INTRODUCTION

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- A gear is a toothed wheel with teeth cut on the periphery of a cylinder or a cone.
- Teeth of one gear meshes with teeth of the other gear, hence it is called a mesh drive or positive drive.
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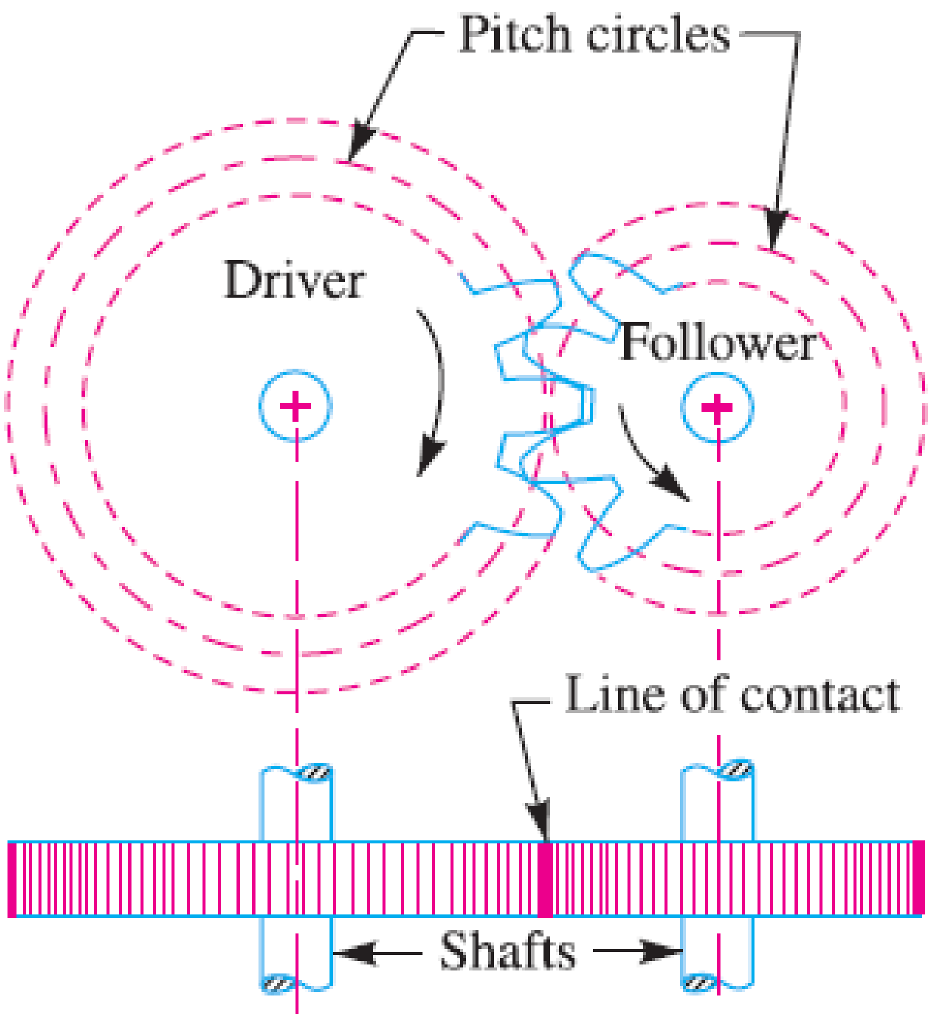
- Rotation of one gear will cause rotation of the other in the opposite direction.

As shown in fig. There are two gears bigger gear is called as **Gear Wheel** and smaller gear is called **Pinion.**



Advantages and Disadvantages of Gear Drives

The following are the advantages and disadvantages of the gear drive as compared to other drives, *i.e. belt*, *rope* and chain drives :

Advantages

1. It transmits exact velocity ratio.
2. It may be used to transmit large power.
3. It may be used for small centre distances of shafts.
4. It has high efficiency.
5. It has reliable service.
6. It has compact layout.

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Types of Gears

The most common way to classify gears is by category type and by the orientation of axes.

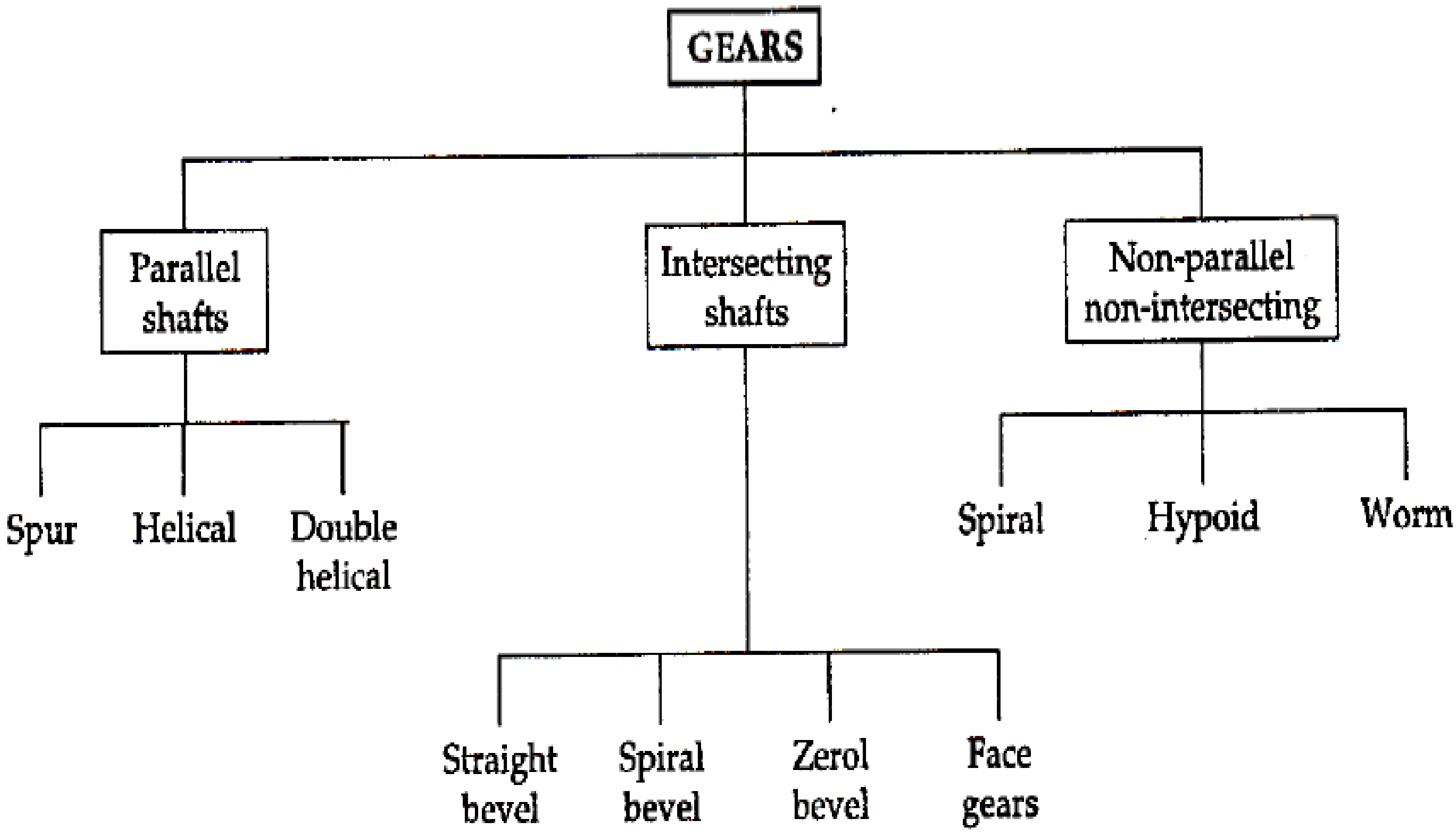
Gears are classified into 3 categories;

- **Parallel axes gears,**
- **Intersecting axes gears, and**
- **Nonparallel and Nonintersecting axes gears.**

Spur gears and helical gears are parallel axes gears.

Bevel gears are intersecting axes gears.

Screw or crossed helical, worm gear and hypoid gears are nonparallel and nonintersecting axes gears.



