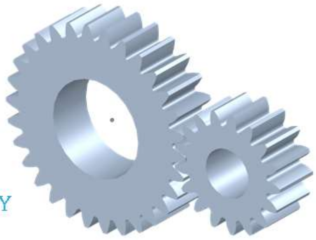
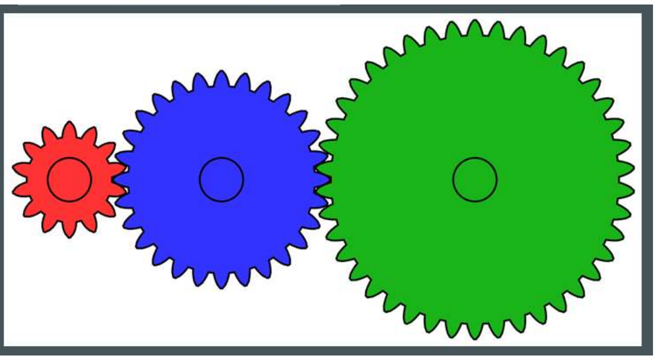
GEARS

TYPES, GEAR GEOMETRY & GEAR TERMINOLOGY

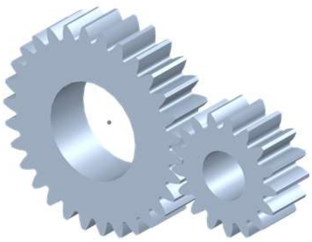




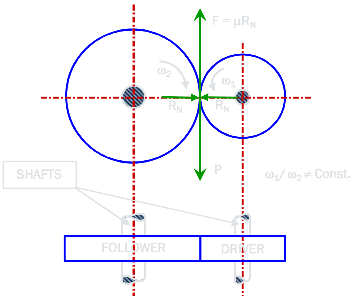
Department of Mechanical Engineering
NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

GEARS or TOOTHED WHEEL

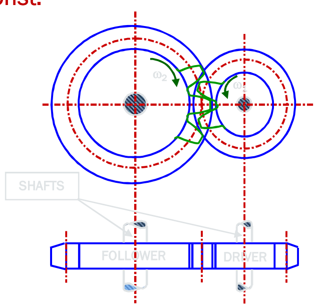
- a toothed element & higher pair mechanism
- Commonly used for transmitting rotary motions from one shaft to another by successively engaging teeth
- Pair of gears are used for transmission of constant angular velocity ratio between two shafts



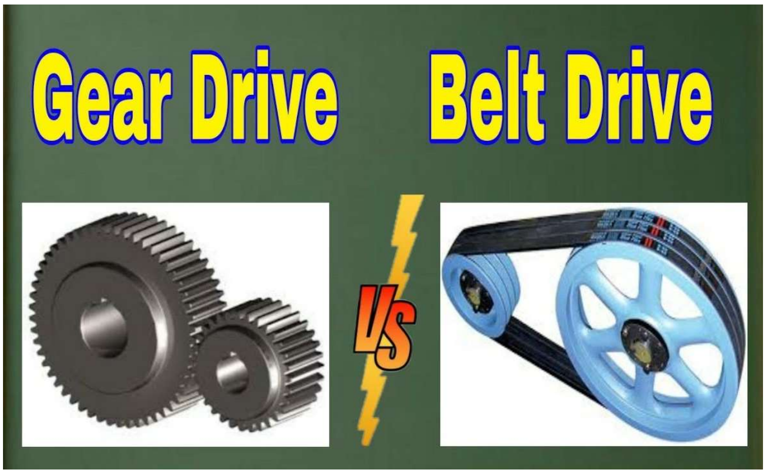
$\omega_1 / \omega_2 = \text{Const.}$



FRICTION WHEEL



GEAR or TOOTHED WHEEL



- ✓ **Positive Drive**
- ✓ **Lower Centre Distance**

Types of Gears

- **Spur gear**
- **Helical gear**
- **Herringbone gear**
- **Bevel gear**
- **Spiral bevel gear**
- **Worm & Worm wheel**
- **Rack & Pinion …**

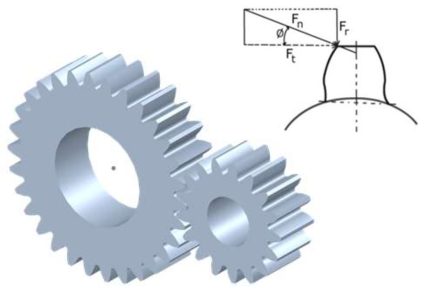
Pinion: *the smaller of two mating gears is called pinion*

Gear or Wheel: *the bigger or larger gear in gear pair is called Gear or wheel*

Types of Gears

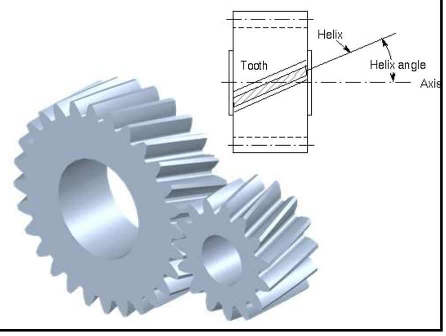
Spur gear

- Spur gears have straight teeth parallel to the axis of rotation
- Mounted on two parallel shafts to transmit motion
- At the time of engagement, entire face width (on straight line parallel to axis of rotation) of the tooth comes in contact with mating tooth. This results in sudden application of the load, high impact stresses & excessive noise at high speeds.
- As teeth are parallel to axis, spur gears are not subjected to axial thrust due to teeth load



