Unit- 2
Chapter - 3

Design of

Spur Gear

INTRODUCTION

- Any toothed member designed to transmit motion to another one, or receive motion from it, by means of successively engaging tooth is called a (toothed) gear.
- 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.
- It is preferred when medium or larger power is to be transmitted.
- Rotation of one gear will cause rotation of the other in the opposite direction.

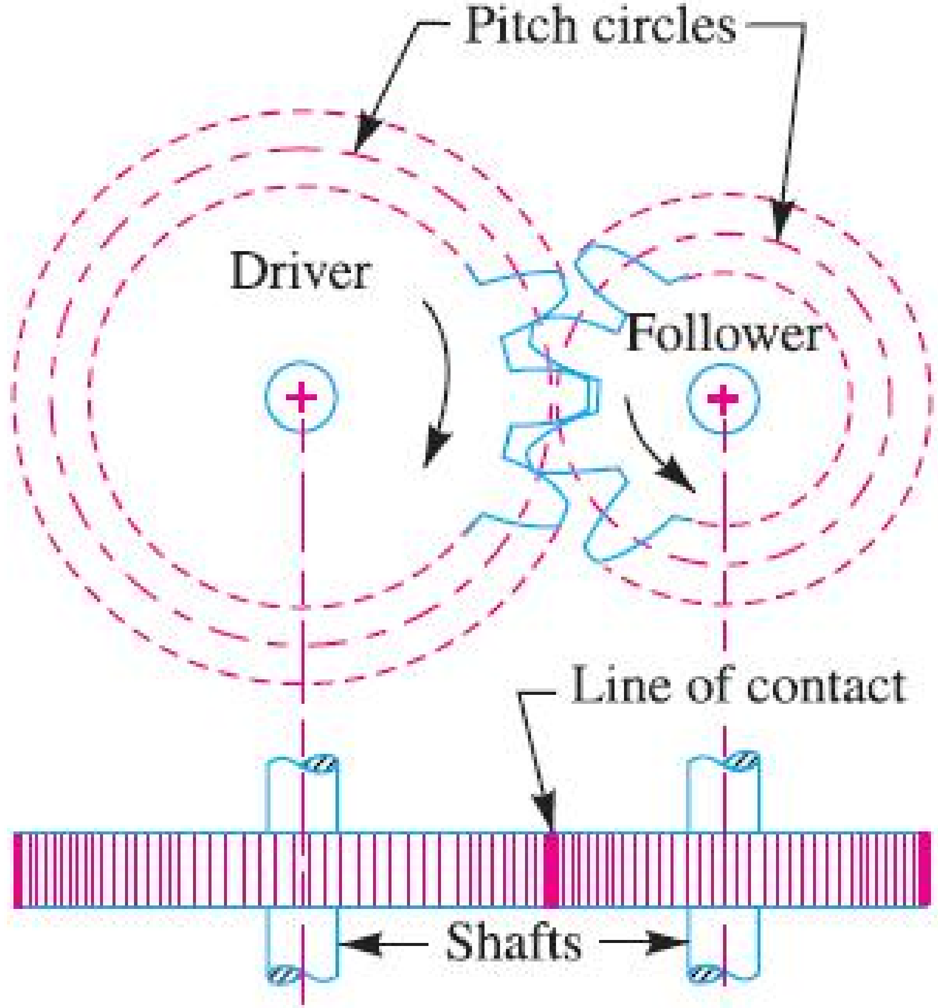
As shown in fig.

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.

Disadvantages

1. Since the manufacture of gears require special tools and equipment, therefore it is costlier than other drives.
2. The error in cutting teeth may cause vibrations and noise during operation.
3. It requires suitable lubricant and reliable method of applying it, for the proper operation of gear drives.

