INTRODUCTION

Power can be transmitted in number of ways i.e by belts, ropes, chains and couplings but gears form very important part of power transmission. With the help of gears definite velocity ratio is achieved and they found applications in many machines such as transmission of automobiles, machine tools, rolling mills, and clocks. A gear is a toothed circular part which mesh with another toothed part to provide specific output. The output may be in the form of speed or torque. The purpose of projections or teeth is to reduce slipping. Two or more gears working together is called a gear train. Intermeshing gears always turn in counter directions.

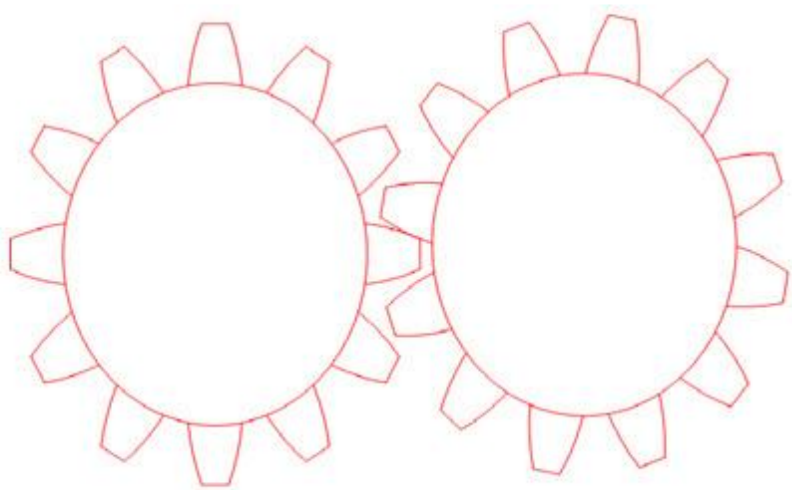

Fig.4.1 Meshing of two gears

Gears of different sizes can be combined together to design different mechanisms depending upon particular requirement. The gears are generally designed to prevent failure against static and dynamic loads. Gears can be made from cast iron, steel, bronze, phenolic resin, nylon and Teflon etc. The major advantages of gear drives include transmission of exact velocity ratio, high efficiency and compact layout.

HISTORY OF GEARS

Gears are as old as any other machinery, the mankind is using. The early Greeks and Romans made considerable use of gears. The Antikythera mechanism is an example of an ancient geared device, that was designed to calculate astronomical positions (built between 150 and 100 BC). The first known geared mill was built about 27 B.C. In the fourth century, BC Aristotle wrote about wheels using friction between smooth surfaces to transmit motion.

Early man used wooden gears to grind wheat and hammer metals. During the beginning of the Christian era gears were used in many machines such as clocks, waterwheels and windmills. Philon of Byzantium, Archimedes, Dionysius of Alexandria and Leonardo da Vinci have made use of gears in various machines.

GEAR CLASSIFICATION

The gears may be classified into three types as discussed below:

1. According to relative position of shafts: The shafts between which motion has to be transmitted may be

1. Parallel
2. Intersecting
3. Non-intersecting and Non-parallel

2. Depending Upon the Peripheral Velocity

a) When the velocity of gears is less than 3m/s, the gears are termed as Low Velocity Gears.

b) When the velocity of gears is between 3m/s to 15 m/s, the gears are termed as Medium Velocity Gears.

c) When the velocity of gears is greater than 15m/s, they are termed as high velocity gears.

3. According to contact of Gears**:**

It may be classified as

i) External Gearing

ii) Internal Gearing

In External Gearing the gears mesh externally while in internal gearing the gears mesh internally with each other.

Parallel Shafts

The following are the main types of gears connecting parallel shafts.

1. Spur Gear

The teeth of spur gears are straight and run parallel to the axis of the shaft.