Classification of Gears

- Categories of Gears

Parallel Axes Gears

- Types of Gears

Spur Gear
Spur rack
Internal gear
Helical gear
Helical rack
Double helical gear

- Efficiency (%)

98.0 – 99.5

- Categories of Gears

Intersecting Axes Gears

- Types of Gears

Straight bevel gear
Spiral bevel gear
Zerol bevel gear

- Efficiency (%)

98.0 – 99.0

- Categories of Gears

Nonparallel and Nonintersecting

- Types of Gears

Screw gear (Efficiency 70.0 – 95.0 %)
Worm gear (Efficiency 30.0 – 90.0 %)

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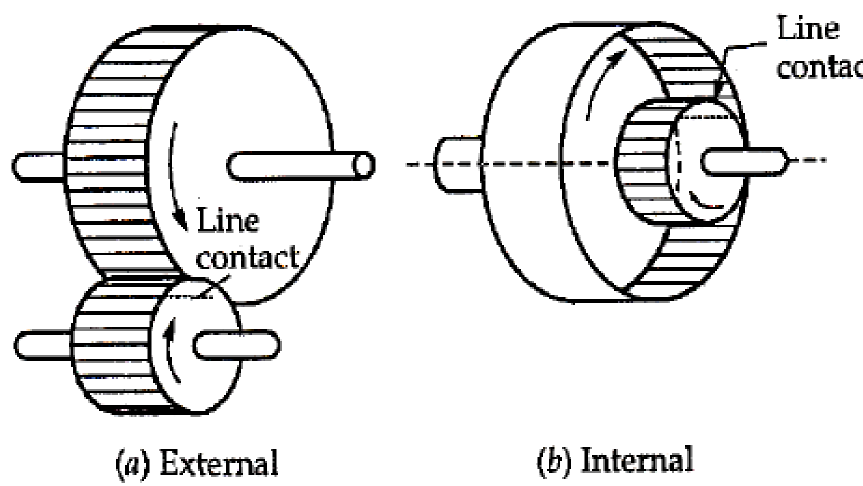

Spur Gears

Helical Gears:

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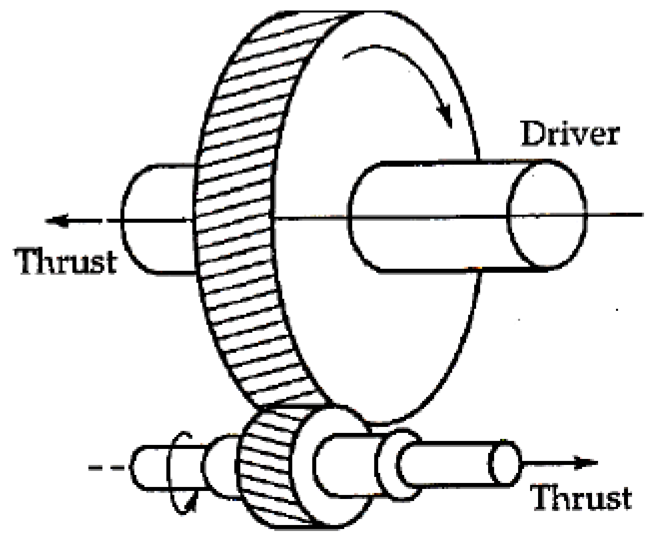
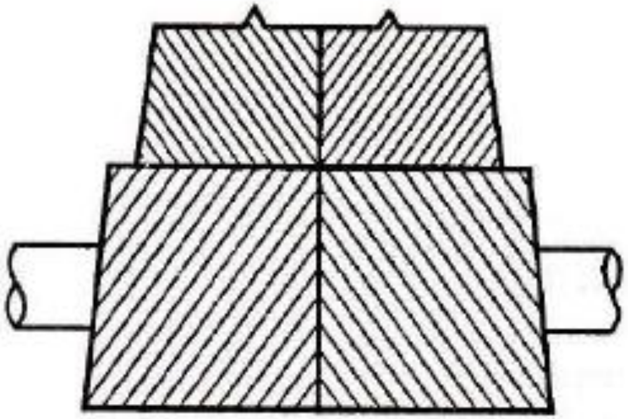


Helical Gears

Herringbone Gears:

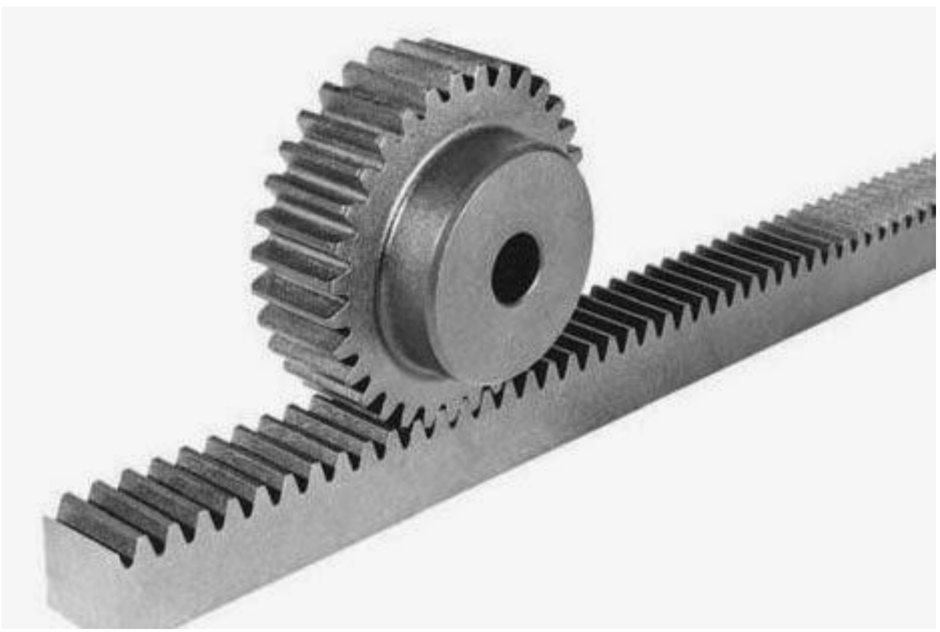
Herringbone gears are also known as **Double Helical Gears**. Herringbone gears are made of two helical gears with opposite helix angles, which can be up to 45 degrees.

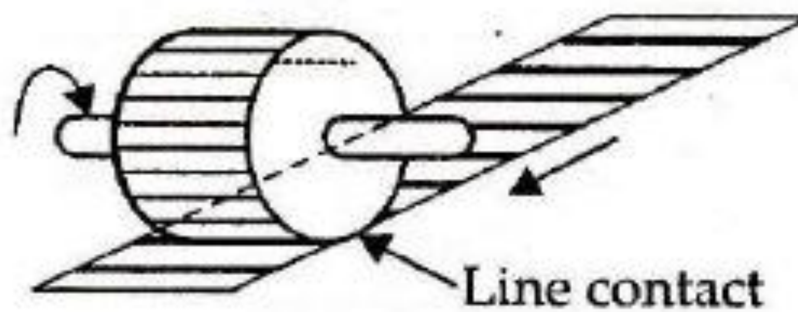


Double Helical (Herringbone) Gears

Rack and Pinion:

In these gears the spur rack can be considered to be spur gear of infinite pitch radius with its axis of rotation placed at infinity parallel to that of pinion. The pinion rotates while the rack translates.





Spur Rack and Pinion

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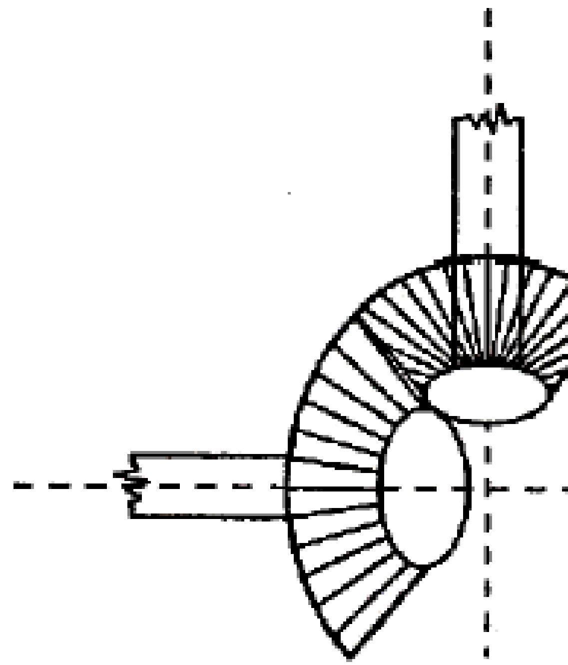
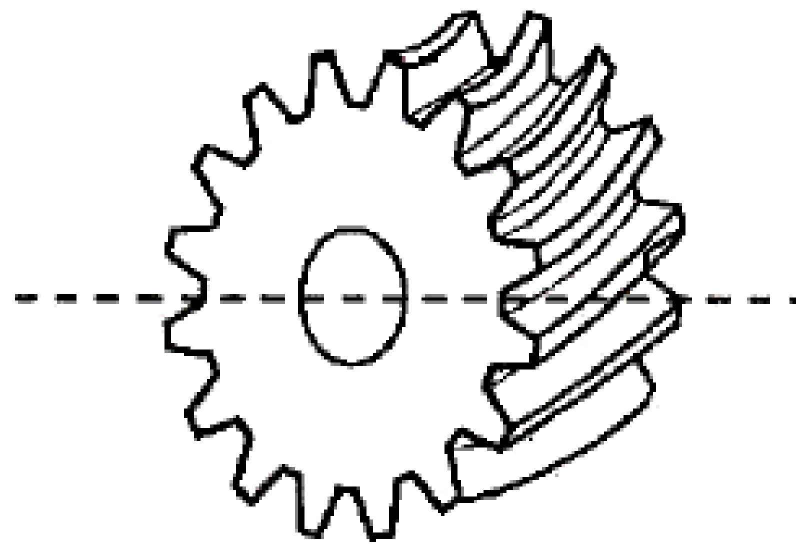
Straight bevel gears are provided with straight teeth, radial to the point of intersection of the shaft axes and vary in cross section through the length inside generator of the cone. Straight Bevel Gears can be seen as modified version of straight spur gears in which teeth are made in conical direction instead of parallel to axis.