Types of Gears

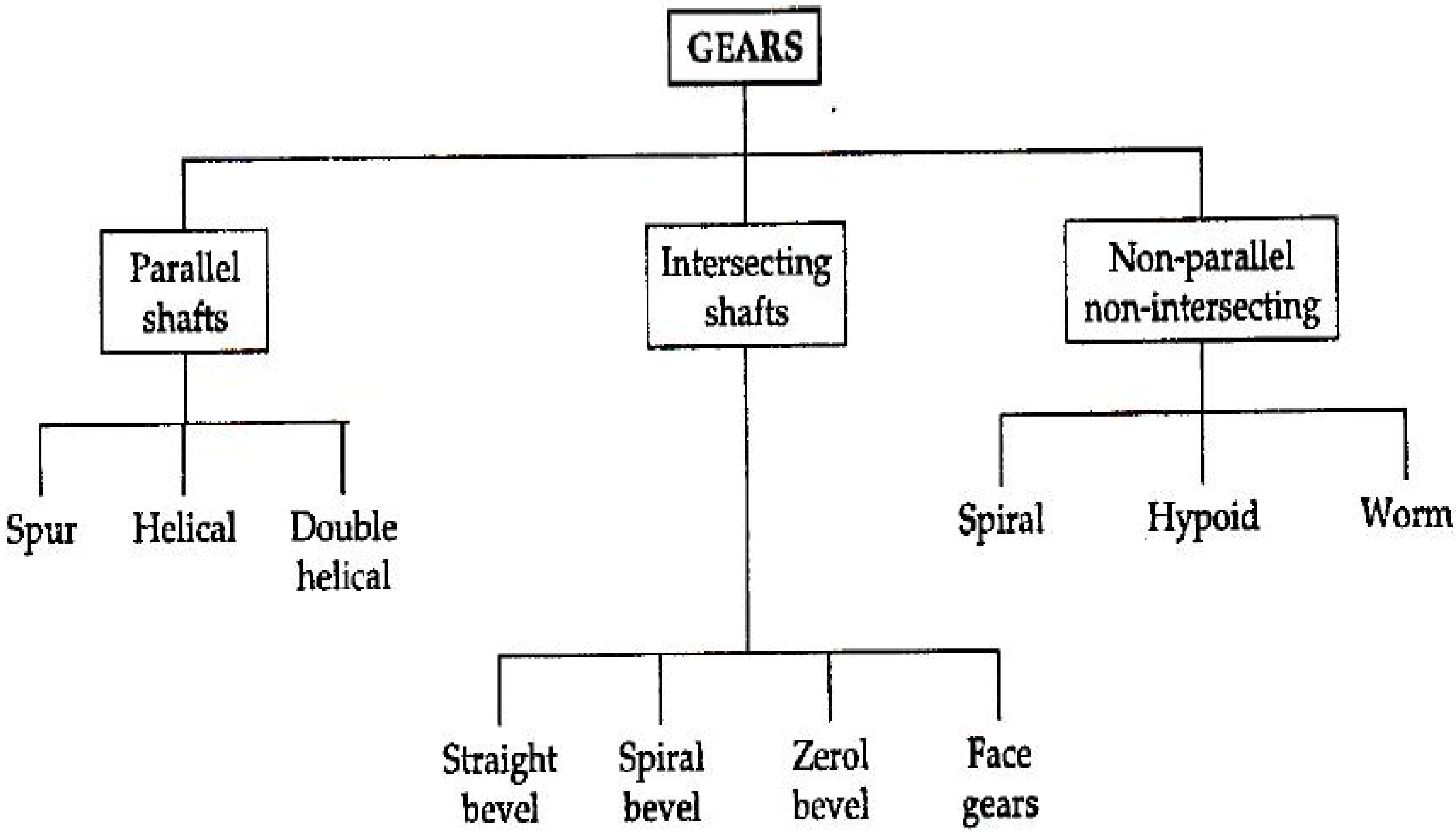
The most common way to classify gears is by category type and by the orientation of axes.
Gears are classified into 3 categories;

- **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

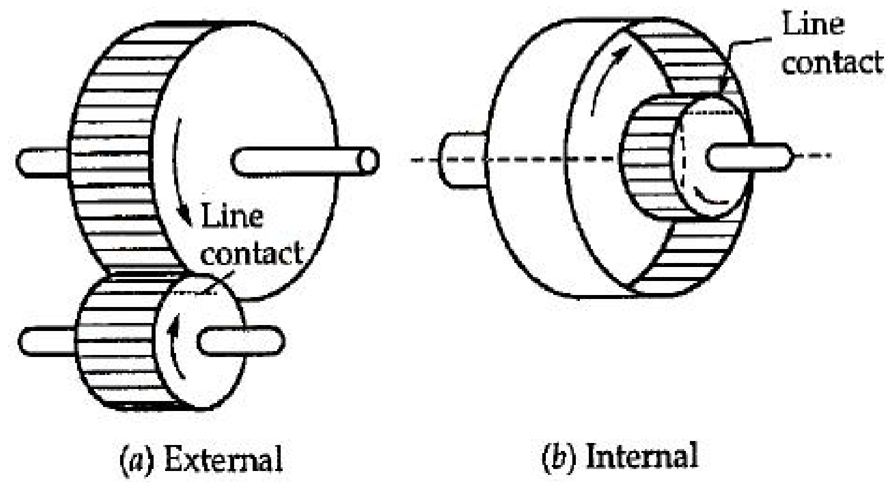
Nonparallel and Nonintersecting

- Types of Gears

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

Spur Gears:

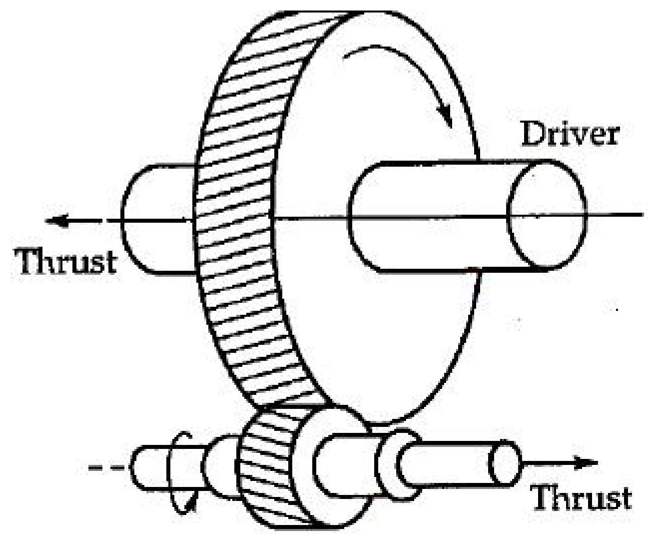
Straight Spur gears are the simplest form of gears having teeth parallel to the gear axis. The contact of two teeth takes place over the entire width along a line parallel to the axes of rotation. As gear rotate , the line of contact goes on shifting parallel to the shaft.