Helical gear

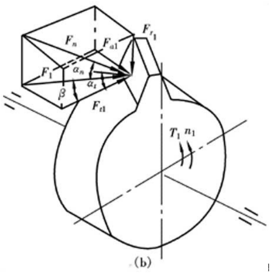
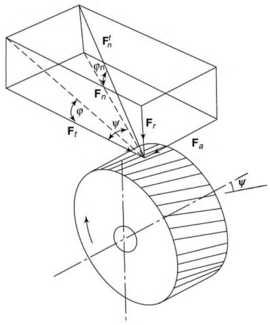
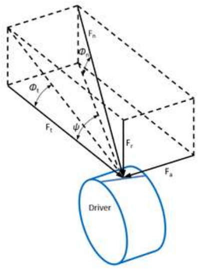
- In helical gear, teeth are inclined at an angle (called helix angle) with the axis of rotation (gear axis) [Helix angle=15° to 25°]
- Contact occurs at the point of leading edge of the teeth during the beginning of engagement. As the gears rotate, the contact extends along a line across the face of the teeth. Thus, the load applied is gradual resulting in low impact stresses & less noise
- The helical gear can be used in higher velocities than spur gears & have greater load carrying capacity

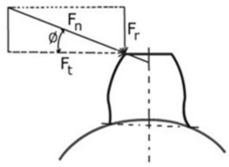


Helical gears

Drawbacks

- As teeth are inclined to gear axis, helical gears are subjected to axial thrust due to force component along the gear axis
- The bearings & the assemblies mounting the helical gears must be able to withstand this axial force.



Double helical gear & Herringbone gear

- Axial thrust which occurs in case of helical gear is eliminated by the use of double helical gears or Herringbone gears
- A double helical gear is equivalent to a pair of helical gears secured together, one having a right-hand helix & the other a left-hand helix. The teeth of the two rows are separated by a groove used for tool run out.
- If the left & the right inclinations of a double helical gear meet at a common apex & there is no groove in between, the gear is known as Herringbone gear.
- The axial thrust of the two rows (left & right inclinations) of teeth cancel each other

Teeth are cut on cylindrical blank or cylinder

Types of Gears

Bevel gear or Straight Bevel gear

- When teeth formed on the truncated cones are straight, the gears are known as Bevel gear or Straight bevel gear
- The teeth are straight, radial to the point of intersection of the shaft axes & vary in cross section throughout their length.
- At the beginning of engagement, straight bevel gears make the line contact similar to spur gears
- Kinematically, bevel gears are equivalent to rolling cones

Mitre gear

- Bevel gears of the same size & connecting two shafts at right angles to each other are known as Mitre gear

Spiral bevel gear

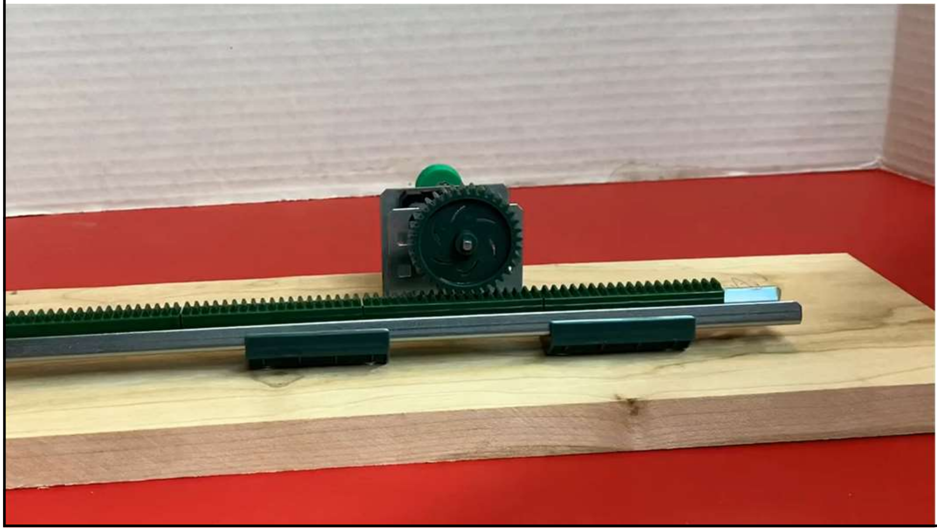
- When teeth formed on the truncated cones are inclined at an angle to the face of the bevel, they are known as Spiral Bevel gear
- They are smoother in action & quieter than straight bevel gears as there is gradual load application.

