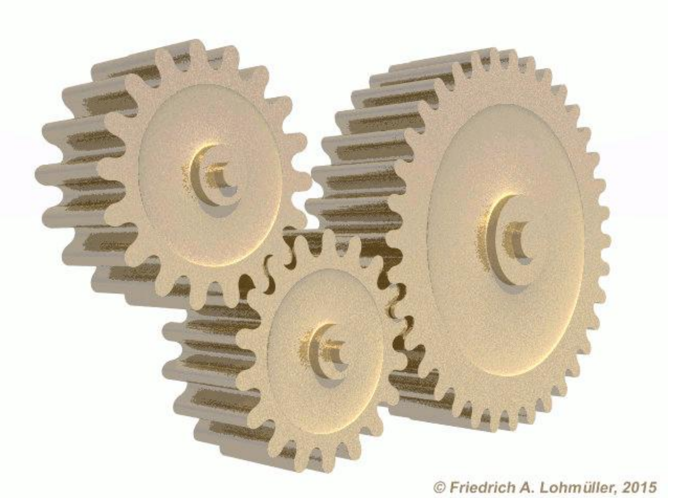
MECHANICAL ENGINEERING SCIENCE

Dr. Mantesh B Khot

Department of Mechanical Engineering

GEAR DRIVES

- Gears are defined as toothed wheels which transmit power and motion from one shaft to another by means of successive engagement of teeth.



Gear drives offer the following advantages compared with chain or belt drives:

- It is a **positive drive** and the velocity ratio remains constant.
- The centre distance between the shafts is relatively small, which results in compact construction.
- It can transmit very large power, which is beyond the range of belt or chain drives.
- It can transmit motion at very low velocity, which is not possible with the belt drives.
- A provision can be made in the gearbox for gear shifting, thus changing the velocity ratio over a wide range.

GEAR DRIVES

Gears can be classified according to the relative positions of their shaft axes as follows:

1) Parallel Shafts

a) Spur Gears

b) Helical Gears

c) Double helical or Herringbone Gears

GEAR DRIVES

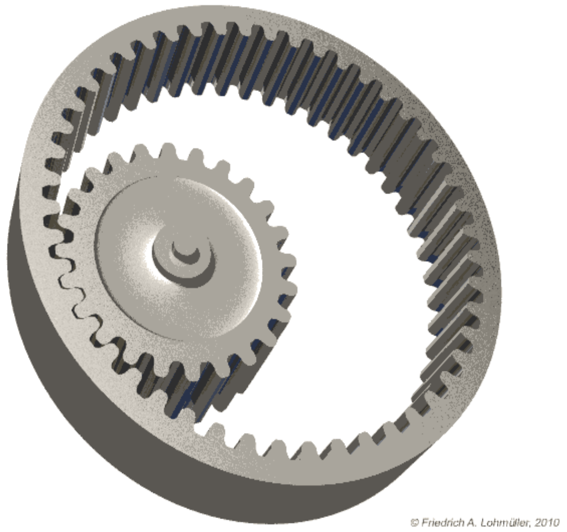
Spur Gears

- They have **straight teeth** parallel to the axes.

- At the time of engagement of the two gears, the contact extends across the entire width on a line parallel to the axes of rotation. This results in **sudden application of the load, high impact stresses and excessive noise at high speeds.**

- If the gears have external teeth on the outer surface of the cylinders, the shafts rotate in the **opposite** direction.

- In an internal spur gear, the teeth are formed on the inner surface of an annulus ring. An internal gear can mesh with an external pinion (smaller gear) only and the two shafts rotate in the **same** direction.



Helical Gears

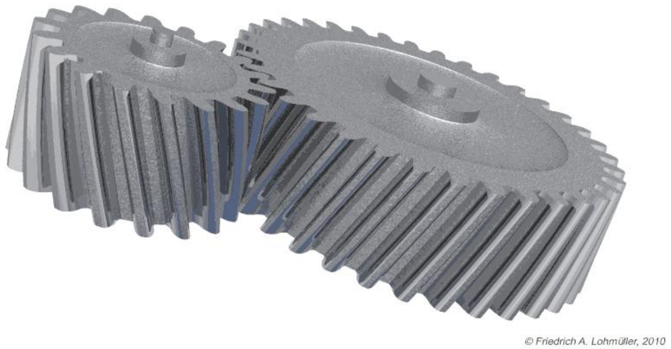
- In helical gears, the teeth are curved, each being **helical** in shape.