Spur Gears

Helical Gears:

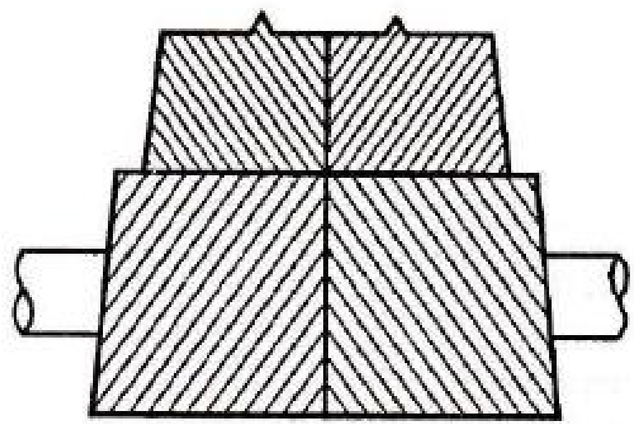
In helical gear teeth are part of helix instead of straight across the gear parallel to the axis. The mating gears will have same helix angle but in opposite direction for proper mating. As the gear rotates, the contact shifts along the line of contact in volute helicoid across the teeth.



Helical Gears

Herringbone Gears:

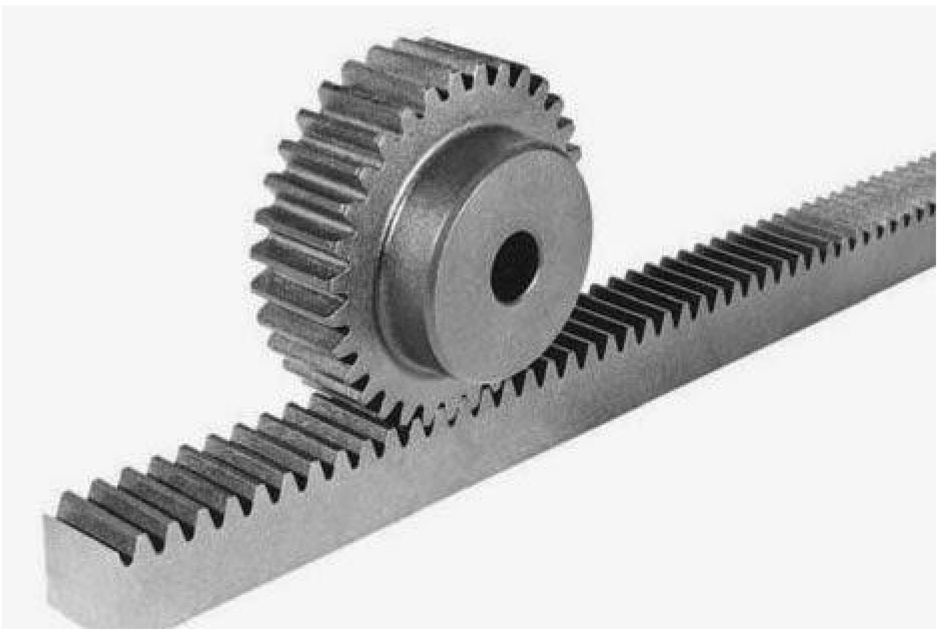
Herringbone gears are also known as **Double Helical Gears**. Herringbone gears are made of two helical gears with opposite helix angles, which can be up to 45 degrees.

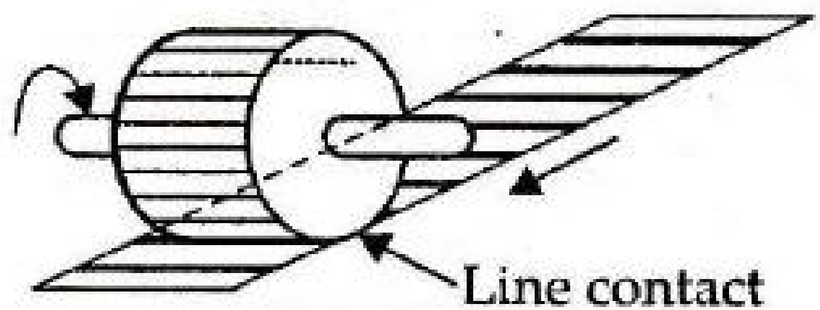


Double Helical (Herringbone) Gears

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.

