacity
- BHP will be maximum at a lower speed than IHP due to less friction losses.
- IHP is directly proportional to air consumption inside the combustion chamber.
- Therefore IHP is proportional to air receiving capacity of engine
- Air capacity is proportional to engine speed.
- Volumetric efficiency is proportional to engine speed if the valve mach index Z = 0.45 to 0.5.
- Therefore, IHP is proportional volumetric efficiency.
- Speed for maximum volumetric efficiency is decided for optimum performance of engine. Other factors affecting combustion efficiency are spark advance and injection advance.
- Decrease of volumetric efficiency with increase in coolant temperature.

INLET VALVE DESIGN:

INLET VALVE-MAX INDEX EXPERIMENT: It is the flow of air (velocity) through inlet valve with fixed short length air inlet manifold, fixed valve timing and fixed compression ratio, but variable valve dia., variable valve lift and variable valve design. The experiment concludes that the volumetric efficiency starts falling very rapidly as mach index 'Z'exceeds 0.5.

Sl.no	Fixed parameter	Variable parameter	Result
01	Short length	Valve diameter.	Volumetric

	inlet manifold. Valve timing Compression ratio.	Valve lift. Valve design.	efficiency starts falling after particular value of Mach Index Z = 0.5

- Inlet valve size should always be such that Mach Index Z does not exceed 0.5 within the operating range of any engine.
- Actually volumetric efficiency is maximum at Z = 0.45 to 0.5
- Thus the maximum IMEP is likely to be obtained at speed corresponding to Z = 0.45 to 0.5.

EFFECT OF OPERATING CONDITIONS ON VOLUMETRIC EFFICIENCY:

Sl.no	Constant parameters	Variable parameter (Bore dia. in cm)	Variable parameter (rpm)
01	Compression ratio 5.7 fuel/air ratio 0.073	15 to 17	400 to 700
02	- do-	10 to 12	600 to 2500
03	- do -	6 to 7.5	1000 to 4000

IMPORTANT POINTS FROM EXPERIMENT:

1. Changes in diameter of engine cylinder have no effect on the volumetric efficiency.

2. Changes in stroke length of engine have no effect on the volumetric efficiency.

3. Changes in piston speed have effect on volumetric efficiency.

Volumetric efficiency Z will be high at 0.45 to 0.5.

Therefore, speed of engine for maximum volumetric efficiency is decided.

EFFECT OF FUEL AND AIR RATIO:

- Combustion temperature increases as the fuel and air ratio increases.
- Fuel and air ratio increases with increasing of load.
- Therefore, combustion temperature increases as the load increases.

Sl.no.	Type of engines	Fuel – air ratio
01	Spark ignition engine	$0.8 < F_R < 1.4$
02	Compression ignition engine	$0.1 < F_R < 0.85$

EFFECT OF DESIGN ON VOLUMETRIC EFFICIENCY:

1. Inlet valve size and design.
2. Valve timing.
3. Exhaust valve size and design.
4. Stroke-bore ratio

VALVE TIMING: Two very important factors of valve timing, which influence the volumetric efficiency, are.

1. Valve overlap angle.

2. Inlet valve closing angle.

EFFECT OF VALVE OVERLAP:

During the valve overlap angle both the inlet valve and the exhaust valve remain open. Thus it can form a bypass passage from inlet valve to exhaust valve.

$P_{Exhaust}$ / P_{Inlet} › 1, the exhaust gas first starts flow into inlet manifold and mixed with fresh air. As soon as the inlet air pressure exceeds exhaust pressure i.e. P_{Inlet} / $P_{Exhaust}$ › 1, the fresh air from inlet starts flow through exhaust shall wash away residual exhaust gases from cylinder. This phenomenon is called scavenging. Thus the by-passed fresh air through exhaust manifold during every suction stroke by advance opening of inlet valve shall help to clean the cylinder as well as reduce the temperature of exhaust gas driven turbo-charger.

INLET VALVE CLOSING:

For very low values of mach index, the pressure in the cylinder at the end of inlet stroke is equal to inlet pressure. Therefore, delaying the closing of inlet valve after bottom dead centre will drive back the fresh mixture into the suction manifold.

At high values of mach index, the cylinder pressure may be much below the inlet pressure at bottom dead centre. Thus it is desirable to delay the inlet valve-closing angle to charge more air into the cylinder (cylinder pressure = inlet air pressure). Therefore, higher the value of mach index more delays in inlet valve closing (i.e. the closing angle after BDC) after the bottom dead centre.

EXHAUST VALVE SIZE DESIGN:

Is the ratio of exhaust valve capacity to inlet valve capacity. I.e. = 0.6 to 1.0.

LOW SPEED ENGINE:

It has an early inlet-valve closing position while a higher speed engine has comparatively later inlet valve closing position. Thus lower speed engine will have higher torque, higher mean effective pressure and higher air consumption than the high-speed engine at the maximum torque speed of the low speed engine. But beyond that speed the trend would reverse i.e. the air consumption, mean effective pressure and the torque will fall rapidly if the low speed engine is run at higher speeds. Thus speed and volumetric efficiency control air consumption.

1. Torque and mean effective pressure do not strongly depend upon speed of the engines, but depend on volumetric efficiency and friction losses. If the displacement volume of engine is doubled torque will also be doubled but not the mean effective pressure.

2. Mean effective pressure is a specific torque, which is variable but independent of the size of the engine.

3. Torque and mean effective pressure are maximum at about half the speed of the maximum power.

4. Higher horsepower comes from high speed since horsepower is proportional to speed and torque. Thus doubling the speed of an engine by increasing volumetric efficiency and decreasing friction can double the horsepower.

5. Friction horsepower rises very rapidly at high speeds because of the reciprocating piston mechanism.

FUEL, AIR AND HEAT BALANCE CALCULATIONS FOR 1000 HP, FOUR STROKE CYCLE DIESEL ENGINE.

I. FUEL REQUIREMENT FOR COMBUSTION

1calorie = 1gm of water to rise by 1°c.

1btu = 1lb of water to rise by 1ft.change.

= 252 calories =0.252kcal.

1calorie/min = 0.00009357 hp

1kcal/min = 0.09357hp

1btu/min = 0.02358 hp.

0.02358 HP = 1 BTU /min

1USA gallon of petrol gives energy = 190000btu

1 USA gallon of diesel (no2) gives energy = 14400btu

1 USA gallon = 3.785 lts

0.02358 HP = 1 BTU /min

1000HP = 1/0.02358 x 1000

= 42408.821 BTU/min

Diesel required per min per 1000HP = 42408.821/144000

= 0.2945057 gallon/min

=17.6703421gallon/hr

= 67.1472999lt/min

I I. AIR REQUIREMENT FOR COMBUSTION

1 gm of diesel requires 17 gm of air

1 litre of diesel requires 12500 litres of air

1000HP Engine requires 201 x 12500 = 2512500litres of air

Gas going out through exhaust = 201 x 12500 x 3 times

= 7537500 litres per hour

Normally pressure on the piston after gas burnt 3 times of compression pressure = 15 x 3 = 45 kg/cm^2

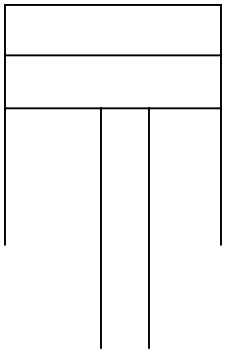
Exhaust pressure = 2 times power produced inside the cylinder

= 2 x 45 kg/cm^2

= 90 kg/cm^2

HEAT BALANCE CALCULATION

FLYWHEEL HP/OUT PUT HP = EXHAUST HP = BHP



- Transformation of gas into heat will give power
- With 100% heat generation inside cylinder during power stroke.
- 33% of heat energy is for producing power
- 30% of heat energy lost through exhaust
- 30% of heat energy lost through cooling
- 7% of heat energy through lost through radiation
- Therefore the actual consumption of = 67.1472999 x 3times = 201 Fuel for generating 1000HP/hr
- To get 100HP output in the flywheel,
- The quantity of diesel is to be burnt inside cylinders = 300HP

1. Flywheel = 100HP
2. Exhaust = 90HP
3. Radiator cooling = 90HP
4. Radiation loss = 21HP

- 100% load = 201 lt/hr corresponding temperature is 1927°C.

slno	% of load	Diesel requirement liters/hour	Temperature of combustion gas with respect to load	Temperature of piston & liner with respect to load in °C (3 time less as the gas expands)
1	100	201	1927	1927 x 30/100 =578.1
2	110	201/100 x 110 = 221.1	1927/100 x 110 = 2119.7°C	1927 x 33/100 = 635.91
3	10	201/100 x 10 = 20.1	1927/100 x 10 = 192.7°C	1927 x 3/100 = 57.81
4	20	201/100 x 20 = 40.2	1927/100 x 20 = 385.4°C	1927 x 6/100 = 115.62
5	30	201/100 x 30 = 60.3	1927/100 x 30 = 578.1	1927 x 9/100 = 173.43

NOTE: The piston made-up of Aluminum alloy will expand and seal properly with liner only if the temperature of piston attained 175°C. Hence the engine should not be allowed to run not less 40% of load.

POWER PRODUCED INSIDE THE CYLINDER

- Power produced inside the cylinder is indicated horse power (IHP)
- Area of piston = πd2
- Length of stroke = L
- Torque = 45 x π x d^2 x L
- Total HP = IHP of 1 cylinder x No. of cylinder
- IHP = FHP + BHP
- BHP = Flywheel HP
- BHP = 2ΠNT/4500

  Where N = RPM
- T = is Turing/ twisting force.

- Torque (lb-ft) = 5252 x HP/RPM
- Torque rise = (PT-RT) x 100/RT
- HP = BLAN/4500
  Where B is break mean effective pressure
  L is length of stroke
  A is area of piston ($\Pi D^2/4$) and N is RPM
- HP = RPM x T/5252
  Where T is torque

A good understanding of the basic four stroke cycle will help in not only understanding the air induction, exhaust, cooling and lubrication systems but also help us to diagnose the problems systematically and thus eliminate the problem once for ever with shortest possible time. Which can help us to make effective way of maintenance.

I. AIR INDUCTION SYSTEM:

Air is drawn into the cylinders through the air induction system. The air induction system must be able to supply cool, clean, fresh and dry air in the correct quantities required by the engine. The maximum power developed by a diesel engine largely depends upon the cubic capacity of the engine and the engine's ability to receive the maximum amount of air possible through this system. Any restriction in the system reduces air supply, as a result, improperly burnt or unburned fuel leaving the exhaust in the form of black smoke causing low power, overheating and high exhaust temperature.

The air induction system consists of air filter, turbocharger, after cooler and inlet manifold. The efficiency of the system is depends upon effective functions of these subsystems.

AIR FILTER:

The purpose of using an air filter is to remove harmful dirt and impurities from the air rushing into the engine. If allowed into the air intake system, dirt or dust will mix with the engine lubricating oil forming an abrasive paste which will wear out piston rings, liners, valve guides, pistons etc. causing increased blow-bye and high lubricating oil consumption.

The dry paper type air filter is the most efficient type of air filter available today and is said to be 99.5% efficient, as compared to oil bath type air filter, which is 93.5% efficient.

TURBOCHARGER:

It consists of centrifugal air compressors feeding the intake manifold mounted on the same shaft as an exhaust gas turbine in the exhaust stream. The turbocharger is fitted in between the intake and

exhaust systems. Exhaust gases pass from the exhaust manifold into the turbine casing and is directed onto the exhaust turbine wheel, the heat and pressure of the exhaust gas spins the turbine wheel, at very high speeds (70,000 rpm to 85,000rpm for cat engines) and the rotating motion is transferred through a common shaft to the compressor wheel. The compressor turbine wheel pulls clean air from the air filter and compresses it and pushes it into the intake manifold. The compressed air is called as boost pressure and is measured in inches of mercury and is dependent on the engine, turbocharger design and power requirements.

ADVANTAGES:

1. As the supply of air is increased inside the combustion chamber, more fuel can be injected in to the cylinder for combustion of more fuel and therefore more power is obtained.
2. The air-fuel ratio can be better controlled through the entire speed range reducing the degree of smoke emitted.
3. By pressurizing the combustion chamber at lower engine speeds enables better combustion and gives lower torque speeds.
4. Since the speed of the turbine wheel is dependent on the exhaust gas, the turbocharger is self-regulating.
5. Altitude compensating. At higher altitudes the atmospheric pressure being less reduces the exhaust back pressure, allowing the turbine wheel to spin more freely, this causes the turbine wheel to spin faster allowing more air to be sent into the engine, this compensates for the reduced oxygen density at high altitudes.
6. Turbocharger acts natural muffler to cut exhaust noise, arrest spark.

INTAKE AIR TEMPERATURE:

This is another important factor relating to the air induction system because of high intake air temperatures. It reduces the quantity of oxygen by decreasing air density, which will not be useful for proper combustion. If the intake air temperature increases by 1 degree, then exhaust temperature will increase by 3 degrees. This causes an expansion of the air, resulting in a reduction of oxygen by weight, being taken into the combustion chamber.

On turbocharged engines, the air entering the intake manifold may reach temperatures of 160^{o}C. It is too hot for even turbocharged engines to supply a sufficient volume of oxygen. With this temperature the engine may be able to burn only a certain amount of diesel depending upon the quantity of oxygen available for combustion. When this situation is encountered, engines may have to use an after cooler for cooling of compressed air. The most commonly used type is the jacket water after cooler.

AFTER COOLER:

It is normally installed between turbocharger and inlet manifolds of the engine to help cool the inlet air. After cooler consists of a bundle of tubes through which the coolant flows. The compressed air from the turbocharger flows around the tubes, passing the heat to the coolant. Thus the after cooler removes heat from pressurized intake air to further increase air density, improve combustion efficiency and reduce exhaust temperature. The inlet air temperature from after cooler is lowered to a temperature near to that of the engine coolant.

EXHAUST SYSTEM

EXHAUST SYSTEM REQUIREMENTS:

The exhaust system of an engine plays an important part in the overall performance and efficiency of a diesel engine, as does the air, fuel, cooling and lubricating systems. A well-designed exhaust system should do its job of removing the waste gases from the combustion chamber as quickly and silently as possible since exhaust restrictions cause performance losses and exhaust temperature increases.

The primary design considerations of the exhaust system are:
1. Minimize exhaust backpressure.
2. Reduce noise.
3. System support and vibration isolation.

FUNCTION OF BREATHER:

Breather is well known for their self-leaning properties. It has two main functions, which are:

1. When the engine operates, some amount of air during compression and power strokes escapes past the piston rings and liner wall and accumulate inside the crankcase along with this, the heat of the engine lubricating oil causes some amount of vapour, both of which have to be vented out. This is where the breather comes into play, the steel wool or mesh traps the oil fumes and causes the vapour to become droplets and fall back into the valve cover.

2. After the engine has operated and has been shut down, the gases in the crankcase cool down causing a vacuum inside the chamber, due to which, fresh air enters through the breather, the dust in the air is trapped by the wire mesh on the breather, filling the vacuum.

COOLING SYSTEM

Engine starts running once the fuel is burnt in all cylinders. While the engine is running, it gets heated. This heat should be continuously removed from the engine to maintain the clearance of mating parts and viscosity of oil etc. Cooling system is actually a heat regulating system. The main reason of having a cooling system is to maintain the temperature of the coolant by dissipating the excess heat so as to keep the engine at normal operating temperature. Normal operating temperatures ensure the best fuel economy, peak engine performance and operation of engine parts within the designed working tolerances.

There are two methods of cooling:

1. Cooling by air
2. Cooling by water

In an internal combustion engine, approximately 1/3 heat produced by combustion is converted into useful work, 1/3 heat goes out as exhaust gas and the remaining 1/3 heat has to be taken away by the cooling system.

So the basic functions of the cooling system are:

1. Circulation
2. Absorption
3. Dissipation
4. Regulation

CIRCULATION:

The water pump driven by the gear train forces the water through the oil cooler, around the cylinder liners and around the fuel injection nozzles and the intake and exhaust valves in the cylinder head. The water then flows to the water temperature regulator or thermostat and then goes to the radiator or heat exchanger.

ABSORPTION:

The coolant absorbs the heat of the combustion from the cylinder liners and carries it to the radiator to be dissipated.

REGULATION:

The water temperature regulator or thermostat maintains the temperature of the coolant to keep the engine operating at the normal working temperature.

OIL COOLER:
Even though the oil cooler is actually part of the lubricating system the coolant flows through the oil cooler tube bundle, whereas, the oil flows around the tubes, the heat of the engine oil is carried away by the coolant thereby protecting the engine from damage by maintaining the oil temperature and pressure.
When the oil is cold, the hot coolant heats up the oil and bring it to the correct viscosity needed by the engine.

THERMOSTAT:

1. The main function of the water temperature regulator or thermostat is to bring the engine to its normal operating temperature as early as possible and keep it at that temperature range till the engine is in operation.
2. The thermostat opens or closes depending on the temperature of the coolant. When the coolant temperature is low the thermostat is in the closed position causing the coolant to (bypass) flow back to the suction side of the water pump, which allows the water to circulate within the engine which in turn increases the temperature of the coolant.
3. As the temperature of the coolant increases it causes the regulator to open allowing the hot coolant to flow through the radiator or heat exchanger, as the temperature of the coolant increases further it causes the regulator to open further to the fully open position. It is important to note that the regulator is an absolute necessity both in summer and winter.

RADIATOR:

The radiator is responsible for cooling the hot water. It has two functions, which are excess heat dissipation and storage of water. The radiator has to dissipate heat to the atmosphere at a rate, which is equal to the amount of heat dissipated by the engine to the coolant in order to maintain a constant temperature. To achieve this radiator must be of the right size to take care of the most adverse conditions, which can be expected.

The radiator consists of three sections i.e. top tank, core and fin area and bottom tank.

I. TOP TANK:

The top tank consists of connections to the regulator housing, fill neck and provision for expansion space. It may also have provisions for pressurizing, overflow, deaeration, thermal sensing devices for fans, shutters, water level etc.

II.CORE AND FIN AREA:

The radiator cores consist of tubes, which carry the coolant and dissipate the heat to the fins and the passing air stream. Fins are attached to the tubes in order to increase the surface area in contact with the air. A shroud or a cowl is fitted onto this area in order to direct the air onto the fins and make use of the entire radiator area for purpose of cooling.

IMPORTANT:
Never operate the engine without a shroud or a cowl, as, the entire radiator area will not be utilized for cooling and the engine will have a problem of overheating.

III. BOTTOM TANK

The bottom tank connects the core area and holds the coolant, which will be sucked by the water pump.

RADIATOR CAP:

The radiator pressure cap consists of a pressure valve, vacuum valve, filler cap and overflow pipe. As the coolant expands during engine operation, the pressure relief valve opens and regulates pressure. When the engine is shut down and begins to cool, the pressure relief valve is closed. The vacuum valve prevents a vacuum in the system by opening and allowing atmospheric air to enter the expansion space and thereby equalize the pressure between the system and the atmosphere. This way the valves assure close regulation of system pressure during the operation and stopping periods. The positive pressure also ensures that the coolant does not boil when the engine is used at high altitude therefore reducing "after boil" and the resultant loss of coolant. Pressurizing the cooling system increases the capacity of the coolant to absorb more heat and results in increased cooling system efficiency. The present radiator cap has the added function of maintaining a positive pressure on the cooling system during engine operation and prevents vacuum formation when the engine coolant temperature comes down.

COOLING FANS:

Cooling fans are provided to aid the flow of air between the radiator tubes. The fan is mounted between the engine and the radiator.

TWO TYPE OF FAN:

1. The blower fan is designed to draw air from the engine side and push it towards the front of the radiator. The other type is known as the sucker type and pulls air from the front of the radiator towards the engine.

FUNCTIONS OF THE LUBRICATING SYSTEM:

Oil is the lifeblood of an engine. The lubricating oil has to perform several basic functions in order to provide adequate lubrication, which is

1. CLEAN: The engine moving parts have to be cleaned.
2. COOL: The heat of the pistons has to be taken away by the lubricating oil.
3. SEAL: The combustion chamber has to be sealed to reduce compression leakage.
4. LUBRICATE: The lubricating oil forms an oil film cushion between moving surfaces and prevents metal to metal contact thereby reducing friction and wear.
5. SUPPORT: T he oil lifts and supports the shafts and keeps it floating on a film of oil.
6. PROTECT: The oil protects metals and working surfaces from corrosion and rust.

ENGINE PARTS THAT REQUIRE LUBRICANT

- Crankshaft bearings
- Crankpins
- Big end of connecting rod
- 4. Small end of connecting rod
- Bushes of gudgeon pin
- Inner wall of cylinder
- Piston rings
- Valve operating mechanism
- Timing gears
- Camshaft bearing
- Water pump
- Turbo charger bearings

OPERATION OF THE LUBRICATION SYSTEM:

Oil is sucked by the oil pump, from the oil pan, and pumped to the engine oil cooler. Here the engine coolant cools the lubricating oil. Then the oil goes through the lubricating oil filters where the dirt, debris and contaminants are removed. Clean lubricating oil flows under pressure into the cylinder block's oil manifold, where, it goes in two directions.

1. Into the engine to lubricate components, such as the bearings, gears, pistons liners, valves etc.
2. And a smaller flow directly to the turbocharger.
3. The oil then returns to the engine oil sump or pan to start the cycle all over again. A bypass valve in the filter allows unfiltered oil to by-pass a plugged filter so that the engine will not suffer a seizure due to lack of lubricating oil. When the lubricating oil is cold, an oil bypass valve mounted at the lubricating oil cooler, bypasses the oil cooler element.

LUBRICATING OILS:

Diesel engines normally operate at lower speeds but at higher pressures and temperatures than petrol engines, which make the job of the lubricating oil a very demanding. Under these conditions, the lubricating oil must function in an expanded capacity. This is where the use of additives is noticed. The amount or type of additives used depends mainly upon the environment in which the engine oil will function.

BASE OIL:

Lubricating oil begins with base stocks, which can be mineral or synthetic in nature. The base stocks provide the basic lubricating properties of an engine. However, unless it is supported with additives, this base oil will deteriorate and degrade very rapidly in some operating conditions. So, depending on the type of base oil different additive chemistries are used.

MINERAL OILS:

Mineral oils are refined from crude oil. The mineral oil stocks are most common for lubricating oils because of their good properties, availability and cost considerations.

ADDITIVES:

These are chemical substances added to an oil in order to improve or impart certain properties.

Additives strengthen or modify certain characteristics of the base oil. Ultimately, they enable the oil to meet the requirements quite beyond the ability of the base oil.

The most common additives are: detergents, dispersants, oxidation inhibitors, alkalinity agents, anti-wear agents, pour point depressants, viscosity index improvers, anti-foam agents.

DETERGENTS:

This is an important component of engine oils that helps control varnish, ring zone deposits, and rust by keeping insoluble particles in

suspension and in some cases, by neutralizing acids. The detergents in use today are: sulfanates, phenates, phosphonates or salicylates.

DISPERSANTS:

Dispersant is an additive, which helps prevent sludge, varnish and other engine deposits by keeping soot particles in a state of suspension, and prevents these particles from getting together or forming a mass. The lubricating oil filter then traps these particles with no damage to the engine.

ALKALINITY AGENTS:

Alkalinity agents' help neutralizes acids. Detergents are also trong neutralizers, changing combustion and oxidation acids into harmless neutralized salts.

OXIDATION INHIBITIORS:

This is an additive, which helps prevent increases in viscosity and oxidation. It also lengthens the service or storage life of the oil. Oxidation is the chemical combination of a substance with oxygen. All petroleum products are subject to oxidation. This degrades their composition and lowers their performance. The oxidation process is accelerated by heat. Light metal catalysts (agents which hasten a chemical reaction) and the presence of water, acids or solid contaminants. These substances react with each other to form sludges, varnishes, gums that can impair equipment operation.

ANTI-WEAR ADDITIVES:

Anti-wear agents reduce friction by forming a film on metal surfaces and by protecting metal surfaces from corrosion and excessive wear.

POUR POINT DISPERSANTS:

These are additives, which keep the oil liquid at low temperatures by preventing the growth and agglomeration of wax crystals.

VISCOSITY INDEX IMPROVERS:

Additives, which help prevent the oil from becoming too thin at high temperatures. Viscosity index improvers are chemicals, which improve the rate of viscosity change with temperature change.

ANTI-FOAM AGENTS:

Additives, which help in controlling foam and prevent air bubbles from entering the lubricating oil pump.