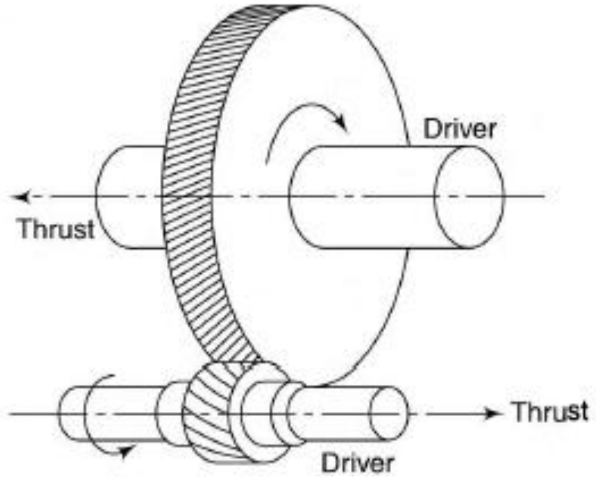
- Two mating gears have the same helix angle, but have teeth of opposite hands.

- At the begining of engagement, contact occurs only at the point of leading edge of the curved teeth. As the gears rotate, the contact extends along a diagonal line across the teeth.

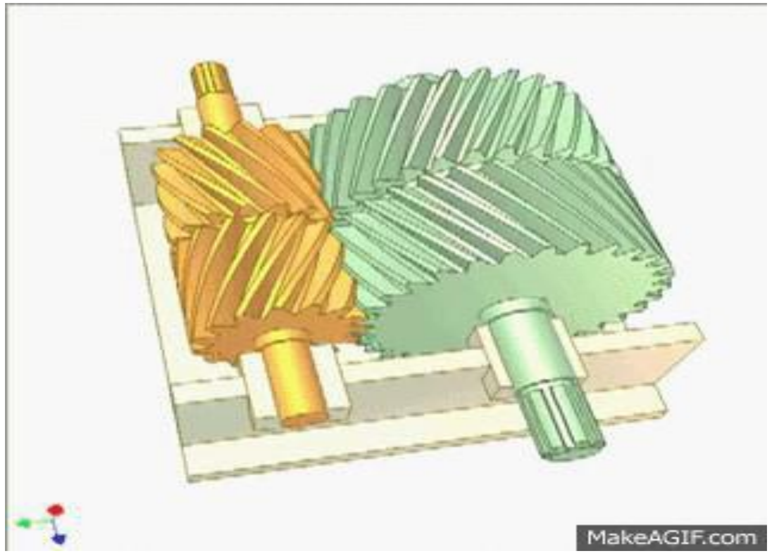
- Thus, the load application is gradual which results in low impact stresses and reduction in noise. Therefore, helical gears can be used at **higher velocities** than the spur gears and have greater load carrying capacity.

- Helical gears have the disadvantage of having **end thrust** as there is a force component along the gear axis.





Double - helical and Herringbone Gears



- A double helical gear is equivalent to a pair of helical gears secured together, one having a right hand helix and the other a left – hand helix.

- The teeth of the two rows are separated by a groove. Axial thrust which occurs in case of a single helical gears is eliminated in double helical gears. This is because the axial thrust of the two rows of teeth cancel each other out. These can be run at high speeds with less noise and vibrations.

- If the left and the right inclinations of a double helical gear meet at a common apex and there is no groove in between, the gear is known as **herringbone gear**.

GEAR DRIVES

2) Intersecting Shafts

a) Straight Bevel Gears

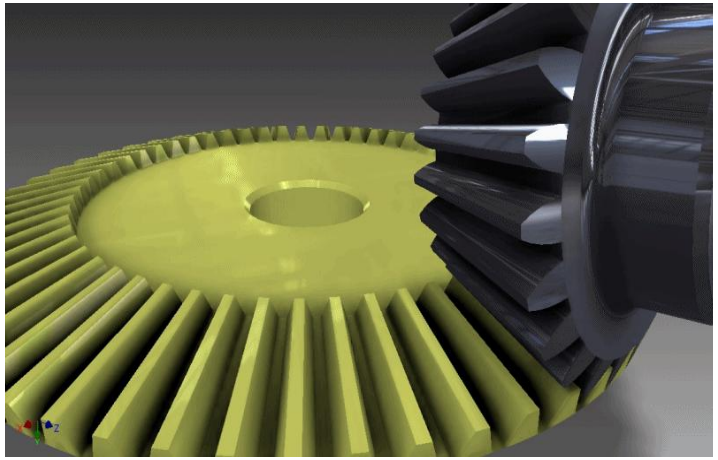
b) Spiral Bevel Gears

GEAR DRIVES

Straight Bevel Gears

- The teeth are straight, radial to the point of intersection of the shaft axes and vary in cross section throughout their length.

- Usually they are used to connect shafts at right angles which run at lower speeds. Gears of same size and connecting two shafts at right angles to each other are known as **mitre gears**.