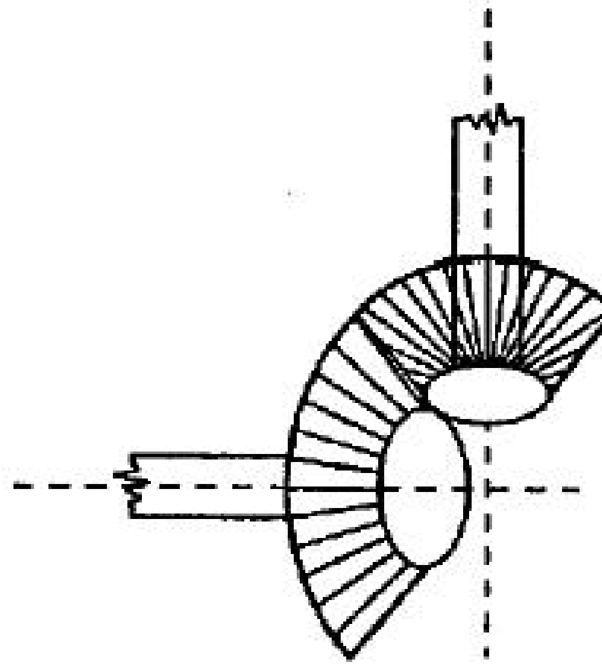




Spur Rack and Pinion

Straight Bevel Gears:

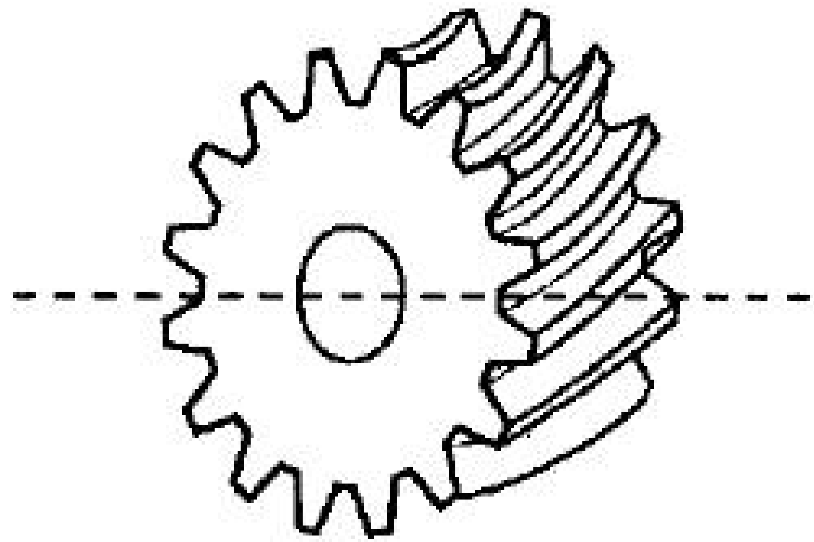
Straight bevel gears are provided with straight teeth, radial to the point of intersection of the shaft axes and vary in cross section through the length inside generator of the cone. Straight Bevel Gears can be seen as modified version of straight spur gears in which teeth are made in conical direction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



Spiral Bevel Gears

Zerol Bevel Gear :

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.

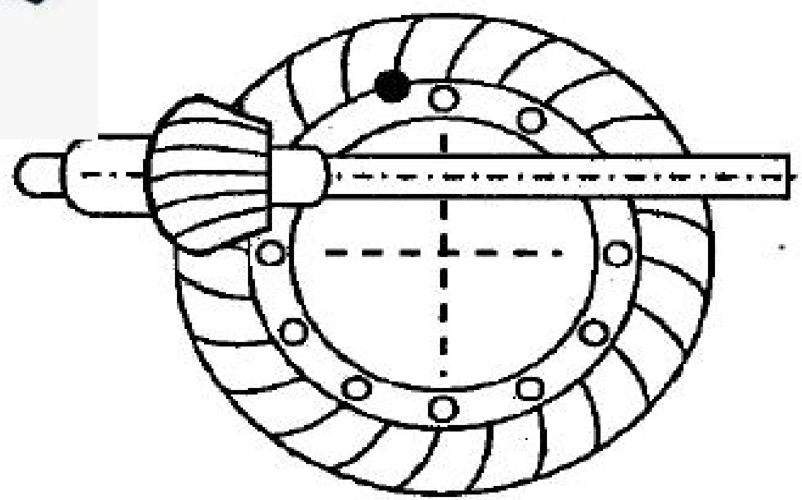
Face gear set with axis angle 135°

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:

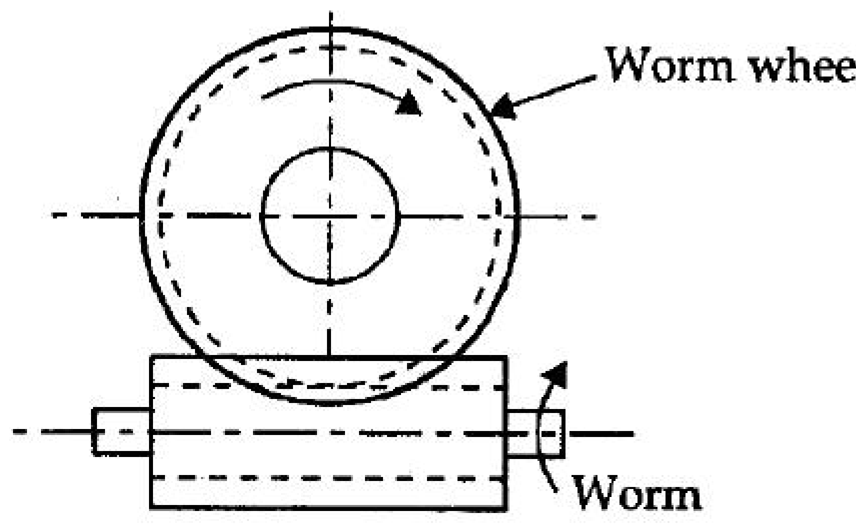
The Hypoid Gears are made of the frusta of hyperboloids of revolution. Two matching hypoid gears are made by revolving the same line of contact, these gears are not interchangeable.