Bevel Gears

Spiral Bevel Gears:

Bevel gears are made with their teeth are inclined at an angle to face of the bevel. Spiral gears are also known as helical bevels.



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The spiral bevel gear having curved teeth, but it should be having zero degree spiral angle is known as zerol bevel gear. The action of teeth and thrust are same as straight bevel gear. The zero bevel gear are quicker in action than straight bevel gear, because the teeth are curved form.

Face gears :

Face gears are the gear wheel with cogs mortised into its face, usually in conjugation with a lantern pinion. Face gear enables the transmission of drive through an angle. Their use in high power, high precision applications have become popular. Face gears have high strength teeth and good contact geometry, which give high torque capability.

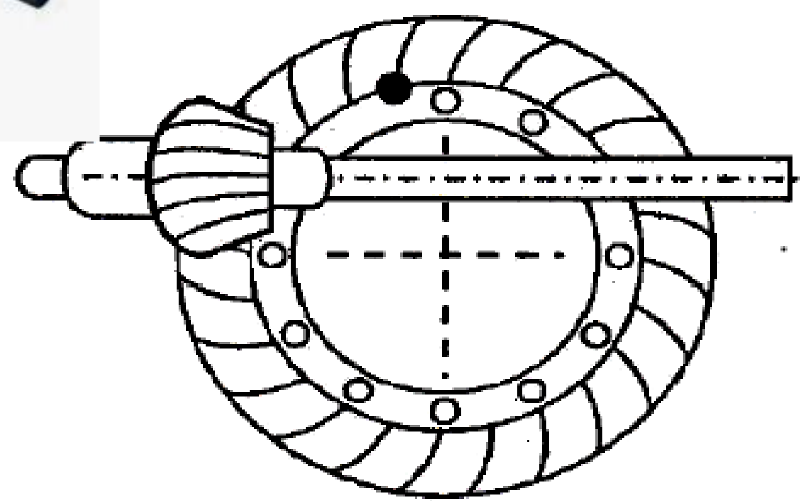
Face gear set with axis angle 135

Spiral Gear:

These gears are mounted on shaft whose axes are intersecting. Spiral bevel gears have curved oblique teeth (spiral), which allow contact to develop gradually and smoothly. They have more contact length and area and less power transmission efficiency compared to straight bevel gears. They are useful for high-speed applications and others requiring less noise and vibration. They are difficult to design and costly to manufacture, as they require specialized and sophisticated machinery for their manufacture. They produce more thrust load on shaft bearings than straight bevel gears.

Hypoid Gears:

The Hypoid Gears are made of the frusta of hyperboloids of revolution. Two matching hypoid gears are made by revolving the same line of contact, these gears are not interchangeable.



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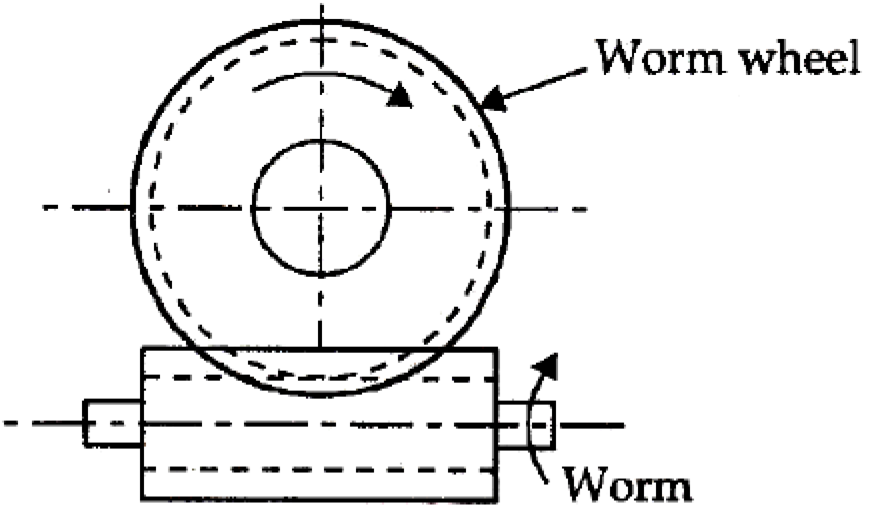
Worm Gears:

The Worm Gears are used to connect skewed shafts, but not necessarily at right angles. Teeth on worm gear are cut continuously like the threads on a screw. The gear meshing with the worm gear is known as worm wheel and combination is known as worm and worm wheel.



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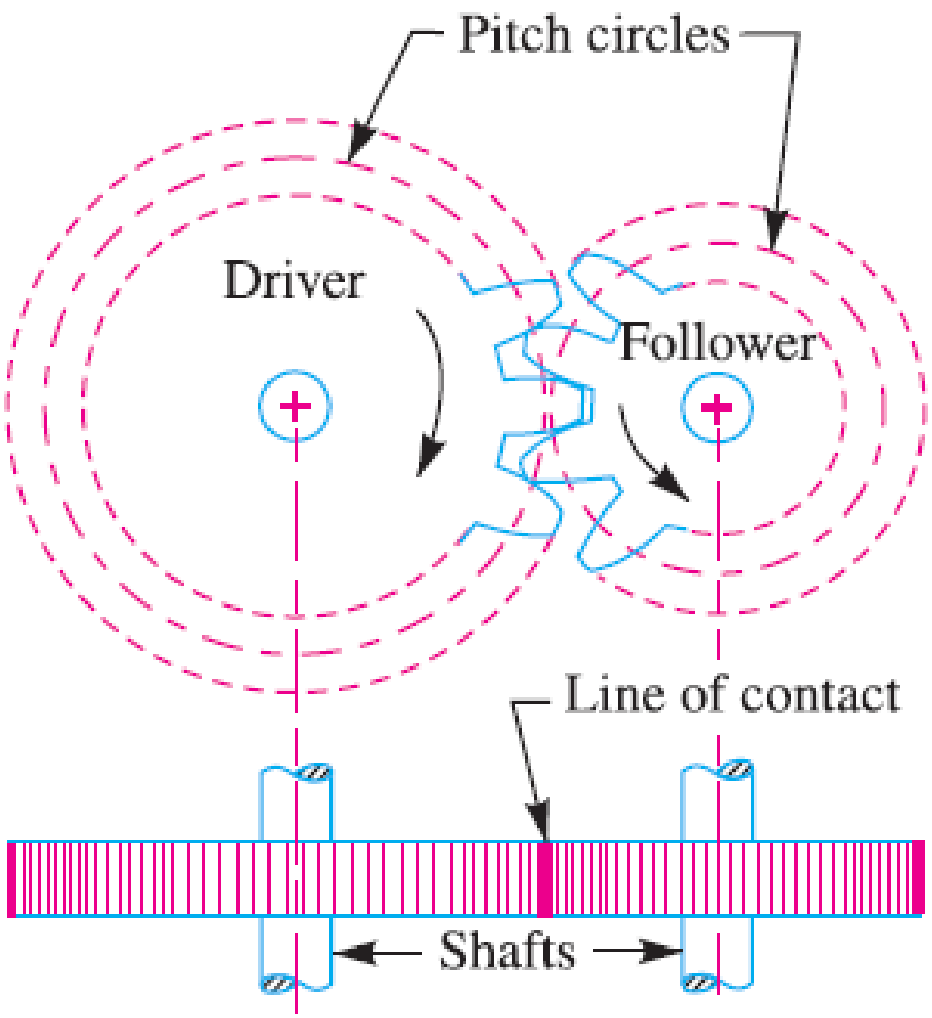