FUEL SYSTEM

The basic function of the fuel system is to supply the right quantity of fuel to the engine, at the right time and at the right pressure required to atomize it thoroughly.

Fuel produces power in a diesel engine when it is atomized and mixed with hot air in the combustion chamber. Pressure caused by the piston rising in the cylinder causes a rapid temperature increase. When fuel is injected, the fuel/air mixture ignites and the energy of the fuel is released to force the pistons downward and turn the crankshaft. A perfect fuel would burn completely, leaving no residue or smoke products. However, there is no perfect fuel.

TYPES OF FUEL INJECTION SYSTEM:

1. Pre-combustion system
2. Direct injection fuel system

PRE-COMBUSTION CHAMBER:

The pre-combustion chamber is separate chamber located in the cylinder head just below fuel nozzle. Combustion begins this chamber causes turbulent flow of fuel/air mixture enter into large chamber (cylinder) where combustion is completed. This is the most effective way of burning the fuel. Due to this turbulent head principle, no diesel knock is developed. The other advantage is that the fuel consumption is reduced. The performance is also improved and the combustion of the fuel is very efficient.

DIRECT INJECTION FUEL SYSTEM:

A direct injection type system generally uses less fuel but it is more sensitive to fuel quality. A direct injection system injects fuel directly into the combustion chamber through several small holes in the fuel nozzle. The fuel is highly atomized and ignites efficiently.

CETANE NUMBER:

The cetane number refers to the property of igniting the fuel easily. If the fuel is at a high cetane number the fuel can ignite easily. It can then ignite at a low temperature. If the cetane is low, the temperature required to ignite the fuel is high. This is not desirable. Also, if the cetane number is low, there is a possibility for the fuel to knock. A high cetane number ensures that the fuel will ignite and burn immediately after the fuel is injected.

Sl.no.	Type of fuel	Properties
01	LPG (liquefied petroleum gas)	1. It is a mixture of butane and propane gases. 2. It is liquefied under normal ambient temperature and moderate pressure. 3. It is a clean burning, non-poisonous, dependable, high calorific value fuel. 4. Very low sulphur content. 5. It is mainly used as a domestic fuel. 6. It is also widely used in industries where very fine degree of temperature control is required.
02	M.S (Motor spirit	1. It is used as fuel in spark ignition engines. 2. It is mainly used in two stroke and four stroke engines of automobiles. 3. It is a highly refined fuel and possesses good anti-knock and volatility characteristics with appropriate stability.
03	ATF (aviation turbine fuel)	1. It is a highly refined transparent fuel having extremely good oxidation and thermal stability with a very low pour point. 2. Application: fuel for jet and turbo propelled aircrafts.
04	HSD (high speed diesel)	Application: fuel for medium and high-speed engines (above 750 R.P.M.)
05	HF-HSD (high flash high speed diesel	HF HSD meets the same specification as normal HSD except that it has a flash point of 66°c minimum against 32°c for normal HSD.

		Sulphur percentage is limited to max. of 1% Application: It is specially recommended for use in diesel engines for naval applications and merchant navy.
06	LSHF-HSD (low sulphur high flash high speed diesel)	It is similar to HF HSD except that sulphur percentage is limited to 0.2%. This is specially recommended for use in certain diesel engines for naval applications and merchant navy. Where low sulphur fuel is recommended
07	LDO (light diesel oil)	LDO is a blend of distillate fuel with a small proportion of residual oil, primarily recommended for slow speed diesel engines operating below 750 rpm Application: Agriculture, marine, furnaces and boilers.
08	FO (furnace oil)	Furnace oil is a dark viscous residual product used as a fuel. Application: Industrial furnaces Steam raising(boilers) Power generation (gas turbine)

BEARING

Bearing allows relative movement between the components of machines while providing some types of location between them. The type of bearing, which can be used, is determined by the nature of the relative movement required and type of constraints, which have to be applied to it.

TYPES OF BEARINGS:

1. Sliding bearing/plain bearing
2. Rolling bearing/antifriction bearing

TYPES OF SLIDING BEARING:

a. Thrust bearing
b. Journal bearing

THRUST BEARING: Thrust bearing transmits a load parallel to the shaft axis (thrust) from the revolving shaft to the frame.

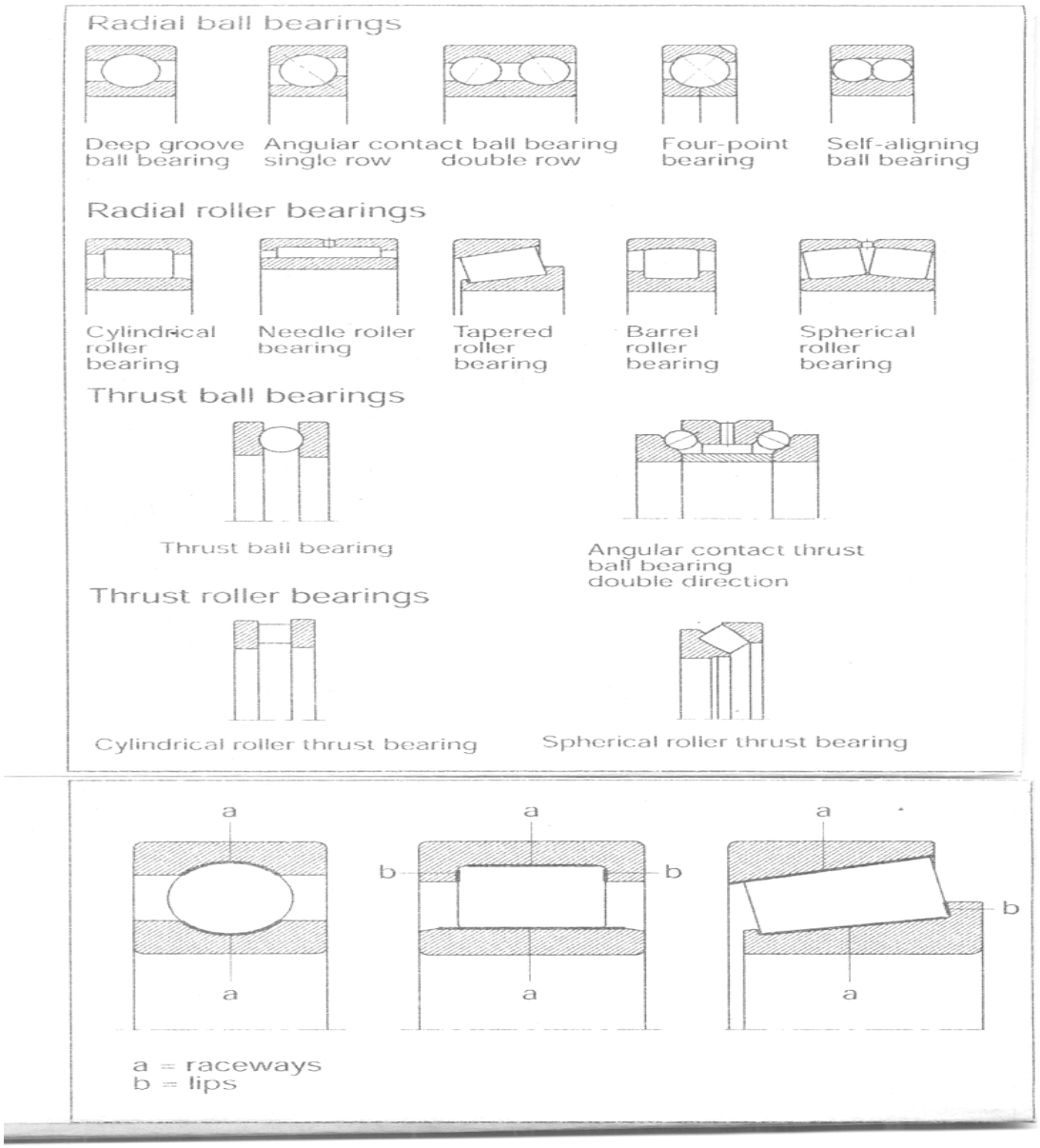
JOURNAL BEARING: Journal bearing supports only the radial load.

TYPES OF ROLLING BEARING/ANTIFRICTION BEARING:

1. Ball bearing
2. Cylindrical roller bearing,
3. Needle roller bearing,
4. Tapered roller bearing,
5. Spherical roller bearing (symmetrical roller)
6. Asymmetrical roller bearing.

Differences between ball bearing and roller bearing

Sl.no.		Ball bearing	Roller bearing
01	Type of rolling elements	Balls	Rollers
02	Load	Suitable for lower load	Suitable for higher load due to larger contact area between rollers and raceways
03	Type of contact	Point contact (contact area is less)	Line contact (contact area is more)
03	Speed	Suitable for higher speeds	Suitable for lower speeds
04	Separable/on-Separable	Yes, both the types are available	Yes, both the types are available
05	Self-aligning capacity	Yes	Yes

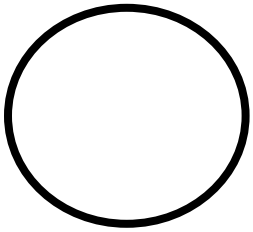


Rolling bearing consist of inner ring, rolling element, outer ring and cage. The inner ring and outer ring guide the rolling elements in the direction of rotation. The rolling elements roll on the raceways of the rings and the cage surrounds the rolling elements to keep them apart.

TYPES OF ROLLING ELEMENTS:

Rolling elements are classified according to their shape into balls, cylindrical rollers, needle rollers, tapered rollers and barrel rollers etc.

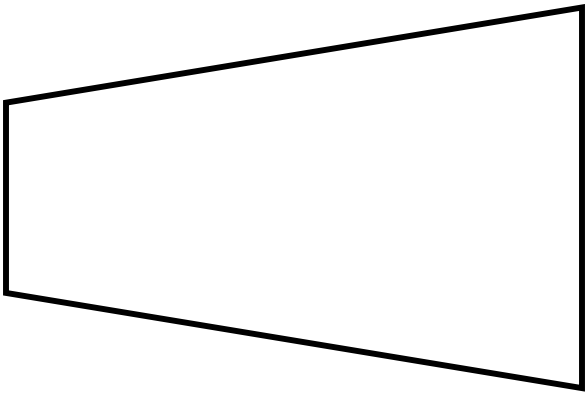
BALL ROLLER



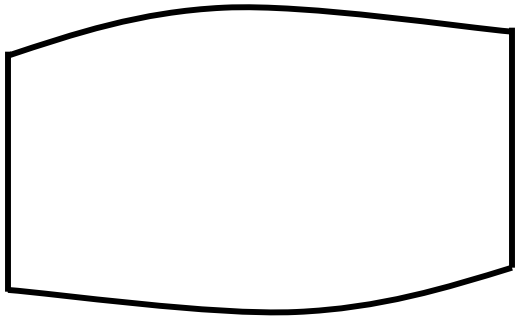
CYLINDRICAL ROLLER

NEEDLE ROLLER

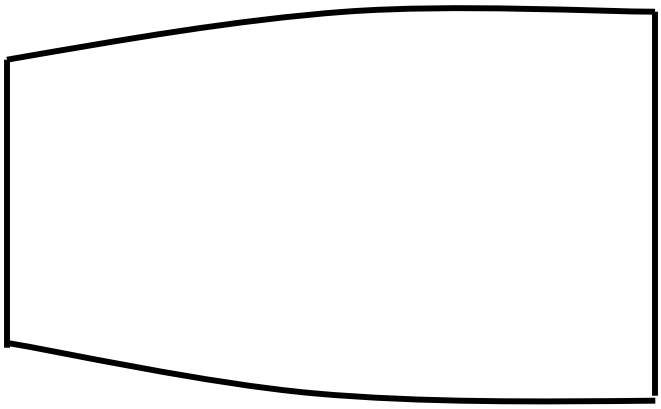
TAPPERED ROLLER



SYMMETRICAL BARREL ROLLER



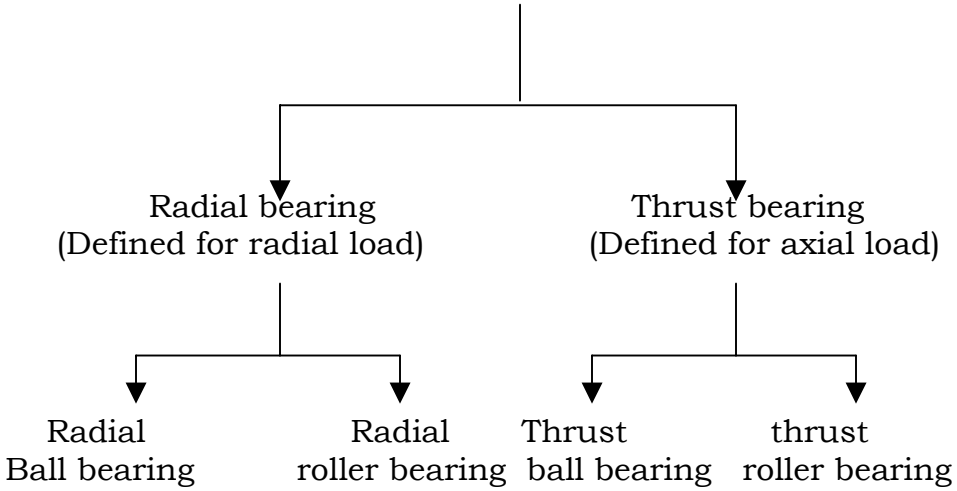
ASYMMETRICAL BARREL ROLLER



FUNCTION OF ROLLING ELEMENT:

1. It has to transmit the force acting on the bearing from one ring to another ring.
2. It has outstanding load carrying capacity can operate with some difficulty at high speeds, but is pre-eminent at low speeds and medium speed.
3. Longer life can be obtained at reduced loads and speeds.
4. Load carrying capacity is depends on as many rolling elements as possible and as big size as possible.

CLASSIFICATION OF ROLLING BEARING BASED ON DIRECTION OF MAIN LOAD



LOAD RATING:

The load rating of a bearing reflects its load carrying capacity and is an important factor in the dimensioning of rolling bearings. Dimensioning is necessary to calculate bearing life, static safety and

cost efficiency. The number and size of the rolling elements, the curvature ratio, the contact angle and the pitch circle diameter of the bearing determine it. Every rolling bearing has a dynamic and a static load rating. The term "dynamic" and "static" refer to the movement of the bearing but not to the type of load.

DYNAMIC LOAD RATING:

The dynamic load rating C is a factor for the load carrying capacity of a rolling bearing under dynamic load at which the bearing rings rotate relative to each other. It is defined as the load, constant in magnitude and direction. A rolling bearing can theoretically accommodate for a nominal rating life of one million revolutions.

SERVICE LIFE:

Is the life during which the bearing operates reliably. The fatigue life of a bearing is the upper limit of the service life. Often this limit is not reached due to wear or lubrication breakdown.

FATIQUE:

Any element, which is subject to cyclic loading, will have one minimum and one maximum load per cycle. Every material has its own molecular energy. Whenever a shaft starts to rotate will be subjected to tensile and compressive force simultaneously which cause extend and contract of the material which will increase surface crack on the shaft surface. Which is the phenomena will be going to loose its particles is known as fatigue failure.

NOMINAL RATING LIFE:

The standardized calculation method for dynamically stressed rolling bearings is based on material fatigue as the cause of failure.

- $L_{10} = (C/P)^p \ 10^6$revolutions

- L_{10} is the nominal rating life in millions, which is reached or exceeded by at least 90% of a large group of identical bearings.

- C is dynamical load rating
- P is equivalent dynamic load rating (for dynamically loaded roller bearing under combined load, the calculation p is based on the equivalent dynamic load.)
- p is life exponent
- p =3 for ball bearings
- p = 10/3 for roller bearings

When the bearing speed is constant, the life can be expressed in hours.

- $L_{h10} = L_h = L \times 10^6/n \times 60$ hours.

- Where $L_{h10} = L_h$

DYNAMIC LOAD RATING COMPARISON: dynamic load rating of a few rolling bearing types with a bore diameter of d = 25 mm

Slno.	Rolling bearing	Dynamic load rating C kN
01	Deep groove ball bearing 6205	14
02	Cylindrical roller bearingNU205E	29
03	Tapered roller bearing 30205A	32.5
04	Spherical roller bearing 22205ES	42.5

STATIC LOAD RATING:

In statically stressed bearings there is no relative motion between the bearing rings. The static load rating Co is a factor for the load carrying capacity of rolling bearing in the middle of the rolling element/raceway contact area. It is most heavily loaded area and defined as load, constant in magnitude. Under this load a total plastic deformation of rolling element and raceway of about 0.01% of the rolling element diameter at the most heavily loaded contact area arises.

Static stress implies that there is no relative movement or a very slow one between the rings ($n<10$ $min^{-1)}$. For these conditions the safety against excessive plastic deformations of the raceways and rolling elements is checked.

STATIC LOAD RATING OF ROLLING BEARING:

slno	Rolling bearing	Static load rating Co N/mm^2
01	Self – aligning ball bearings	4600
02	All other ball bearings	4200
03	All roller bearings	4200

CONTACT ANGLE OF RADIAL & THRUST BEARING

The rolling elements transmit loads from one ring to the other in the direction of the contact lines. The contact angle α is the angle formed by the contact lines and the radial plane of the bearing.

SELECTION OF BEARING

Each type of bearing has characteristic features, which make it particularly suitable for certain application. However, it is not possible to lay down hard and fast rules for the selection of bearing types since several factors must be considered and assessed relative to each other.

The recommendations, which follow, will, for a given application, serve to indicate those details of greatest importance in deciding the type of bearing to be used.

sln o	Service factors	Characteristic	Sliding	Rolling
01	Mechanical requirement	Load is: a. Unidirectional b. Cyclic c. Starting d. Unbalance e. Shock f. Emergency	 Good Good Poor Good Fair Fair	 Excellent Excellent Excellent Excellent Excellent Fair
02	Do	Speed limited by	Turbulence and temperature rise	Centrifugal loading and dynamic effects
03	Do	Misalignment tolerance	Fair	Poor in ball bearings Good in spherical roller bearings Poor in cylindrical roller bearings
04	Do	Starting friction	Poor	Good
05	Do	Space requirement	Small	Large
07	Do	Type of failure	Often permits limited emergency operation after failure	Limited operation may continue after fatigue failure but not after lubricant failure
08	Do	Damping	Good	Poor
09	Do	Type of lubricant	Oil, grease, dry lubricants, other fluid and air or gas	Oil or grease
10	Do	Lubrication quantity	Large, except in low speed (boundary lubrication)	Very small (except large amount of heat to be removed system)
11	Do	Noise	Quiet	May be noisy, depending upon quality of bearing and resonance
12	Do	Power consumption	Varies as $\eta b \omega^2 d^2$	Varies widely depending upon type of

			ψ	lubrication. Varies directly as speed. Usually the speed lower than slider bearing.
13	Environmental conditions	Low temperature starting	Poor	Good
14	Do	High temperature operation	Limited by lubricant	Limited by lubricant
15	Economic life	Life of bearing	Unlimited (except for cyclic loading)	Limited by fatigue properties of bearing metal
16	Maintenance	For effective maintenance	Clean lubricant is required	Clean lubricant is required. (Occasional attention is required for grease lubrication)
17	Cost	Cost of bearing	Cost is less in mass production or simpler types	Cost is intermediate, but standardized, varying little with quantity

I .MECHANICAL REQUIREMENT

1. Space requirement
2. Load and speed
3. Misalignment tolerance
4. Precision
5. Rigidity
6. Starting friction
7. Noise
8. Type of failure
9. Damping quality
10. Type of lubricant
11. Power consumption

2. ENVIRONMENTAL CONDITION

a. Low temperature starting
b. High temperature operation

3. ECONOMIC

a. Long life

b. Easy to maintain
c. Cost effect
d. Easy to replace

SPACE REQUIREMENT OF ROLLING BEARING

Sl.no	Limitation	Deciding factor	Shaft size	Selection of bearing
01	Bore diameter	Bore dimension is predetermined by machine design	Smaller diameter Larger diameter	Deep groove ball bearings are normally selected. Cylindrical roller bearing, spherical roller bearing and also some extent deep grove ball bearings can be considered
02	Radial space	Do	If radial height between shaft and bore is limited	Bearing with small sectional height must be selected. They are: 1. Needle roller bearings with or without inner ring. 2. Certain series of deep groove ball bearings and spherical roller bearings.
03	Axial space	Do	If width of the bore is limited	Narrow width bearings must be selected where the axial space is limited. Some series of deep groove ball bearing and cylindrical roller bearings can be used.

BEARING LOADS:

1. Magnitude of load.
2. Direction of load.

MAGNITUDE OF LOAD:

This is normally the most important factor in determining the size of bearing. Generally, roller bearings can carry greater loads than ball bearings of the same external dimensions due to large area of contact between rolling elements and rings (line contact). Ball bearings are mostly used to carry light and medium loads, while roller bearings are often the only choice for heavy loads and large diameter shafts.

DIRECTION OF LOAD

1. Radial load.
2. Axial load.
3. Combined load (both radial and axial).

RADIAL LOAD:

Bearings, which are chiefly used for radial loads, are referred to as radial bearings. They have a nominal contact angle $\alpha_0 \leq 45^{0.}$ Roller bearings are suitable for higher radial loads than ball bearings of the same size. Cylindrical roller bearings (type N, NU) having one ring without flanges and Needle roller bearings can carry only radial loads. All other types of radial bearings can carry both radial and axial loads.

AXIAL LOAD:

Bearings, which are chiefly used for axial loads, are referred to as axial bearings. They have a nominal contact angle $\alpha_0 > 45^{0.}$ Thrust ball bearings and angular contact thrust ball bearings can accommodate axial forces in one or both directions depending on the design. For especially high axial loads, cylindrical roller thrust bearings or spherical roller thrust bearings are given preference. Spherical roller thrust bearings, in addition to very heavy axial loads, can also carry a certain amount of simultaneously acting radial load. Double row angular contact thrust ball bearings can carry axial loads at higher speeds than thrust ball bearings and are used on machine tool spindles. The remaining thrust bearing types are only suitable for axial loads.

COMBINED LOAD:

- This applies when a bearing loaded by both radially and axially and the resulting load acts on the bearing simultaneously.
- The most important feature affecting the ability of a bearing to carry an axial load is its angle of contact. The greater this angle the more suitable is the bearing for axial loading.
- Double and single row angular contact ball bearings and taper roller bearings are mainly used for combined loads.
- Deep groove ball and spherical roller bearings are also used.
- Self –aligning ball bearings and cylindrical roller bearings can also be used to a limited extent for carrying combined load.
- Duplex bearings and spherical roller thrust bearings should only be considered where axial loads predominant.
- Single row angular contact ball bearings, taper roller bearings and cylindrical roller bearings of type NJ can carry axial loads in one direction only. Where the direction of the load varies two such

bearings arranged to carry axial loads in opposite directions must be used.

- Where the axial component constitutes a large proportion of the combined load, a separate thrust bearing can be provided for carrying the axial load independently of the radial load. In addition to thrust bearings, suitable radial bearings may also be used to carry axial loads only.

  Example: deep groove ball or duplex bearings.
- In order to ensure that these bearings are only subjected to axial loading, the outer rings must have radial clearance in their housings.

LIMITING SPEEDS:

- The permissible operating temperature limits the speed of rotation of a rolling bearing.
- Bearings with low frictional resistance and correspondingly little internal heat generation are most suitable for high rotational speeds.
- For radial loads, the highest bearing speeds are obtainable with deep groove ball bearings or cylindrical roller bearings.
- For combined loads, the highest bearing speeds are obtainable with angular contact ball bearings.

MISALIGNMENT TOLERANCE

1. Angular misalignment
2. Axial displacement

ANGULAR MISALIGNMENT

a. Misalignment can be caused by shaft deflection under load, when the bearings are fitted in housings positioned on separate bases and at a large distance from one another or when it is impossible to machine the housing seating at one setting.
b. Where the shaft can be misaligned relative to the housing, bearing capable of accommodating such misalignment are required, namely self-aligning ball bearings, spherical roller bearings, spherical roller thrust bearings and spherical plain bearing.
c. Spherical plain bearings are suitable for tilting or rotational, oscillatory movements.