Hypoid Gears

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.



Worm Gears

Chapter - 4

Design of

Helical Gear

Terms used in Helical Gears

1. Helix angle

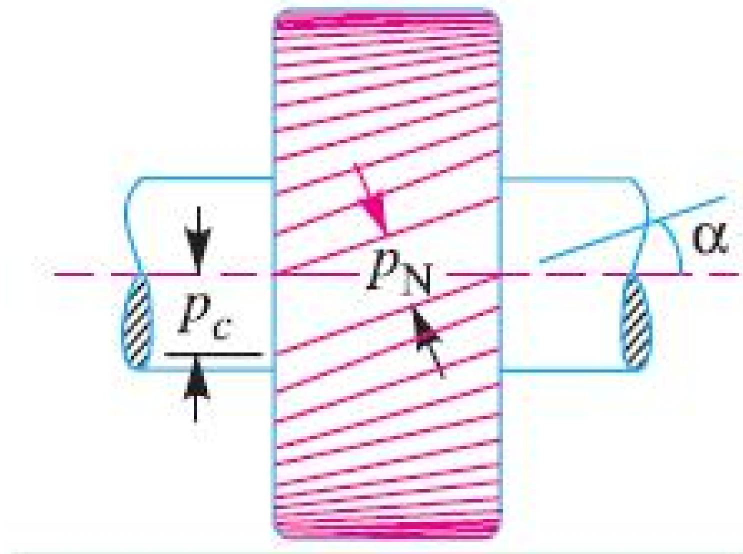
It is a constant angle made by the helices with the axis of rotation.

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,

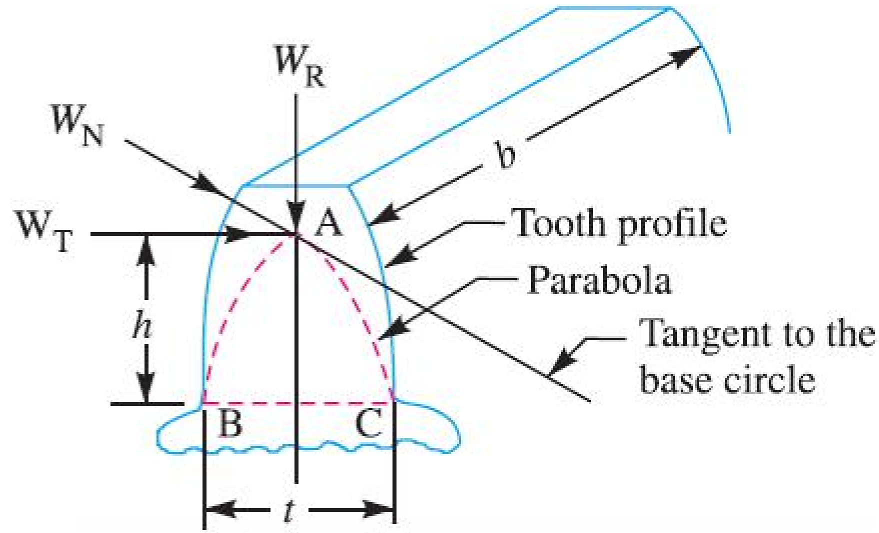
$$p_N = p_c \times \cos\alpha \qquad \text{Where , } p_c = \pi \times m$$

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

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

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

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

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

Chapter - 5

Design of Bevel Gear

The bevel gears are used for transmitting power at a constant velocity ratio between two shafts **whose axes intersect at a certain angle**.

The elements of the cones, as shown in Fig. 1 intersect at the point of **intersection of the axis of rotation**.

In Fig. 2, the elements of both cones **do not intersect** at the point of shaft intersection.