GEAR DRIVES

Spiral Bevel Gears

- When the teeth of a bevel gear are inclined at an angle to the face of the bevel, they are known as **spiral bevels or helical bevels.**

- They are smoother in action and quieter than straight tooth bevels as there is gradual load application and low impact stresses. Of course, there exists an axial thrust calling for stronger bearings and supporting assemblies.

- These are used for the drive to the differential of an automobile.

GEAR DRIVES

2) Skew Shafts (Neither parallel nor intersecting)

a) Hypoid Gears

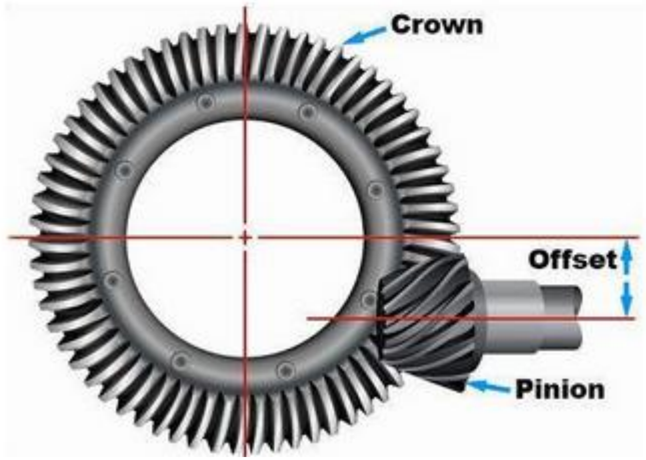
b) Worm Gears

Hypoid Gears

- Hypoid gears are a type of spiral bevel gears, with the difference that hypoid gears have axes that are non-intersecting and not parallel.

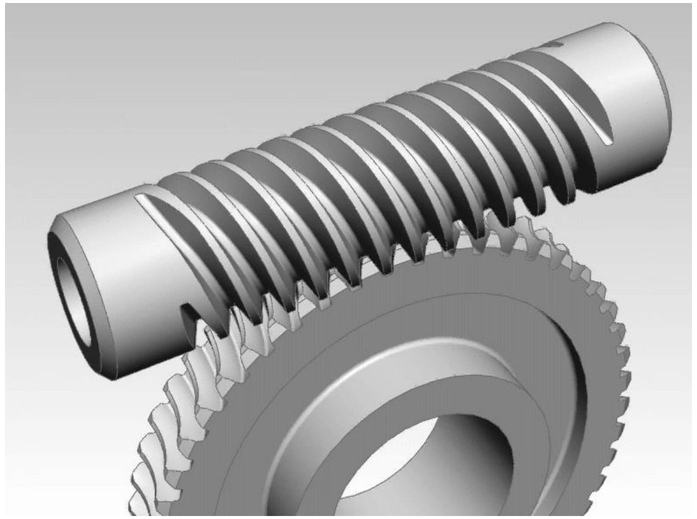
- In other words, the axes of hypoid gears are offset from one another. The basic geometry of the hypoid gear is hyperbolic, rather than having the conical geometry of a spiral bevel gear.

- The most common application for hypoid gearboxes is in the automotive industry, where they are used in rear axles, especially for large trucks. With a left-hand spiral angle on the pinion and a right-hand spiral angle on the crown, these applications have what is known as a "below-center" offset, which allows the driveshaft to be located lower in the vehicle.



GEAR DRIVES

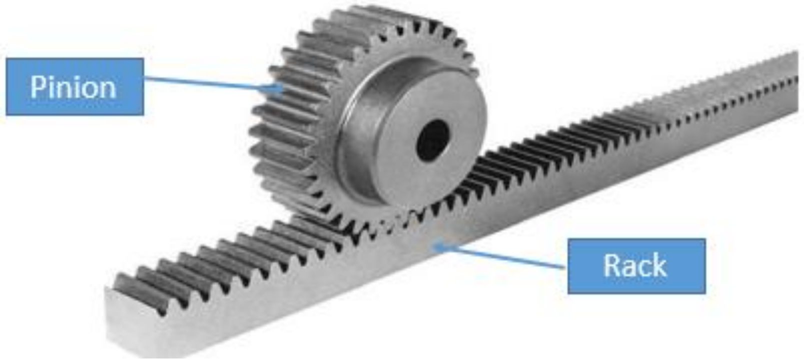
Worm Gears



- The worm gears consist of a worm and a worm wheel.
- The worm is in the form of a threaded screw, which meshes with the matching wheel.
- Worm gear drives are used for shafts, the axes of which do not intersect and are perpendicular to each other.
- Worm gear drives are characterized by high speed reduction ratio.