AXIAL DISPLACEMENT

1. Length compensation within the bearing.
2. Length compensation within the bearing fit.

LENGTH COMPENSATION WITHIN THE BEARING:

- Usually, a locating bearing (fixed end) and a floating bearing/non-locating (free or floating end) are used for the bearing arrangement of a shaft.
- The floating/non-locating bearing can be displaced axially thus preventing cross-location by shaft expansion by heat or contraction by cold.
- The cylindrical roller bearings having one ring without flanges or needle roller bearings are particularly suitable for use as free bearings. Their internal design permits axial displacement of the inner and outer rings in both directions. The inner and outer rings can therefore be mounted with interference fits.
- Tapered roller bearings and angular contact ball bearings are not suitable for a floating bearing arrangement because they must be adjusted for flawless running.

LENGTH COMPENSATION WITHIN SLIDING FIT:

Non-separable bearings, such as deep groove ball bearings and spherical roller bearings, are also mounted as floating bearings. One of the two bearing rings is then provided with a loose fit and needs no axial mating surface, so that the loose outer ring can move in the housing bore and the loose inner ring on the shaft seat.

SEPARABLE BEARINGS:

These are bearings whose rings can be mounted separately. This is advantageous where both rings have tight fits.

Example: Four- point bearings double row angular contact ball bearings with split inner ring, cylindrical roller bearing, tapered roller bearings, thrust ball bearings, cylindrical roller thrust bearings and spherical roller thrust bearings.

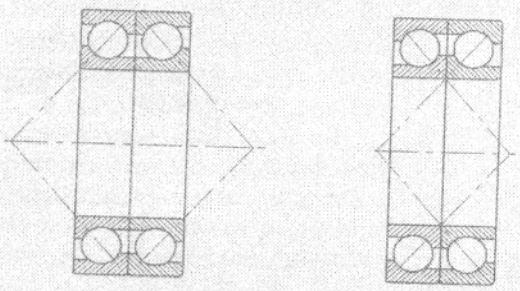
NON- SEPARABLE BEARINGS:

- When using a non-separable bearing like deep groove ball or spherical roller bearings as a non-locating bearing, it must be mounted to allow axial freedom either on its shaft seating or in its housing.

- Deep groove ball bearings, single-row angular contact ball bearings, self-aligning ball bearings, barrel roller bearings and spherical roller bearings.

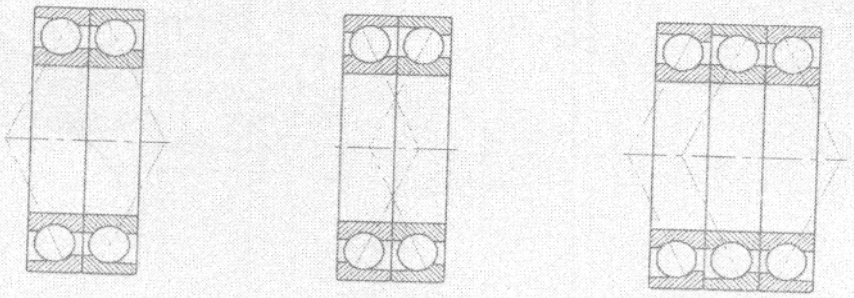
- Depending on application requirements the bearings may be arranged in three different ways.

▼ Angular contact ball bearing pair of universal design as locating bearing
a = O arrangement, b = X arrangement



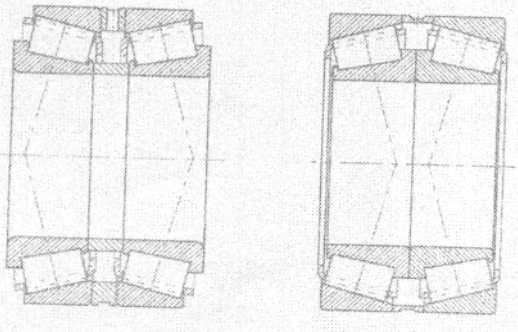
a b

▼ Spindle bearings of universal design as locating bearing
a = O arrangement, b = X arrangement, c = tandem-O arrangement



a b c

▼ Tapered roller bearing pair as locating bearing
a = O arrangement, b = X arrangement



a b

TANDEM ARRANGEMENT:

In tandem arrangement the lines of action of the load through the ball contacts of each bearing are parallel. In this arrangement the bearings can only carry axial loads in one direction and in general they must be adjusted against a third bearing which carries any axial loads in the reverse direction.

BACK-TO-BACK ARRANGEMENT:

The lines of action of the load through the ball contacts diverge at the bearing axis. Axial loads can be carried in either direction, but only by one bearing. The back-to-back arrangement gives a relatively rigid bearing arrangement, which can also accommodate tilting moments in an axial plane.

FACE-TO-FACE ARRAGEMENT:

The lines of action of the load through the ball contacts converge at the bearing axis. Thrust loads can be carried in either direction, but only one bearing. The bearing arrangement and is less suitable for tilting moments.

PRECISION:

Rolling bearings with a high degree of precision are required for shafts where stringent demands are made on running accuracy, e.g. machine tool spindles and also usually for shafts rotating at very high speeds.

Deep groove ball bearings, single row angular contact ball bearings, double row cylindrical roller bearings and angular contact thrust ball bearing are manufactured to high degrees of precision both as regards running accuracy and dimensions.

NOISE:

While rolling bearings have an intrinsically low noise level there are applications, for example electric motors, where this is an important factor in bearing selection. Deep groove ball bearings are normally selected for this type of application.

RIGIDITY:

Elastic deformation in a loaded bearing is very small and in most instances can be ignored. However the bearing rigidity is of importance in some case, e.g. machine tool spindles.

Because of the greater area of contact between the rolling elements and raceways, roller bearings, e.g. cylindrical roller bearings or taper roller bearings, deflect less under load than ball bearings. Suitable preloading can increase the rigidity of the bearings.

MODE OF BEARING FAILURES

- Failure due to contamination during fitting

- Failure due to damage during fitting
- Failure due to mounting errors
- Failure due to defective materials
- Failure due to defective sealing
- Failure due to Corrosion
- Failure due to improper material
- Failure due to improper design
- Failure due to improper lubrication

FAULT DETECTION

- Collect the evidence
- Analyses the evidence
- Locate the fault
- Determine the cause and remove
- Rectify the fault
- Check the system

Type of tools using for mounting of bearing

- Mechanical tools
- Hydraulic tools
- Electrical heaters

The life of antifriction bearing depends on load, speed and design factor.

1. LOAD

- Axial load
- Radial load
- Combination of both

2. SPEED

- Low speed
- Medium speed
- High speed

3. DESIGN FACTOR

4. OPERATING FACTOR

- Speed, load viscosity and temperature

GUIDE LINES FOR BEARING CLEARANCE

- 0.001" + 0.001d for normal bearing
- 0.002" + 0.001d for heated bearing
- In any case c/d should not be > 0.002
- Ideal would be 0.0013(0.0005 to 0.0018)

BEARING LIFE

- Bearing life (L) = (C/P) POWER X million revolution
  Where material fatigue is the cause of failure
- C0- Basic dynamic load rating
- C1- static load rating
- P- Actual load
- X- 3 for ball bearing and 3 1/3 for roller bearing
- L10 = L/RPM x 60 Hrs

FACTORS AFFECTING LIFE OF BEARING

1. Pressure
2. Temperature
3. Speed.
4. Surface roughness
5. Installation and alignment

TYPE OF SEAL

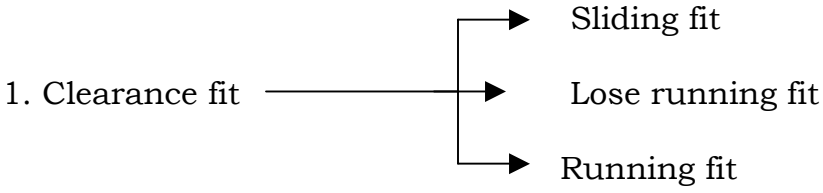
- Static type
- Dynamic type

SEALING MATERIAL

- Leather
- Cork
- Impregnated fibres
- Felt
- Rubber
- Synthetic rubber
- Elastomers

TYPE OF FITS:

- Transition fit
- Clearance fit
- Interference fit



2. Transition fit – most of the bearing transition fit in the bearing housing

3. Interference fit- shaft and bearing (shaft dia.> bearing inner dia.

INTERNAL CLEARANCE OF BEARING

- C1 –Too tight
- C2 – tight clearance
- CN – normal
- C3 -- loose
- C4 --extra loose
- C5 –too loose

STANDARD

- Shaft dia. designated by small letter
- Hole dia. Designated by capital letter
- Basic hole system “H” follow basic hole system

BEARING MATERIAL

- Tin based bait metal.
- Medium lead based alloy.
- High aluminum base alloy.
- Tin base alloy has minimum loss of material due to corrosion
- Copper base alloy has maximum loss of material due to corrosion.

BEARING CORROSION

- Acid corrosion
- Sulpher corrosion
- Aqueous acid

TYPES OF LUBRICATION

- Hydro static
- Hydrodynamic
- Elasto- hydrodynamic
- Boundary
- G 0.005 DB
  Where D –bearing outer dia in mm and B –bearing width in mm

For better hydrodynamic lubrication

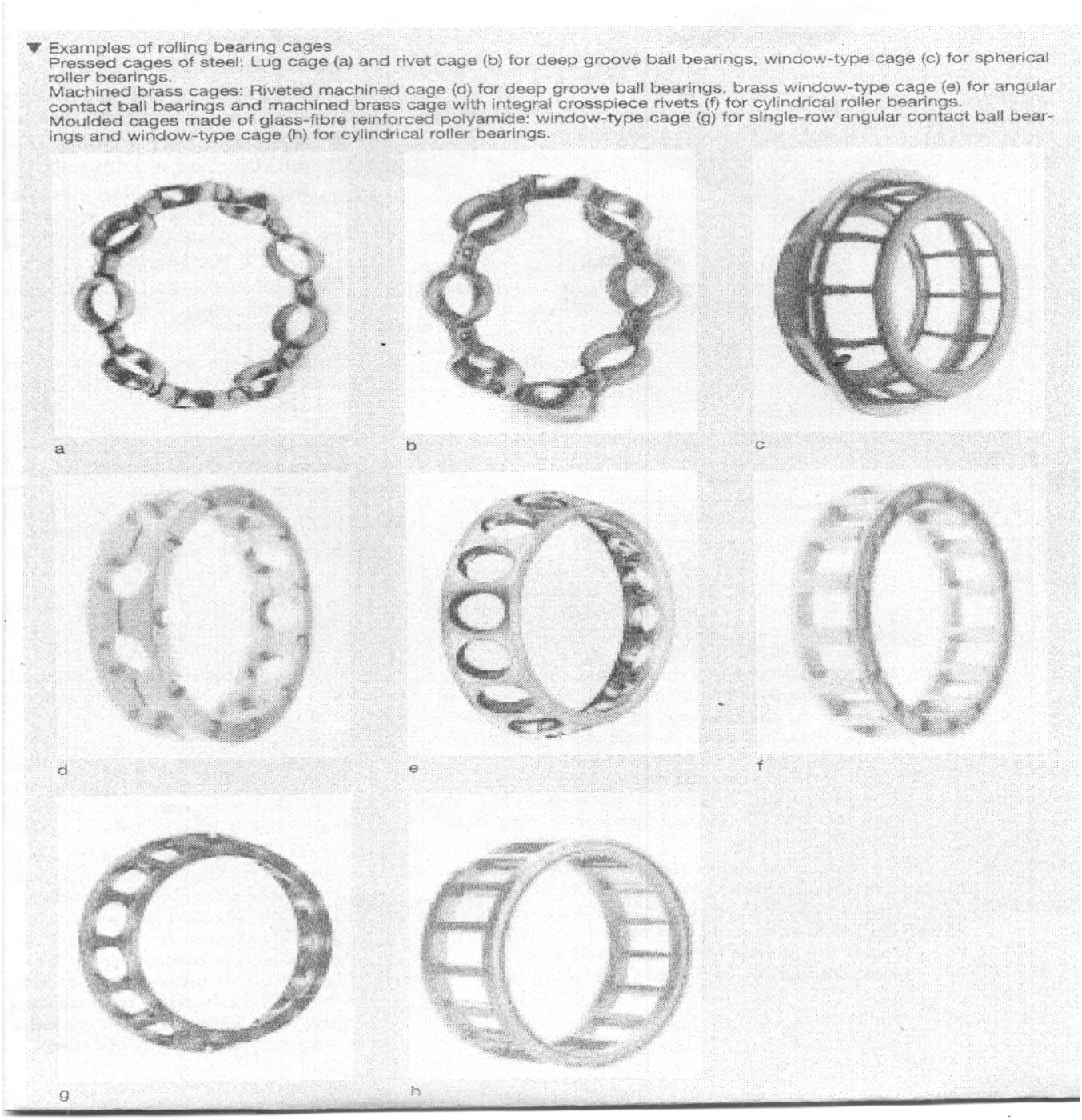
- L/D ratio should be less than 1
- L –Length of bearing
- D dia of bearing

The life of antifriction bearing depends on load and speed.

- Coefficient of friction = μ F/W
- F = tracking force
- W = weight (or) power
- In case of anti friction bearing the coefficient of friction almost fixed between 0.01"to 0.03".

- All engines crankshaft journal bearing design on the basis of hydrodynamic lubrication system by means of wedge action.
- Plain bearings are suitable for high speed
- Roller bearings are suitable for high load and low speed
- Ball bearings are suitable for low load and medium speed

CAGES



The cage is an important component of a rolling bearing:

- It keeps the rolling elements apart to prevent mutual contact.
- It keeps the rolling elements evenly spaced to ensure a more even load distribution.
- It guides the rolling elements in the unloaded bearing zones.
- It prevents the rolling elements from falling out of separable and slew able bearings, thereby facilitating bearing mounting.

BEARING LUBRICATION

The most common application of a lubricant is to bearings, which are endless uses in machineries.
Good bearing properties in any part are obtained when the surface has large number of irregularities, i.e. a large number of hills and valleys. The hills in irregular surface reduce the metal-to-metal contact and the valleys help to retain the film of lubrication. Majority of bearing designs aim for a minimum oil film thickness in order to determine the maximum load that a bearing will support. The value of film thickness depends on bearing size, type, expected misalignment, possible load and speed variation and designer's experience with particular machine.

HYDRODYNAMIC LUBRICATION:
Wherever mating surfaces are need to be completely separated by a viscous film, hydrodynamic lubrication is must for such condition.

ELASTOHYDRODYNAMIC LUBRICATION:
Where elastic deformation at the contact interface allows greater load carrying ability needs elastohydrodynamic lubrication.
BOUNDARY LUBRICATION:
Where adsorbed films protect contact surfaces exposed to slow speeds or high loads.
MIXED FILM LUBRICATION:
An intermediate condition occurs in hydrodynamic or elastohydrodynamic bearings.

OIL LUBRICATION OF PLAIN OR JOURNAL AND BUSH BEARINGS

When a journal rotates in a plain bearing, which is receiving oil in adequate quantity, a fluid film of oil is built up by virtue of the viscosity of the oil as a result of rotation of the journal in the bearing. Under suitable conditions this oil film prevents metallic contact

between the journal and the bearing. While frictional resistance to the movement of the journal depends mainly on the speed of rotation of the journal and viscosity of the oil under the conditions existing in the film. Using oils of progressively lower viscosities may reduce friction. But in every case, depending on speed and load, there is a lower limit of viscosity below which a fluid film is not fully maintained and metal-to-metal contact is likely to occur. In practice, therefore, it is usual to employ oils of sufficient viscosity to provide a safety margin. The effect of operating temperature on viscosity must not be overlooked.

To ensure fluid film lubrication, the bearing must at all times be flooded with oil. So the oil must be supplied to the bearing at a rate equal to that at which it escapes. The rate of escape depends on the viscosity of the oil (less viscous oils escape more rapidly) and on such factors as bearing clearances and the mechanical condition of the bearing. Speaking generally, the greater the load, the lower the speed; or the larger the clearances the more viscous the lubricant must be. Conversely, lighter loads, higher speeds and smaller clearances necessitate oils of relatively low viscosity. Viscosity requirement also varies directly with surface specifications and bearing mean pressures. Selection of right kind of viscosity oil is to give most effective lubrication under all possible conditions.

- The viscosity required for any given set of conditions depends on size, speed, load and temperature of the bearing.
- Over lubrication should be avoided.
- Oil level should not be above the centre of the bottom-rolling element when the bearing is not rotation.
- Suitable method is used to apply the oil depends mainly on the running speed of the bearing to avoid overheating problem due to churning of oil.

sl	Method of oil lubrication	Speed of machine
01	Oil bath and splash systems	Low and medium speed
02	Circulating systems	Medium speed
03	Spray or mist	High speed

Cleanliness in handling and applying the lubricant is most important to reduce wear, and every precaution should be taken to prevent impurities and moisture getting into bearings. Correct alignment is also a matter of obvious importance in preventing overheating and wear.

Complete separation of the member of a sliding surface bearing during operation results in extremely low friction and unlimited life.

ANTIFRICTION BEARING

1. Ball bearing
2. Roller bearing
3. Needle bearing
4. Tapered roller bearing

The main duties of ball and roller bearing lubricants are:

1. To reduce friction between the rolling elements and the separator or cage, and between the rolling elements and the races at any point where true rolling is absent.
2. To reduce friction between the ends of rollers and the guiding surfaces which form part of the inner or outer race.
3. To assist in dissipating heat generated within the bearing.
4. To protect the highly polished working surfaces of the bearing from corrosion and rusting.
5. To assist in sealing the bearing against the entry of contaminants such as dust and moisture

The methods used to apply grease are governed by the design of the bearings and by conditions of operation.

sl	Method of grease lubrication	Periodicity of greasing
01	Grease packing	Applicable where periodic addition of fresh grease is not required.
02	Compression cup or pressure gun application	Employed where the addition of fresh grease is periodically necessary.
03	Centralized pressure systems	For severe service where the rate of consumption makes it necessary to add fresh grease at frequent and regular intervals.

GREASE

Drop point (temperature):

- It is the point at which grease become liquid.

Liquid Lubricant + Thickener +Additives =Grease

Classification of grease based on thickener

	Thickener	Water resistance	Drop point (temperature)
01	Calcium base (lime)	Good	175°C
02	Sodium base (soda)	Poor	250°C
03	Lithium base	Extremely good	300°C

Calcium base----water resistance
Sodium base ----to take heavy loads
Lithium base----multi purpose

CALCIUM BASE GREASE

1. Water resistant.
2. Adhesive grease.
3. Suitable for moderate operating temperature.
4. Suitable for excessive moisture.
5. Excellent mechanical and thermal stability.
6. Good antirust and excellent resistance properties
7. Recommended for use in ball and roller bearing.

USES

1. Chassis lubrication of automotive vehicles, including commercial vehicles, tractors and heavy duty equipment.
2. Wheel bearing
3. Water pumps operating at moderate temperature.
4. Plain bearing operating under moderate temperature and light load conditions.
5. Suitable for plain bearings operating in wet conditions

SODIUM BASE

1. High melting point characteristic.
2. Poor water resistance quality.

USES

1. Suitable for ball and roller bearings of wheels and electrical equipment.

LITHIUM BASE GREASE

1. Multifunctional
2. High temperature.
3. High drop point
4. Good thermal and structural stability.

5. High degree of resistance to oxidation.
6. Provides protection against rusting and corrosion.
7. Excellent shear stability
8. High load carrying capacity.
9. Suitable for shock loads at temperatures up to about 130*c.
10. Recommended for heavy duty roller and plain bearings.

USES

1. Automotive vehicles for all grease lubricated parts.

sl	Oil lubricant	Grease lubricant
1	Oil is generally considered to be more effective lubricant and is to be preferred if the sealing arrangements are adequate, especially where the operating temperature or surface speed of the balls or rollers is high.	It is usual to employ grease as a lubricant where temperatures and speeds are not excessive and the sealing arrangements do not offer satisfactory lubrication by oils.
2	Oil doesn't have self sealing properties and hence protecting the bearing against the entry of contaminants is less.	Grease possesses excellent self sealing properties and protects the bearing against the entry of contaminants
3	Viscosity of oil at low or moderate rates of shear lowers than grease and so the bearing reaches hydrodynamic or full film stage less than grease.	Viscosity of grease at low or moderate rates of shear remains much higher than lubricating oil in general and so the bearing reaches hydrodynamic or full film stage more rapidly than with oil
4	Suitable for high speed application due to more effective cooling system	At high speed , frictional losses are high and more frictional heat is also generated due to limitation in cooling system
5	The method used to apply the oil depends mainly on the running speed of the bearing.	The method used to apply the grease is governed by the design of the bearings and by conditions of operation.

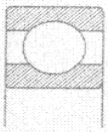
9BALL BEARING NO.6306

- ✓ First two digits (i.e. 06) multiply by 5 gives bearing bore dia. in mm.

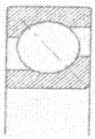
- ✓ Third digit (3) indicates width of the bearing.
- ✓ Fourth digit indicate type of ball bearing
  Ex: 6 series for deep groove ball bearing

▼ Examples of basic codes for the designation of bearing series and bearing bores according to DIN 623

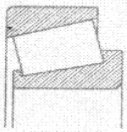
Deep groove ball bearing
Width series 0
Diameter series 2
06 · 5 ≙ 30 mm bore
6206



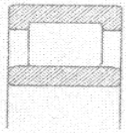
Angular contact ball bearing, single row
Width series 0
Diameter series 3
05 · 5 ≙ 25 mm bore
7305B



Tapered roller bearing
Width series 0
Diameter series 2
09 · 5 ≙ 45 mm bore
30209A



Cylindrical roller bearing
Lips on outer ring
Width series 2
Diameter series 3
14 · 5 ≙ 70 mm bore
NU2314E



▼ Designation for metric tapered roller bearings according to DIN ISO 355

Example: T 3 D B 045

Bearing bore in mm

Ratio of bearing width to cross section height

Width series $\frac{T}{(D-d)^{0.95}}$

	over	to
A	reserved	
B	0.50	0.68
C	0.68	0.80
D	0.80	0.88
E	0.88	1.00

Code letter for tapered roller bearings

Contact angle range

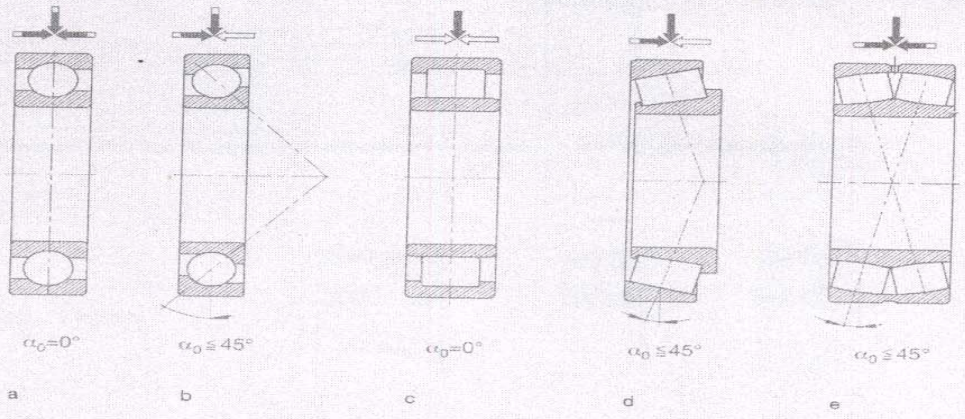
Angle series	Contact angle range over	to
1	reserved	
2	10°	13°52'
3	13°52'	15°59'
4	15°59'	18°55'
5	18°55'	23°
6	23°	27°
7	27°	30°

Ratio of outside diameter to bore

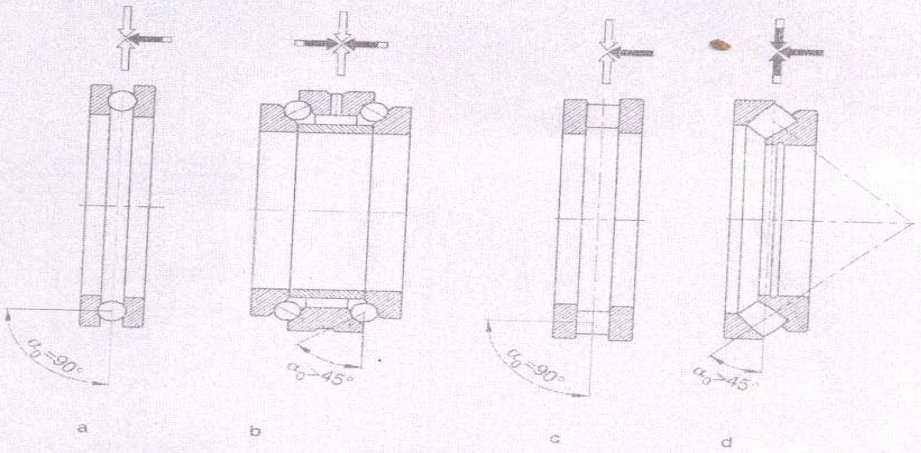
Dia-meter series $\frac{D}{d^{0.77}}$

	over	to
A	reserved	
B	3.40	3.80
C	3.80	4.40
D	4.40	4.70
E	4.70	5.00
F	5.00	5.60
G	5.60	7.00

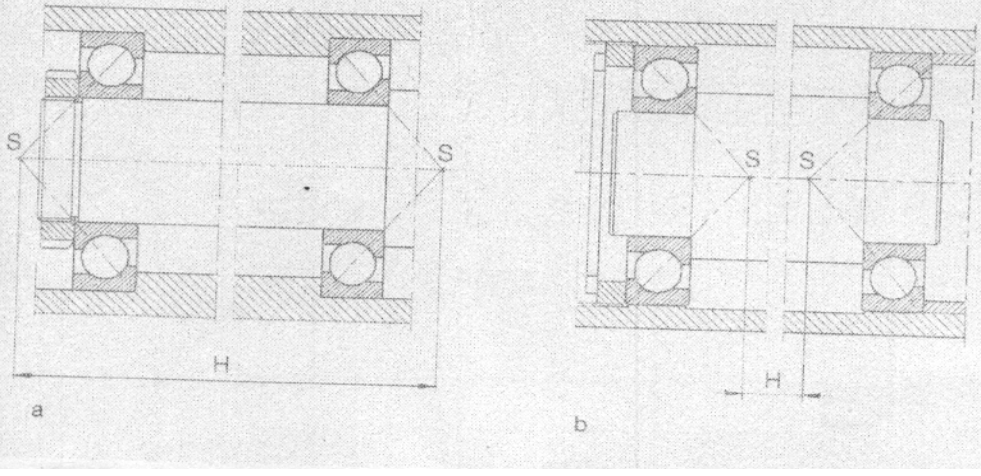
▼ Radial bearings with a nominal contact angle $\alpha_0 \leqq 45°$ predominantly for radial loads
a = deep groove ball bearing, b = angular contact ball bearing, c = cylindrical roller bearing NU, d = tapered roller bearing, e = spherical roller bearing



▼ Axial bearings with a nominal contact angle $\alpha_0 > 45°$ predominantly for axial loads
a = thrust ball bearing, b = angular contact thrust ball bearing, c = cylindrical roller thrust bearing, d = spherical roller thrust bearing



▼ Adjusted bearing arrangement with angular contact ball bearings in O arrangement (a)
Adjusted bearing arrangement with angular contact ball bearings in X arrangement (b)



BELT, CHAIN AND GEAR DRIVES

BELT DRIVE

In industries, normally mechanical power is transmitted from one shaft to another by means of belt, rope and chain drives.