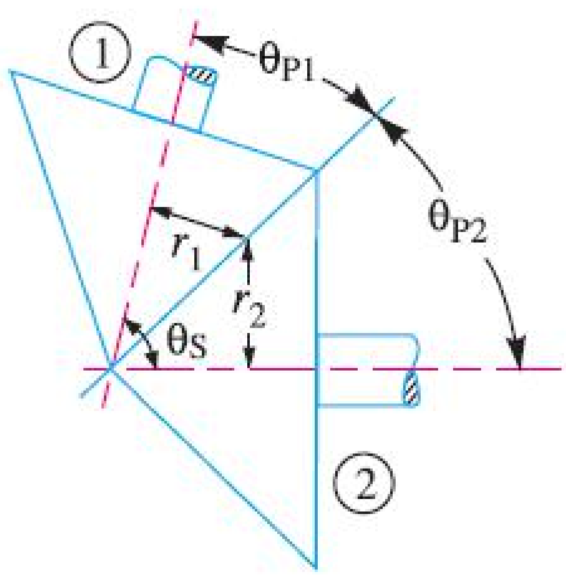


Fig. 1

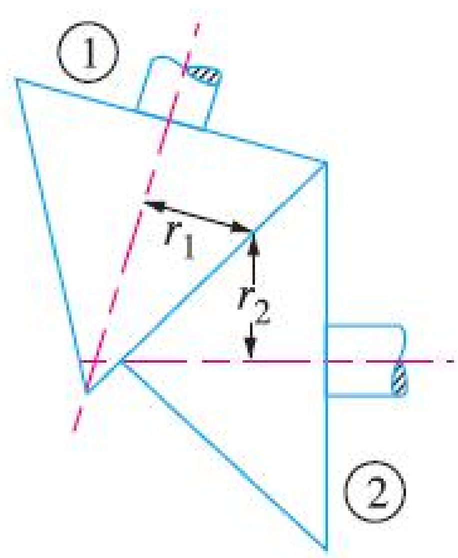
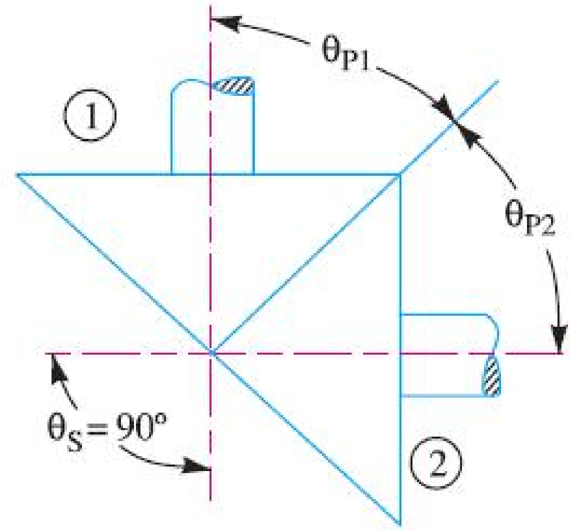


Fig. 2

Classification of Bevel Gears

(a) Mitre gears. When equal bevel gears (having equal teeth and equal pitch angles) connect two shafts whose axes intersect at right angle, as shown in Fig. (a), then they are known as **mitre gears.**



(*a*) Mitre gears.

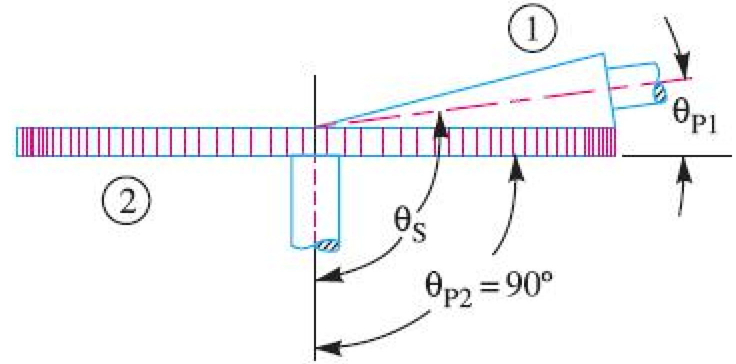
(b) Angular bevel gears. When the bevel gears connect two shafts whose axes intersect at an angle other than a right angle, then they are known as **angular bevel gears.**

Mitre gears

Angular bevel gears

(c) Crown bevel gears.

When the bevel gears connect two shafts whose axes intersect at an angle greater than a right angle and one of the bevel gears has a pitch angle of 90º, then it is known as a crown gear.