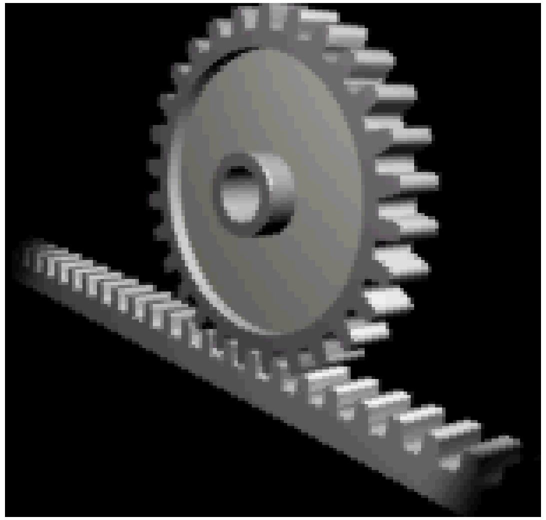
GEAR DRIVES

Spur Rack and Pinion



- Spur rack is a special case of a spur gear where it is made of infinite diameter.

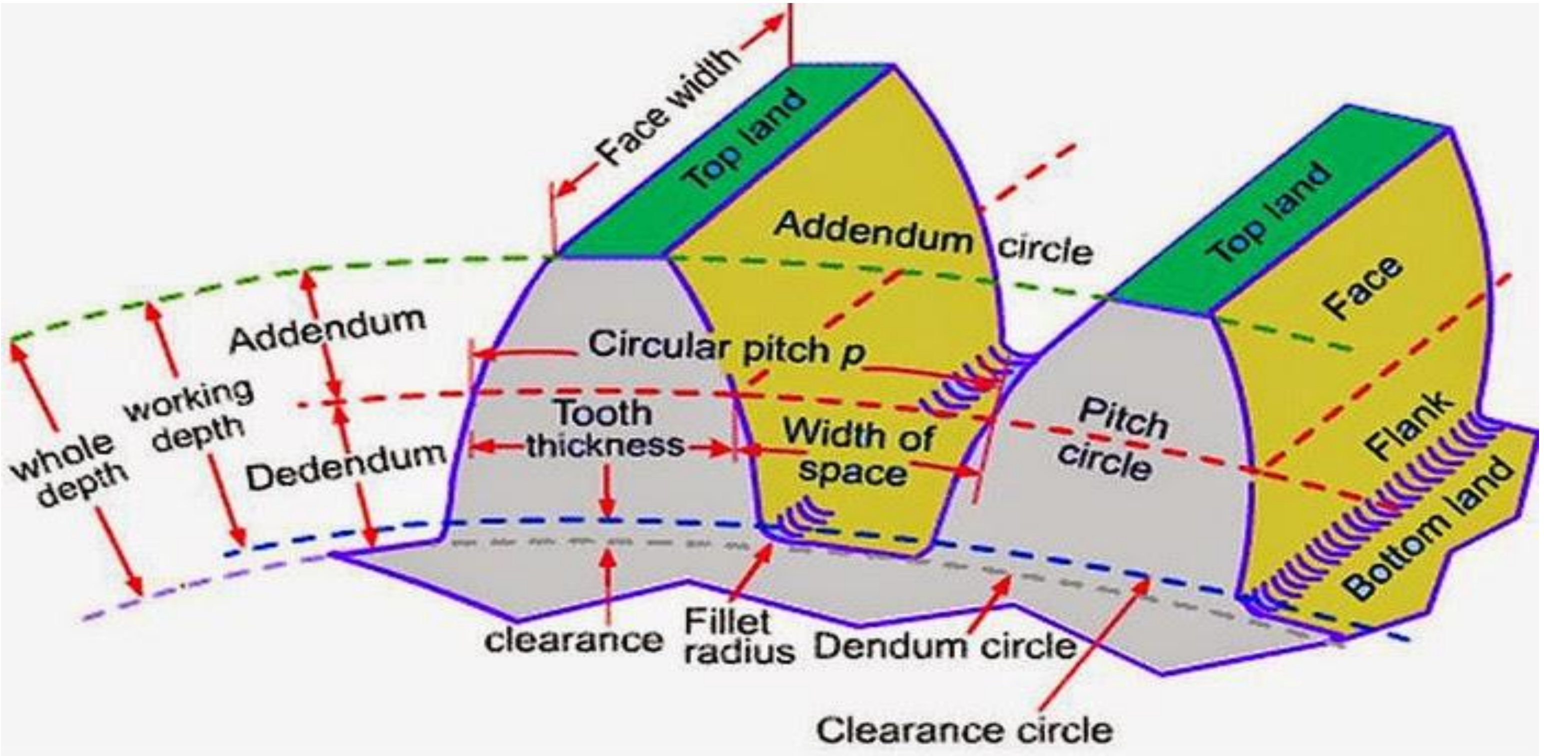
- The spur rack and pinion combination converts rotary motion into translator motion, or vice versa.