Worm & Worm wheel

- Used to transmit rotary motion between non-parallel & non-intersecting shafts
- There are screw threads on the worm & teeth on the worm wheel

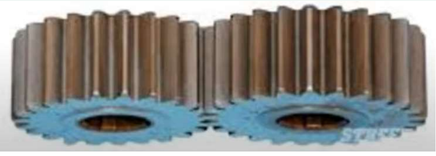
Rack & Pinion

- Convert rotary motion to linear motion and vice-versa



Spur Gear Vs. helical Gear

Spur Gear	Helical Gear
Teeth are parallel to axis of gear or motion axis	Teeth are inclined to axis of gear or motion axis
Imposes only radial load on bearings	Imposes radial load & axial thrust load on bearings
At the time of engagement, entire face width (on straight line parallel to axis of rotation) of the tooth comes in contact with mating tooth. (Sudden engagement of teeth)	Contact occurs at the point of leading edge of the teeth during the beginning of engagement. As the gears rotate, the contact extends along a line across the face of the teeth. (Gradual engagement of teeth)
This results in sudden application of the load, high impact stresses & vibration & excessive noise at high speeds	Thus, the load applied is gradual resulting in low impact stresses & less noise, smooth & quite operation
Low velocity application & less load carrying capacity	can be used in higher velocities than spur gears & have greater load carrying capacity
Low to medium speed application	Relatively high speed application



Classification of Gears

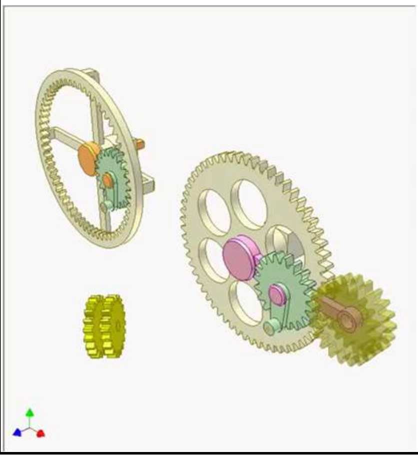
According to the relative position of axes of shafts

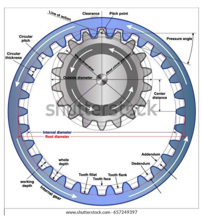
- **Parallel**
  - Spur gear
  - Helical gear
  - Double helical gear & Herringbone gear
- **Intersecting**
  - Straight Bevel gears
  - Spiral Bevel gear
- **Non-parallel & non-intersecting**
  - Worm & Worm wheel

Classification of Gears

According to the type of gearing:

- **External gearing**
- **Internal gearing**
- **Rack & Pinion**





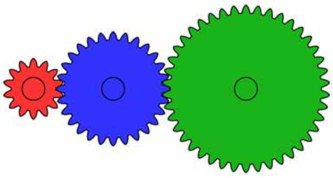
Classification of Gears

According to the peripheral velocity of the gears:

- **Low velocity :** < 3 m/s
- **Medium velocity :** 3 m/s to 15 m/s
- **High velocity :** > 15 m/s

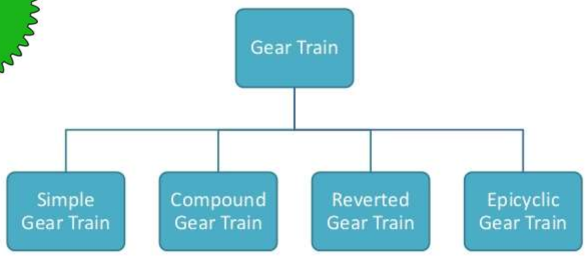
ADVANTAGES and DISADVANTAGES of GEAR drive

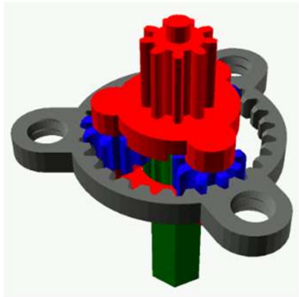
ADVANTAGES	DISADVANTAGES
1. Transmits exact velocity ratio	**1. Costly drive**
2. Transmit heavy torque *(wide range of power transmission)*	**2. Special manufacturing tools**
3. Has high efficiency	**3. Noise for error tooth cutting**
4. Has reliable & simple service	**4. Vibration for incorrect tooth profile**
5. Compact Design	**5. Need suitable lubrication**



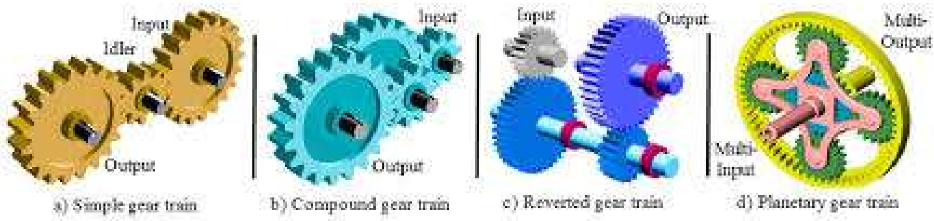
Gear Train : A combination of gears that are used for transmitting motion from one shaft to another shaft