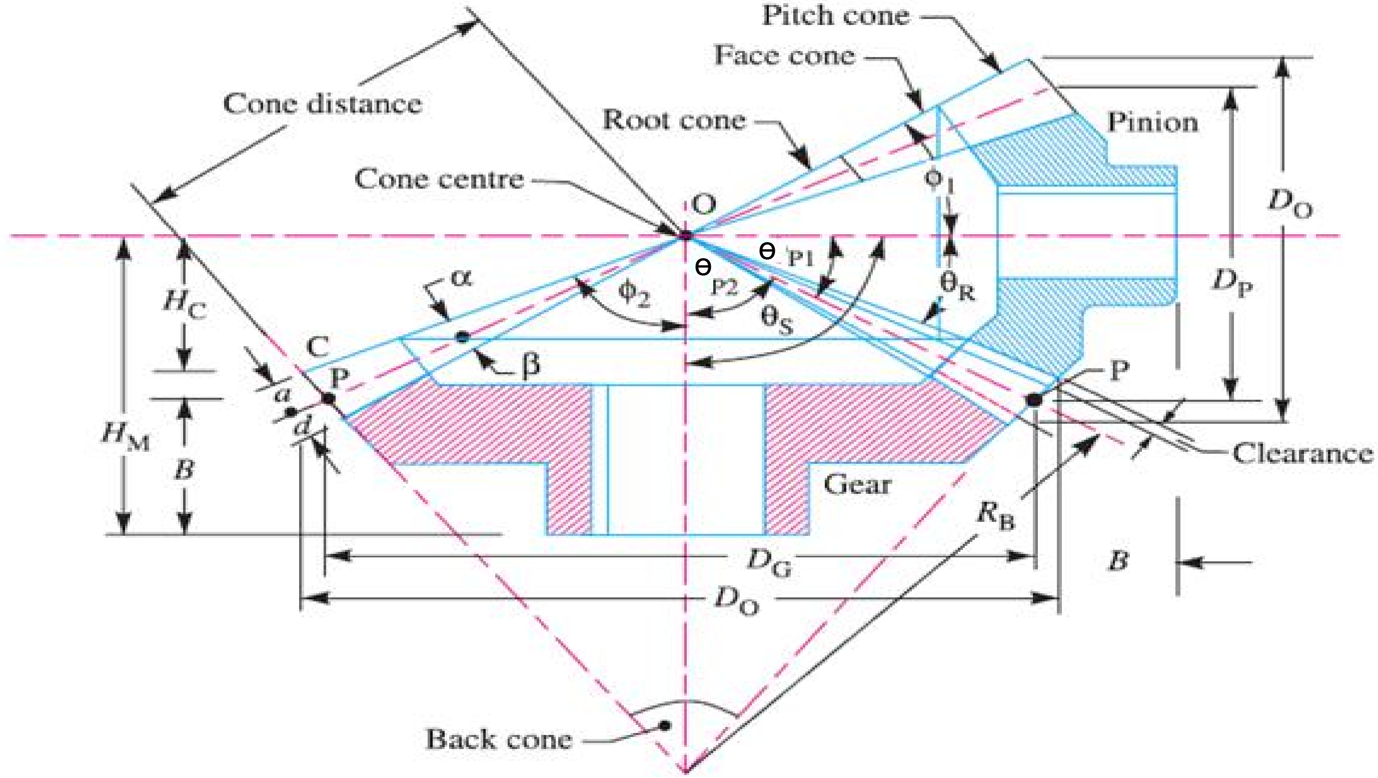


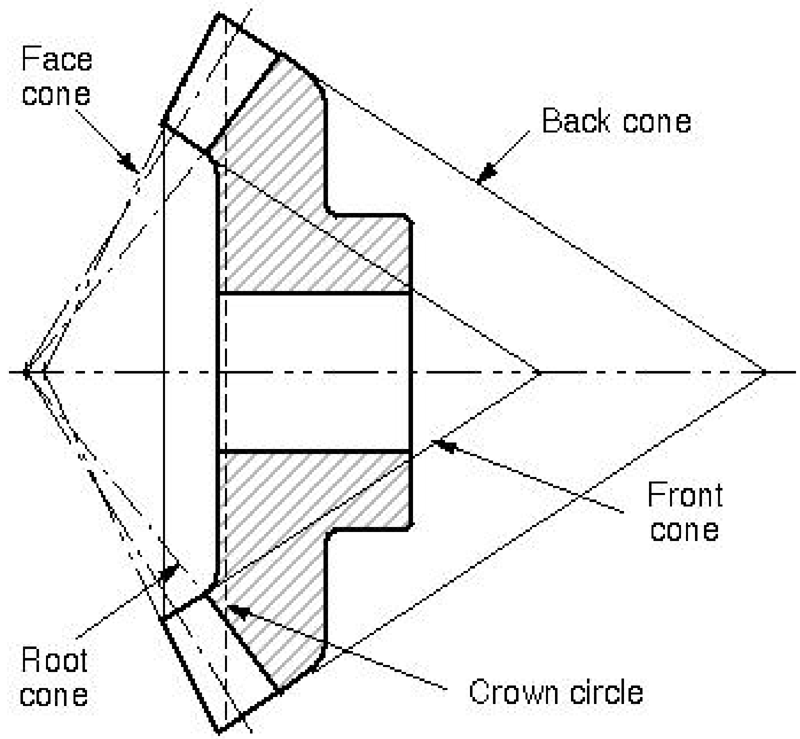
(*b*) Crown bevel gear.

(d) Internal bevel gears.

When the teeth on the bevel gear are cut on the inside of the pitch cone, then they are known as internal bevel gears.