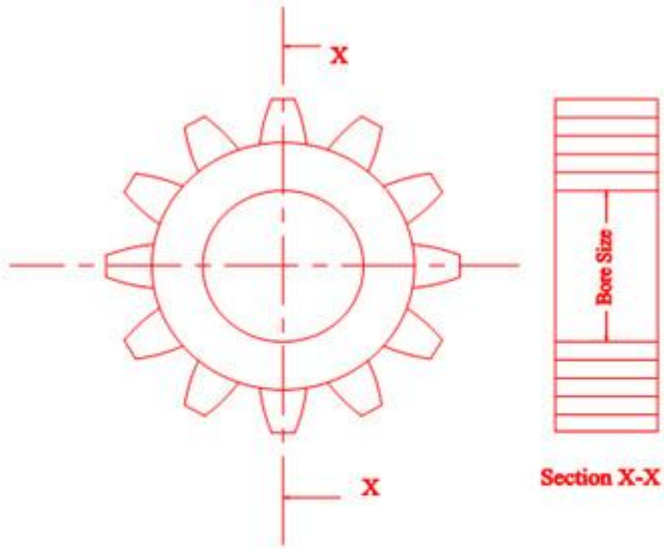

Fig.4.2 Spur gear

Spur gears may have external or internal contact depending on the type of layout. They are the most common type of gear and are quite simple to manufacture. Spur gears are mainly used in tractor transmissions, blenders, clothes dryers, and flour mills.

2. Helical Gear

Just like spur gears, helical gears are also used connect parallel shafts to transmit power. In helical gears teeth are cut at an angle which results in quiet and smooth running operation by providing more contact area at the time of teeth engagement.

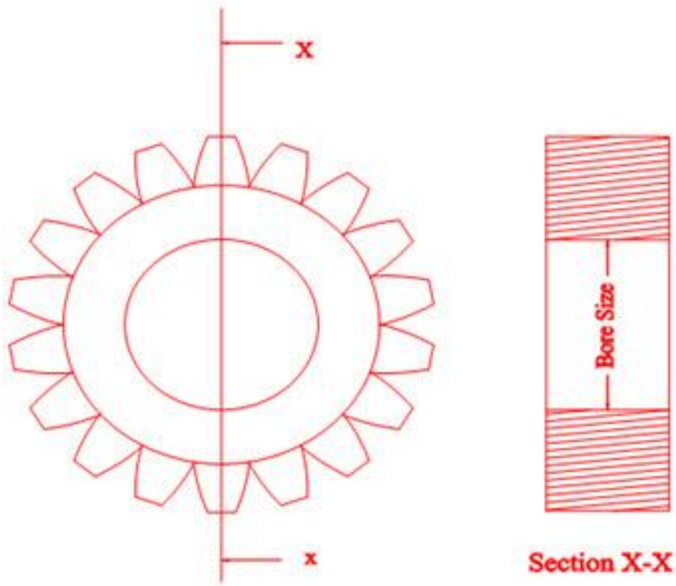

Fig.4.3 Helical gear

The applications of helical gears are in automobile transmission, machine tools, and compressors.

3. Herringbone gears:

Since Herringbone gears look like two helical gears joined together, so they may be referred as "double helical gears. Herringbone gears generally find applications in heavy duty vehicles.

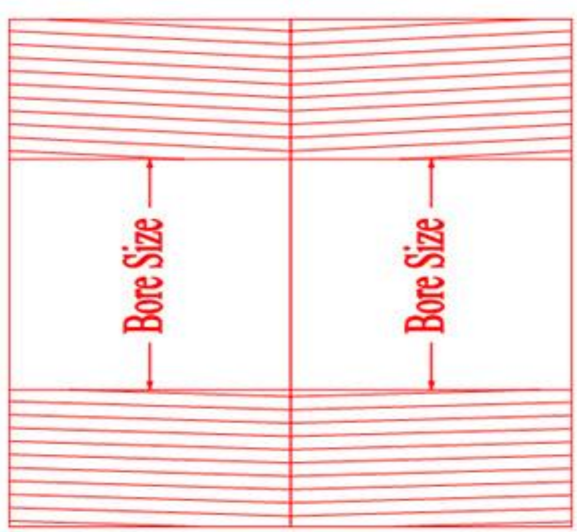

Fig.4.4 Herringbone gears (or double-helical gears)

4. Rack and pinion

A rack is a straight gear that meshes with smaller gear (pinion) to convert rotary power and motion in a linear movement or vice-versa.