Types of Gear Train

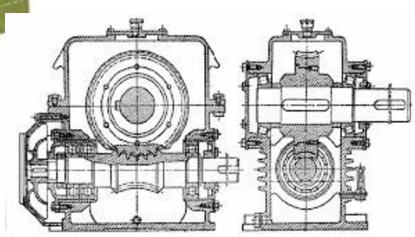




Epicyclic : axes of rotation of the gears are not fixed in space



Applications



Applications

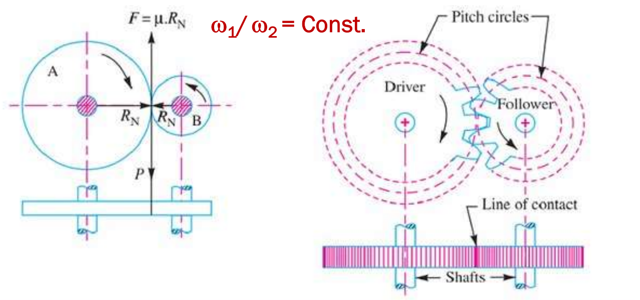
Spur Gear Geometry

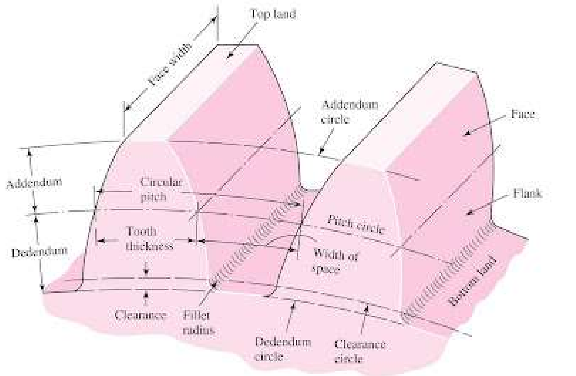
&

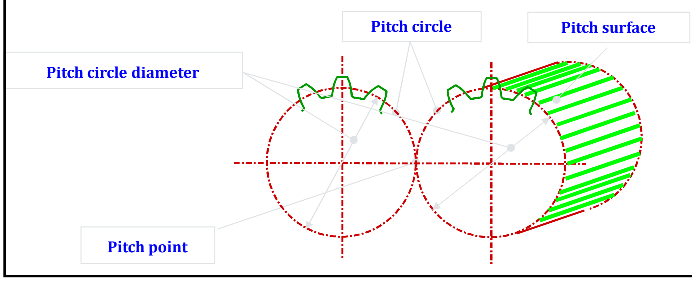
Spur Gear Terminology

Gear Terminology

$\omega_1 / \omega_2 = \text{Const.}$







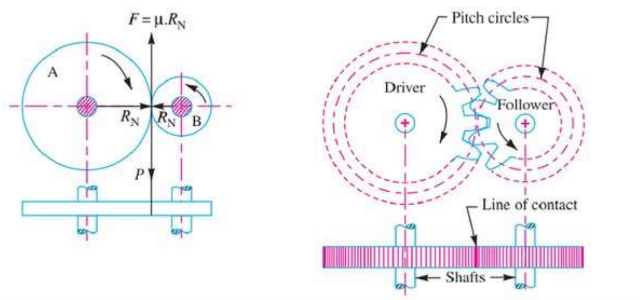
Pitch cylinders

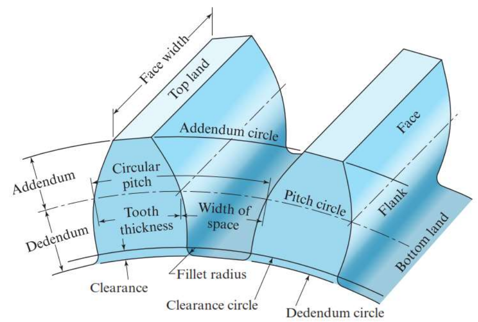
- an imaginary friction cylinders, which by pure rolling together, transmit the same motion as the pairs of gears.

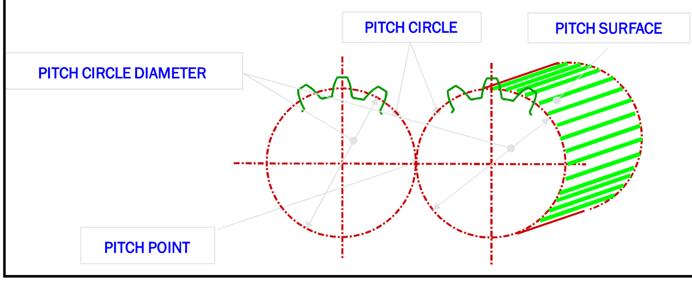
Pitch circle :

- an imaginary circle gives same motion of actual gear on pure rolling action.

Gear Terminology







Pitch circle diameter :

- diameter of pitch circle or pitch cylinder, also known as pitch diameter.

Pitch point :

- point of contact of two pitch circles.

Pitch surface :

- surface of pitch cylinder.

Line of centres:

- A line through the centre of rotation of a pair of mating gears.

Gear Terminology

Top Land : Surface of the top of the tooth

Bottom Land : Surface of the bottom of the tooth between adjacent fillets

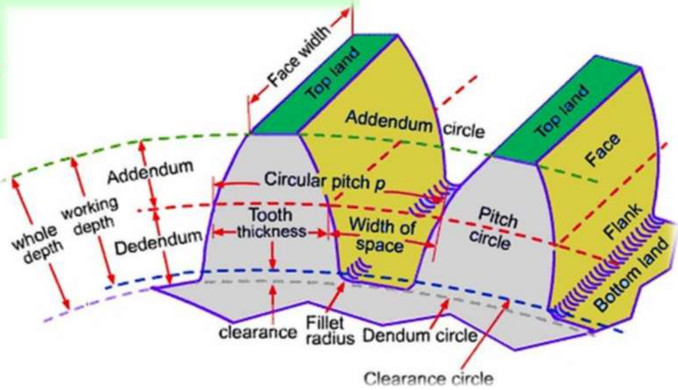
Face : Tooth surface above pitch surface.