Types of belt

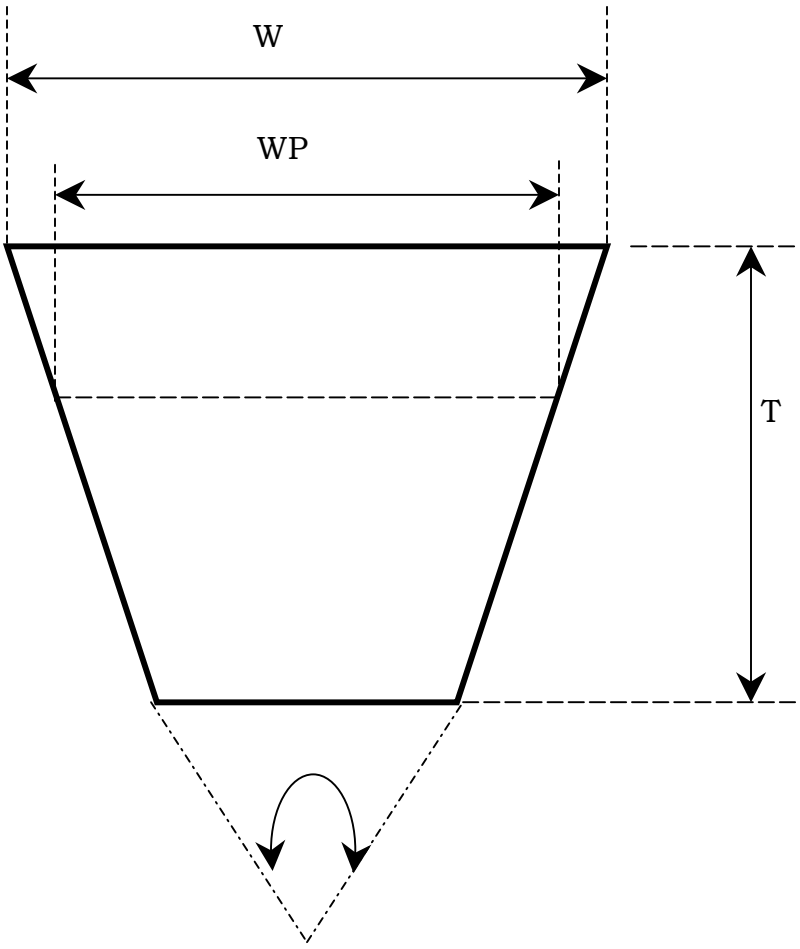
sl	Classification of belt	Power transmission capacity	Distance between driver and follower	Relative motion	Contact area
1	flat belt	moderate	Not more than 10 m	Partly turning and partly sliding	Belt runs over the plat pulleys
2	v-belt	high	Not more than 2m	Partly turning and partly sliding	a) V-belt runs in the grooved pulley. b) Effect of the groove is to increase the frictional grip between belt and pulley. c) V-belt is in contact with side faces of the groove not with bottom to have good grip.
3	Circular belt or rope	high	Not more than 5m	Partly turning and partly sliding	a) Rope runs in the grooved pulley. b) Effect of the groove is to increase the frictional grip. c) Rope is in contact with side faces of the groove not at the bottom to have good grip.

TYPES OF BELT DRIVE

SL NO		Direction of rotation	Tension of belt
01	Open belt drive	Wheels move in the opposite direction	Tension of the belt is more in the lower side of the drive
02	Cross belt drive	Wheels move in the same direction	Tension of the belt is more in the upper side of the drive.

V-BELT DIMENTIONS

.

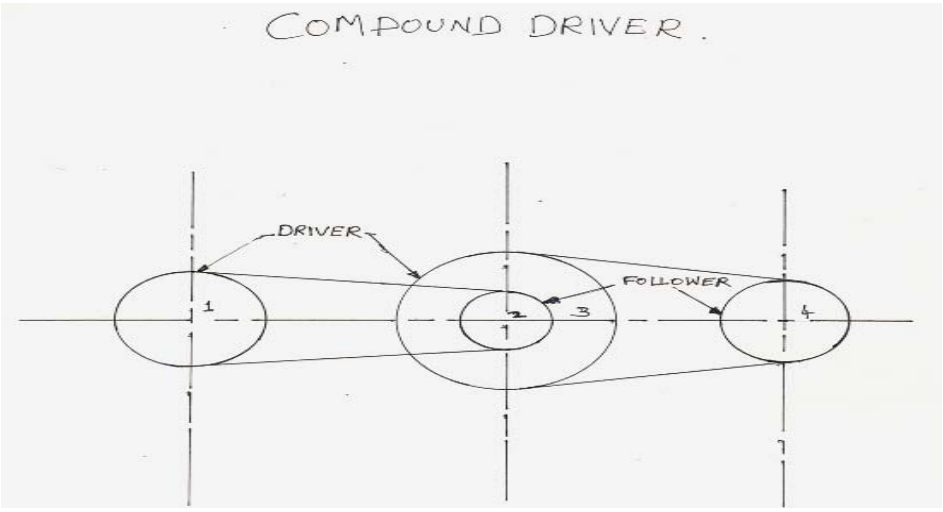


- W – National top width.
- WP - Pitch Width.
- T – Nominal Height.

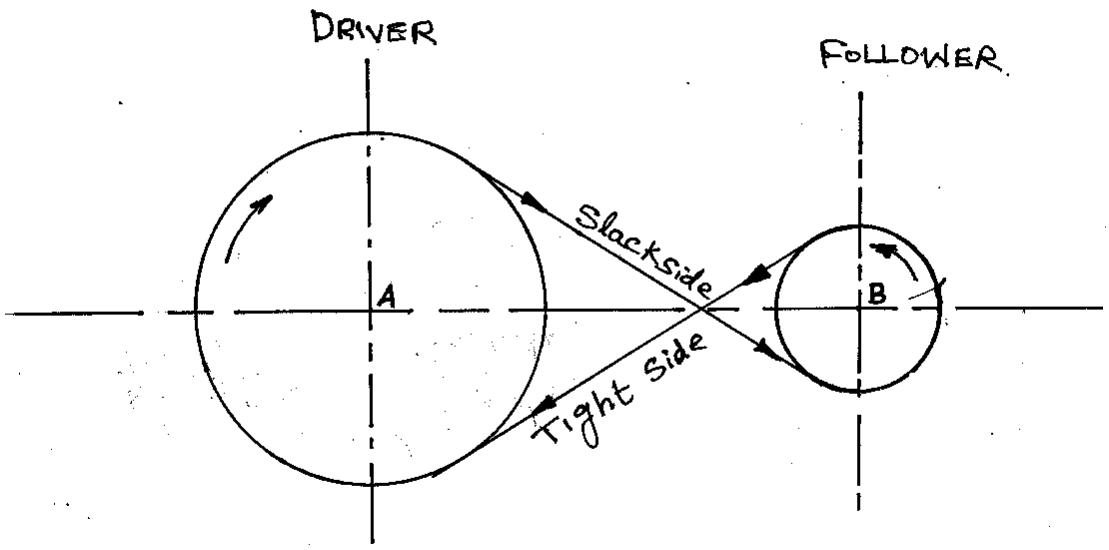
Cross section symbol	Pitch width WP In mm	Nominal top width W in mm	Nominal height T in mm	Nominal angle In degree
Z	8.5	10.0	6.0	40
A	11.0	13.0	8.0	40
B	14.0	17.0	11.0	40
C	19.0	22.0	14.0	40
D	27.0	32.0	19.0	40
E	32.0	38.0	23.0	40

When the driver rotates, it carries the belt due to grip between its surface and the belt. The belt, in turn, carries the driven pulley which starts rotating. The grip between the pulley and belt is obtained by friction, which arises from the pressure between the belt and the pulleys. This frictional grip, if required, is increased by tightening

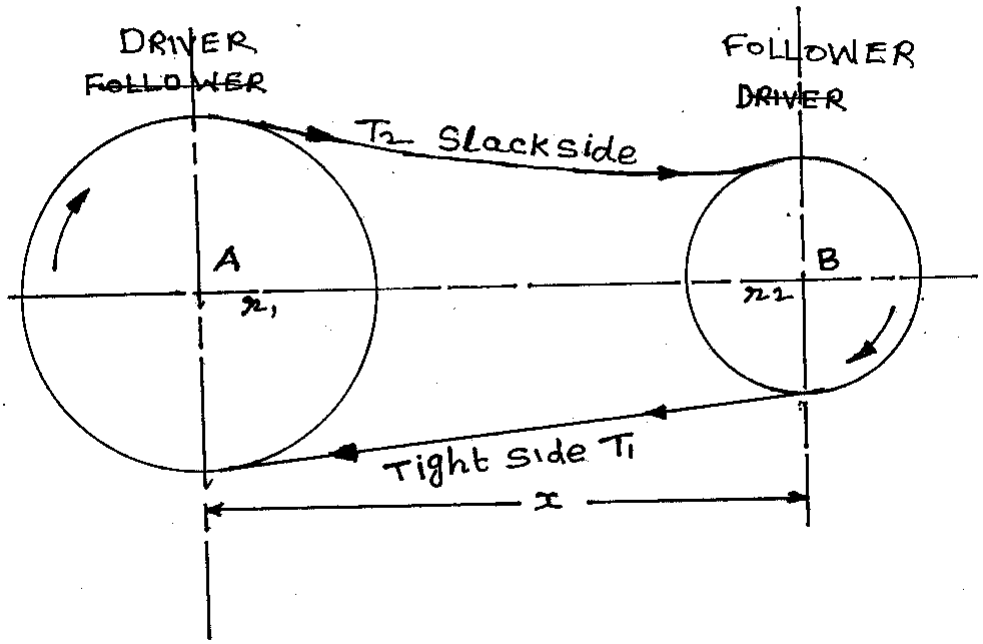
The forward motion of the belt without carrying the driven pulley with it is called slip of the belt. It will reduce the velocity ratio of the system. In order to increase the grip, the belt is tightened up. When tangential force exceeds the frictional resistance slipping will take place between pulley and belt. Then no further more tightening, Chain drive will replace the belt drive to eliminate slippage and obtain perfect velocity ratio. Chain drive is a combination of chain and sprocket /wheel. The projection of the wheel fit into cavities in the chain and moves together without slipping and ensure perfect velocity ratio



CROSS BELT DRIVE



OPEN BELT DRIVE



CHAIN DRIVE

TYPES OF CHAIN

6. Bush roller chain
7. Inverted tooth / silent chain

BUSH ROLLER CHAIN: Consists of

a. Pins
b. Bushes
c. Rollers
d. Outer plates / pin link plates
e. Inner plates / roller link plates

Pin posses through the bush which is secured in the holes of the roller between the two sides of the chain.
The rollers are free to rotate on the bush which protects the sprocket wheel teeth against wear.

ADVANTAGE:

1. Extremely strong.
2. simple in construction
3. It gives good service under severe conditions.
4. It can be used where there is a little lubrication.

DISADVANTAGE:

1. It makes little noise due to impact of the rollers on the sprocket / wheels.
2. When one of these chains elongates slightly due to wear and stretching of the parts, then the extended chain is of greater pitch than the pitch of the sprocket wheel teeth. The rollers then fit unequally into the cavities of the wheel. The result is that the total load falls on one tooth or on a few teeth. The stretching of the parts increase wears of the surfaces of the roller and of the sprocket wheel teeth.

ADVANTAGE OF INVERTED TOOTH CHAIN OVER BUSH ROLLER CHAIN:

1. It will eliminate both stretching and noise.
2. When the chain stretches and the pitch of the chain increases, the links ride on the teeth of the sprocket wheel at a slightly increased radius. This automatically corrects the small change in the pitch. There is no relative sliding between the teeth of the inverted tooth chain and the sprocket wheel teeth when properly lubricated. This chain gives durable service and runs very smoothly and quietly.

Power transmission system in precision machine requires definite velocity ratio to eliminate the effect of slippage. Positive drive like gears are very useful when the distance between shaft is very near.

VELOCITY RATIO:

$\Pi D_1N_1 = \Pi D_2N_2$

$D_1N_1 = D_2N_2$

VELOCITY RATIO = $N_2/ N_1 = D_1/ D_2$

DIFFERENCE BETWEEN CHAIN DRIVE AND BELT DRIVE

SL NO	CHAIN DRIVE	BELT DRIVE
01	No possibility of slippage. we can obtained perfect velocity ratio	Possibility of belt slippage imperfect velocity ratio
02	Requires less space	Requires more space
03	Suitable for short distance	We can use for long distance
04	Transmission efficiency is more	Transmission efficiency is less
05	Cost is more	Cost is less
06	Requires more maintenance	Requires less maintenance
07	Lubrication is required	Lubrication is not required

CHAIN LUBRICATION

Most chain drives need regular lubrication to reach their expected life. Good quality, non- detergent, petroleum-based oil that flows freely into chain joints at the operating temperatures should be used. Thick oils or greases should not be used because they cannot flow to internal chain surfaces.

The oil supply must be kept clean and the chain drive should be shielded from abrasive debris and moisture. Oil should be applied to the upper edges of link plates in the slack or lower span of the chain. This allows oil to reach the pin and bushing area. Oil must be applied to each row of link plates in multiple strand chain.

The lubricant must be applied often enough to prevent a reddish-brown or rusty discoloration of oil in the chain joints. The rusty discoloration indicates joints are becoming dry.

There are three basic types of roller chain drive lubrication: manual or drip, oil bath or slinger disk and oil stream.

DRIP LUBRICATION:

Drip lubrication allows oil from a reservoir to drop on upper link plate edges as the chain is moving. Recommended flow rates range from 4 to 10 drops per minute at low chain speeds (50 to 100 FPM) to a minimum of 20 drops per minute at higher chain speeds (200 to 300 FPM). These flow rates are for each side of each strand of chain. The amount of oil must be enough to prevent a rusty discoloration of oil in the chain joints.

OIL-BATH LUBRICATION:

The chain runs through oil in the sump of an oil tight housing. The oil level should just reach the pitch-line of the chain at its lowest point of operation. A long section of chain running through the bath causes the oil to foam and overheat.

Oil level in the sump should be checked after every 8 hours of operation. At the same time the sump should be checked for foaming, leaking and oil temperature over 180°F. if any of these conditions are found, the problem should be corrected.

OIL STREAM LUBRICATION:

Oil stream lubrication is required for high speed and high power drives. An oil pump continuously sprays a high volume stream of oil on each strand of chain in the lower span to both lubricate and cool the drive.

The oil level in the reservoir should be checked after every 8 hours of operation. The drive should also be checked for leakage and oil temperature above 180°F.

INSPECTION/SERVICE:

An effective maintenance program for roller chain should include correct type and adequate amounts of lubrication, replacement of worn chains and sprockets and elimination of drive interferences. It is important to set up a lubrication and inspection/correction schedule to ensure that all required maintenance is carried out.

A newly installed drive should be inspected and serviced after about 100hours of operation. Drives should then be serviced after every 500hours of operation. Drives running in severe conditions or heavy

shock loading should be serviced after every 200hours of operation. However the oil change period can be followed as per recommendation of OEM and oil manufacturer.

When drives are serviced, the lubrication system, drive alignment, chain tension, chain and sprocket wear, and drive interference should be checked. If the chain is dirty, it should be cleaned with a nonflammable solvent and re-lubricated.

Manual lubrication intervals should be verified. Drip flow rates and oil drop direction should be checked. Orifices used with oil stream lubrication should be open. Oil should be changed at every normal inspection.

Check the inside surfaces of chain roller links and sprocket flange faces. If these surfaces are noticeably worn, check for drive misalignment. Use a feeler bar and machinist's level to verify parallelism and level. A straightedge should be used to check alignment of sprockets. Inspect chain tension by measuring the amount of chain movement in the slack span and adjust as required. Many drives are adjusted by changing center distances or moving an idler.

Check chain wear by measuring chain length over the number of pitches nearest to 1 ft. if that measured length is 3% (approximately 0.36in.) over nominal, the chain is worn and should be replaced. A chain worn less than 3% can cause a drive to operate roughly or lose timing. When this happens, the chain has reached the end of its useful life and should be replaced.

Sprocket wear can be checked by examining chain engagement and tooth condition. If the chain binds or engages and disengages roughly or the sprocket tooth tips are hooked the sprocket teeth are worn and the sprocket should be replaced.

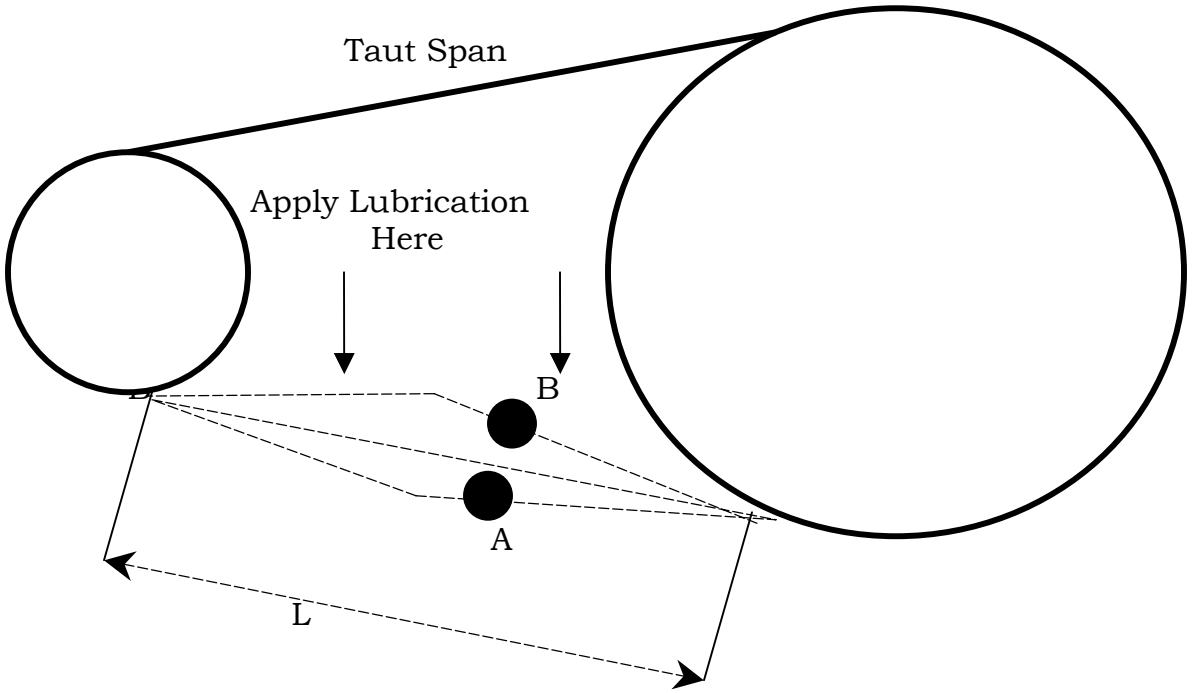
Do not run a new chain on worn sprockets or vice versa. The chain or sprocket wears rapidly or becomes damaged.

Inspect the chain for any sign of rubbing or striking other equipment. This condition shortens chain life and should be corrected as soon as possible.

Remove any buildup of debris or foreign material in sprocket teeth. A relatively small amount of debris at the bottom of sprocket teeth can cause tensile loads great enough to break the chain.

Inspect the chain for broken, cracked or deformed parts. If any are found, replace the entire chain. Even if the rest of the chain appears to be in good condition, it probably has hidden damage and could fail at any time.

CHAIN TENSION



RECOMMENDED MID-SPAN MOVEMENT, AB, IN.

	Tangent length between sprockets, L, in.								
Drive centre-line	5	10	15	20	30	40	60	80	100
Horizontal to 45 deg	0.25	0.5	0.75	1	1.5	2	3	4	5
Vertical to 45 deg	0.12	0.25	0.38	0.5	0.75	1	1.5	2	2.5

NOTE: Incorrect tension causes excessive wear or erratic performance.

Worn sprocket teeth should never be built up with weld and ground down. It is impossible to achieve correct tooth profiles and the chain will be damaged.

CLASSIFICATION OF GEARS

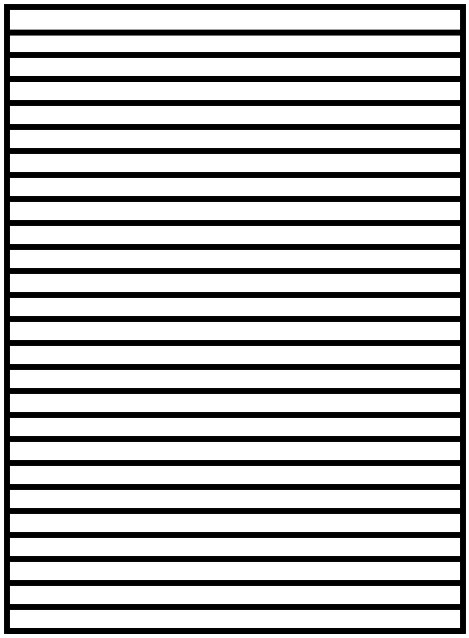
sl.	Position of axis of the shaft	Peripheral velocity of gears	Types of gearing	Position of teeth on the surfaces of gears
01	a)Parallel b)Intersecting c) Non intersecting and non parallel	a) low velocity up to 3m/s b) Medium velocity 3m/s to 15m/s c) high velocity more than 15m/s	External Internal Rack and pinion	1) Teeth 2) Straight inclined teeth 3) Curved teeth

TYPES OF GEARS:

1) Spur gear
2) Helical gear
3) Herringbone gear
4) Bevel gear
5) Helical bevel gear
6) Spiral gear/skew bevel gear/ screw gear.