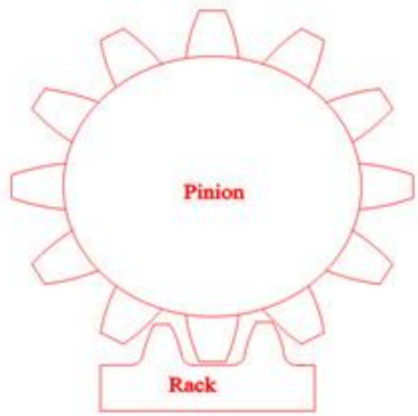

Fig.4.5 Rack and pinion

INTERSECTING SHAFTS

The following are the main types of gears connecting intersecting shafts.

1. Bevel Gear

Bevel gears find applications which generally require power transmission at right angles. The teeth on such gears may be straight, spiral or hypoid. The bevel gear has many applications such as differential of automobiles, printing machines, and processing plants.

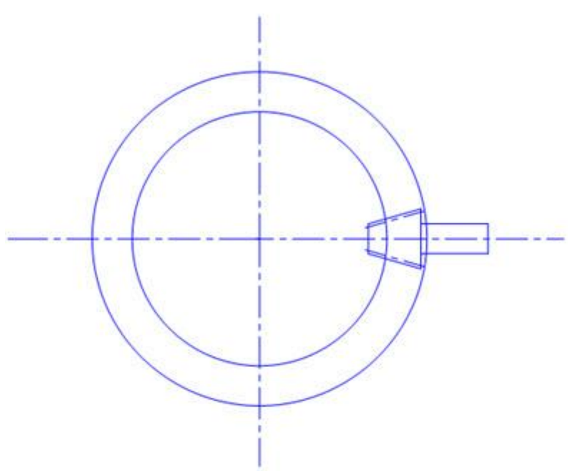

Fig.4.6 Bevel gears

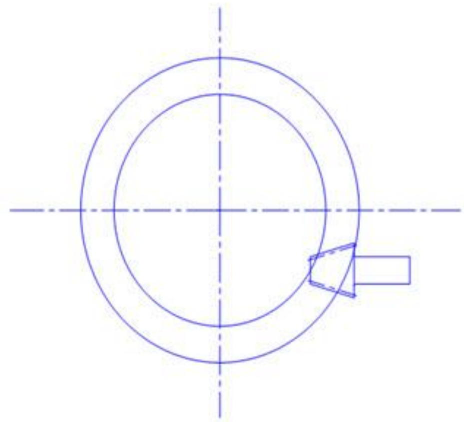

Fig.4.7 Hypoid gear

NON-INTERSECTING AND NON-PARALLEL (SKEW SHAFTS)

The following are the main types of gears connecting non intersecting and non-parallel shafts.

1. WORM AND WORM GEAR

The major function of worm gear is that of speed reduction. With the help of worm gears speed reductions greater than 300:1 can be achieved. Such types of gears are generally used in automobile steering mechanism.

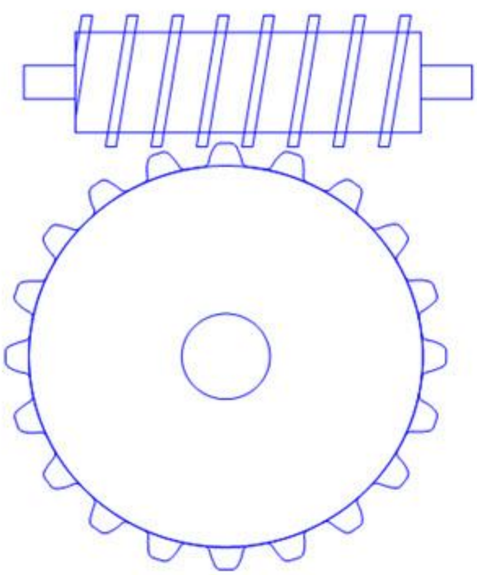

Fig. 4.8 Worm and worm gear

GEAR TERMINOLOGY

The Bureau of Indian standards (BIS) in their codes IS: 2458(1965) and IS: 2467(1965) has defined various parameters of gears as such:

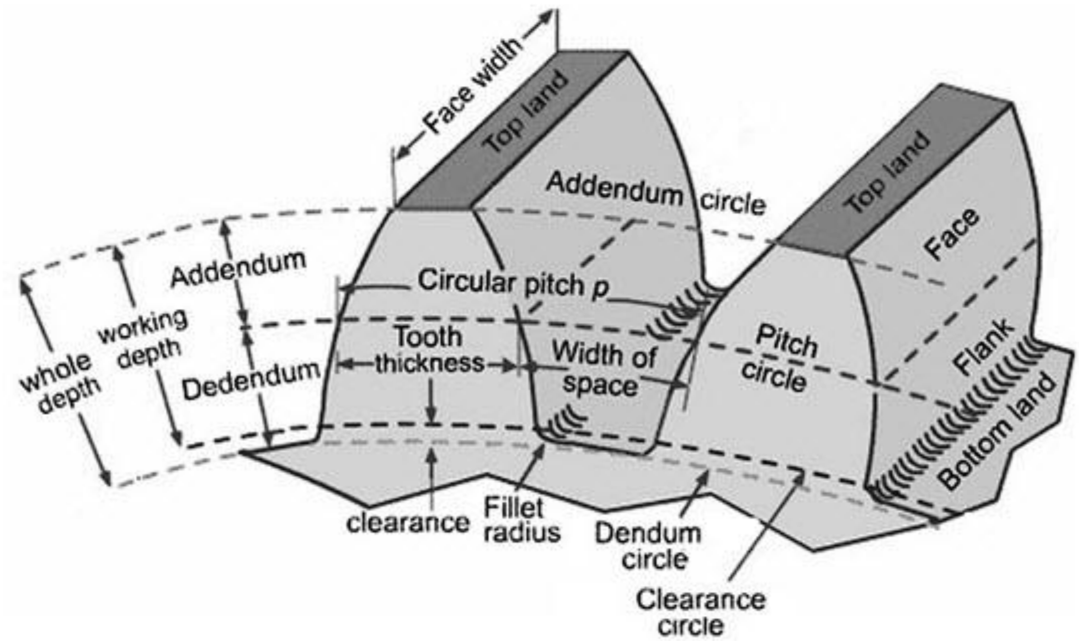

Fig 4.9 Gear Terminology

- **Pitch circle**: It is theoretical circle which divides the gear into two imaginary parts addendum and dedendum.
- **Pitch circle diameter**: it is also called PCD or bolt circle diameter. Pitch circle diameter as the name suggests is the diameter of pitch circle. Circular parts are assembled with other parts by passing bolts through holes drilled at PCD.
- **Addendum**: The vertical height along the circumference from the pitch circle to the gear top is called addendum.
- **Addendum circle**: it is an imaginary circle passing through top of gear.
- **Dedendum**: The vertical height along the circumference from the pitch circle to the bottom of gear is called **Dedendum**.
- Dedendum circle: it is an imaginary circle passing through bottom of gear.

- **Clearance**: The difference between the dedendum of one gear and the addendum of the mating gear.
- **Face and Flank of a tooth**: Axially the pitch circle divides the tooth in to two parts. The portion axially above the pitch circle is called face and below pitch circle is called flank.
- **Tooth thickness**: The thickness of the tooth along the pitch circle is called tooth thickness
- **Tooth space**: It is the distance between adjoining teeth of a gear.
- **Fillet:** A curvature called fillet is provided to connect tooth to the root circle
- **Pitch point**: Where two gears mesh their point of contact is called pitch point.
- **Backlash**: When gears mesh, there is clearance between the tooth of two mating gears. This clearance is referred to as backlash
- **Pressure angle**: The angle between the common normal at the point of tooth contact and the common tangent to the pitch circles. It refers to the angle through which forces are transmitted between meshing gears.
- **Diametral pitch:** The diametral pitch is the number of teeth divided by the pitch diameter.

$$\text{Diametral Pitch} = \frac{\text{Number of teeth}}{\text{PCD}}$$

- **Module** is defined as Pitch diameter divided by number of teeth.

$$\text{Module} = \frac{\text{PCD}}{\text{Number of Teeth}}$$

According to fundamental law of gearing, if the gears have meshed properly, the line of action should be straight and pass through the Pitch Point of the gears. Two tooth profiles that satisfy the above condition and used extensively in gear manufacturing process are involute and cycloidal profiles. An involute curve can be imagined as it is traced by a point on a stretched string during its unwinding from a cylinder. Whereas when two generating circles roll on the pitch circle they trace the cycloidal tooth profile. Involute profiles have constant pressure angle, are easy and cheap to manufacture but cycloidal profile tooth have variable pressure angle, more precise to manufacture so are relatively costlier than involute profiles. Pressure angle is necessary for quiet operation of gears. In cycloidal gears, the pressure angle is maximum at the start and end of engagement and is zero at pitch point. So the running of cycloidal gears is little noisy. But at the same time cycloidal gears are more robust due to wider flanks. Exact center distance has to be maintained in cycloidal gears while in the involute gears the center distance of mounting shafts can be varied by adding correction factor.