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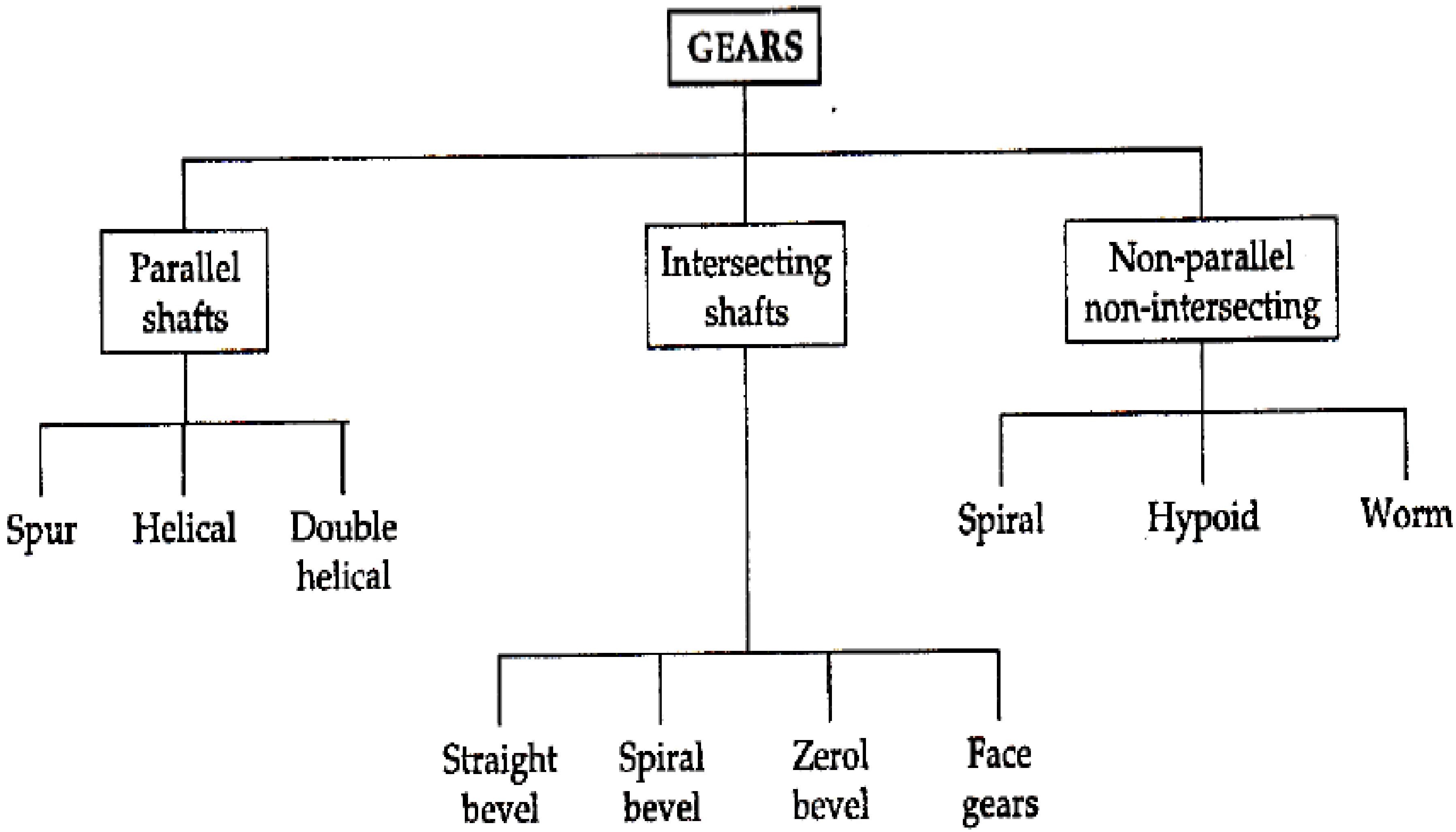

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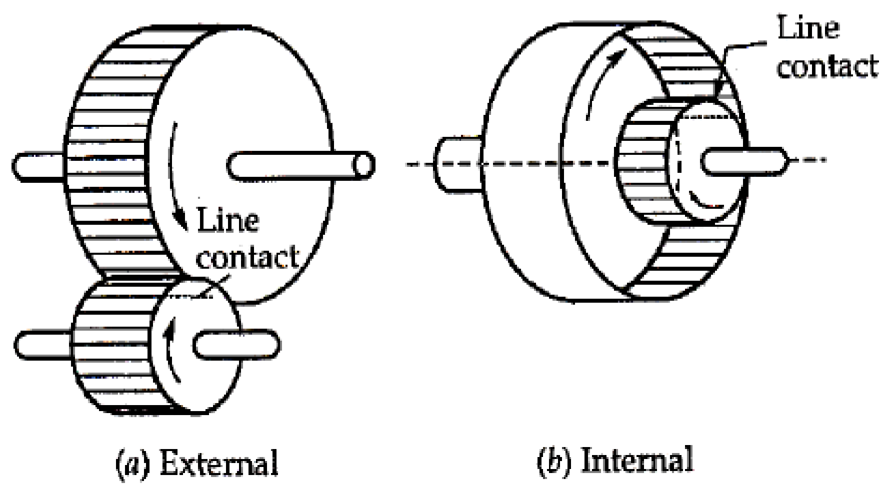

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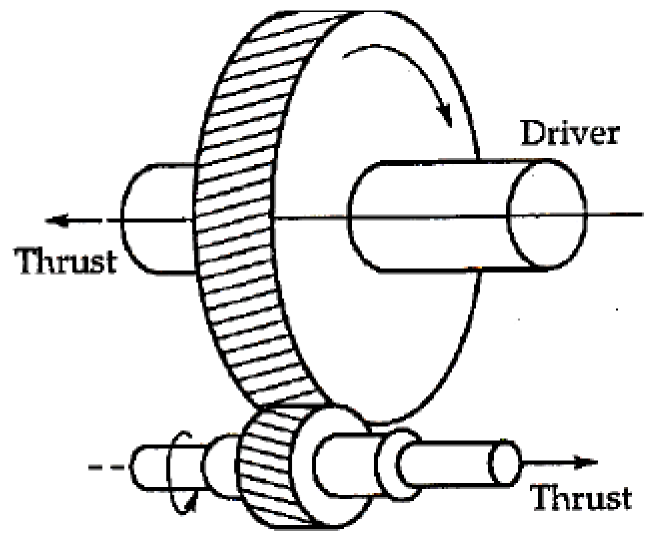

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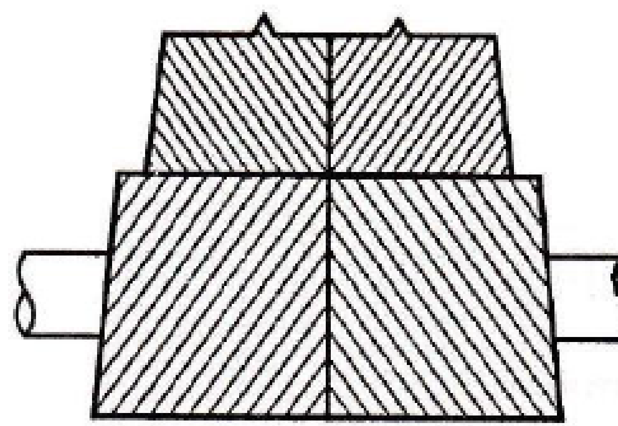

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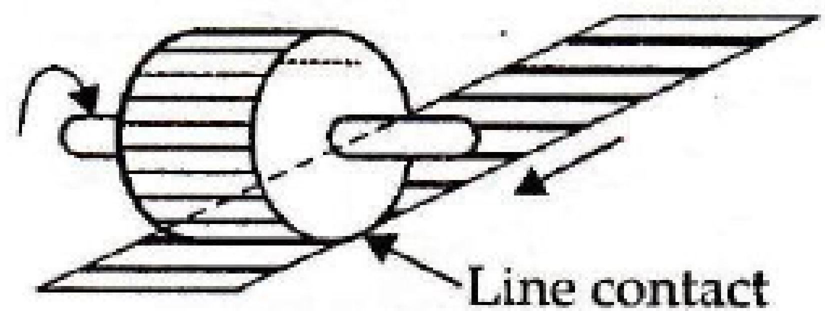

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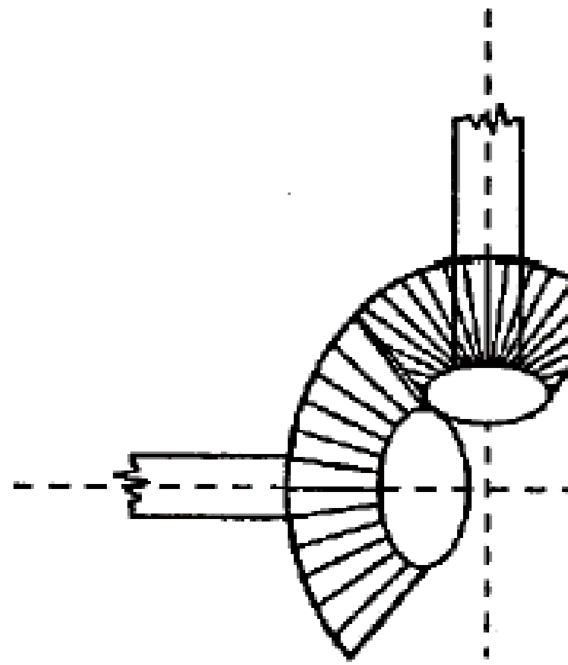