Flank : Tooth surface between pitch surface & bottom land.

Face Width : Tooth width along gear axis

Profile : Curve formed by the flank and face.

Fillet Radius : Radius connects dedendum circle to tooth profile.



Gear Terminology

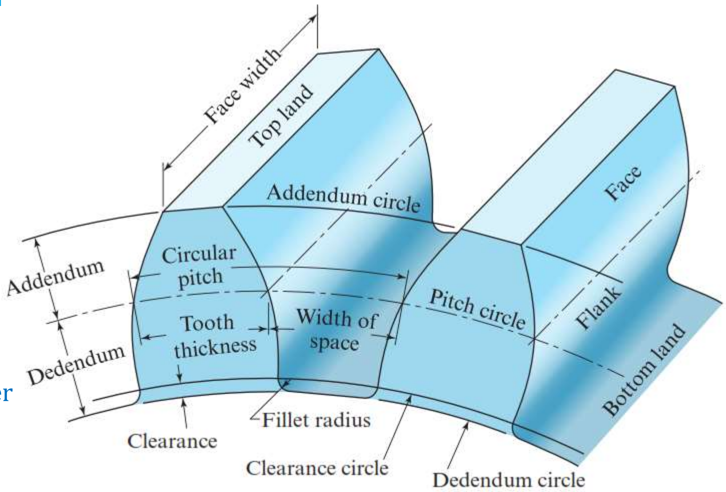
Pitch
- Circular pitch (p)
- Diametral pitch (P)

Circular Pitch

The distance measured along the circumference of the pitch circle from a point on one tooth to the corresponding point of the adjacent tooth

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

Where,
d=Pitch circle diameter
T=number of teeth
p=Circular pitch



Pitch angle

The angle subtended by the circular pitch at the centre of the pitch circle.

Gear Terminology

Pitch
- Circular pitch (p)
- Diametral pitch (P)

Circular Pitch (p)

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

Where,
d=Pitch circle diameter
T=number of teeth
p=Circular pitch

Diametral pitch (P)

The number teeth per unit length of the pitch circle diameter

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

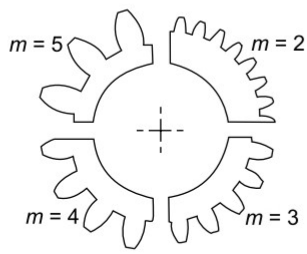
$$pP = \frac{\pi d}{T}\frac{T}{d} = \pi$$

Gear Terminology

Diametral pitch (P)

The number teeth per unit length of the pitch circle diameter

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

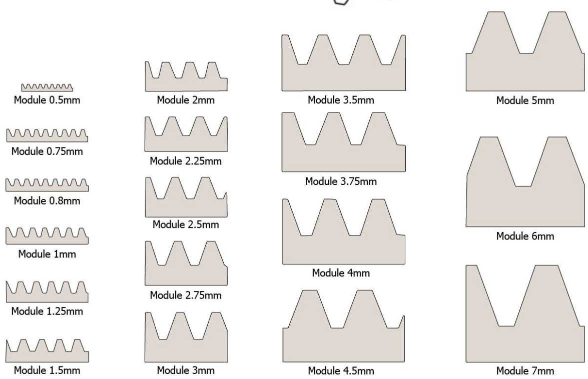


Module (m)

The ratio of pitch circle diameter (in mm) of gear to the number teeth
The reciprocal of the diametral pitch

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

Where,
d=Pitch circle diameter (mm)
T=number of teeth
m=module (mm)



Preferred	1, 1.25, 1.5, 2, 2.5, 3, 4, 5, 6, 8, 10, 12, 16, 20, 25, 32, 40, 50
Next choice	1.125, 1.375, 1.75, 2.25, 2.75, 3.5, 4.5, 5.5, 7, 9, 11, 14, 18, 22, 28, 36, 45

Gear Terminology

Addendum circle : circle through top land of the teeth, concentric to pitch circle

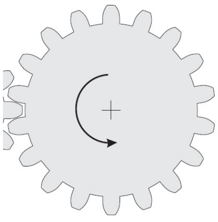
Dedendum circle : circle through bottom land of the teeth, concentric to pitch circle.

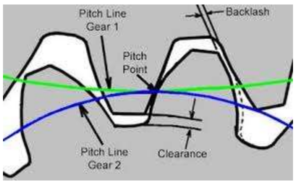
Clearance circle : circle touching addendum circle of meshing gear, concentric to pitch circle.

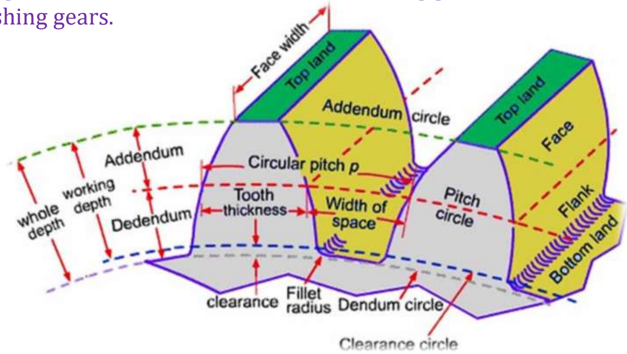
Addendum : tooth height from pitch circle to top of tooth i.e radial dist. between pitch circle & addendum circle

Dedendum : tooth depth from pitch circle to bottom of tooth i.e radial dist. between pitch circle & dedendum circle

Clearance : the amount by which the dedendum of a gear exceeds the addendum of the mating gear or radial distance between dedendum circle and addendum circle of meshing gears.