GEAR TRAINS

When two or more gears mesh it is called a **gear train.** Gears mesh with each other to transmit rotational motion from one shaft to another. There is a **driver** gear and a **driven** gear and the **gear ratio** produced by the train depends on the number of teeth on each gear. As already described the meshing gears rotate in opposite directions and in order to have the same direction of rotation of the driver gear and the driven gear an idler gear is added between the driver and driven gears.

VELOCITY RATIO

Velocity ratio of gear train is defined as the ratio of the speed of the driver gear to the speed of the driven gear and the ratio of speed of two meshing gears varies inversely as the number of teeth.

$$\text{Speed ratio} = \frac{\text{Speed of driver gear}}{\text{Speed of driven gear}}$$

$$= \frac{\text{No.of teeth on driver gear}}{\text{No.Of teeth on driven gear}}$$

Or

$$\text{Speed ratio} = \frac{1}{\text{Train Value}}$$

TYPES OF GEAR TRAINS

1. Simple gear train
2. Compound gear train
3. Planetary gear train

SIMPLE GEAR TRAIN

As the name suggests this is the simplest type of gear train in which one gear is mounted on single shaft. Such gear trains are generally used where there is no constraint of space and large centre distance can be maintained between the gear mounting shafts. The gear ratio produced by the train depends on the number of teeth on each gear. Idler gears have no effect on the speed ratio or train value of gear train. For different gear ratios, different combinations of gears are required. It may be worth mentioning here that meshing gears must have same module.

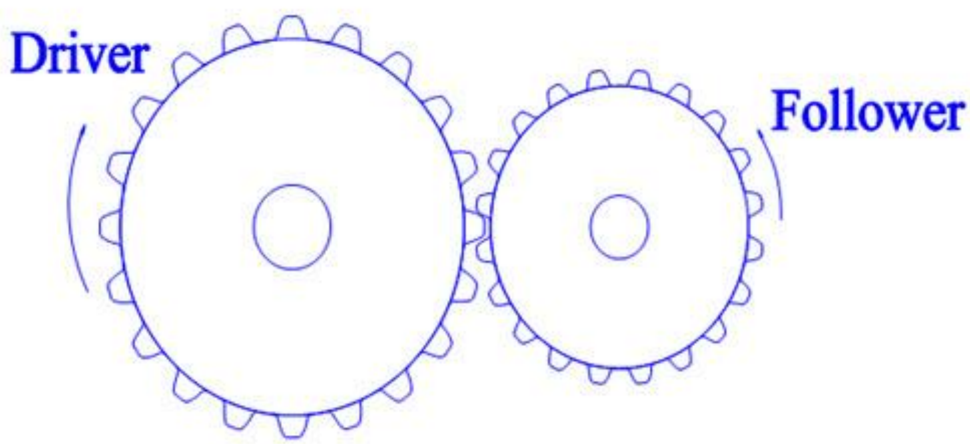

Fig 4.10 Simple Gear Train

COMPOUND GEAR TRAIN

In Compound gear train more than one gear rotate on single shaft. Such type of gear trains are used where the designer wants a compact layout and when large changes in speed or power output are needed.