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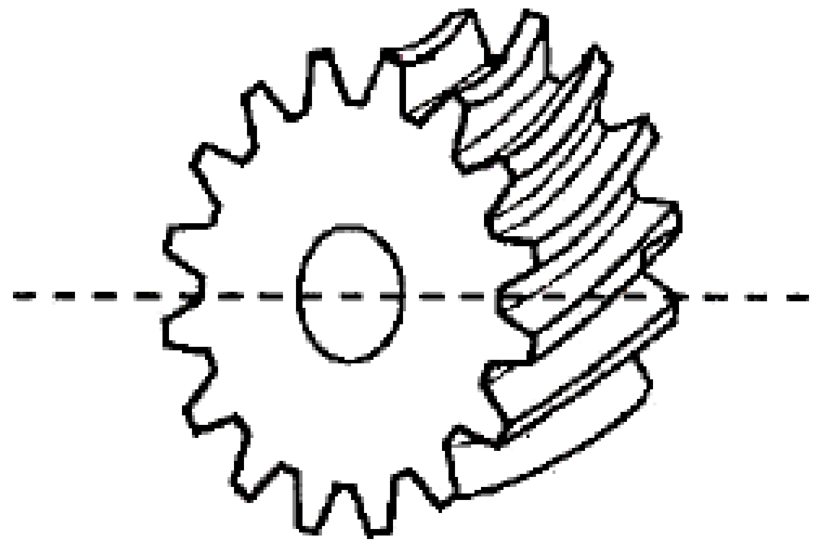

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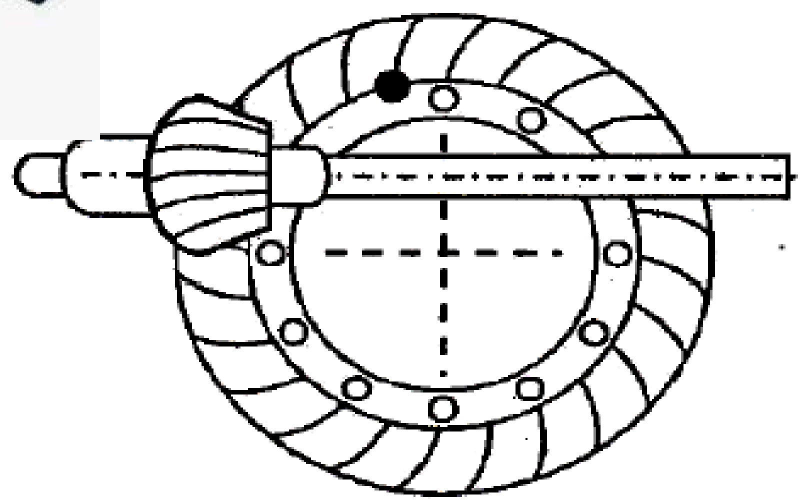

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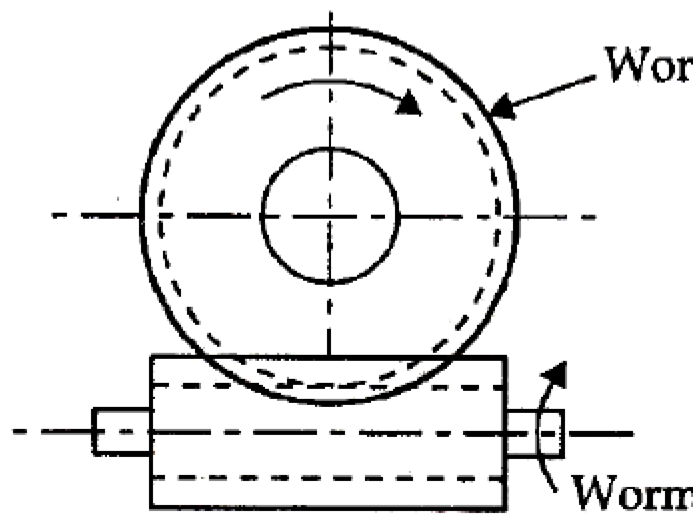
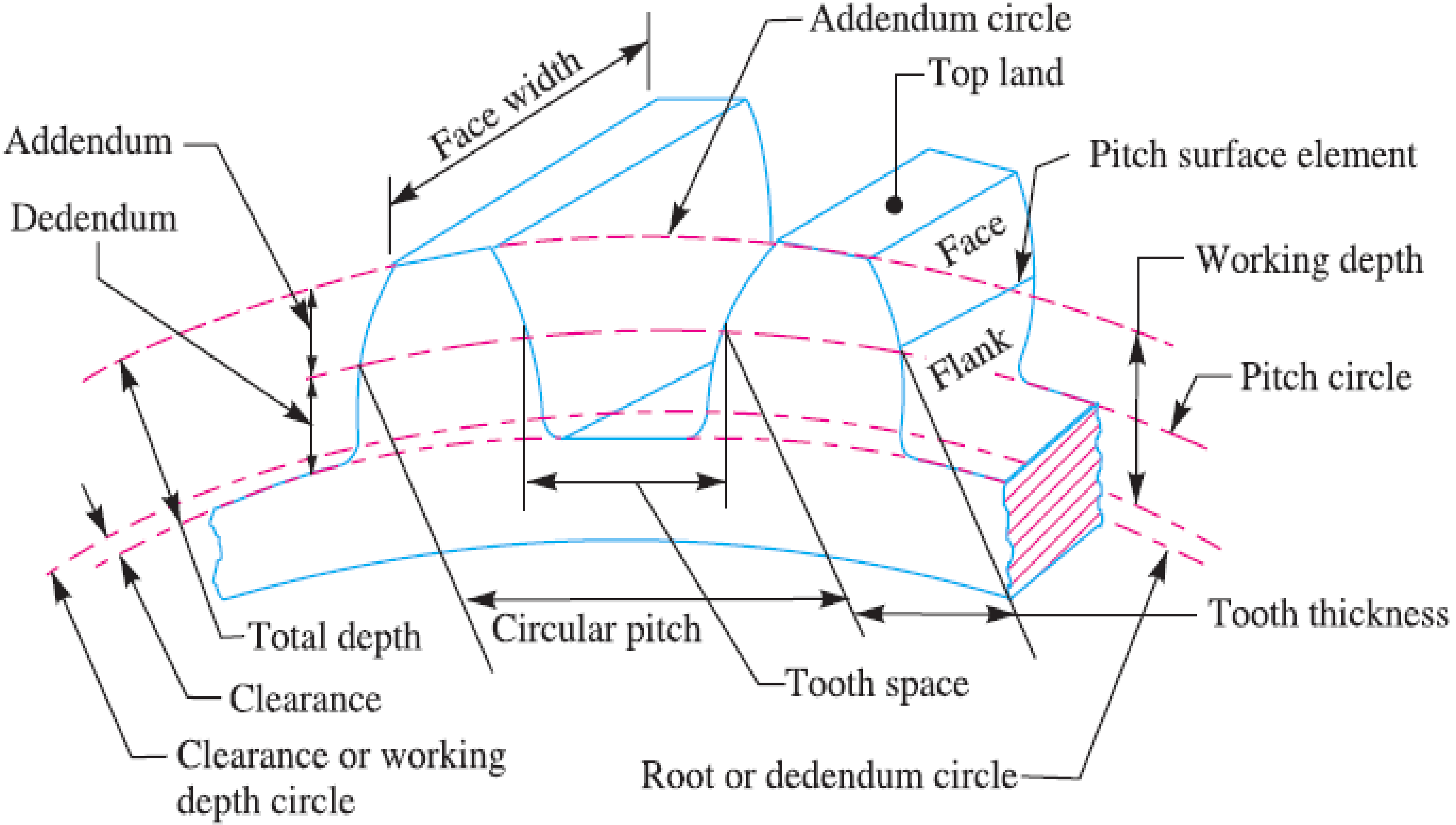
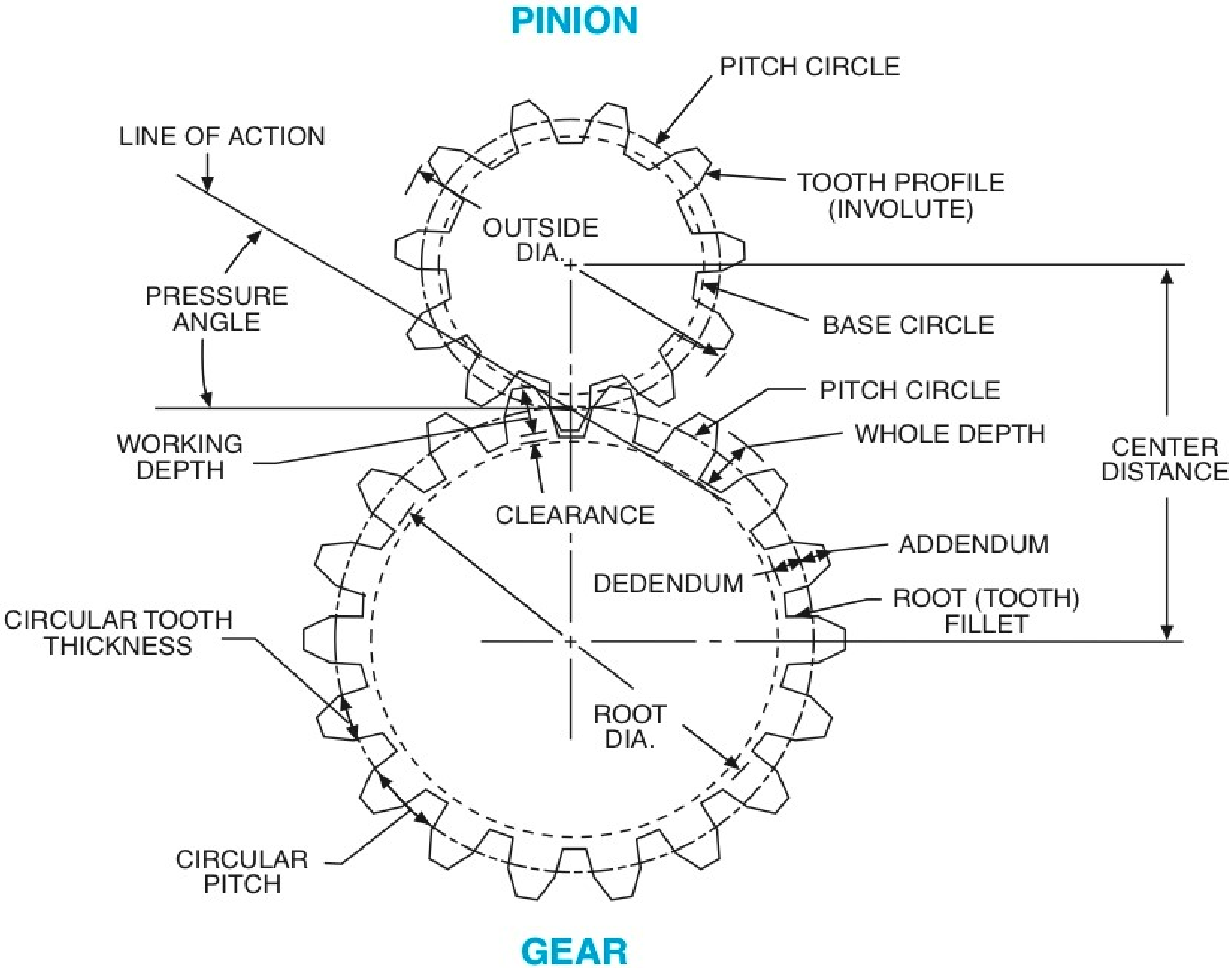