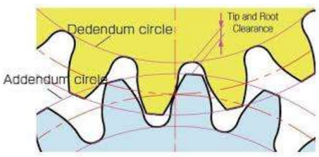


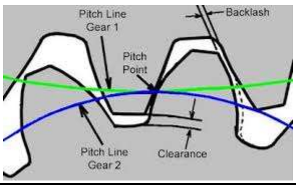
Gear Terminology

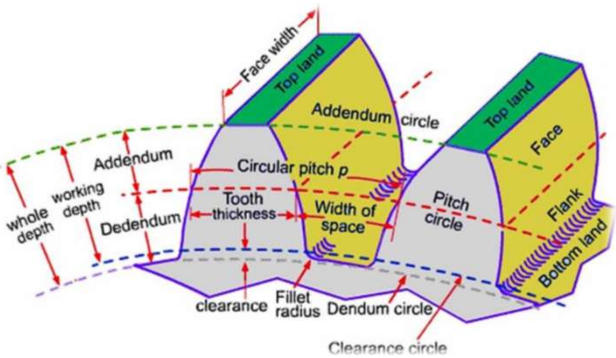
Full depth of teeth : total radial depth of the tooth space
Full depth=Addendum+Dedendum

Working depth of teeth : the maximum depth to which a tooth penetrates into the tooth space of the mating gear
Working depth=Sum of addendums of the two mating gears

	Standard value (mm) (20° full depth Involute)
Addendum	m
Dedendum	1.25×m
Addendum circle diameter	d+2×m
Dedendum circle diameter	d-2×1.25×m
Clearance	0.25×m







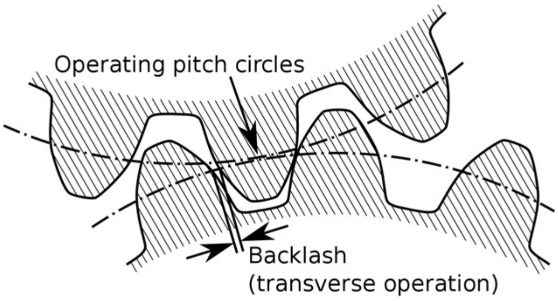
Gear Terminology

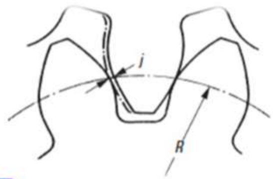
Tooth thickness : thickness of the tooth measured along the pitch circle

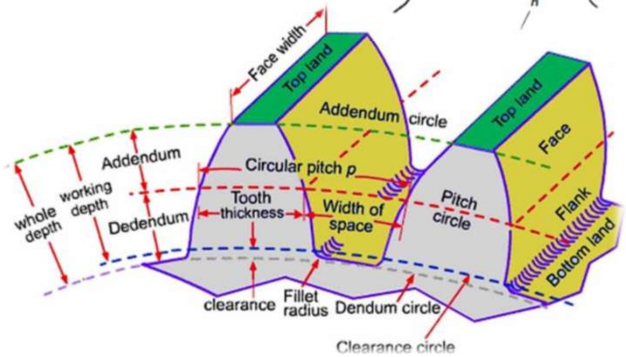
Space width : width of the tooth space along the pitch circle

Backlash : the difference between the space width & the tooth thickness along the pitch circle
Backlash=Space width – Tooth thickness

Face width : the length or width of the tooth parallel to the gear axis







Velocity ratio

It is the ratio of angular velocity of the driving gear to the angular velocity of driven gear

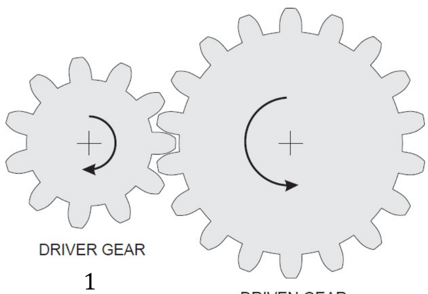
Velocity ratio= Angular velocity of driver gear (ω_1)/ Angular velocity of driven gear (ω_2)

Velocity ratio= ω_1/ω_2

Velocity ratio= N_1/N_2 $\qquad \omega_1=2\pi N_1/60$; $\omega_2=2\pi N_2/60$

Velocity ratio= d_2/d_1 $\qquad \pi d_1 N_1=\pi d_2 N_2$

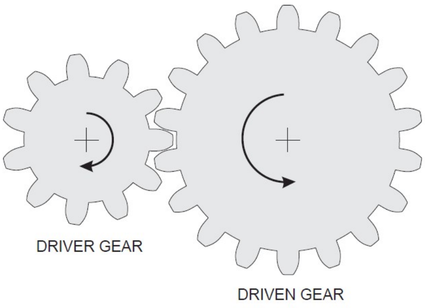
Velocity ratio= T_2/T_1 $\qquad m=d_1/T_1=d_2/T_2$



	Max. Velocity Ratio
Spur gear	6:1
Helical gear	10:1
Worm gear	100:1

Example 1

Two spur gears have a velocity ratio 4:1. the driven gear has 80 teeth of 8 mm module & rotates at 240 rpm. Calculate: (i) the number of teeth, (ii) the speed of the driver, (iii) the pitch line velocities



Solution:

Number of teeth on driven gear (T_2)=80 teeth
RPM of driven gear (N_2)=240 rpm.