- Example – It is used in a lathe in which the rack transmits motion to the saddle.

GEAR DRIVES

Gear Terminology

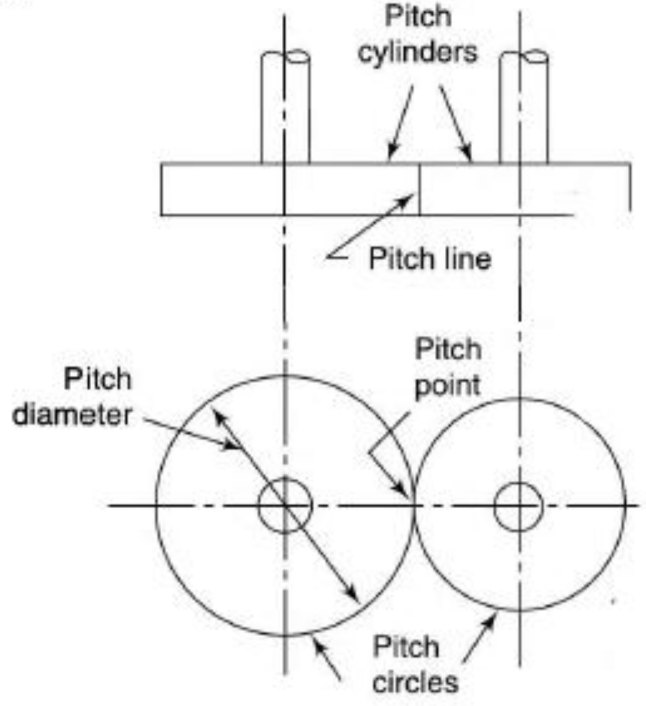


Gear Terminology

- **Pitch cylinders** – Pitch cylinders of a pair of gears in mesh are the imaginary friction cylinders, which by pure rolling together, transmit the same motion as the pair of gears.

- **Pitch circle** – It is the circle corresponding to a section of the equivalent pitch cylinder by a plane normal to the wheel axis.

- **Pitch diameter** – It is the diameter of the pitch circle.

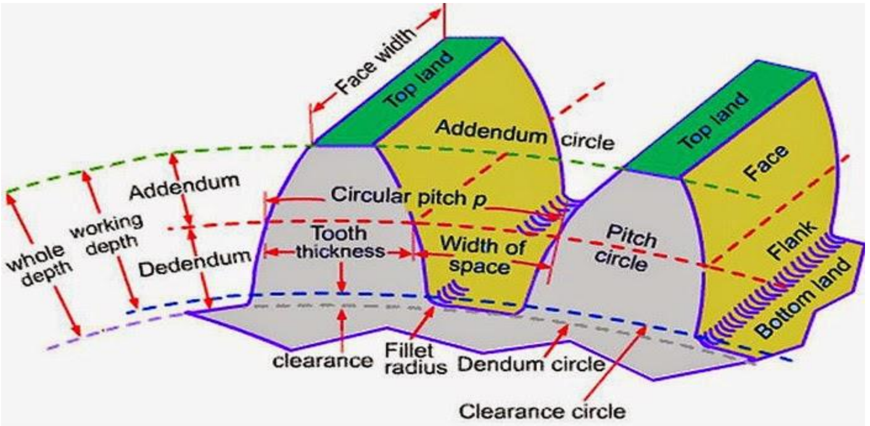


GEAR DRIVES

Gear Terminology

- **Pitch** – It is defined as follows.

a) **Circular Pitch** – It is the distance measured along the circumference of the pitch circle from a point on one tooth to the corresponding point on the adjacent tooth.



$$p = \frac{\pi d}{T}$$

where p = circular pitch; d = pitch diameter; T = number of teeth

GEAR DRIVES

Gear Terminology

- **Pitch** – It is defined as follows.

b) **Diamentral Pitch** – It is the number of the teeth per unit length of the pitch circle diameter in inches.

$$P = \frac{T}{d}$$

It can be seen that

$$pP = \frac{\pi d}{T}\frac{T}{d} = \pi$$

The term diametral pitch is not used in SI units.

GEAR DRIVES

Gear Terminology

- **Pitch** – It is defined as follows.

c) **Module** – It is the ratio of the pitch diameter to the number of teeth. The term is used in SI units in place of diametral pitch.

$$m = \frac{d}{T}$$

Also,

$$p = \frac{\pi d}{T} = \pi m$$

Pitch of two mating gears must be same.