Worm Gears

Design of Spur gear

Gear Terminology





Terminology of Spur gear

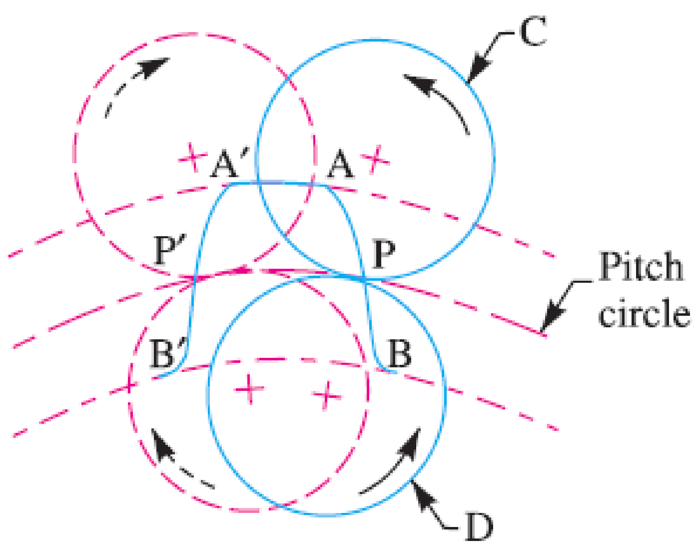
Gear ratio (i): The ratio of the number of teeth of the wheel (gear) to that of the pinion is called gear ratio.

Transmission ratio (i): The ratio of the angular speed of the first driving gear of a train of gears to that of the last driven gear is called transmission ratio.

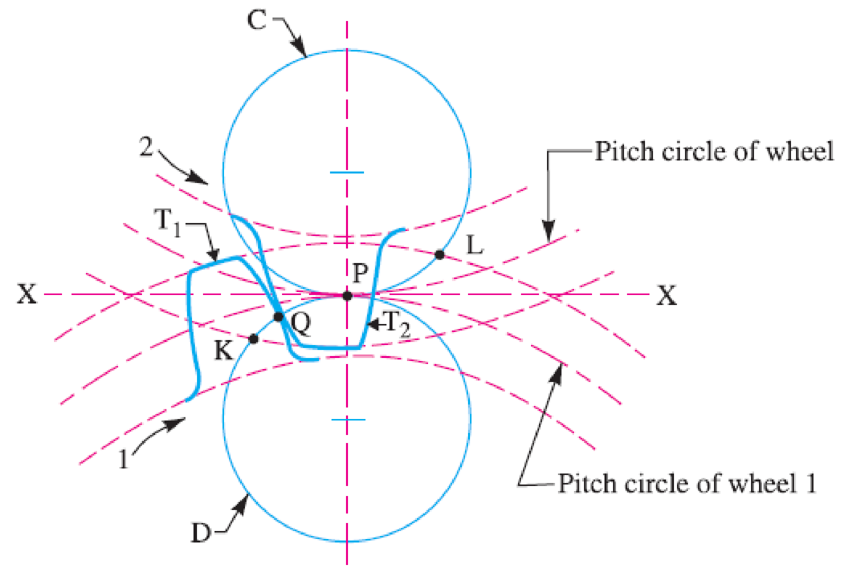
Cycloid: A plane curve described by a point on a circle (generating circle), which rolls without slip on a fixed line (base line) is known as cycloid.

Involute: A plane curve described by a point on a straight line which rolls without slip on a fixed circle is known as involute.

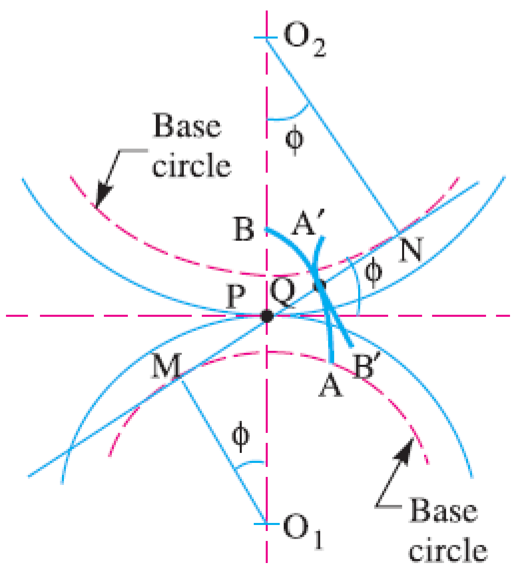
Base circle: In an involute cylindrical gear, the base circle of the involutes of the tooth profiles is known as base circle.



Construction of cycloidal teeth of a gear



Construction of two mating cycloidal teeth



Construction of involute teeth of a gear

Face width. It is the width of the gear tooth measured parallel to its axis.

Pitch circle. It is an imaginary circle which by pure rolling action, would give the same motion as the actual gear.

Pitch circle diameter. It is the diameter of the pitch circle. The size of the gear is usually specified by the pitch circle diameter. It is also called as pitch diameter.

Pressure angle or angle of obliquity. It is the angle between the common normal to two gear teeth at the point of contact and the common tangent at the pitch point. It is usually denoted by φ. The standard pressure angles are 1
14 /2° and 20°.

Addendum. It is the radial distance of a tooth from the pitch circle to the top of the tooth.

Dedendum. It is the radial distance of a tooth from the pitch circle to the bottom of the tooth.

Addendum circle. It is the circle drawn through the top of the teeth and is concentric with the
pitch circle.

Dedendum circle. It is the circle drawn through the bottom of the teeth. It is also called root
circle.

Note : **Root circle diameter** = Pitch circle diameter × cos φ, where φ is the pressure angle.

Circular pitch. It is the distance measured on the circumference of the pitch circle from a point of one tooth to the corresponding point on the next tooth. It is usually denoted by p_c

Mathematically,

Circular pitch $p_c = \pi D/T$

where D = Diameter of the pitch circle, and

T = Number of teeth on the wheel.

Note : If D_1 and D_2 are the diameters of the two meshing gears having the teeth T_1 and T_2 respectively; then for them to mesh correctly,

$$p_c = \frac{\pi D_1}{T_1} = \frac{\pi D_2}{T_2} \quad \text{or} \quad \frac{D_1}{D_2} = \frac{T_1}{T_2}$$

Diametral pitch. It is the ratio of number of teeth to the pitch circle diameter in millimetres. It denoted by Mathematically,

$$\text{Diametral pitch, } p_d = \frac{T}{D} = \frac{\pi}{p_c} \qquad \ldots\left(\because p_c = \frac{\pi D}{T}\right)$$

where T = Number of teeth, and

D = Pitch circle diameter.