Velocity ratio= N_1/N_2 $\quad 4= N_1/240 \quad N_1=240\times4=960$ rpm

Velocity ratio= T_2/T_1 $\quad 4= 80/T_1 \quad T_1=80/4=20$

Module $m=d_1/T_1=d_2/T_2 \quad 8=d_1/20 \quad d_1=160$ mm

$\omega_1=2\pi N_1/60$; $\omega_2=2\pi N_2/60$

Pitch line velocity $(v_p)= \omega_1 r_1=\omega_1 d_1/2=2\pi N_1 d_1/(60\times2)$

Pitch line velocity $(v_p)= 2\pi\times960\times160/(60\times2)=8038.4$ mm/s

Example 2

The number of teeth of a spur gear is 40 & it rotates at 200 rpm. What will be its pitch line velocity if it has a module of 2 mm?

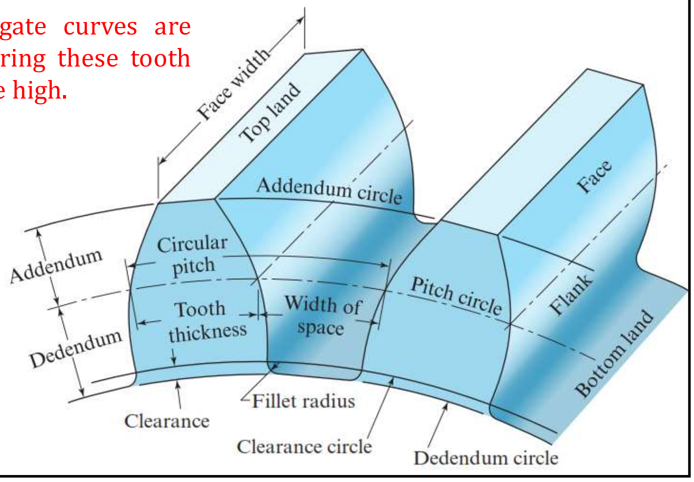
Forms of Gear Tooth

- Two curves of any shape that fulfil the law of gearing can be used as the profiles of teeth.
- An arbitrary shape of one of the mating teeth can be taken & applying the law of gearing the shape of the other can be determined. Such gears are said to have Conjugate Teeth.
- Even though a large number of conjugate curves are possible, real problem lies in manufacturing these tooth profiles in large quantities. The cost will be high.
- Difficulties in interchangeability

Thus, there arises the need to standardize forms of gear tooth

Common forms of gear teeth

- **Involute profile tooth**
- **Cycloidal profile tooth**

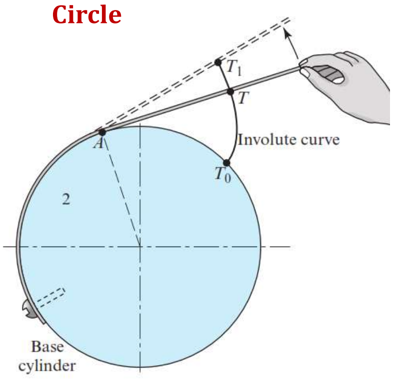


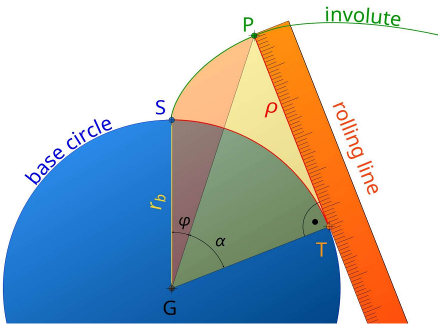
Involute profile tooth

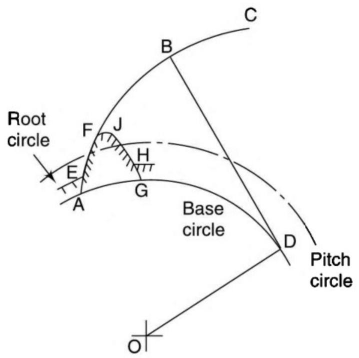
An involute is defined as the locus of a point on a straight line which rolls without slipping on the circumference of a circle

It is the path traced by the end of a taut cord (string/thread) as it is unwound from a stationary cylinder or circle. The string is always tangent to the cylinder or circle.