Gear Terminology

- **Velocity ratio** – The velocity ratio is defined as the ratio of the angular velocity of the driven gear to the angular velocity of the driving gear.

Let **d = pitch diameter, T = number of teeth, ω = angular velocity (rad/s), N = angular velocity (rpm);** Subscript 1 = driving gear (driver), Subscript 2 = driven gear (follower)

$$\text{VR} = \frac{\text{angular velocity of follower}}{\text{angular velocity of driver}}$$

$$= \frac{\omega_2}{\omega_1}$$

$$= \frac{N_2}{N_1} \qquad (\omega = 2\,\pi\,N)$$

$$= \frac{d_1}{d_2} \qquad (\because\ \pi\,d_1 N_1 = \pi\,d_2 N_2)$$

$$= \frac{T_1}{T_2} \qquad \left(p = \frac{\pi d_1}{T_1} = \frac{\pi d_2}{T_2}\right)$$

Gear Trains

- A gear train is a combination of gears used to transmit motion from one shaft to another.

- It becomes necessary when it is required to obtain large speed reduction within a small space.

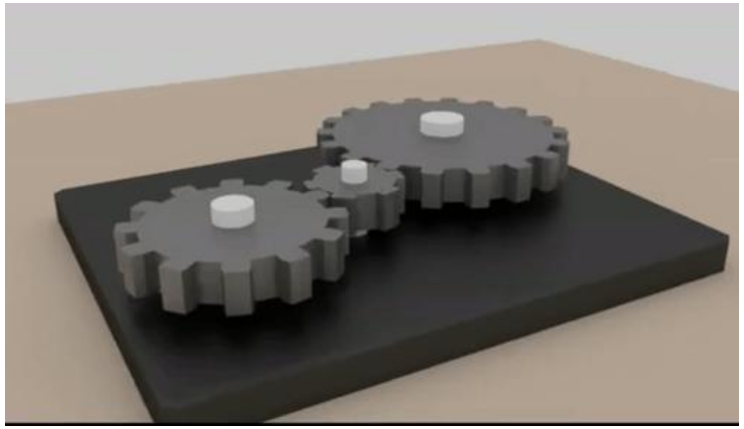
- Main types of gear trains –
  1) **Simple gear train**
  2) **Compound gear train**
  3) **Reverted gear train**
  4) **Planetary or epicyclic gear train**

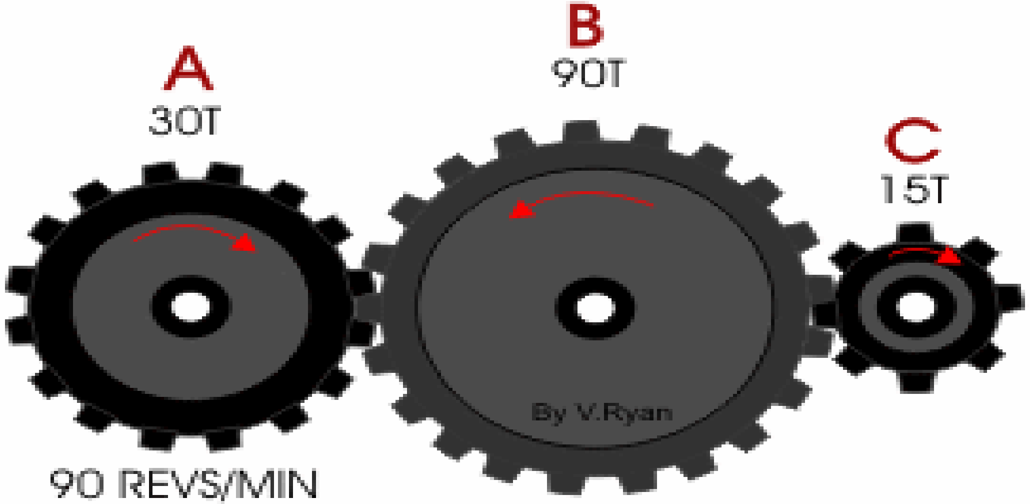
GEAR DRIVES

Simple Gear Train

- A series of gears, capable of receiving and transmitting motion from one gear to another is called a simple gear train.

- In the simple gear train, the gear axes remain fixed relative to the frame and each gear is on a separate shaft.