SPUR GEAR:

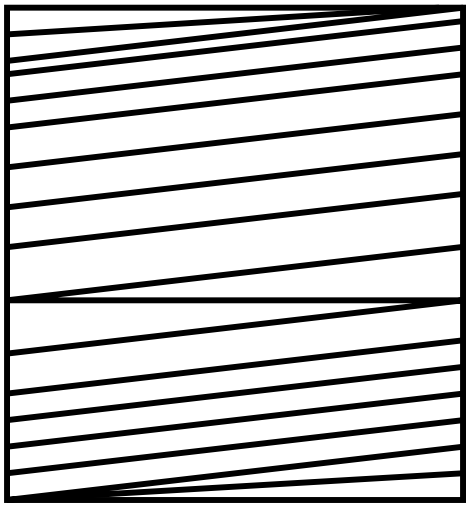
1) Shafts are parallel and co-planar.
2) Teeth are parallel to the axis of wheel.



3) Line contact.

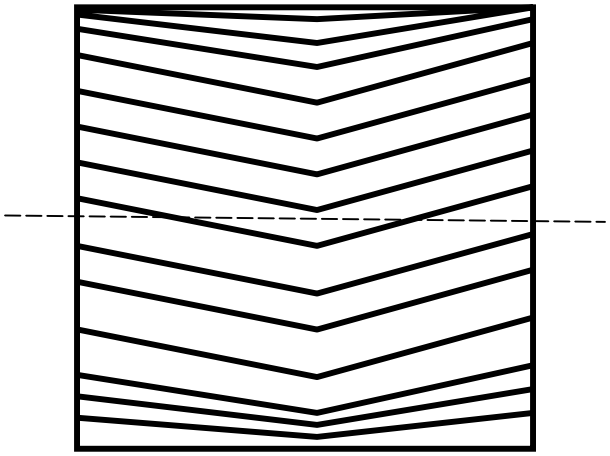
HELICAL GEAR:

1. Shafts are parallel and co-planar
2. Another name of spur gear is called helical gear.
3. Teeth are inclined to axis of wheel.
4. Helical may be right handed on one wheel and left handed on the other wheel of a simple gear train.
5. It provides gradual engagement and continuous contact of the engaging teeth.
6. Its drive is smooth and efficiency is high.
7. Contact of teeth produce axial thrust.
8. Line contact.



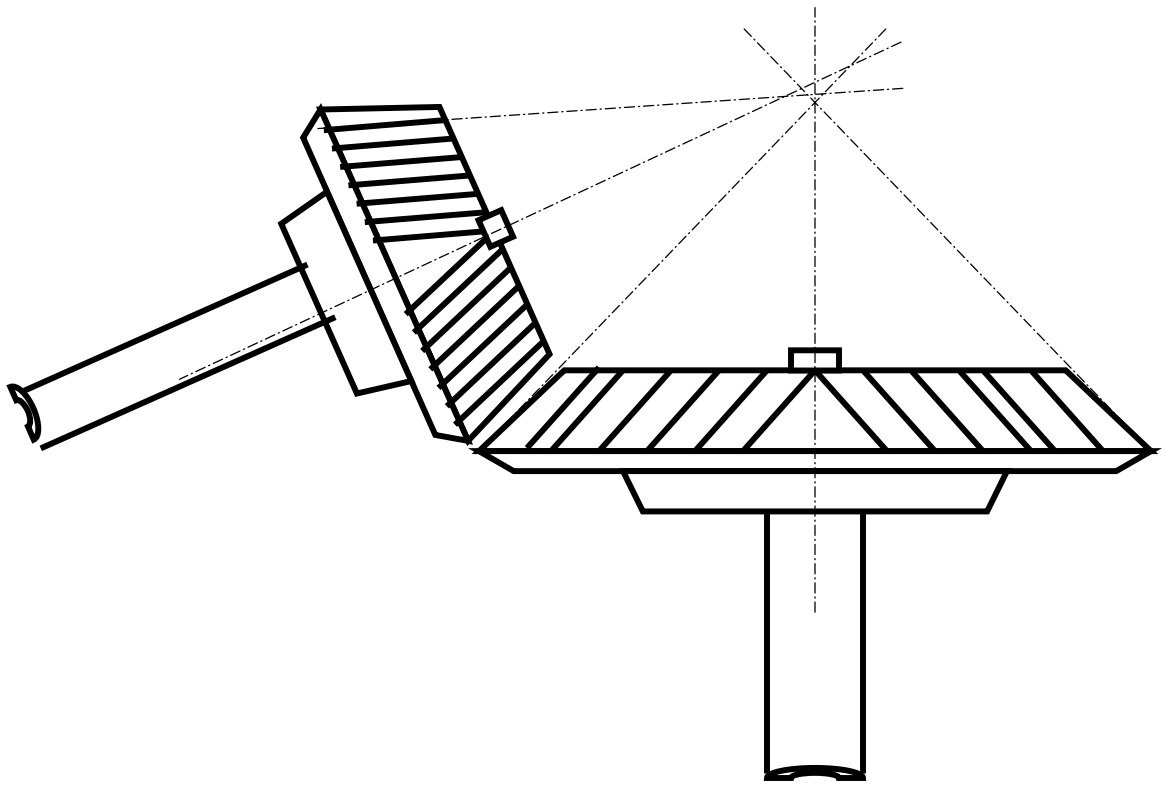
HERRINGBONE GEAR:

1) Double helical is called herringbone gear.
2) Axial thrust is zero.
3) It is replacement for helical gear where axial thrust must be zero.



BEVEL GEAR:

1) Shafts are nonparallel, intersecting and co-planar.
2) Line contact.



HELICAL BEVEL GEAR:

1) Shafts are nonparallel, intersecting and co-planar.
2) Another name of bevel gear is called helical bevel gear.
3) Teeth are inclined to the face of the bevel.
4) Line contact.

SPIRAL/ SKEW BEVEL/ SCREW GEAR:

1) Nonparallel, nonintersecting and non co-planar.
2) Suitable for small power transmission.
3) Point contact.

TYPES OF GEARING

SL	External gearing	Internal gearing	Rack and pinion
	a) two shafts mesh externally with each other b) large wheel is spur wheel and	o shafts mesh internally th each other b)large heel annular and small heel pinion c)direction of rotation	a)gear of a shaft meshes externally and internally with the gears in a

	small is pinion c) direction of wheels are alike	is like	straight line such a type of gear is called rack and pinion b) the

GEAR TRAIN

Depending on velocity ratio and relative position of the axes of shafts, two or more gears are arranged to mesh with each other to transmit power is called gear train.

Types of gear train:

1) Simple gear train
2) Compound gear train
3) Inverted gear train
4) Epicyclical gear train

The clearance between the teeth of two meshing gears is called back lash.

SCREW THREADS

The threads cut on the surface of a screw are called external threads whereas those cut in a hole are called internal threads. Threaded joints are highly reliable in operation and can be obtained in a wide range suitable for different conditions. They are relatively cheaper to produce due to standardization and efficient methods of manufacturing. Normally screwed fastenings remain tight under static loads; however, many of these fasteners become loose under the action of cyclic loads or machine vibration.

PARTS OF SCREW THREAD:

PITCH: It is the distance between the corresponding points on the consecutive thread measured parallel to the axis of screw.

LEAD: It is the distance that a nut will advance along the axis of thread in one turn or revolution. In single start thread, lead is equal to pitch.

L=p

Where

L = lead

P = pitch

In double start thread L = 2p

For multi start thread L = n x p

ANGLE OF THREAD: The angle included between the sides of the thread is known as angle of thread.

CREST: Crest is the top surface joining the two sides of a thread.

ROOT: It is the bottom surface joining the sides of two adjacent threads.

FLANK: It is the surface between the crest and the root of thread.

DEPTH OF THREAD:

- ✓ It is defined as the distance measured perpendicular to the axis.
- ✓ Thread depth = (Major diameter – Minor diameter) x ½.

THREAD DIAMETERS:

A thread has following three diameters:

- ✓ Major or outside diameter or Nominal diameter
- ✓ Minor diameter or core diameter or Root diameter.

1) Pitch diameter or mean effective diameter.

MAJOR DIAMETER:

- ✓ It is the largest diameter of screw thread.
- ✓ Major diameter = minor diameter + 2 x depth of thread.

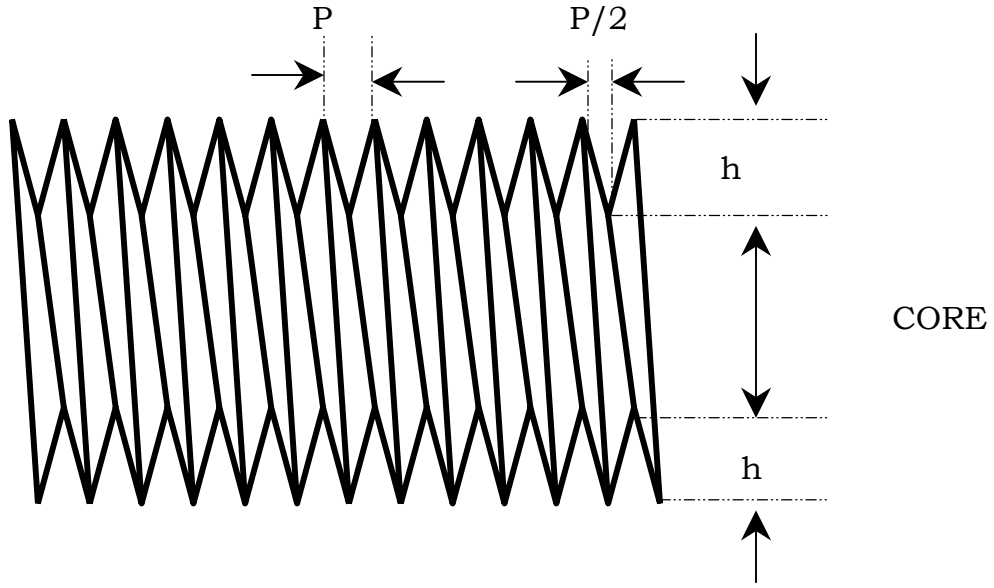
MINOR DIAMETER: It is the smallest diameter of a screw thread.

PITCH DIAMETER:

It is defined as the diameter of an imaginary cylinder, which would pass through the threads at such points that the width of grooves and the width of threads cut by the surface of cylinder are the same.
Pitch diameter = Major diameter – depth of thread.

LEFT HAND THREADS:

- ✓ A left hand thread advance into a threaded hole when turn anti-clockwise.

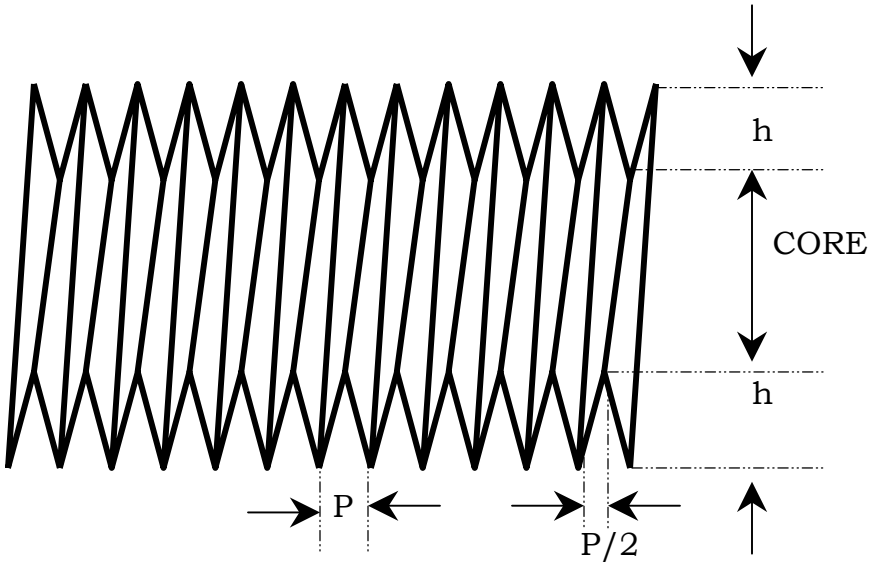


LEFT HAND THREADS

- ✓ In this thread,
  1. h = height of thread
     = 0.64 p

Where p = pitch of thread.
Slope of thread = p/2

RIGHT HAND THREAD:
A thread is said to be right hand thread if it advances into a threaded hole when turned clockwise.



RIGHT HAND THREADS

In this thread, h = 0.64 p
Where p = pitch of thread.

TYPES OF THREADS:

- British association threads (BA).
- V threads.
- British standard whitworth thread (B.S.W.).
- Square thread.
- Acme thread.
- Buttress knuckle thread.
- Knuckle Thread.
- American standard thread (national).
- Metric thread.

BRITISH ASSOCIATION THREAD: British association threads are rounded V threads. The thread angle is 47½° and they have fine pitches. They are used on screws for precision work such as instruments.

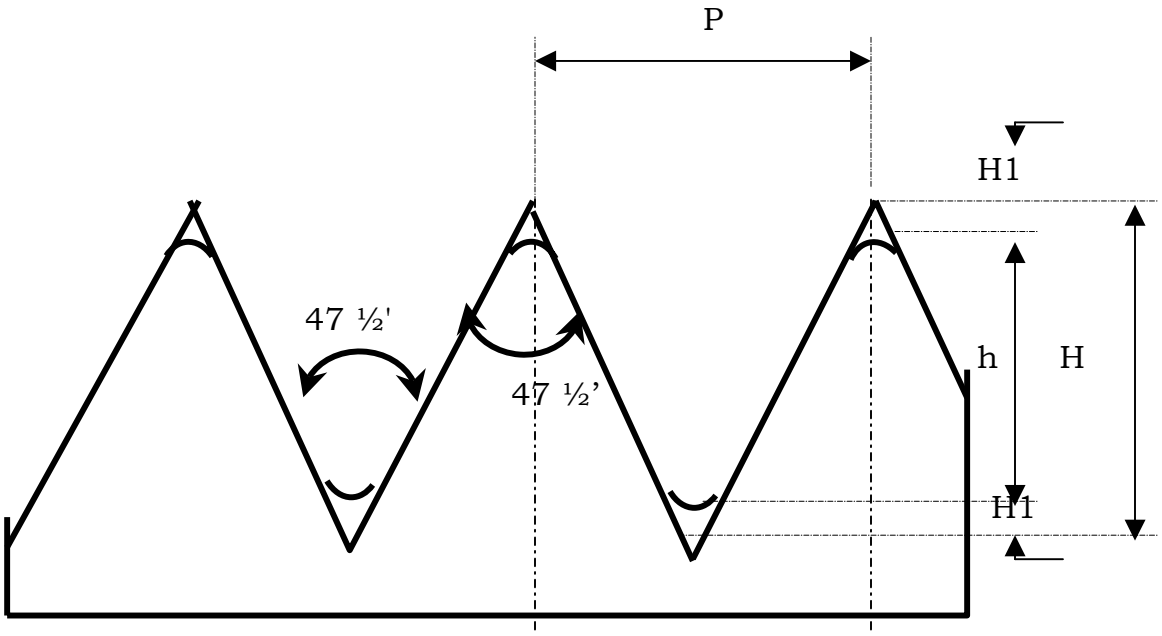
- ✓ h = 0.6 p
- ✓ H = 1.136 p

- ✓ $H_1 = 0.236\ H$

  Where

  p = pitch

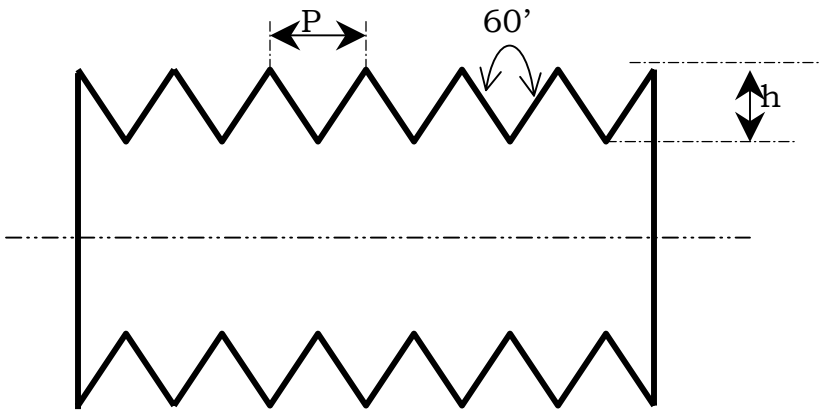
  h = depth of thread.



BRITISH ASSOCIATION (B.A) THREADS.

V THREADS: the V threads do not have rounded corner and their thread angle is 60 °. V threads are stronger than square threads and can be easily cut with the machine or with the help of a tap and die.

h = 0.866 p

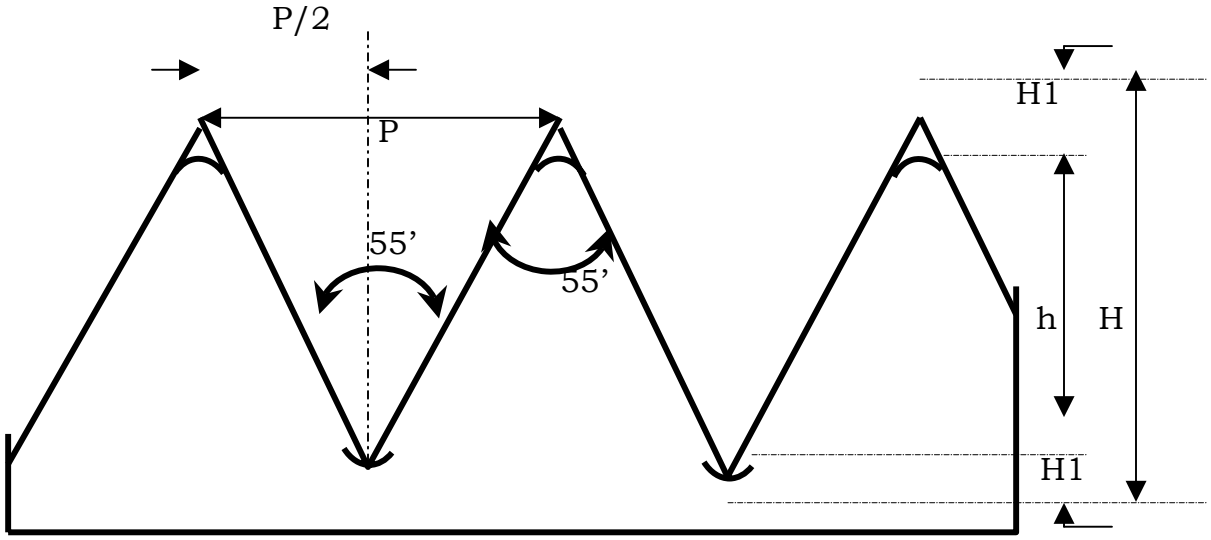


V- THREAD

BRITISH STANDARD WHITWORTH THREAD (B.S.W.)

They are rounded V threads and have an angle of 55^o. Its rounded top or crest is not so easily abraded as in V threads and the rounded groove bottom reduces the stress concentration that occurs at sharp corners. They are used on bolts, screwed fastenings and British standard pipe threads.

- ✓ h = 0.64 p
- ✓ H = 0.96 p
- ✓ H_1 = H/6

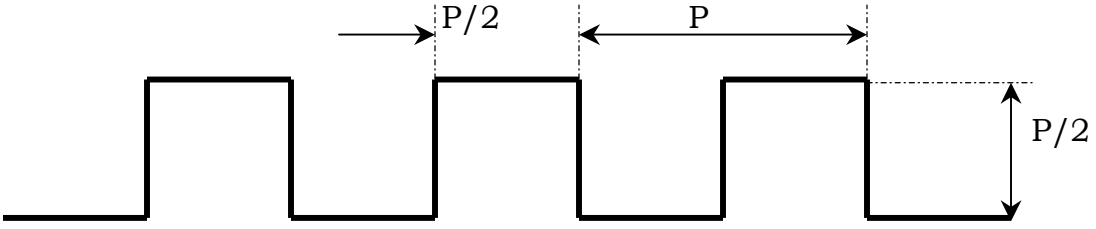


BRITISH STANDARD WHITWORTH (B.S.W) THREADS.

SQUARE THREAD:

The section of the thread is square. The mechanical efficiency of this thread is more than V threads. It is most commonly used for driving purposes and transmission of motion. Square threads can be used in lathe, vices and screw jack.

- ✓ Depth of the thread h = p/2
- ✓ Width of thread = p/2
- ✓ Where p = pitch

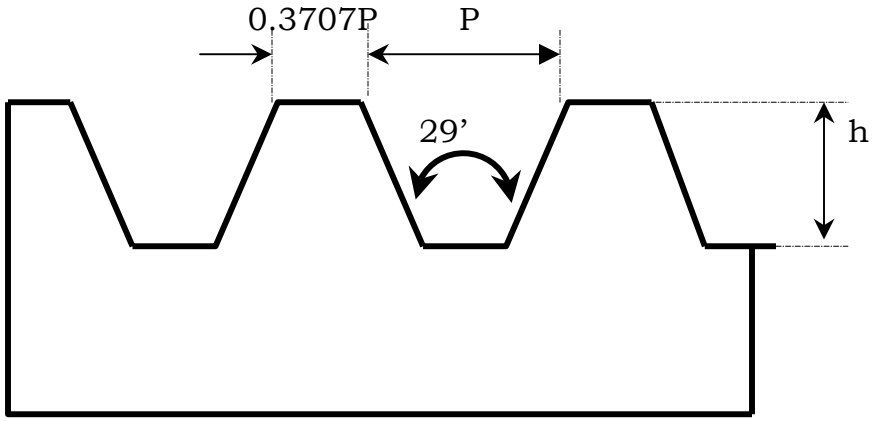


SQUARE THREAD.

ACRME THREAD:

This thread is stronger than square threads and can be easily produced as dies may be used in cutting this thread. This thread is used on lead screws of lathes, as it is easier to engage a split nut with this thread.

- ✓ h = p/2 + 0.25 mm
- ✓ Thread angle = 29 °

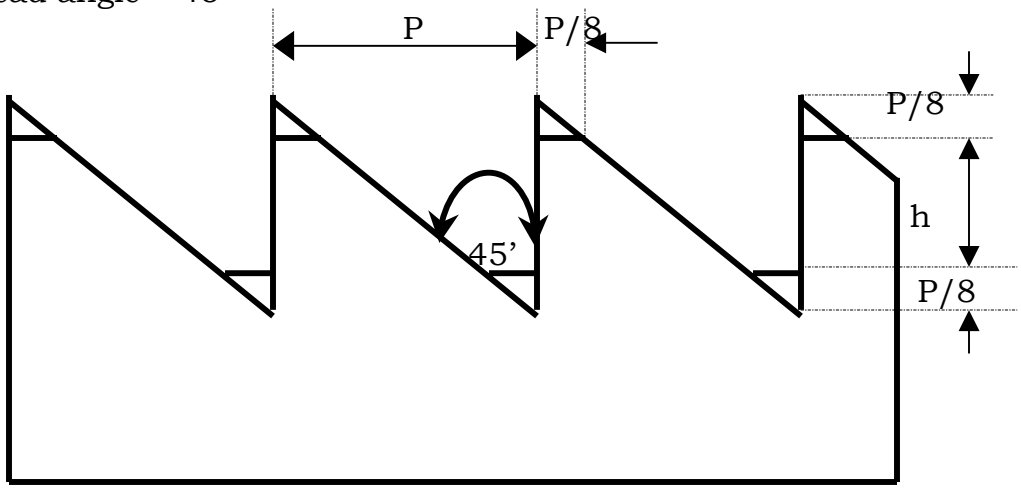


ACME THREAD

BUTTRESS THREAD:

These threads are used to resist axial loads in one direction only. The spindles of bench vices have buttress threads. Buttress thread has the efficiency of square thread.