The circle on which the straight line rolls or from which the string is unwound is known as **Base Circle**

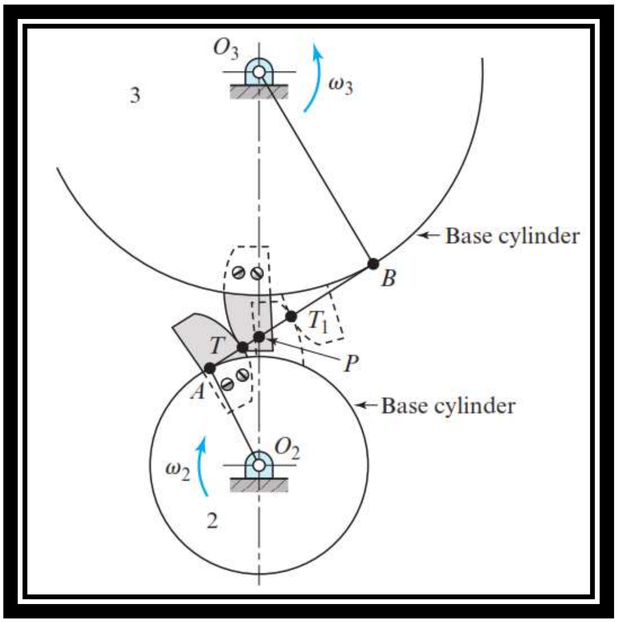






Forms of Gear Tooth

Involute profile tooth



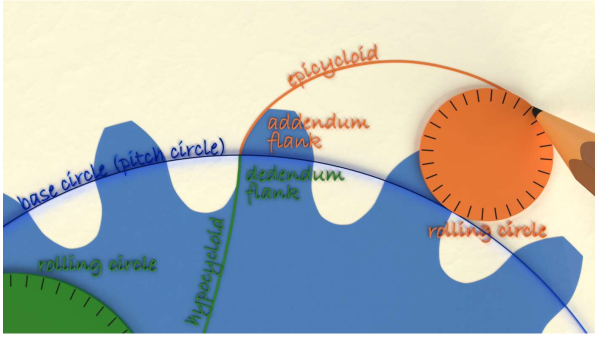
Forms of Gear Tooth

Cycloidal profile tooth

The cycloidal profile is made of two curves:

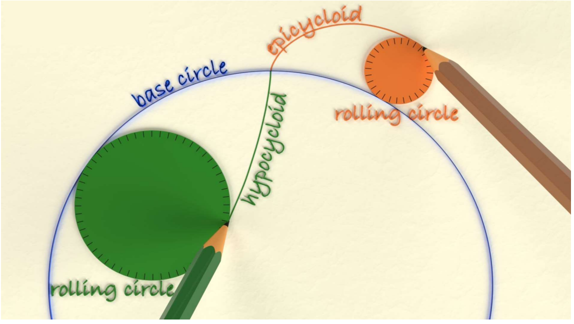
Hypocycloid : Hypocycloid curve (Concave curve) below the pitch circle

Epicycloid : Epicycloid curve (Convex curve) above the pitch circle



Hypocycloid :
curve traced by a point on the circumference of a generating circle which rolls inside of a fixed circle without slipping.

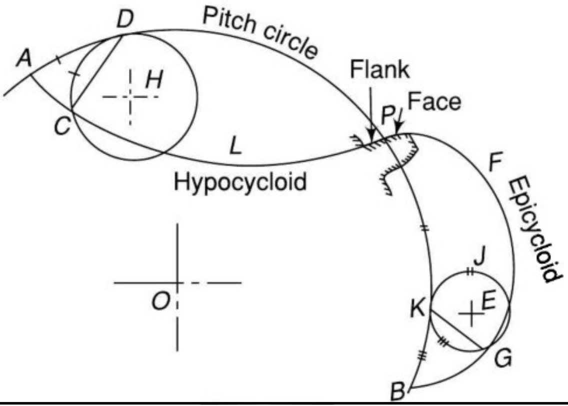
Epicycloid :
curve traced by a point on the circumference of a generating circle which rolls outside of a fixed circle without slipping.



Cycloidal teeth

Epicycloid :
curve traced by a point on the circumference of a circle which rolls outside of pitch circle without slipping.

Hypocycloid :
curve traced by a point on the circumference of a circle which rolls inside of pitch circle without slipping.



Involute profile Vs. Cycloidal profile

Involute profile teeth	Cycloidal profile teeth
Center distance can be varied within limit without changing velocity ratio.	Exact center distance to be maintained to transmit a constant velocity ratio
Pressure angle remains constant from start to end of engagement. This results in smooth running of the gears	Pressure angle is max. at start, zero at pitch point and again max. at end of engagement. This results in less smooth running of the gears
Face and flank are generated by single curve. It involves single curve for teeth resulting in simplicity of manufacturing & of tools. These are cheaper	Face is generated by epicycloid and flank is generated by hypocycloid. This complicates the manufacturing. These are costlier
Interference can occur if the condition of minimum number of teeth on a gear is not followed. **Undercut is necessary to remove interference.**	Interference does not occur at all
Thinner flank for same pitch & thus are weaker as compared to the cycloidal form for the same pitch	Wider flank for same pitch & thus are stronger
Two convex surfaces are in contact & thus there is more wear	A convex flank of one gear always has contact with a concave face of mating gear resulting in less wear

Line of action or Pressure line

The force which the driving tooth exerts on the driven tooth, is along a line from the pitch point to the point of contact of the two teeth. This line is also the common normal at the point of contact of the mating gears & is known as the **Line of action** or the **Pressure line.**

The line of action is the common tangent to the base circles of mating gears.

Pressure angle or Angle of obliquity

The angle between the pressure line & the common tangent to the pitch circles is known as pressure angle

The pressure angle must be kept small for more power transmission & lesser thrust on the bearings.

Standard pressure angles are 20° and 25°. Gears with 14.5° pressure angle have become almost obsolete.