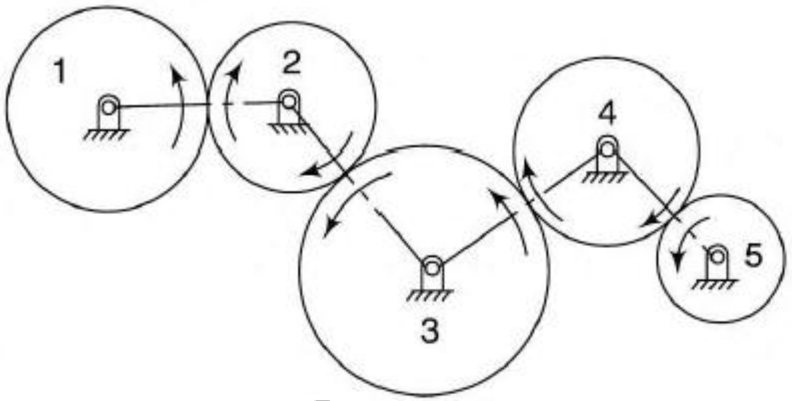


GEAR DRIVES

Simple Gear Train

- **Speed ratio of a gear train** – It is the ratio of the speed of the driving to that of the driven shaft.

- Let T = number of teeth on a gear; N = speed of gear in rpm



$$\frac{N_2}{N_1} = \frac{T_1}{T_2} \qquad \left[\text{Also } \frac{\omega_2}{\omega_1} = \frac{2\pi N_2}{2\pi N_1} = \frac{N_2}{N_1}\right]$$

and

$$\frac{N_3}{N_2} = \frac{T_2}{T_3}, \frac{N_4}{N_3} = \frac{T_3}{T_4} \text{ and } \frac{N_5}{N_4} = \frac{T_4}{T_5}$$

Multiplying,

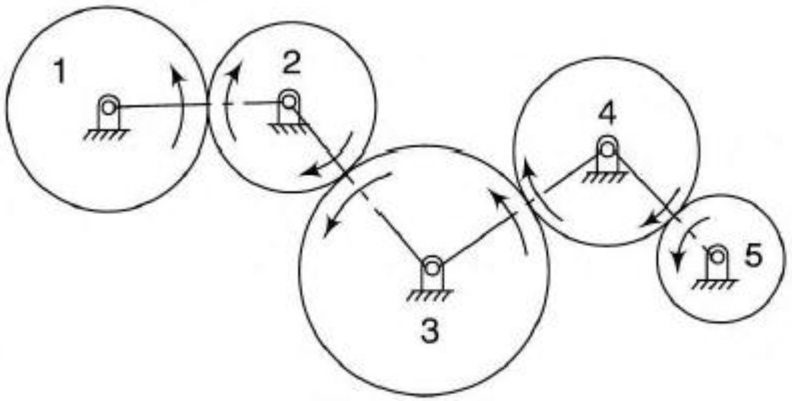
$$\frac{N_2}{N_1} \times \frac{N_3}{N_2} \times \frac{N_4}{N_3} \times \frac{N_5}{N_4} = \frac{T_1}{T_2} \times \frac{T_2}{T_3} \times \frac{T_3}{T_4} \times \frac{T_4}{T_5}$$

GEAR DIVES

Simple Gear Train

➢ Speed ratio is given by,

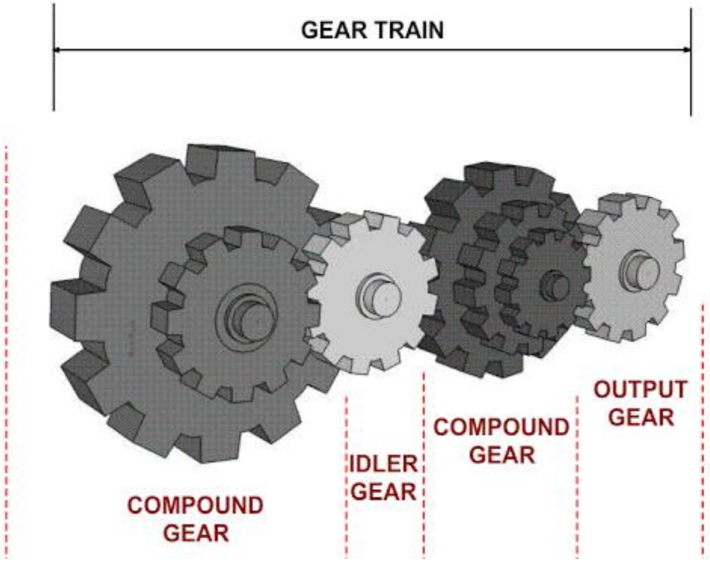
$$\frac{N_1}{N_5} = \frac{T_5}{T_1}$$



➢ Thus it is seen that the intermediate gears have no effect on the speed ratio and therefore they are known as ***idlers***.