Module. It is the ratio of the pitch circle diameter in millimetres to the number of teeth. It is usually denoted by m.

Mathematically,

Module, m = D / T

Systems of Gear Teeth

The following four systems of gear teeth are commonly used in practice.

- **14 /2° Composite system,**
- **14 /2° Full depth involute system,**
- **20° Full depth involutesystem, and**
- **20° Stub involute system.**

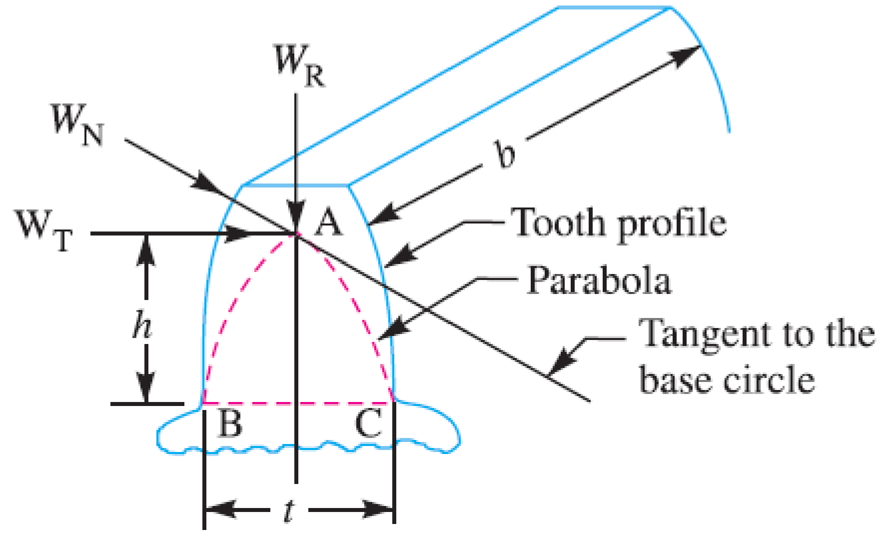
•The 14 /2° composite system is used for **general purpose gears**. It is stronger but has no interchangeability. The tooth profile of this system has cycloidal curves at the top and bottom and involute curve at the middle portion. The teeth are produced by formed milling cutters or hobs.

•The tooth profile of the 14 /2° full depth involute system was developed for use with gear hobs for **spur and helical gears**.

The tooth profile of the 20° full depth involute system may be cut by hobs.

- The increase of the pressure angle from 14 /2° to 20° results in a stronger tooth, because the tooth acting as a beam is **wider at the base**.
- The 20° stub involute system has a strong tooth to take **heavy loads**.

Beam Strength of Gear Teeth – Lewis Equation



$$y = 0.124 - \frac{0.684}{T}, \text{ for } 14\tfrac{1}{2}^\circ \text{ composite and full depth involute system.}$$

$$= 0.154 - \frac{0.912}{T}, \text{ for } 20^\circ \text{ full depth involute system.}$$

$$= 0.175 - \frac{0.841}{T}, \text{ for } 20^\circ \text{ stub system.}$$

Permissible Working Stress for Gear Teeth in the Lewis Equation

$$C_v = \frac{3}{3 + v}, \text{ for ordinary cut gears operating at velocities upto 12.5 m / s.}$$

$$= \frac{4.5}{4.5 + v}, \text{ for carefully cut gears operating at velocities upto 12.5 m/s.}$$

$$= \frac{6}{6 + v}, \text{ for very accurately cut and ground metallic gears operating at velocities upto 20 m / s.}$$

$$= \frac{0.75}{0.75 + \sqrt{v}}, \text{ for precision gears cut with high accuracy and operating at velocities upto 20 m / s.}$$

$$= \left(\frac{0.75}{1 + v}\right) + 0.25, \text{ for non-metallic gears.}$$

Ex. 1 A pair of straight teeth spur gears is to transmit 20 kW when the pinion rotates at 300 r.p.m. The velocity ratio is 1 : 3. The allowable static stresses for the pinion and gear materials are 120 MPa and 100 MPa respectively.

The pinion has 15 teeth and its face width is 14 times the module. Determine : 1. module; 2. face width; and 3. pitch circle diameters of both the pinion and the gear from the standpoint of strength only, taking into consideration the effect of the dynamic loading.

The tooth form factor y can be taken as

$$y = 0.154 - \frac{0.912}{\text{No. of teeth}}$$

and the velocity factor C_v as

$$C_v = \frac{3}{3+v}, \text{ where } v \text{ is expressed in } m/s.$$

EX. 2: A gear drive is required to transmit a maximum power of 22.5 kW. The velocity ratio is 2 and r.p.m. of the pinion is 200. The approximate centre distance between the shafts may be taken as 600 mm. The teeth has 20° stub involute profiles. The static stress for the gear material (which is cast iron) may be taken as 60 MPa and face width as 10 times the module.

Find the module, face width and number of teeth on each gear.

Check the design for dynamic and wear loads. The deformation or dynamic factor in the Buckingham equation may be taken as 80 and the material combination factor for the wear as 1.4.

EX. 1 A bronze spur pinion rotating at 800 r.p.m. drives a cast iron spur gear at a transmission ratio of 5 : 1. The allowable static stresses for the bronze pinion and cast iron gear are 84 MPa and 105 MPa respectively.

The pinion has 23 standard 20° full depth involute teeth of module 6 mm. The face width of both the gears is 70 mm. Find the power that can be transmitted from the standpoint of strength.

EX. 2 A pair of straight teeth spur gears, having 20° involute full depth teeth is to transmit 9 kW at 250 r.p.m. of the pinion. The speed ratio is 2.5 : 1. The allowable static stresses for gear of cast iron and pinion of steel are 60 MPa and 105 MPa respectively. Assume the following:

Number of teeth of pinion = 16; Face width = 14 times module; Velocity factor $(C_v) = \dfrac{4.5}{4.5 + v}$,

v being the pitch line velocity in m / s; and tooth form factor $(y) = 0.154 - \dfrac{0.912}{\text{No. of teeth}}$

Determine the module, face width and pitch diameter of gears. Check the gears for wear; given $\sigma_{es} = 600$ *MPa*; $E_P = 200$ *kN/mm²* *and* $E_G = 100$ *kN/mm²*.

EX. 1 A bronze spur pinion rotating at 1100 r.p.m. drives a cast iron spur gear at a transmission ratio of 5 : 1. The allowable static stresses for the bronze pinion and cast iron gear are 84 MPa and 105 MPa respectively.

The pinion has 20 standard 20° full depth involute teeth of module 7 mm. The face width of both the gears is 85 mm. Find the power that can be transmitted from the standpoint of strength.

EX. 2 A pair of straight teeth spur gears, having 20° involute full depth teeth is to transmit 15 kW at 450 r.p.m. of the pinion. The speed ratio is 4 : 1. The allowable static stresses for gear of cast iron and pinion of steel are 60 MPa and 105 MPa respectively. Assume the following:

Number of teeth of pinion = 16; Face width = 14 times module; Velocity factor $(C_v) = \frac{4.5}{4.5 + v}$,

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Determine the module, face width and pitch diameter of gears. Check the gears for wear; given $\sigma_{es} = 600$ MPa; $E_P = 200$ kN/mm^2 and $E_G = 100$ kN/mm^2.

EX. 1 A bronze spur pinion rotating at 600 r.p.m. drives a cast iron spur gear at a transmission ratio of 4 : 1. The allowable static stresses for the bronze pinion and cast iron gear are 84 MPa and 105 MPa respectively.
The pinion has 16 standard 20° full depth involute teeth of module 8 mm. The face width of both the gears is 90 mm. Find the power that can be transmitted from the standpoint of strength.

EX. 2 A pair of straight teeth spur gears, having 20° involute full depth teeth is to transmit 12 kW at 300 r.p.m. of the pinion. The speed ratio is 3 : 1. The allowable static stresses for gear of cast iron and pinion of steel are 60 MPa and 105 MPa respectively. Assume the following:

Number of teeth of pinion = 16; Face width = 14 times module; Velocity factor $(C_v) = \frac{4.5}{4.5 + v}$,

v being the pitch line velocity in m / s; and tooth form factor $(y) = 0.154 - \frac{0.912}{\text{No. of teeth}}$

Determine the module, face width and pitch diameter of gears. Check the gears for wear; given $\sigma_{es} = 600$ MPa; $E_P = 200$ kN/mm² and $E_G = 100$ kN/mm².

<u>Design of</u>

<u>Helical Gear</u>

Terms used in Helical Gears

1. Helix angle

It is a constant angle made by the helices with the axis of rotation.