Terms used in Bevel Gears

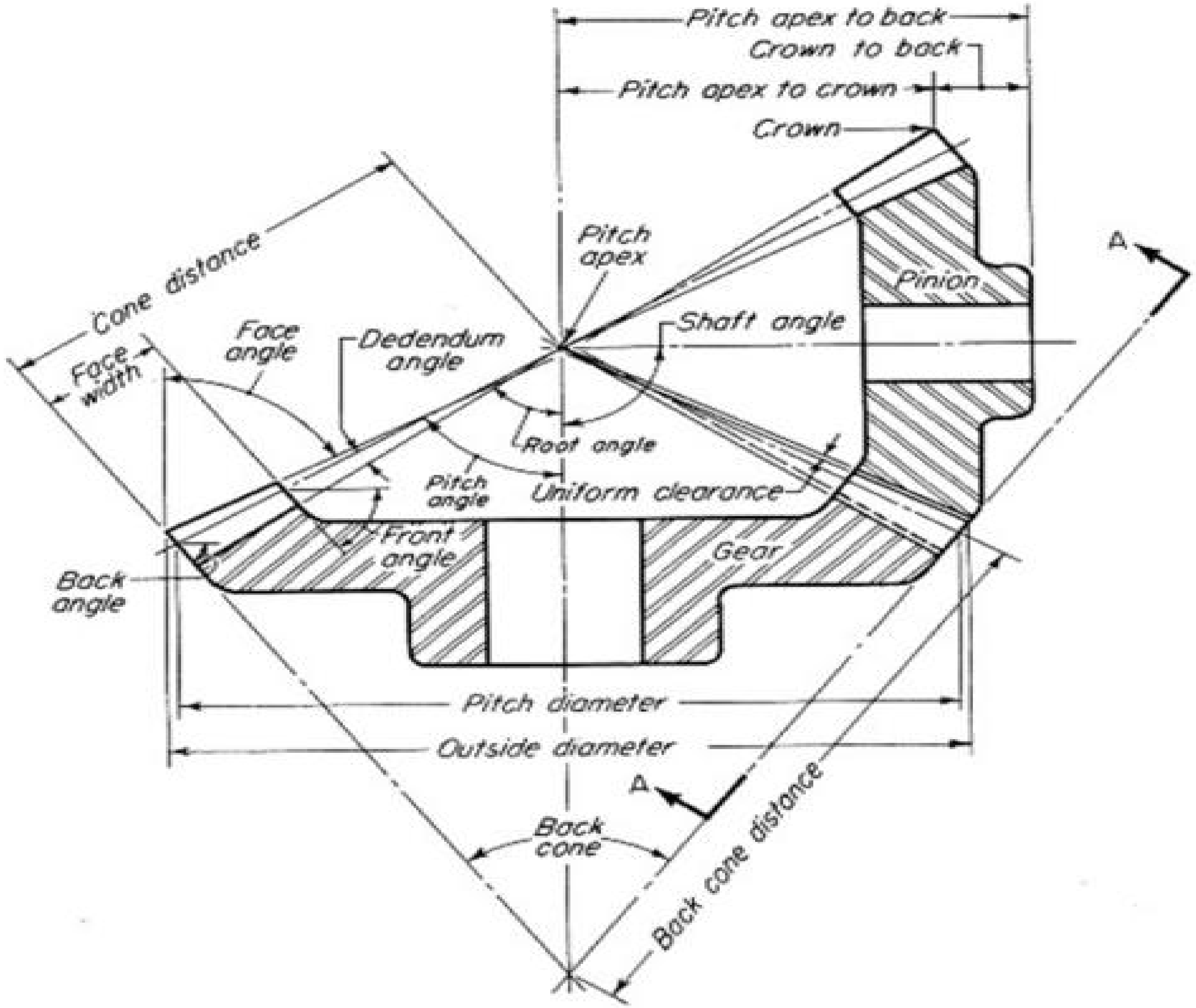




A **pitch cone** is the imaginary cone in a bevel gear that rolls without slipping on a pitch surface of another gear.

The **root cone** is the imaginary surface that coincides with the bottoms of the tooth spaces in a bevel gear.

The **face cone**, also known as the **tip cone** is the imaginary surface that coincides with the tops of the teeth of a bevel gear.

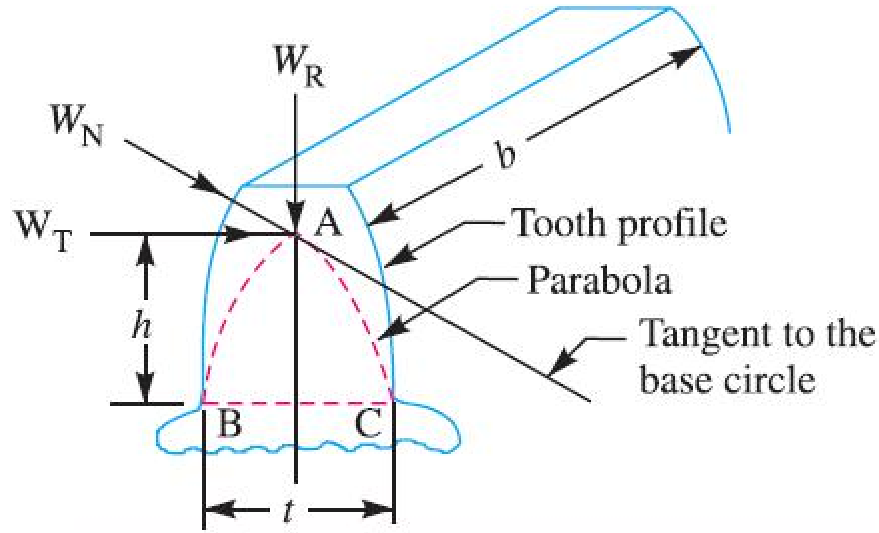

Pitch apex to back
Crown to back
Pitch apex to crown
Crown
Pitch apex
Cone distance
Face angle
Dedendum angle
Face width
Shaft angle
Pinion
Root angle
Pitch angle
Uniform clearance
Front angle
Back angle
Gear
Pitch diameter
Outside diameter
A
A
Back cone
Back cone distance

C_v = Velocity factor,

$$= \frac{3}{3 + v}$$, for teeth cut by form cutters,

$$= \frac{6}{6 + v}$$, for teeth generated with precision machines,

Beam Strength of Gear Teeth – Lewis Equation
Tooth form Factor



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

Proportions for Bevel Gear

The proportions for the bevel gears may be taken as follows :

1. Addendum, a = 1 m

2. Dedendum, d = 1.2 m

3. Clearance = 0.2 m

4. Working depth = 2 m

5. Thickness of tooth = 1.5708 m

where m is the module.