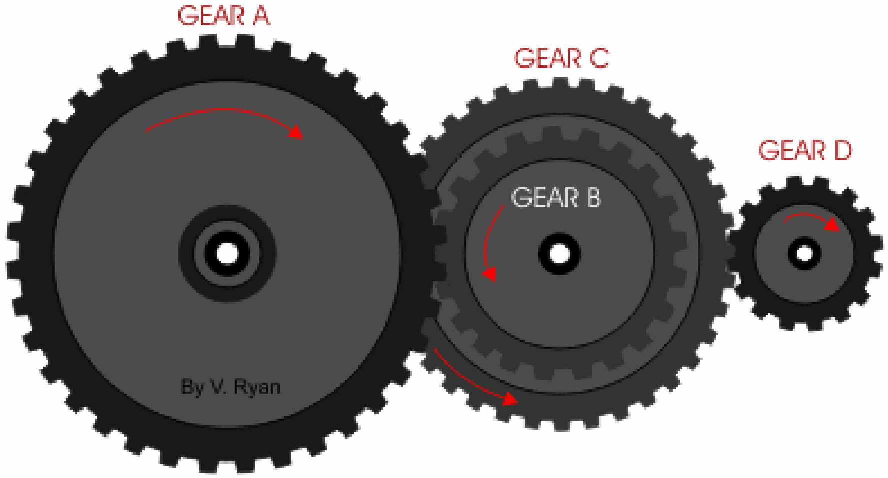
GEAR DRIVES

Compound Gear Train



- When a series of gears are connected in such a way that two or more gears rotate about an axis with the same angular velocity, its known as compound gear train.

- In this type, some of the intermediate shafts, i.e., other than the input and the output shafts, carry more than one gear.



GEAR DRIVES

Compound Gear Train

$$\frac{N_2}{N_1} = \frac{T_1}{T_2}, \quad \frac{N_4}{N_3} = \frac{T_3}{T_4} \text{ and } \frac{N_6}{N_5} = \frac{T_5}{T_6}$$

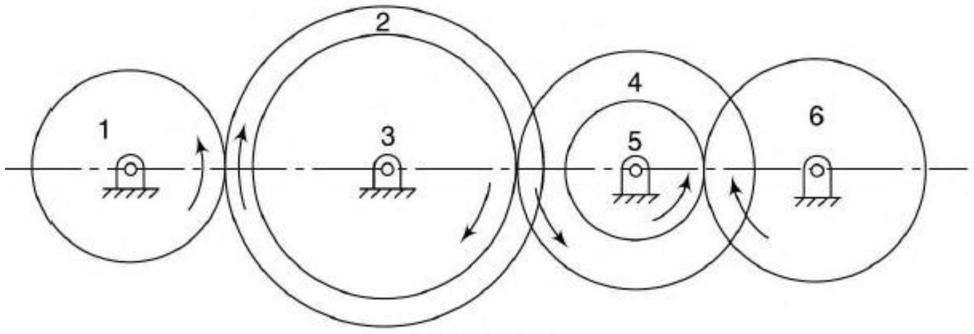
or

$$\frac{N_2}{N_1} \times \frac{N_4}{N_3} \times \frac{N_6}{N_5} = \frac{T_1}{T_2} \times \frac{T_3}{T_4} \times \frac{T_5}{T_6}$$

or

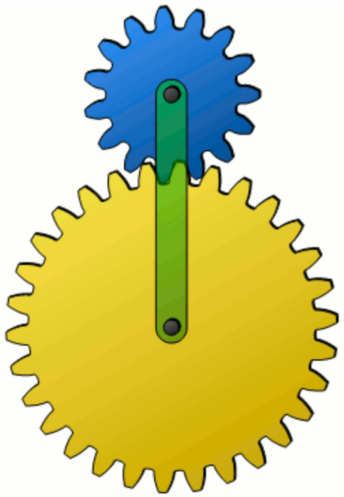
$$\frac{N_2}{N_1} \times \frac{N_4}{N_2} \times \frac{N_6}{N_4} = \frac{T_1}{T_2} \times \frac{T_3}{T_4} \times \frac{T_5}{T_6}$$

$$\frac{N_6}{N_1} = \frac{T_1}{T_2} \frac{T_3}{T_4} \frac{T_5}{T_6}$$



GEAR DRIVES

Planetary or Epicyclic Gear Train



- A gear train having a relative motion of axes is called a ***planetary*** or an ***epicyclic gear train***.
- In an epicyclic gear train, the axis of at least one of the gears also moves relative to the frame.
- Usually the wheel that rolls outside is known as **epicyclic** wheel. The term epicyclic emerges from the fact that the wheel traces an epicyclic path.
- Large speed reductions are possible with epicyclic gears and if the fixed wheel is annular, a more compact unit could be obtained. Important applications are in transmission, computing devices etc.

THANK YOU

Dr. Mantesh B Khot
Department of Mechanical Engineering
mahanteshbk@pes.edu
+91 87 2202 4584