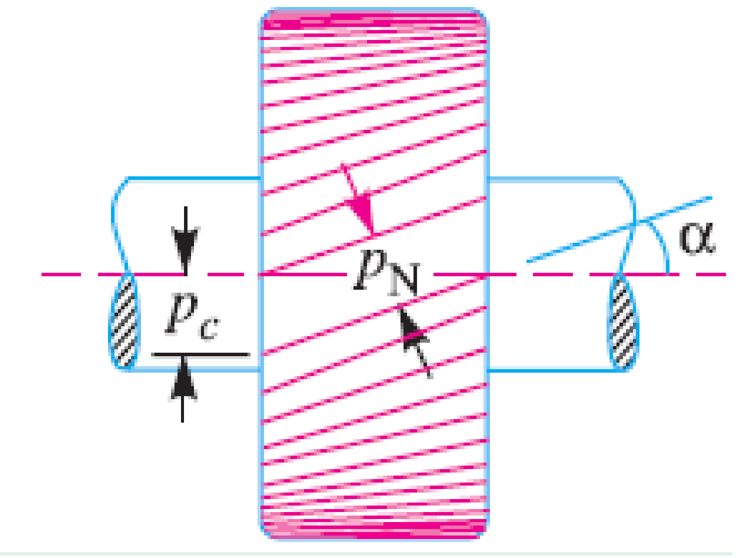
2. Axial pitch

It is the distance, parallel to the axis, between similar faces of adjacent teeth.

It is the same as circular pitch and is therefore denoted by $\mathbf{p_c}$.

The axial pitch may also be defined as the circular pitch

in the plane of rotation or the diametral plane.



Helical gear
(nomenclature)

3. Normal pitch

It is the distance between similar faces of adjacent teeth along a helix on the pitch cylinders normal to the teeth.

It is denoted by $\mathbf{p_N}$.

The normal pitch may also be defined as the circular pitch in the normal plane which is a plane perpendicular to the teeth.

Mathematically, normal pitch,

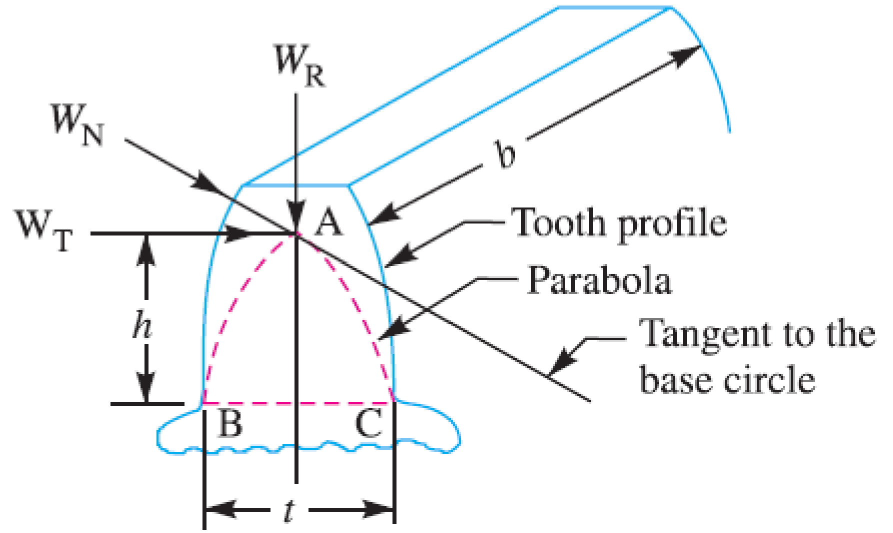
$$p_N = p_c \times \cos \alpha \qquad \textit{Where}, \; p_c = \pi \times m$$

Note: If the gears are cut by standard hobs, then the pitch (or module) and the pressure angle of the hob will apply in the normal plane. On the other hand, if the gears are cut by the Fellows gear-shaper method, the pitch and pressure angle of the cutter will apply to the plane of rotation.

The relation between the normal pressure angle (**Φ_N**) in the normal plane and the pressure angle (**Φ**) in the diametral plane (or plane of rotation) is given by

$$\tan \phi_N = \tan \phi \times \cos \alpha$$

Beam Strength of Gear Teeth – Lewis Equation
Tooth form Factor



$$y = 0.124 - \frac{0.684}{T_E}, \text{ for } 14\tfrac{1}{2}^\circ \text{ composite and full depth involute system.}$$

$$= 0.154 - \frac{0.912}{T_E}, \text{ for } 20^\circ \text{ full depth involute system.}$$

$$= 0.175 - \frac{0.841}{T_E}, \text{ for } 20^\circ \text{ stub system.}$$

Velocity factor (C_v) may be taken as follows for Helical Gear

$$C_v = \frac{6}{6+v}, \text{ for peripheral velocities from 5 m / s to 10 m / s.}$$

$$= \frac{15}{15+v}, \text{ for peripheral velocities from 10 m / s to 20 m / s.}$$

$$= \frac{0.75}{0.75+\sqrt{v}}, \text{ for peripheral velocities greater than 20 m / s.}$$

$$= \frac{0.75}{1+v} + 0.25, \text{ for non-metallic gears.}$$

EX. 1: A pair of helical gears are to transmit 15 kW. The teeth are 20° stub in diametral plane and have a helix angle of 45°. The pinion runs at 10 000 r.p.m. and
has 80 mm pitch diameter.

The gear has 320 mm pitch diameter. If the gears are made of cast steel having allowable static strength of 100 MPa;
determine a suitable module and face width from static strength considerations and check the gears for wear, given
σ_{es} = 618 MPa.

EX. 1 : A helical cast steel gear with 30° helix angle has to transmit 35 kW at 1500 r.p.m. If the gear has 24 teeth, determine the necessary module, pitch diameter and face width for 20° full depth teeth. The static stress for cast steel may be taken as 56 MPa. The width of face may be taken as 3 times the normal pitch. What would be the end thrust on the gear? The tooth factor for 20° full depth involute gear may be taken as

$$y' = 0.154 - \frac{0.912}{T}$$

Where T_E represents the equivalent number of teeth.

EX. 2 : Design A helical cast steel gear with 45° helix angle has to transmit 50 kW at 1800 r.p.m. If the gear has 35 teeth, determine the necessary module, pitch diameter and face width for 20° stub teeth. The static stress for cast steel may be taken as 56 MPa. The width of face may betaken as 12.5 module.

EX. 3 : A helical cast steel gear with 15° helix angle has to transmit 70 kW at 1200 r.p.m. If the gear has 20 teeth, determine the necessary module, pitch diameter and face width for 14 ½ involute system. The static stress for cast steel may be taken as 56 MPa. The width of face may be taken as 5 times the normal pitch. What would be the end thrust on the gear?

EX. 1 : A helical cast steel gear with 30° helix angle has to transmit 40 kW at 1700 r.p.m. If the gear has 22 teeth, determine the necessary module, pitch diameter and face width for 20° full depth teeth. The static stress for cast steel may be taken as 56 MPa. The width of face may be taken as 3 times the normal pitch. What would be the end thrust on the gear? The tooth factor for 20° full depth involute gear may be taken as

$$y' = 0.154 - \frac{0.912}{T}$$

Where T_E represents the equivalent number of teeth.

EX. 2 : Design A helical cast steel gear with 45° helix angle has to transmit 60 kW at 1500 r.p.m. If the gear has 32 teeth, determine the necessary module, pitch diameter and face width for 20° stub teeth. The static stress for cast steel may be taken as 56 MPa. The width of face may betaken as 12.5 module.

EX. 3 : A helical cast steel gear with 15° helix angle has to transmit 40 kW at 1000 r.p.m. If the gear has 23 teeth, determine the necessary module, pitch diameter and face width for 14 ½ involute system. The static stress for cast steel may be taken as 56 MPa. The width of face may be taken as 2 times the normal pitch. What would be the end thrust on the gear?

EX. 1 : A helical cast steel gear with 30° helix angle has to transmit 32 kW at 900 r.p.m. If the gear has 18 teeth, determine the necessary module, pitch diameter and face width for 20° full depth teeth. The static stress for cast steel may be taken as 56 MPa. The width of face may be taken as 3 times the normal pitch. What would be the end thrust on the gear? The tooth factor for 20° full depth involute gear may be taken as

$$y' = 0.154 - \frac{0.912}{T}$$

Where T_E represents the equivalent number of teeth.

EX. 2 : Design A helical cast steel gear with 45° helix angle has to transmit 90 kW at 2200 r.p.m. If the gear has 38 teeth, determine the necessary module, pitch diameter and face width for 20° stub teeth. The static stress for cast steel may be taken as 56 MPa. The width of face may betaken as 12.5 module.

EX. 3 : A helical cast steel gear with 15° helix angle has to transmit 73 kW at 1100 r.p.m. If the gear has 26 teeth, determine the necessary module, pitch diameter and face width for 14 ½ involute system. The static stress for cast steel may be taken as 56 MPa. The width of face may be taken as 4 times the normal pitch. What would be the end thrust on the gear?