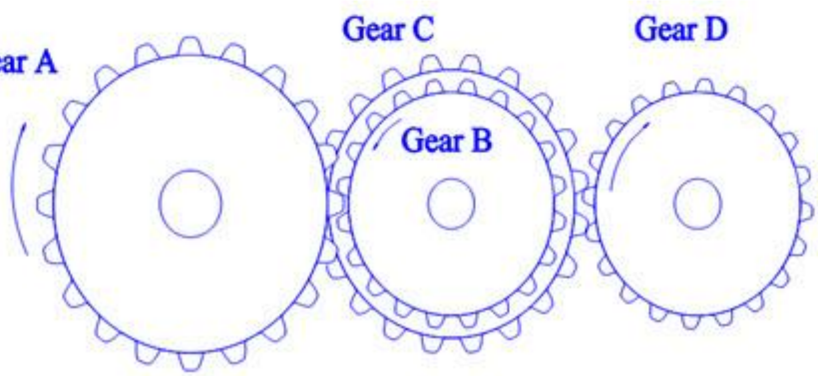

Fig 4.11 Compound Gear Trains

Speed ratio of compund gear train is given by

$$\text{Speed ratio} = \frac{\text{Speed of first driver}}{\text{Speed of lastdriver}}$$

$$= \frac{\text{Product of number of teeth on driven}}{\text{Product of number of teeth on driver}}$$

Epicyclic Gear Train

Epicyclic means to move upon and around in circular manner. Consider the diagrammatic representation of simple epicyclic gear train in the fig 4.12. In this gear train gear B meshes with gear A. Considering the arm AB to rotate about axis of gear A, then the gear B is forced to rotate upon and around gear A.

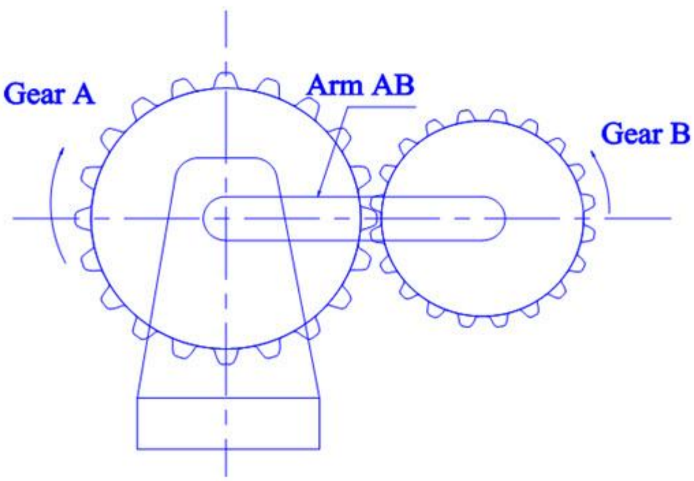

Fig 4.12 Epicyclic Gear Train

Compound epicylic gear trains are also referred to as **Planetary gear trains**. In such gear trains one or more gears orbit about the central axis of the train.

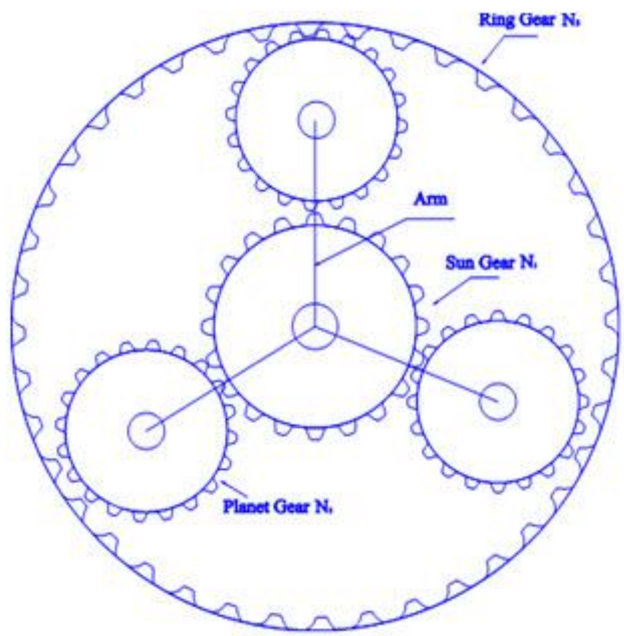

Fig 4.13 Planetary Gear Train

As shown in the figure 4.13 the sun gear, N_1 engages all three planet gears simultaneously. All three planet gears are attached to a plate (the planet carrier), and they engage the inside of the ring gear. The output shaft is attached to the ring gear, and the planet carrier is held stationary. Different gear ratios can be produced depending on which gear is used as the input, which gear is used as the output, and which one is held stationary. The major applications of Epicylic Gear train is in differential of automobiles, lathe machines etc.