- ✓ h = height (depth) of thread
  = 3/4 p
- ✓ Thread angle = 45 °

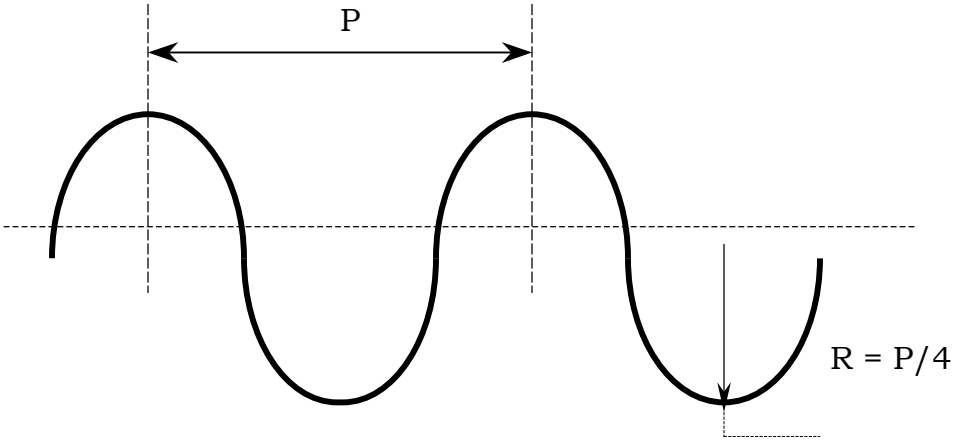


KNUCKLE THREAD:

It can easily resist great strain and rough use. It can be easily cast or rolled but cannot be easily made on machine. It is used in railway carriage coupling screws and in electric bulbs and sockets, and on objects made up of glass, plastics etc.

- ✓ Radius at top and bottom = p/2
- ✓ Depth (h) = p/2

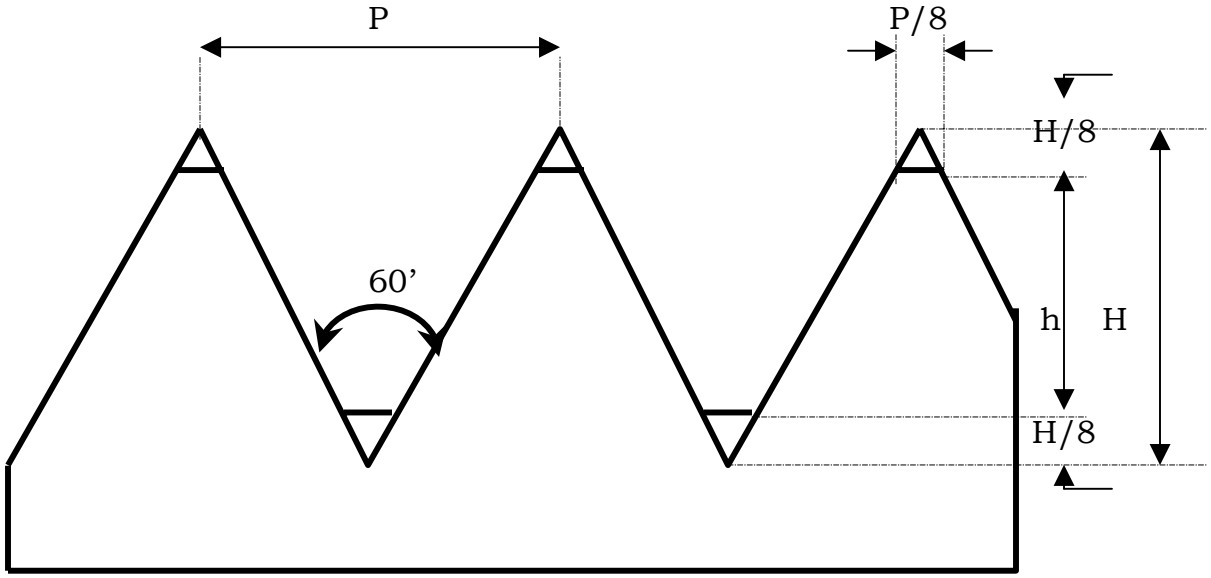
KNUCKLE THREAD



AMERICAN STANDARD THREAD (NATIONAL):

This thread is similar to V thread in which 60 ^{o} angles has been retained but the top and root has been flattened. This thread is used for nuts, bolts, and screws and tapped holes.

- ✓ H = 0.866 p
- ✓ h = 3/4 H



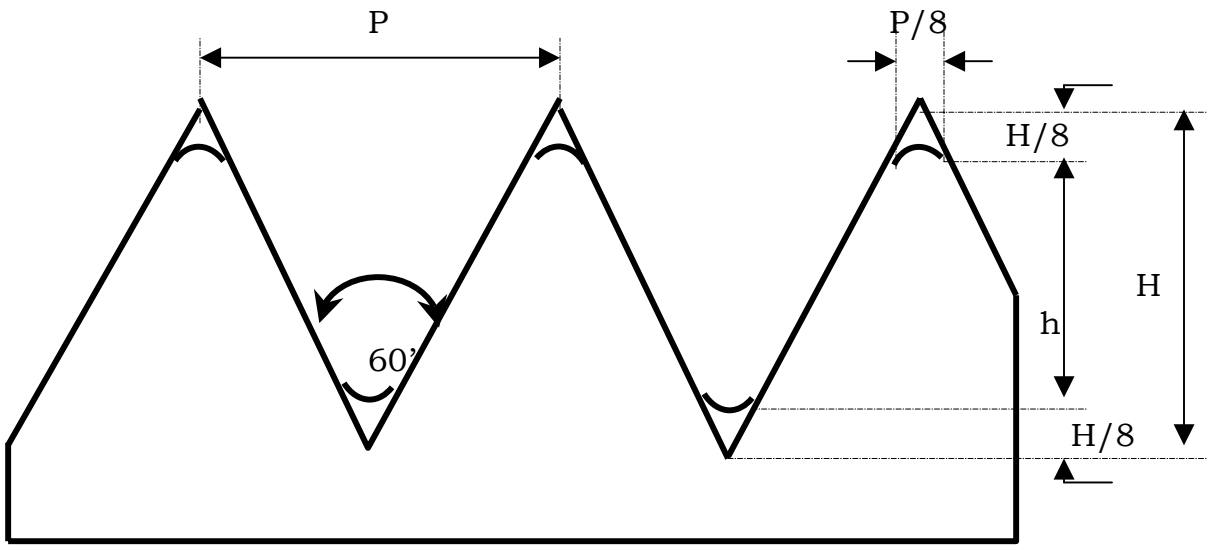
AMERICAN (NATIONAL) STANDARD THREAD.

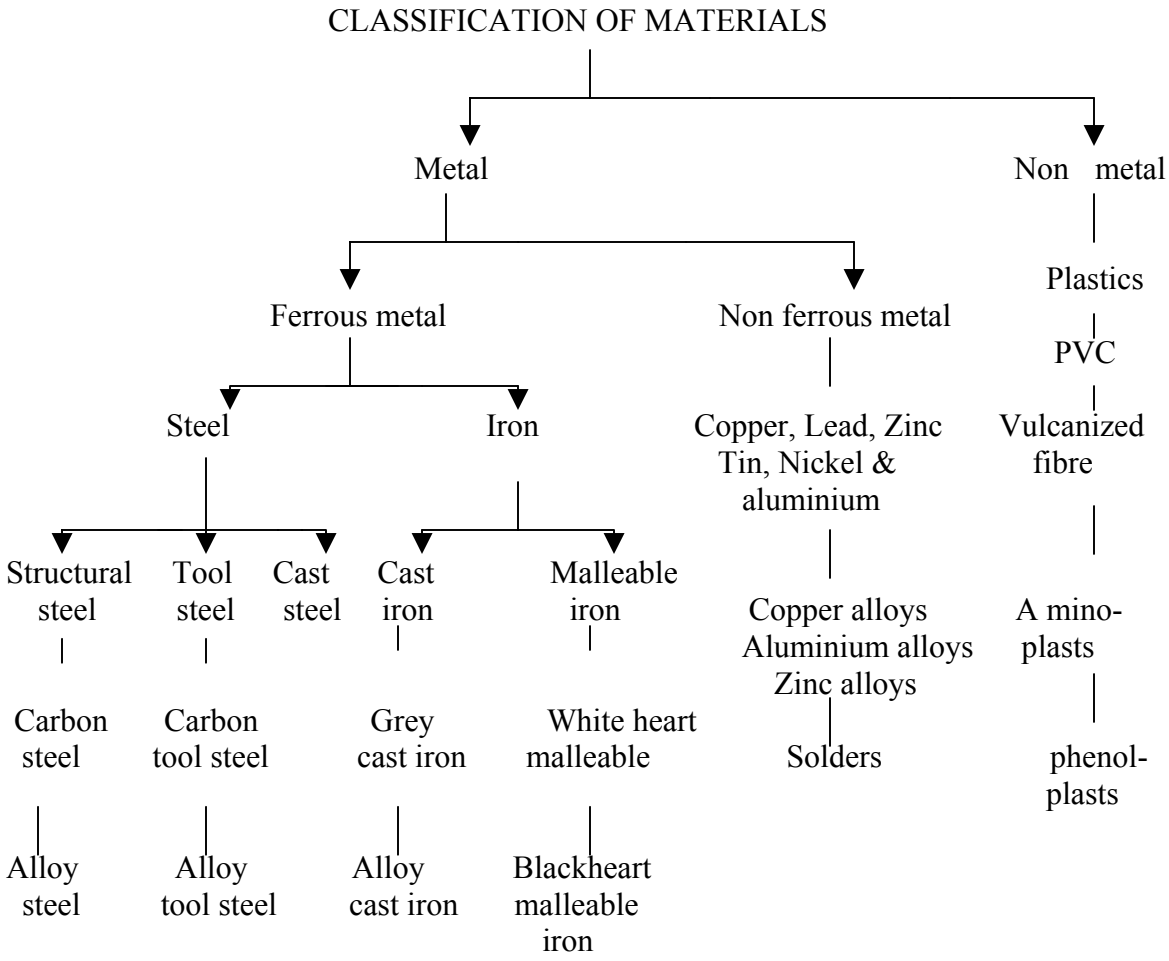
METRIC THREAD:

The letter M followed by diameter and pitch, the two being separated by the sign X designs metric threads.

For example: M 12 x 1.25 C

- Diameter of threaded part =12 mm
- Pitch of the thread = 1.25 mm
- C stands for coarse thread.
- If the thread is fine, letter f is used.
- Thread angle is 60 °





All the materials are made of atoms. An atom of an element is the smallest particle that retains the physical characteristics of that element.

Pure metals find few applications in engineering, because they are difficult to produce in pure condition and also they have poor strength in the pure form. Pure metals are relatively weak and soft compared with ordinary structural materials, but their hardness and strength increase with decrease in grain size. Two important characteristics of metals are their tendency to strain harden and to recrystallise. Whenever any metal is plastically deformed its grains change in shape from a roughly spherical form to an elongated one. The metal becomes harder and stronger as it is deformed. This effect is known as strain hardening and is most pronounced in the grained metals.

When a strained metal is heated, there is a temperature at which new spherical crystals first begin to form from the old deformed ones. This temperature is known as the recrystallisation temperature and process is

called strain recrystallisation or process annealing. For iron it occurs at about 650^{o}C.

Pure iron is soft and has got silvery white colour. It is strongly magnetic in the presence of a magnetic field or electric current. It doesn't have retention power in the absence of magnetic field or current. The power of retentivity of magnetism of pure iron is improved by the addition of other elements such as carbon, cobalt or nickel. Iron loses its magnetic properties when heated to 770^{o}C. it again attains its magnetic properties when cooled below 770^{o}C.

CLASSIFICATION OF IRON AND STEEL

Iron as available commercially is not a high purity metal, but contains other chemical elements which have profound effects on its physical and mechanical properties. The amount and distribution of these elements are dependent upon the method of manufacture. The most important commercial forms of iron are:

1. Pig iron
2. Cast iron
3. Grey cast iron
4. White cast iron
5. Malleable cast iron
6. Wrought iron
7. Steel
8. Carbon steel
9. Alloy steel

PIG IRON: All iron produced in blast furnace is called pig iron. Iron ore, coke and limestone are charged into a blast furnace to produce pig iron. Pig iron has impurities such as phosphorus, silicon, manganese, sulphur and carbon. Pig iron can be regarded as an impure form of cast iron and it is the raw material for practically all iron and steel products.

IMPURITIES AND THEIR EFFECTS IN PIG IRON

Sl.no.	Element	%	Effects
01	phosphorus	0.4% to 1.0%	It increases fluidity of molten iron for moulding processes.
02	Sulphur	0.4% to 1.0%	Iron become hard and produces unsound castings.
03	silicon	1.0% TO 4.0%	Silicon decreases the hardness and strength of iron. Silicon acts as

			softener in cast iron as it increases the free carbon and decreases the combined carbon. By adding nickel and copper we can increase the strength of the iron.
04	Manganese	0.2% to 1.5%	Reduce the sulphur content Increase tensile strength Increase hardness of cast iron
05	Carbon	4% to 4.5%	Source of carbon in steel is coal. Carbon in pig iron increases its hardness.

Due to presence of these impurities in pig iron, pig iron is too brittle and possesses very little strength and ductility. it can not be shaped into different articles by processes such as forging or hammering.

CAST IRON

CAST IRON: is an alloy of iron with a carbon content of 2-5%, silicon content of 1-3% and manganese of up to 1%. It has very low ductility, low strength and brittle. Weldability of cast iron is poor due to high carbon content.

Pig iron is melted in cupola furnace with scrap steel or scrap iron to control the percentage of carbon and impurities and then cast into moulds of the desired shape. It is then called cast iron. Cast irons have relatively high carbon content (1.5% to 5%) where as steels contain up to 2% carbon.
Carbon in cast iron can be present in two forms:

1. Combined carbon as carbide.
2. Graphite is a mechanical mixture.

Cast iron having all the carbon in graphite form is soft, easily machinable metal having high damping capacity and high compressive strength and has self-lubricating characteristics. But tensile strength, ductility and impact strength are much lower than steel owing to the weakening effect of the graphite flakes. It is used for basic structure of machine tools and structural members loaded in compression.

Cast iron which has got high content of carbon in the form of carbide is hard, brittle and unmachinable and has got resistance to wear. Slow cooling helps the formation of graphite and when the rate of cooling is rapid cementite is formed. Close grained iron containing

graphite and pearlite is the strongest, toughest and best finishing type of cast iron. Cast iron has lower melting point as compare to steel (1135 to 1250^{o}C)
Steel melting point is 1500 ^{o}C

DIFFERENT FORMS OF CAST IRON AND THEIR EFFECTS

Sl.no.	elemen t	Raw material	proce ss	Carbon formation and the effects
01	Grey cast iron	Pig iron + scrapped casting + coke scrapped casting is used to control alloying element	Cupo la furna ce	Slow cooling helps the formation of graphite which makes the metal soft, machinable, high damping capacity, high compressive strength and self-lubricating characteristics. But makes tensile strength, ductility and impact strength low. Used for basic structure of machine tools and structural members loaded in compression. Rapid /sudden cooling helps the formation of carbide which makes iron hard, brittle and unmachinable. Grey cast iron tensile strength 1500 to 4000kg/cm^2, hardness 155 to 320 HB, compressive strength is 3 to 4 times than tensile strength.
02	White or chilled cast iron	Low phosphor us pig iron+steel scrap	Air furna ce/cu pola furna ce	Carbon is cementite form, very hard, brittle and wears resistance iron. Hardness of 400 brinell by keeping silicon below 1% and carbon about2%. Toughness and strength can be doubled by adding nickel 4.5%&chromium1.5%.harness for this composition is 700Brinell.It is almost unmachinable used where abrasion resistance is required. The rapid conduction of heat from surface of casting makes metal hard in the outer surface and softer in the inner surface. Metal is very useful in making railway carriage wheel.
03	Mallea ble cast	annealing the white cast iron	Anne aling is	The annealing process consists of heating it slowly to 870 ^{o}C and keeping at this temperature for 25 to 60 hours,

	iron		slow heating of metal	depending upon size and then cooling slowly. It is tougher than grey cast iron and more resistant to bending and twisting. It is used for various automobile, tractor and plough parts gear housing.
04	Ductile / nodular cast iron	Grey iron +magnesium	ladle	Magnesium controls the graphite and thus makes the iron become high fluidity, low melting point castability,strength toughness, high tensile strength(4400 to 7000kg/cm^2), wear resistance, pressure tightness weldability and machinability and excellent casting quality.
05	Alloyed cast iron	Grey cast iron+ alloying compound	Air or electric furnace	Improvement in strength, hardness, corrosion resistance and response to heat treatment NICKEL: upto 5% for improving machinability, hardness, strength and corrosion resistance, lower hardening temp, aid quench hardened without cracking. CHROMIUM: upto 3% promote formation of carbides to increase hardness and corrosion MOLYBDENUM: upto1.5% improves strength and wear resistance. VANADIUM: upto 0.5% promote carbide formation, increase strength and hardness COPPER: addition of small quantity improve corrosion resistance

IMPORTANT PROPERTIES OF CAST IRON

SL.NO.	PROPERTIES	
01	Mechanical	1. Tensile strength 1350 to 5350 kg/cm^2 2. Elastic limit is close to its ultimate breaking strength. 3. with static loading the ultimate strength of cast iron in tension is less than that in compression 4. the impact strength of most cast iron is low

		5. The damping capacity or the ability to absorb vibration is high.
02	machinability	Cast iron has wide range of mach inability that is, from very good to the most unmachinability.
03	Weldability	The weldability of all the cast irons is quite low due to presence of high carbon. Preheating is required before welding of cast iron
04	Corrosion resistance	Rust formation is very slow and slower in comparison to alloy steel. Cast irons are remarkably good for withstanding all acids except hot HCL.
05	High temperature usefulness	Grey cast iron can be used where the pressure vessel operating temperature upto 340^{o}C

WROUGHT IRON:

It is a purer form of pig iron. It is produced from pig iron by burning out impurities like C, Si, Mn, P and sulphur in a puddling furnace. Pig iron contains 6% or more impurities but their percentage reduced to about 1% in wrought iron. Carbon content is reduced to about 0.02%. A minute quantity of slag is incorporated.

PROPERTIES:

1. It is a pure form of pig iron.
2. It can be readily worked.
3. It can be welded at temperature close to its melting point.
4. It is ductile when cold and has good forming qualities.
5. Its corrosion resistance is superior to mild steel due to presence of slag.
6. It has good machining and threading qualities.
7. It's ability to hold protective metallic and paint coatings are good.
8. Wrought iron is very soft at low percentage of impurities.
9. Its melting point is high due to low carbon content.
10. It can not be used as casting alloy.
11. It has very little use due to poor strength.
12. It has got good fatigue resistance.
13. It can be obtained in the form of plates, sheets, forged billets, structural shapes bars, piping and tubing.

USES OF WROUGHT IRON:

1. It is used for making pipes, bars for stay bolts, engine bolts and rivets etc due to high corrosion and fatigue resistance.
2. It is used for making plate due to soft and ductile.

3. It is used for making special chains and crane hooks due to its good weldability and high impact strength.
4. It is extensively used in forging application.

STEEL

Pig iron is refined and mixed with desired elements in a definite proportion to make steel. Steel is an alloy of iron and iron carbide (cementite form). The essential difference between cast iron and steel is that steel never contains graphite or free carbon. Steel normally contain 0.1% to 2.2% carbon iron whereas cast iron 2.4% to 4.2% carbon. With increase carbon content in steel, the hardness, tensile strength and yield strength increase; but impact strength, reduction of area and elongation are reduced. Steel can be divided into three categories, namely carbon steel, alloy steel and stainless steel.

CARBON STEEL:

Carbon steel is an alloy of iron and carbon with varying quantities of manganese, silicon, phosphorus and sulphur. It has got variety of application for engineering purposes due to the wide range of physical properties obtainable by changes in carbon content and heat treatment.

- ✓ Iron is 90%
- ✓ Carbon determine physical properties of steel
- ✓ Manganese is very essential for steel of all type.

PERCENTAGE OF ALLOY ELEMENT AND THEIR EFFECT IN CARBON STEEL

Sl.no.	Alloy element	% of alloy	Effect of alloy element
01	carbon	0.83%	Increase the tensile strength Increase the hardness Decrease the ductility and weldability
02	Manganese	0.2% to 0.8%	Increase the tensile strength Increase the hardness Decrease the weldability
03	Phosphorus	0.005% to 0.12%	Increase the tensile strength Increase the hardness
04	Sulphur	0.005%	Lower the toughness and transverse ductility. Imparts brittleness to remove chips in machining operation.
05	Silicon	0.1% to 0.35%	Promotes increase of grain size and deep hardening properties.
06	Copper	0.25%	Increase the resistance to atmospheric corrosion

CARBON STEEL CAN BE FURTHER CLASSIFIED INTO

Sl.no.	classification	% of carbon	Uses
01	Low carbon steel	0.05% to 0.25%	1. Used for making sheet, strip, tubing wire nails rivets, screws and parts to be case hardened etc. 2. Sheets for deep drawing applications for obtaining maximum amount of plasticity. 3. Galvanised sheets can also be made. 4. It is extensively used for welding into tubes for construction of furniture, automobiles, refrigerators etc.
02	Structural steel	0.20% to 0.35 %	Suitable for both welded and riveted construction
03	Machinery steel	0.30% to 0.55%	Forging steel contain carbon between 0.3% to 0.40% and are used for making axles, bolts, pins, connecting rods, crank shafts etc. It can be readily forged after heat treatment
04	Tool steel	0.60% to 1.30%	1. Water hardening tool steel contains 0.7% to 1.30% carbon, low cost, good toughness and excellent machinability. It is used for making files, twist drills, shear knives chisels, hammers and forging dies. 2. Shock resistance tool steels contain alloy combinations of chromium-tungsten, silicon-molybdenum, or silicon-manganese with 0.6% carbon. They have good hardenability with outstanding toughness and wearing quality but easily distort. 3. Cold work tool steel posses high wear resistance and hardenability but develop little distortion. 4. Air hardening tool steel are used to make larger sizes of tools and dies. 5. Oil hardening tool steel is non-

			deforming die steel. It can be used for all types of medium life tools and dies, easy to machine and harden uniformly. 6. Hot work tool steel is either chromium based or tungsten based alloy. It posses fine non-deforming, hardenability, toughness and resistance to heat with fair machinability and wear resistance. It is used for making blanking, forming, extrusion and casting dies, hot-blanking dies, hot punching dies, forging and die-casting dies, where temperature may rise to 540^{o}C. 7. High speed steels are either tungsten or molybdenum base alloy possess all properties except toughness. They are used in metal cutting up to 593 ^{o}C.
			Steel for both helical and flat springs, which is hardened and tempered after forming, is usually supplied in an annealed condition. For small springs, plain carbon steel is satisfactory; whereas alloy steel (chrome-vanadium or silicon-manganese) is used for large springs.

ALLOY STEEL:

Alloy steels are not suitable for forming. They are usually forged for parts like gears, bearings, crankshafts, connecting rods, etc. where good strength and toughness are required. By induction hardening, their surface becomes hard and can take high compressive load and core remains tough.

STAINLESS STEELS:

Stainless steel is iron base alloy that has a great resistance to corrosion. The property of corrosion resistance is obtained by adding chromium only or by adding chromium and nickel together. It is very slightly oxidisable. This slight oxidation forms a very thin, transparent,

and very tough film of oxide on the surface of stainless steel. This acts as a protective coating and does react with many corrosive materials. Within a temperature range of 237 ^{o}C to 980 ^{o}C, it exhibits strength, toughness and corrosion resistance superior to other metals. It is thus ideally suited for handling and storage of liquid helium, hydrogen, nitrogen and oxygen that exist at cryogenic temperature.

CLASSIFICATION OF STAINLESS STEEL

Sl.no.	Classification	% of alloy element	Effect
01	Austenitic stainless steels	16 to 24% chromium & 6 to 22% nickel	Non-hardenable & non-magnetic. Good for cold working processes. Find uses in food processing, dairy industry, textile industry and pharmaceuticals
02	Martensitic stainless steels/ chromium steel	16% chromium & 0.7% carbon	Hardenable & magnetic. They are very hard and possess strain-resisting properties and therefore, are used for utensils, surgical and dental instruments, and springs for high temperature operation, ball valves and seats.
03	Ferritic stainless steels	12 to 27% chromium	Magnetic & non-hardenable. Very low carbon content& possess ductility, excellent corrosion resistance & ability to be worked hot or cold. They are extensively used in kitchen equipment, diary machinery, heat exchangers boiler tubing, screws

			bolts, nuts interior decorative work, and automobile trimmings and for chemical equipment to resist nitric acid corrosion.
04	Low chromium stainless steels	4 to 6% chromium	Oxidation resistant properties at high temperature.

NOTE: Alloys having 50% or more iron are categorized as steel
Alloys having less than 50% iron are categorized as non-ferrous alloys.

NON-FERROUS METALS:

COPPER:

- ✓ It has great resistance to corrosion
- ✓ It has good strength at moderate temperature
- ✓ It is very ductile and can be worked into complex shapes.
- ✓ It can be very easily welded, soldered and riveted.
- ✓ It has got very high heat conductivity and electrical conductivity.
- ✓ It is used for making copper wire.
- ✓ Brass is the cheapest copper alloy
- ✓ Copper is best-suited where high thermal or electrical conductivity is desirable.

LEAD:

- ✓ Lead is a soft and weak metal.
- ✓ It is very malleable and ductile.
- ✓ Its tensile strength is 150kg/ cm^2
- ✓ Its melting point is 327 ^oC
- ✓ It is very heavy and resistance to corrosion.
- ✓ It has a high density, low melting point and high boiling point.
- ✓ It can be easily melted, cast, rolled and extruded.
- ✓ It has got low elastic limit, high coefficient of thermal expansion and has got very high anti-frictional
- ✓ Property.
- ✓ It is a good insulator against nuclear reactor.

ALUMINIUM:

- ✓ Aluminium is a silver white metal.
- ✓ It is light in weight.
- ✓ It is very weak and ductile and melts at 660^{o}C.
- ✓ Its tensile strength is 600kg/ cm^{2}.
- ✓ It is a good electrical and thermal conductor.
- ✓ It is a good reflector of light and a good radiator of energy.
- ✓ It is a non-magnetic.
- ✓ It is resistant to atmospheric corrosion.
- ✓ It has good tensile strength in the form of alloys.
- ✓ It can be easily worked due to its ductility.

STRUCTURAL APPLICATION:

Due to light weight and high tensile strength, it is used for the construction of aeroplanes, buses, tracks, train, ships, roofing, sheeting, windows, stair rails, furniture etc.

ELECTRICAL INDUSTRY:

- ✓ It is used for making cables to carry current.
- ✓ It is used in induction motor winding.

CRYOGENIC APPLICATION:

Cryogenic means science of low temperature. Cryogenic application is close connection with missiles, rockets and space navigation. It's tensile and yield strength increase with decrease of temperature.

ZINC:

- ✓ Zinc is a weak metal.
- ✓ It resists corrosion
- ✓ Its tensile strength is 1550kg/cm^{2}
- ✓ Zinc is used as a protective coating for steel (the method is called galvanizing)
- ✓ Zinc is applied on steel by hot dipping or by electroplating (the method is called electro-galvanizing).
- ✓ It is used for roof and battery containers.

TIN:

- ✓ It is a soft metal having very low tensile strength of 130kg/ cm^{2}
- ✓ Its melting point is 232 ^{o}C

COPPER-ZINC ALLOY IS BRASS

Sl.no.	% of alloy element	Alloy	Effect
01	Copper 57% to70% Zinc 5% to 45%	Copper-Zinc alloys is Brass	High resistance to corrosion, easily machinable and acting as good bearing material. Brass is formed by working. Brass has greater strength than copper
02	Copper88% Tin 2 to 12% Copper 83% Tin10% Zinc2%	Copper –Tin alloy is Bronze Copper –Tin-Zinc alloy is Gun metal	Harder and stronger alloy than brass. Bronze is formed by casting. Bronze can be readily cast and machined. If zinc is added bronze gun metal is formed. Being a highly resistance to corrosion, it is used for marine fittings, valves and fittings for water and general services, engine parts , steam fittings and hydraulic machinery.
03	5 to 11% Aluminium	Copper – Aluminium alloy is Aluminium bronzes	High tensile strength 5600kg/ cm^2. High corrosion resistance against acid. Good casting properties. Used for making valves, pumps.
04	70 to 90% tin 7 to 24% antimony 2 to 24% copper	Bearing metal/Babbitt metal	Bearing should be made from a material which is tough and hard. Tin reduces brittleness and increases compression strength. The tin base alloys compared to the lead-base alloys have better resistance to corrosion in acidic oils but have considerably higher cost. The alloy of 80% copper, 10% tin and 10% lead is most commonly used for general machinery. Alloy with 70% copper, 16% tin and 14% lead is very useful for higher pressures. In internal combustion engines for higher load, straight copper lead alloys with 21% lead, and balance copper with small amount of nickel or tin are used.

05	Tin 50% Lead50% Copper +zinc + little tin	Soft solder Hard solder	It is used for joining two metals It melts at a lower temperature than the metals to be joined. Used for joining copper and brass

Compared to thermoplastics, thermosetting materials have greater tensile and impact strength, higher temperature resistance, and greater hardness. Their physical properties come close to machining those of metals. Thermoplastic materials provide a much wider range of corrosion and erosion resistance than thermosets.

EMF Series always measure corrosion tendency of metal not alloy.

Galvanic series always measure corrosion tendency of metal and alloy.

The current flows from higher potential to lower potential.
The electron flows from lower potential to higher potential. i,e. opposite to current flow.

CORROSION:

Corrosion is an electrochemical phenomenon. If oxidation and reduction take place simultaneously it is known as electro chemical reaction. Five types of reaction take place.

- ✓ Oxidation reaction(release of election)
- ✓ Transfer of electron
- ✓ Consumption
- ✓ Movement of cat ion cathode
- ✓ Movement of an ion to anode
- ✓ If we stop any one of the above, we can stop corrosion.

DIFFERENT STANDARDS

- SAE: Society of Automotive engineers
- AISI: American iron and steel industries
- ASTM: American society of testing materials
- EN/BS: British standard
- DIN: Deutstch industrially normen/german standards
- JIS: Japan specification
- GOST: Russian specification

WELDING

Welding is a process of joining two metals either by heating the materials to suitable temperature with or without the application of pressure or by the application of pressure alone and with or without the use of filler material.

Now-a-days welding is extensively used in almost all engineering industries. The best examples are automobile industry; aircraft machine frames, structural work, tanks, machine repair work, ship building, pipe-line fabrication in thermal power plants, oil exploration industries, refineries and fabrication of metal structure etc.

ADVANTAGES OF WELDING OVER OTHER JOINT

1. Welded joints have high corrosion resistance compared to bolted and riveted joints.
2. Welded joints are fluid tight for tanks and vessels.
3. Welded structures can be altered easily and economically.
4. Many different types of joints are possible in welded joints.
5. Small section of structure can be fabricated and transported from different places for large size buildings, bridges and structures and welded during assembly.

I. CLASSIFICATION OF WELDING PROCESS BASED ON ENERGY TRANSFER

Sl.no	Application of energy	Form of energy for welding	Welding process
01	Electrical energy	Converted to heat energy	Arc welding, Resistance welding
02	Mechanical energy	Converted to heat energy	Friction welding
03	Chemical energy	Converted to heat energy	Gas welding, Explosive welding
04	Light energy	Converted to heat energy	LASER welding
05	Sound energy	Converted to heat energy	Ultrasonic welding

II. CLASSIFICATION BASED ON TYPE OF WELDING

Sl.no.	Type of Welding	Process
01	Fusion welding	This process involves fusion of the base metal to complete the weld. Fusion weld not requires application of pressure. The welding may be completed with or without addition of filler material.
02	Solid state welding	These are the processes in which the two sides of a joint are brought into intimate atomic contact either by mechanical deformation or by atomic diffusion or by a combination of both. Examples: 1.Cold pressure welding----Mechanical deformation at room temperature. . 2. Hot pressure welding----Uses heat to render the metal ductile. 3. Friction welding----------Employs rubbing at the interface to generate heat. 4. Pressure butt welding--Used to join two pieces of metal with heat generated by electric arc, electric induction or electric resistance across the joint. 5. Diffusion welding-------Employs modest deformation but the temperature and its duration are sufficient to allow atomic diffusion across the interface.

III. CLASSIFICATION BASED ON MODE OF WELDING

Sl.no.	Mode o f welding	Job description	Examples
01	Manual welding	Welding operation is performed and controlled by welder. Here the movement of feeding of electrode and welding speed done by welder himself.	Manual metal arc welding
02	Semi – automatic welding	Welding operation is performed and controlled by both welder and machine. Here welding speed given by welder and wire is drawn and fed by the motorized wire feeder into the welding torch.	MIG welding
03	Mechanized welding	A machine under constant observation and control of an operator does welding operation. Here motors control both wire feeding and the welding speed in mechanized manner.	SAW welding
04	Automatic welding	Machine performs the entire welding operation without constant observation and adjustment of the controls by an operator. Here the machine may or may not do the loading or unloading of the work.	Welding robots

SOLDERING

It is a process of joining two metals by heating them to a suitable temperature and by using a filler metal having a melting point not exceeding 450^{o}C and below the melting point of the base materials. The filler material is distributed between the closely fitted surfaces of the joint by capillary action. Soldering is done on tin-lead alloys.

TYPE OF SOLDERING:

1. Dip soldering
2. Induction soldering
3. Iron soldering
4. Torch soldering

5. Furnace soldering
6. Infra red soldering
7. Resistance soldering
8. Wave soldering

BRAZING

It is a process of joining two metals by heating them to a suitable temperature and by using a filler metal having a liquidus above 450^{o}C and below the solidus of the base materials. The filler material is distributed between the closely fitted surfaces of the joint by capillary action. A braze is a special form of weld, the base metal is theoretically is not melted. The four most common brazing joint designs are the lap, the butt, the butt-lap, and the scarf.

TYPE OF BRAZING:

1. Diffusion brazing
2. Dip brazing
3. Induction brazing
4. Infra red brazing
5. Resistance brazing
6. Torch brazing

MANUAL METAL ARC WELDING

The heat required for metal arc welding is generated by the electric arc formed between metallic electrode (+ve) and base metal (-ve). When the welder touches the plate to be welded with the electrode, it directly short circuits the power supply and immediately a heavy current flows which melts the tip of the electrode like blowing of the fuse, thus initiating the welding arc. If the welder maintains the arc gap, the arc continues to remain stable and the arc heat melts the plate, electrode and the flux coating. The electric arc produces high amount of heat and light. The flux covering of the electrode melts in the arc heat and produces a large volume of gases and the slag. The gases cover the arc and shield it from reacting with the atmospheric air. The slag covers the molten metal pool until it solidifies. The slag can be removed after welding. The flux also provides filler metal with alloying elements to increase the strength of the weld joint. The electrode is consumed in the arc during welding. Thus electrode coatings do much to increase the quality of the weld

Manual metal arc welding is the most common, versatile and inexpensive welding technique. The electrode used for metal arc welding is made up of solid metallic wire. Its diameter is varying from 1.6mm to 6.3mm and length varying from 250mm to 450mm

Metal arc welding needs power source, which may be either a transformer or generator or transformer-rectifier supplying AC/ DC power. For achieving high quality welding, thyristor controlled or transistor controlled or inverter based power sources are employed. These latest type of power sources are having feedback controls to deliver the required amount of voltage and current to the welding arc to achieve desired weld quality.

The transfer of metal from the tip of the electrode (+ve) to the base metal (-ve) is actually a method of short-circuiting. The electrode makes contact with the base metal every 1/400 sec. This creates a problem in the welding machine where the short circuit plays havoc with the amperage control within the machine. This short-circuiting of the electrode has four basic stages:

- The heat stage
- The deformation stage
- The contact stage
- The pinch-off stage

GOOD WELDING

↓

Requires

↓

- *Good machine/ Good power source*
- *Right material/ Good consumable*
- *Good workmanship/ skilled welder*
- *Proper method/ Good technique*

LIMITATIONS

- *Unknown base metal*
- *Limited facilities*
- *Highly contaminated weld spot*
- *Ill effect of heat*
- *Heat of arc 7000^{o}C*
- *HEAT = $I \times I \times R \times T = I^2RT$*

Where I –current
R- Resistance
T- Temperature

RESISTANCE ARC WELDING

1. *Long arc*

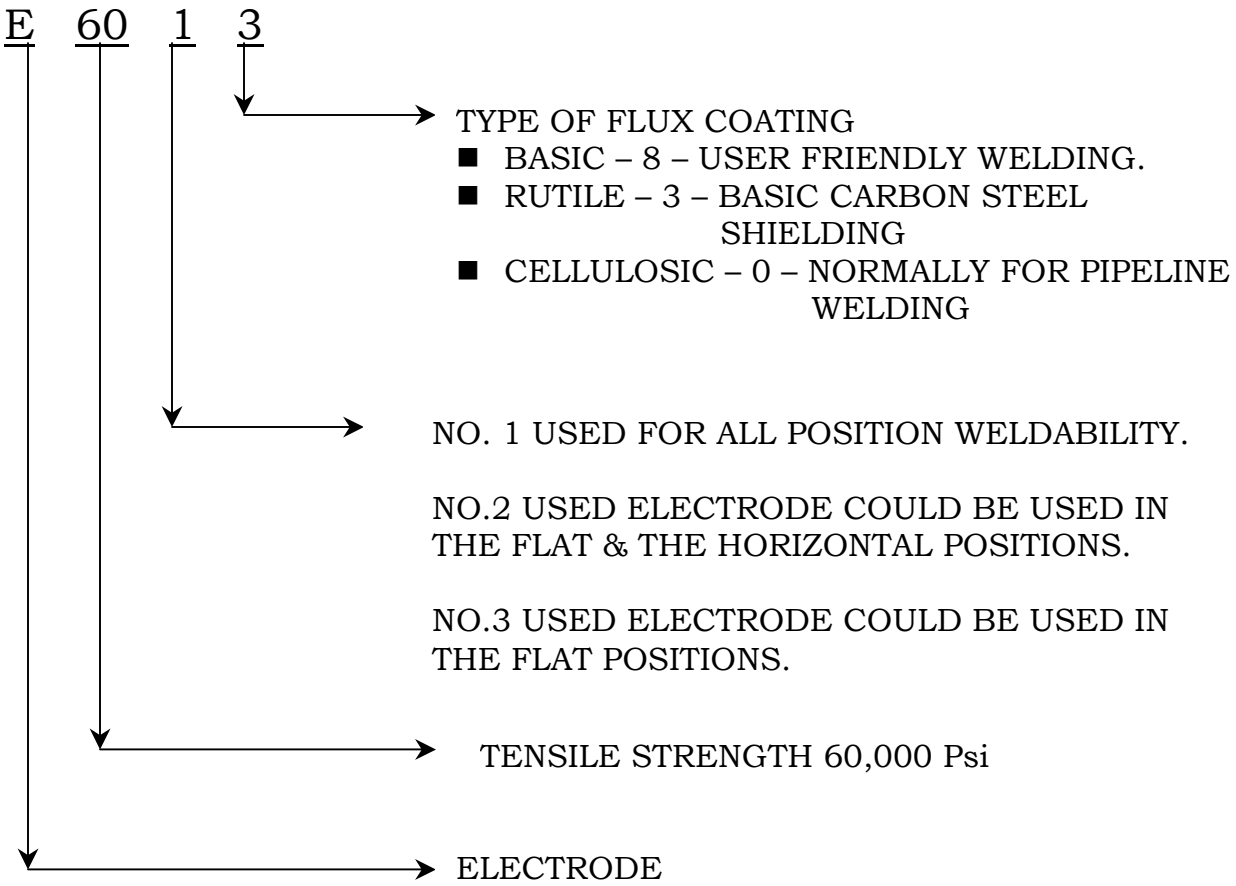
2. *Short arc*
3. *Medium arc*
4. *Frigid arc*

WELDING DEFECTS

The following defects may occur due to longer arc cap and high current setting.

1. *Crack*
2. *Crater-sudden withdrawal of welding electrode*
3. *Blow hole*
4. *Lock of fusion*
5. *Spatter – moisture observation*
6. *Slag inclusion*
7. *Under cut – improper current setting*
8. *Distortion - high current*
9. *Arc blow – improper ear thing*
10. *Lack of fusion*
11. *Porosity—mainly happens cast iron welding*
12. *Lack of penetration*

CARBON STEEL



Sl no	Parent metal	Welding electrode
01	Carbon steel	E6013, E7018, E8018, E6010, E11018
02	Cast iron	XYRON223, 2240, CPCI 026 C.I. for high silicon Si. For carbon
03	Stainless steel	E308-16, E308L-16, E316-16, E347-16 ----AWS codified specs ↓ ↓ ↓ ↓ SS304 SS3044 SS316 SS347 ---- Base metal specs

There are two major classifications of coatings on the electrodes:

- Lightly dusted electrodes
- Semi coated electrodes

The classification of electrodes based on the thickness of the flux covering on the electrodes. The coatings on electrodes can be made of many different materials and can serve many purposes. Several materials commonly used are:

- Titanium dioxide
- Ferromanganese
- Silica flour
- Asbestos clay
- Calcium carbonate
- Cellulose with sodium silicate etc often used to hold ingredients together.

CAST IRON WELING

Any metal having carbon content of more than 1.6% is classified as cast iron. These cast iron metals having free carbon elements. During welding of cast iron metals, these free carbons combine with welding material and become iron carbide. Which is hard and brittle results welding crack. So high nickel content welding electrodes are used to eliminate such problem. Nickel is a noble metal, which is soft but tough and suitable element for cast iron welding. Normally cast iron electrodes having more than 85% nickel composition.

CAST IRON WELDING PROCEDURE

- Clean surface
- Locate crack by DP test
- Drill hole end of crack for further propagation of crack during welding
- Pre heat to remove oil/grease
- Make U groove
- Pre heat 150^{o}C to 200^{o}C
- Correct selection of electrode
- Low current, short arc and low bead
- Pre heat is required for cast iron and high carbon steel to avoid expansion and contraction.
- Grey cast iron----------XYRON224, XYRON223
- Cast iron + Steel joint-------XUPER2240
- Cast iron welding and good machining----XUPER XYRON242
- Cast iron critical joint -------- XUPER2233
- Cast iron smallest dia of electrode CGS680 can use for any kind of steel welding
- Low alloy and low carbon steel welding------ CGS660
- Slow cool the job by putting asbestos after cast iron welding

STAINLESS STEEL

- Carbon 0.03 to 0.05%
- Stainless steel having 11.5% chromium not more than 30%
- Chromium oxide protects the stainless steel against corrosion.
- Nickel 8 to 20% increase toughness
- Austenitic stainless steel ---201, 202 &300 Series
- Austenitic stainless steel welding electrode 316L where L low carbon.
- Ferritic stainless steel ---405, 430 &446 Series

IMORTANT POINTS TO REMEMBER

- Arc gap = Dia. Of electrode (thumb rule)
- Carbon is enemy of welding.
- % of carbon in cast iron is › 1.6%.
- % of carbon in stainless steel is 0.03% to 0.05%.
- Stainless steel should not be allowed to red hot. It should be welded with very low current.
- Cast iron should be welded with short arc, low current, and low bead
- Cast iron electrode having 85% nickel composition.
- Normally welding angle between 75^{o} to 80^{o}.

- Pre heating is essential for both cast iron and steel welding
- AWS- American welding society.
- ASTM American society for testing materials.
- NEMA—National electrode manufacturer's association.

TIG WELDING

Tungsten inert gas welding is also known as gas tungsten arc welding. In this welding, an arc is struck between a non-consumable tungsten electrode and the base metal. The tungsten electrode is called non-consumable electrode as it melts only at around 2800^{o}C and in the arc heat all other metals melt at much lower temperatures. The TIG arc is shield by inert gas like argon, helium or a mixture of both. A filler wire may or may not be used. AC power source is used for aluminium alloys and DC for all other metals.

During TIG welding, an arc is struck between anode and cathode, more heat is observed at anode and less heat at the cathode. Hence in TIG welding the tungsten electrode is always connect to the negative polarity of the power source so that the electrode does not melt. Since the tungsten has high melting point, it is brittle and breaks easily. Hence generally the electrode is not touched with the plate to strike arc but a high frequency unit is used to initiate the arc. The HF unit is actually a high voltage, high frequency unit that generates around 3 kV voltage and 3MHz frequency, which ionizes the gap between the electrode and the plate thus enabling the arc to jump from the electrode to the plate. This is an ideal process for welding of non-ferrous metals and stainless steel in limited thickness. It is used as root pass in pressure vessels where welding from inside is not possible.

MIG WELDING

Metal inert gas welding is also known as gas metal arc welding. In this welding, fusion is achieved by an electric arc formed between work pieces and at the same time continuous solid wire electrode is also fed through a welding torch at controlled speeds. Inert gas argon flows through the torch and forms a blanket over the weld puddle to protect it from atmospheric contamination. If the gas supply is argon or helium, then the process is called MIG welding. If the shielding gas is only CO_2, then the welding process is called CO_2. If the shielding gas is a mixture of argon and CO_2 then the process is called MAG welding.

The MIG welding can be semi-automatic or mechanized. This is highly amenable for robot welding or robot manipulation. Generally a constant potential type of power source is used. This may be a

transformer-rectifier, thyristoris controlled, transistor controlled or inverter type of power source, which may be chosen depending on the quality requirement.

GMA welding is gradually replacing SMAW and TIG welding. Most metals can be easily welded including aluminium, carbon steels, stainless steels, low alloy steels, nickel, copper, magnesium and titanium.

MAG/ CO_2

Metal active gas welding is a variation of MIG welding in which the inert gas is replaced by gas mixtures or carbon dioxide, which are chemically active.

Argon +1 to 2% O_2 for alloy steels and stainless steels. Argon+3 to 5% O_2 for carbon steels and low alloy steels. CO_2 for carbon steels. CO_2 welding is replacing manual metal arc welding in the fabrication of structural, pipes, automobile products storage tanks and machinery etc.

FLUX CORED ARC WELDING

This is an extension of MIG/MAG welding where solid wire is replaced by flux-cored wire. The equipment and accessories are the same. Generally flux cored wires require additional gas shielding like CO_2 and some times some flux cored wires are self shielding type which do not call for additional gas shielding. The main advantage of flux-cored wire is that we can easily alter the desired levels of alloying elements during manufacture. The process will produce a light slag, which can be easily removed.

SUBMEREGED ARC WELDING

This is a completely mechanized process. The electrode is a continuous metallic wire in the form of coil. It is fed automatically in to the arc at a constant speed. A layer of flux covers the arc. The power source used is generally a constant potential power source, transformer or a transformer-rectifier. It is of high capacity varying from 750 to 3000 amps. The welding head is mounted on a trolley, which travels along the joint. Alternately the welding head is stationary and the job is moved under it. The wire diameter varies from 2.4mm to 6.3mm. The feed rate varies from 5m/min to 15m/min. The wire can be solid cored or flux cored wire. The process gives very high productivity, and excellent weld quality. This process is used for welding of mild steels, high tensile steels, low alloy steels and stainless steels. It is ideal for heavy thickness welding. It is used in fabrication of ships, plate girders, pressure vessels, pipes and penstocks, for welding surfacing and strip cladding. In strip cladding wire is in the form of strips of size say 1.6mm*75mm wide. To achieve better deposition rates out of this process, tandem welding with 2 or more torches are used.

STUD WELDING

This is an arc welding process in which the arc is struck between a metal stud or similar part and the base metal. The arc heats the mating ends to a proper temperature after which they are brought together under pressure. Operator positions the stud, held in a portable pistol shaped tool called stud gun. Once initiated the welding time and final driving a timing device controls home of stud of stud to complete the weld automatically. A ceramic ferrule is used with each stud. The ferrule concentrates the heat, prevents in flux of air to the molten metal and confines the molten metal to the weld zone.

GAS WELDING (OXYACETYLENE WELDING)

In this process the melting of the base metal is achieved by means of a gas flame, which derives its intense heat from the combustion of fuel with oxygen. The most commonly used gas is acetylene. The oxygen supports higher combustion; the acetylene is the fuel for the combustion. Filler metal may or may not be used. Equipment for gas welding consists of oxygen and acetylene cylinders, pressure regulators that reduce the high cylinder pressure to the required working pressure, a torch where two gases are mixed and hoses, which connect the regulators to the torch. This is used for welding metals of low melting points and operations as soldering, brazing and thermal spraying.

Acetylene gas under pressure becomes very unstable and in the Free State will explode before reaching a pressure of 30 psi. This instability places special requirements on the storage of acetylene. A storage cylinder is filled with a mixture of calcium silicate, a material that is 92% porous. The cylinder is then filled with acetone, which is the solvent agent of acetylene gas and which has an absorptive capacity of up to 35 volumes of acetylene per volume of acetone per atmosphere of pressure. This enables about 420 volumes of acetylene to be compressed at 250 psi. Under these conditions, the gas is present in the form in which it is to be used. Acetylene comes out of the acetone solution at a slow constant rate as the pressure in the cylinder is released. The rate, however, depends on the temperature of the gas.

CaC_2 + $2H_2O$ = C2H2 + Ca $(OH)_2$

Calcium Carbide water acetylene hydrated lime

The combination of oxygen and acetylene to support maximum combustion has been found to be

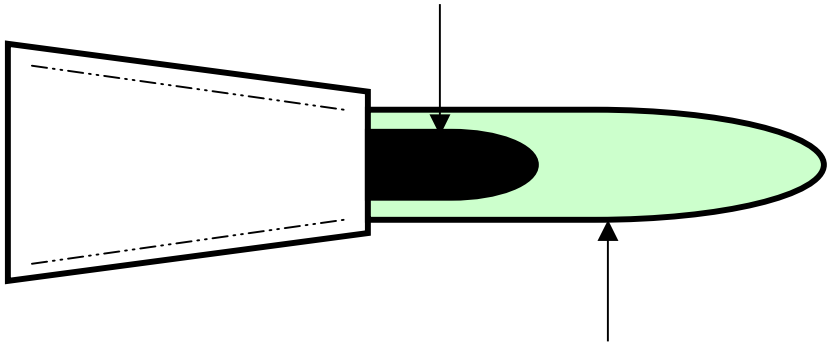
$$2C_2H_2 + 5O_2$$

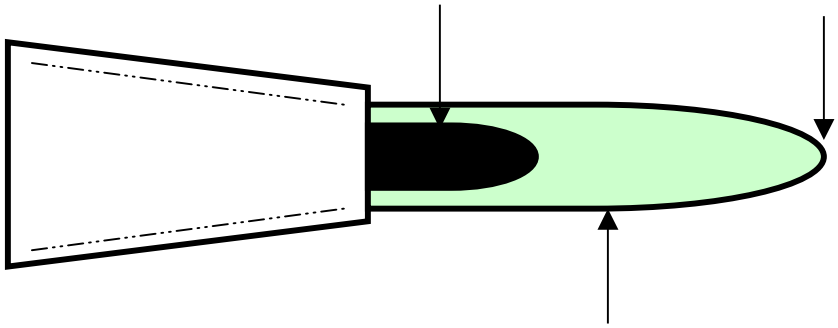
That is, 2 volumes of acetylene and 5 volumes of oxygen for the complete burning of the two gases. Upon the complete burning or combustion the residue is

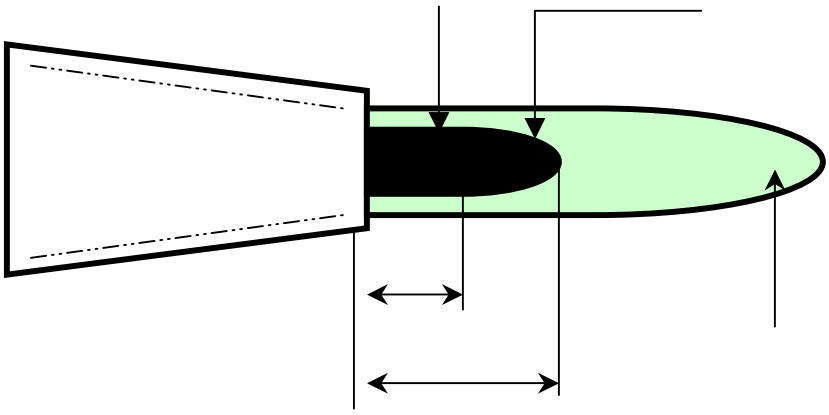
$$4CO_2 + 2H_2O$$

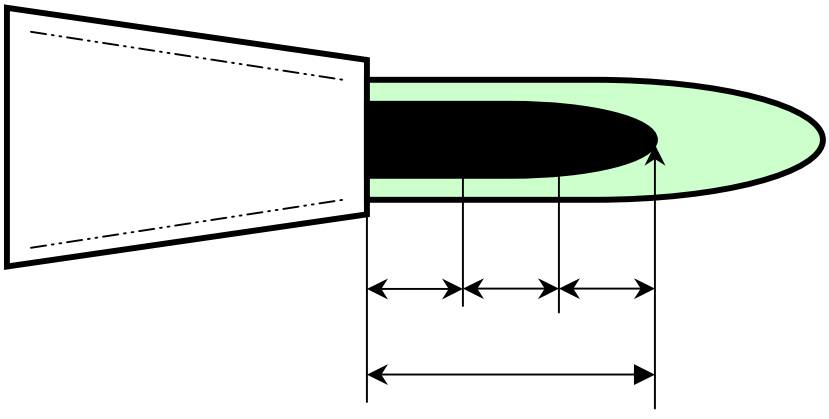
BURN TEMPERATURE

Inner cone temperature----5000 to 6300^{o}F
Middle of envelope --------- 3800^{o}F
Extreme end of envelope--- 2300 ^{o}F









FLAME ADJUSTMENT

Oxygen and acetylene can be ejected from the torch tip in three possible gas mixtures:

- Excess acetylene

- Equal mixture
- Excess oxygen

EXCESS ACETYLENE MIXTURE

The lower inner-cone temperature is associated with carbon-rich mixtures (excess acetylene in the mixture). This is called carburizing or reducing flame and is characterized by three stages of combustion i.e. first, intermediate feather & secondary. The carburizing flame does not completely consume the available carbon; therefore, its burning temperature is lower and the leftover carbon is forced into the metal. The molten weld puddle appearing to boil characterizes this action. After this carbon-rich weld bead solidifies, the weld will have a pitted surface; these pits can extend through the entire weld bead; the bead will also be hardened and extremely brittle because of the excessive amount of carbon that was injected into the molten base metal. This excess of carbon, however, is an ideal condition when welding high –carbon steel.

BALANCED OR NEUTRAL FLAME

The two-stage flame with hissing sound is neutral flame having right proportion for complete burning. It is the most used flame in both the welding and the flame cutting of metals. It has little effect upon the base metal or the weld bead and usually produces a clean-appearing, sound weld bead with properties equal to the base metal properties. The inner cone of the neutral flame is not hot enough to melt most of the commercial metals, and the secondary combustion envelope is an excellent cleaner and protector of ferrous metals.

EXCESS OXYGEN MIXTURE

The highest cone temperature is associated with the oxygen rich mixture (excess oxygen in the mixture). This is called oxidizing flame and is characterized by two stages of combustion i.e. first & secondary. It gives off a loud roar sound. The oxidizing flame injects oxygen into the molten metal of the weld puddle, causing the metal to oxidize or burn too quickly, as demonstrated by the bright sparks that are thrown off the weld puddle. Also, the excess of oxygen causes the weld bead and the surrounding area to have a scummy or dirty appearance. However, a slightly oxidizing flame is helpful when welding most copper-base metals, zinc-base metals, and a few types of ferrous metals, such as manganese steel and cast iron. The oxidizing atmosphere creates a base-metal oxide that protects the base metal. For example, in welding brass, the zinc alloyed in the copper has a tendency to separate and fume away. The formation of a covering copper oxide prevents the zinc from dissipating.

OTHER HEAT SOURCES

Many fuels can be used to weld metals, but the oxyacetylene flame is the most versatile and the hottest of all the flames produced by the various gas heat sources. Some of the more common fuels in use are natural gas, propane, map, hydrogen, and butane.

ATOMIC HYDROGEN WELDING

In this process an arc is struck between two tungsten electrodes using AC power supply. Streams of hydrogen gas are passed from orifices around the electrodes in to the arc. Here the molecules of hydrogen dissociate in to molecules at a point a few millimeters away from the arc and liberate intense heat which melts the base metal. The hydrogen gas acts as a carrier of heat. Filler metal may or may not be used. As on date this process is nearly obsolete.

ELECTROGAS WELDING

This process is an extension of MIG/MAG welding designed for single pass vertical welding of steel plates in the thickness range of 10 to 38mm. The two plates are held vertically with a gap of 12mm regardless of plate thickness. The wire electrode is introduced downwards in to the cavity formed by two plates to be joined and two movable water-cooled copper chill blocks. The cavity is kept free of air by the shielding gas usually a mixture of argon and CO_2. The wire diameter may be 1.6mm to 2.4mm. The welding head is suspended from elevator mechanism, which provides automatically control of vertical travel speed during welding. The welding head is automatically raised as the molten metal is building up. The welding is completely automatic. This technique is used in shipyards, and in fabrication of storage tanks and large dia. pipes.

THERMIT WELDING

This process utilizes the intense heat developed during the reaction between iron oxide and aluminium. When a mixture of three parts of iron oxide and one part of a aluminium by weight is locally with a special ignition powder a vigorous reaction takes place which proceeds rapidly through the mass, resulting in the formation of aluminium oxide and iron and a considerable amount of heat. The heat is sufficient to melt iron and oxide slag. In carrying out Thermit welding the Thermit mixture is placed in a refractory crucible above the pieces to be welded. The molten metal from reaction is guided to the joint top be welded by a sand mould which is fastened around the work. By virtue of its superheat the Thermit metal melts a portion of base metal with which it comes in contact. This process is commonly used for welding rails of railway tracks.

ELECTROSLAG WELDING

This process is similar to the electro-gas welding process designed for making butt-welding in the vertical position in one single pass, and the plate thickness can vary from 12.5mm to 500mm. The welding heat is provided by a small quantity of flux which is converted in to a conductive molten slag by its resistance to the electric current passing between the continuously fed wire or wires (up to three wires for 500mm plates) and the parent plates. The hot molten slag melts the filler wire and the joint surfaces and also shields the weld pool which mover up along full cross section of the joint as welding progresses. There is no arc and welding is quiet and spatters free. A pair of water-cooled copper shoes fitted on each side of the joint retaining the molten metal and slag pool and acts as a mould to cool and shape the weld surfaces. The copper shoes move automatically along upward as welding progresses.

FIRECRACKER WELDING

This is a semi-automatic version of MMA welding. A specially designed heavy-coated electrode, which can be of any length up to 2 meter, is laid on the seam of a grooved butt joint or along the root of a tee joint. It is then clamped down with a water-cooled copper bar or heavy square section, which is grooved to accommodate the electrode. The copper bar is nearly as long as the electrode. The bar end is clamped in a holder. The arc is struck at the striking end, and the electrode gradually consumes by itself, making the butt or fillet weld of the same length as the electrode. The copper block helps to prevent overheating of the electrode and to maintain intimate contact between the electrode and the joint.

PLASMA WELDING

This is an extension of TIG welding. In plasma welding torch, plasma energy is concentrated and ensures its most efficient utilization for welding cutting and spraying. The tip of the tungsten electrode is located within the torch nozzle while the nozzle has a small opening which constricts the arc. As argon gas is fed through the arc it becomes heated to the plasma temperature range (30000^{o}F to 60000^{o}F). The plasma tail flame issues from the torch nozzle acts as a jet of tremendous velocity. The plasma arc is of two types. One is transferred arc and other is non-transferred arc. In the latter the arc is formed between the electrode and the orifice inside the torch. The process is used for welding of steels stainless steels, copper, aluminium, titanium, model and inconel. Plasma MIG welding is a development of plasma welding process. Plasma process is used for cutting application very efficiently.

MICRO-PLASMA WELDING

This is a modified plasma welding process using DC current range of 0.1 to 10 amps. It is capable of welding extremely thin sheets and foils in the thickness range of 0.05 to 1.6mm.

ELECTRON BEAM WELDING

In this process fusion is achieved by focusing a high power density beam of electrons on the area to be joined up on striking the metal, the kinetic energy of the high velocity electrons changes to thermal energy causing the metal to melt and the beam passes through the thickness of the plate thus making a keyhole. As the beam is moved the keyhole also is moved leaving behind the molten metal to solidify. The electrons are emitted from a tungsten filament heated to approximately 3000^{o}C. The electron gun the job and the fixtures are kept in a vacuum chamber. Very high welding speeds, high purity of welds and a very good control of weld parameters are possible to obtain by using this process. EB welding is highly suitable for welding of refractory metals such as tungsten, molybdenum, columbium, tantalum and metals, which oxidize readily such as titanium, beryllium, and zirconium. It can also be used to join aluminium steel and ceramics. EB machine is highly expensive but its use is justified for critical applications such as nuclear and aerospace components fabrication.

LASER WELDING

In this process, fusion is achieved by direction a highly concentrated beam to a fine spot. The word LASER is an abbreviation of light amplification by stimulated emission of radiation. An intense flashlight is thrown on a special man made ruby, 100 mm in dia. containing about 0.5% by weight of chromium oxide. The flashlight pumps the chromium atoms to a higher state of energy. Each of these excited atoms emits red light and thereby excites neighboring atoms, which also gives off red light, which is in phase with the collided red light wave. The red light gets continuously amplified. The parallel ends of rods are mirrored to bounce the red light back and forth within the rod. When a certain critical intensity of pumping is reached, the chain reaction collisions become numerous enough to cause a burst of red light. The mirror at the front end of the rod is only a partial reflector allowing the burst of light to escape through it. The light output is focused and used to achieve welding, cutting, surfacing, hardening etc. depending on the lasing medium, we have solid, liquid, gas and semiconductor lasers. Laser beam can be used to weld other difficult to weld metals such as nickel tungsten, steel, titanium and columbium. This can also be used for cutting hylam, rubber, plastic, paper, and cloth etc. Lasers are used in medical, electronic, aerospace and fabrication industries.

RESISTANCE SPOT WELDING

In this process, a spot of weld is made between overlapping sheets by means of two cylindrical copper alloy electrodes, one on top and the other at the bottom, which carry a high current. The electrodes also clamp the work and apply pressure when the metal at the joint gets sufficiently heated by electrical resistance. A tiny button of fused metal from interface is called nugget. The electrodes are retracted after the weld is completed. The process is used in large scale in automobile production.

Heat generated (H) = I^2RT

Where

I = current

R = resistance of the interface

T = time of application of current

RESISTANCE SEAM WELDING

This is similar to spot welding except that the copper alloy electrodes are in the form of circular rollers. The overlapping sheets are held under constant pressure between the roller electrodes, which rotate at constant speed and carry current. A series of spot welds whose nuggets are overlapping on each other are formed which give the appearance of a continuous seam. A common application of seam welding is in the manufacture of steel drums.

PROJECTION WELDING

This is a modified method of making single or multiple spot welds. Projection welds are made by providing an embossment or projection on one of both of the contacting base metal surfaces to localize the pressure and current flow at a particular point.

FLASH BUTT WELDING

This process is an extension of resistance butt-welding. The parts to be joined are gripped in the clamps and their interfaces are gradually brought into contact to complete the secondary circuit. When the welding voltage of up to about 10 volts is applied at the clamps, current flows through the initial points of contact causing them to melt. The platen on which the movable clamp is mounted is moving forward while this takes place, fresh contacts are made and then there is a continuous flashing of sparks. Flashing is allowed to continue until the surfaces to be joined are uniformly heated or molten. At the point extra pressure is applied to the moving platen so that the tubes are forged together and the molten metal is expelled and weld joint is achieved.

RESISTANCE BUTT WELDING

This process is also known as upset welding or simply butt-welding. Here, the resistance to the passage of electric current raises the temperature of the joint across the interface of the joint. The parts to be joined (usually wires and rods) are held in clamps, one stationary and the other movable, which act as conductors for the low-voltage electric supply and also apply force. This force or pressure is applied only after the abutting surfaces have reached a temperature slightly below the melting point, which results in the upsetting of the metal. Uniform and accurately mating surfaces are desirable to exclude air and give uniform heating. The process is commonly used during rod rolling and wire drawing operations to join the ends.

STITCH WELDING

This is an extension of spot welding, in which a series of overlapping spot welds are made in the same manner as stitching cloth. Stitch welding may be performed with a normal spot welding machine or with a specially designed one, which automatically makes spot welds in a continuous series.

MULTIPLE SPOT WELDING

This is a modification of spot welding, in which two or more welds can be obtained from each transformer secondary.

SERIES SPOT WELDING

In series welding, a portion of the secondary current bypasses any weld nugget being formed. This shunt current passes through one of the panels being welded. Generally, two welds are made per transformer secondary.

ROLLER SPOT WELDING

In this process, a series of intermittent spot welds are made using wheels or rollers as electrodes. The rollers are power driven and are stopped while individual welds are made. Current is passed intermittently when the electrodes are stationary.

FOIL BUTT-SEAM WELDING

This is a modification of seam welding, in which thin narrow strips of metal are introduced between one or both of the circular electrodes and the work piece. The joint edges are held in the same plane instead of being overlapped. The strips help to localise the melting and to avoid reduction of section thickness at the joint. The process is being used successfully on the shells of rail-coaches.

INDUCTION PRESSURE WELDING

In this process, the current is induced by high frequency induction process in the job. Due to electrical induction the job is heated. When a suitable temperature is reached, the weld is consolidated by a forging action of the joint. This is generally used in manufacture of tubes.

EXPLOSIVE WELDING

In this process, two pieces of metal are impacted together at an extremely high velocity of impact achieved by the detonation of an explosive charge. The result is a solid-state weld completed in microseconds without any noticeable deformation. The process has been used to prepare clad plates involving dissimilar metals, and in welding tubes to tube sheets in heat exchangers.

FRICTION WELDING

In this process, friction is employed to generate heat between two sliding or rotating metal surfaces. Placing the pieces to be welded in chucks on a common horizontal axis usually carries out the process. One part is rotated and other remains stationary. Pressure is applied to generate enough heat to reach a bonding temperature within a few seconds. At this point, rotation is stopped very quickly and pressure is maintained or increased until welding is complete. Friction welder helps in achieving consistently high quality of joints each within a few seconds in various similar and dissimilar metal combinations.

ULTRASONIC WELDING

This is a solid state welding process for joining similar or dissimilar metals by application of high frequency vibratory energy to work pieces held together under moderate static pressure. The equipment consists of a frequency converter, which changes 50Hz power to the high frequency 15-60 KHz required by ultrasonic head. The head has a piezo-electric transducer, which converts the high frequency electrical output into vibratory mechanical motion and wave-guides, which transmits the vibratory waves to the tools and into the weldment. The job is clamped while welding. The process is used to weld plastics, thin foils and dissimilar metals.

DIFFUSION BONDING

In this process union between specially prepared mating surfaces takes place as a result of diffusion that occurs due to high temperature and pressure exerted for a sufficiently long time. The pressure is low enough to ensure that there is no plastic flow or deformation. The extended time of several minutes at elevated temperatures (which will cause oxidation) requires that the joint be made in protective atmosphere

or vacuum. Sometimes thin inserts are placed between the mating surfaces to speed up diffusion and ensure strong welds.

PNEUMATIC SYSTEM

Fluid power system using air as medium for developing, transmitting, controlling and utilizing power is called pneumatic system.

ADVANTAGE OF AIR:

- Available in plenty
- Compressible
- Easily storable
- Transportable
- Insensitive to temperature
- No risk of explosion and fire- hence it is safe
- Clean and non pollutant
- Fast expandable
- Suitable for high speed operation
- Learnable technology
- Easy to operate
- Low cost energy

Why dry and clean compressed air is necessary for pneumatic system?

- Atmospheric air contains:
- Nitrogen

- Oxygen
- Carbon dioxide
- Water vapor
- Other gases like neon
- Dust
- Smoke

Compressed air should free from all contaminant for better and efficient operation of pneumatic system and its component. It is also helps the component for longer life.

NOTE: Compressor having the capacity of 3 m^3/min at 7.5 bar produced 40 liters of water per day.

Problems in pneumatic system due to contamination of air:

- Corrosion
- Pressure losses
- Increase the tool wear
- Faults in pneumatic controls
- Delay in response time
- Expensive down time

So dry is needed in the pneumatic systems to avoid problems in operation and maintenance.

DRY AND CLEAN AIR: Free from all contaminants and having

- 78% of nitrogen molecules
- 21% of oxygen molecules and
- 01% of other gases

What is compressed air? How achieve it?

Pressurized atmospheric air is called compressed air. Compressor is converting mechanical energy into gas energy by means of compressing air at desired working pressure.

Why compressed air is needed?

Compressed air is needed to carry energy for work at different locations/ areas/equipment.

GENERAL APPLICATION OF PNEUMATIC SYSTEM

- Power application
- Process application
- Control application

APPLICATION IN RIG

- Power application

Ex: starting of engine, engaging clutches

- Control application

Ex: driller's console

TYPE OF VALVES

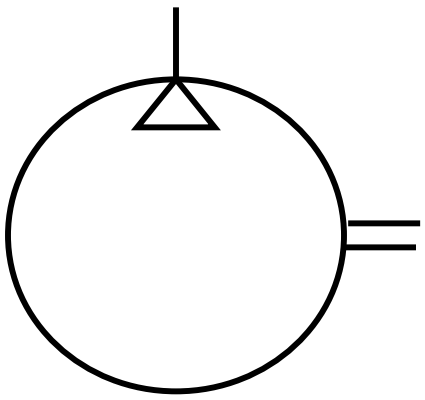
1. Directional control valve
2. Non-return valve
3. Pressure control valve
4. Flow control valve
5. shut-off valve

The various types of valves are used in the pneumatic system to control, regulate and direct the flow of compressed air according to operational requirement.

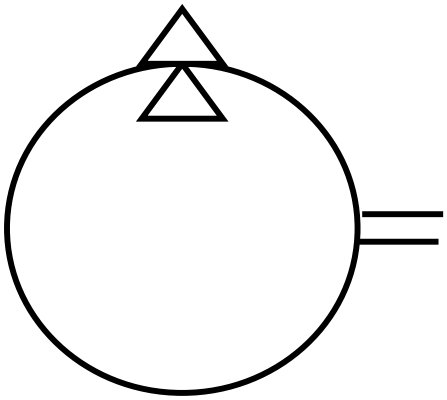
VARIOUS TYPES OF PNEUMATIC VALVES AND THEIR FUNCTIONS

Sl.no.	Description	Functions
01	Directional control valve	On/off function
02	Over ride valve	Cracking pressure
03	Relief valve	Limiting pressure
04	Pressure reducing valve	Reducing pressure
05	Flow control valve	Regulate flow
06	Check valve	Permits flow of air in one direction
07	Shuttle valve	Permits flow of air in two direction
08	Normally open (solenoid valve)	Normally open position
09	Normally closed (solenoid valve)	Normally closed position

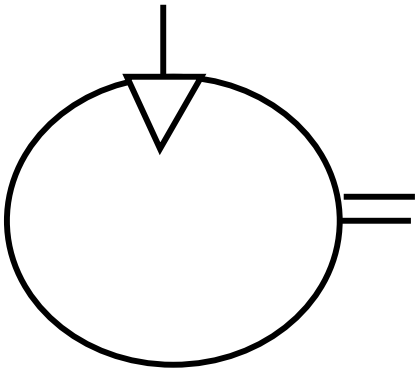
COMPRESSOR



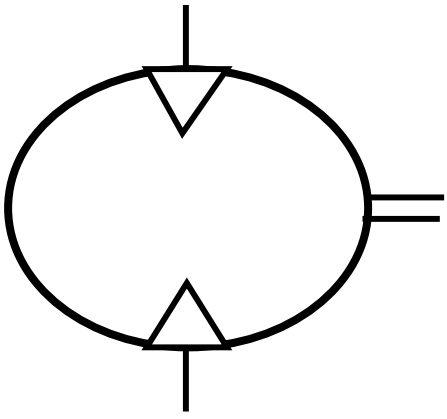
VACUUM PUMP



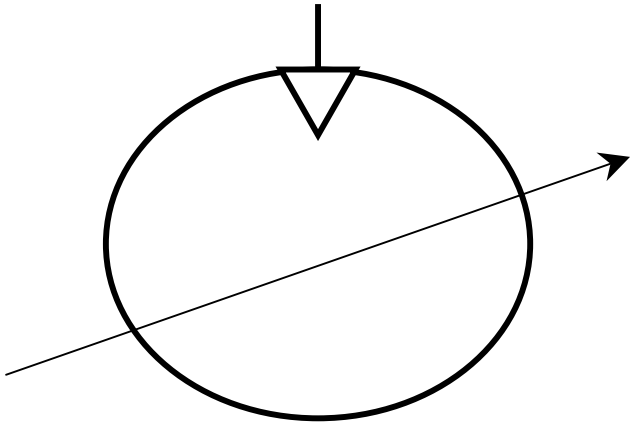
PNEUMATIC CONSTANT – RATE MOTOR WITH ONE DIRECTION OF FLOW



PNEUMATIC CONSTANT – RATE MOTOR WITH TWO DIRECTIONS OF FLOW



PNEUMATIC MOTOR WITH ADJUSTABLE DISPLACEMENT VOLUME ONE DIRECTION OF FLOW



PNEUMATIC MOTOR WITH ADJUSTABLE DISPLACEMENT VOLUME TWO DIRECTIONS OF FLOW