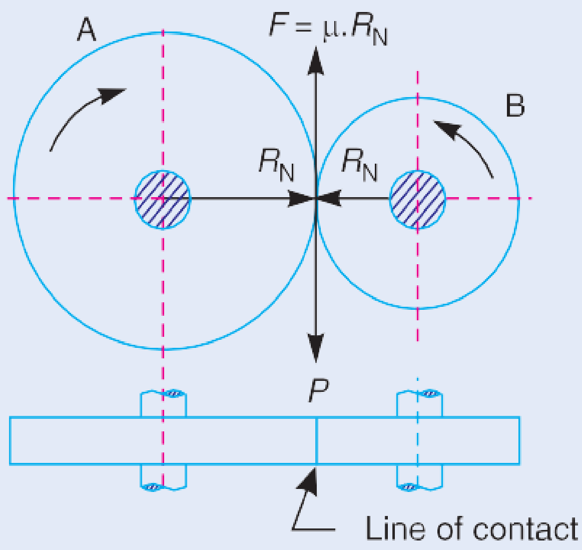
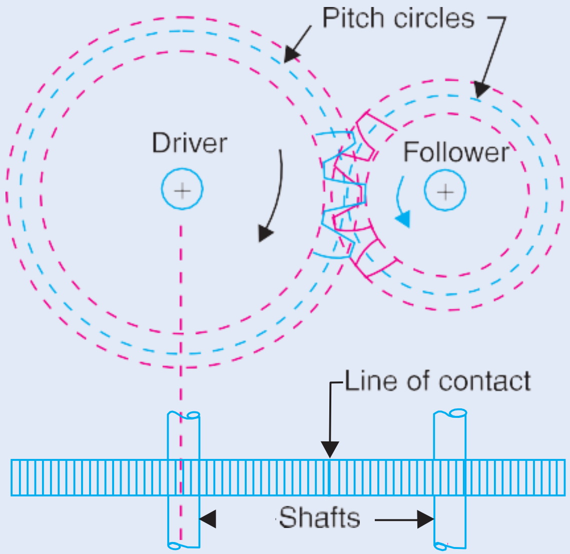
GEARS

Gears can be simply defined as multi toothed wheels intended to transmit power or motion from one shaft to the other by means of successive engagement of teeth

Friction Wheels

The motion and power transmitted by gears is kinematically equivalent to that transmitted by friction wheels or discs.





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The wheel *B* will be rotated so long as the tangential force exerted by the wheel *A* does not exceed the maximum frictional resistance between the two wheels. But when (*P*) exceeds the (*F*), slipping will take place between the two wheels. Thus the friction drive is not a positive drive.

Thus A friction wheel with the teeth cut on it is known as ***toothed wheel* or *gear*.** The usual connection to show the toothed wheels is by their **pitch circles.

Advantages and Disadvantages of Gear Drive

Advantages :

It transmits exact velocity ratio.

It may be used to transmit large power.

It has high efficiency.

It has reliable service.

It has compact layout.

Disadvantages :

The manufacture of gears require special tools and equipment.

The error in cutting teeth may cause vibrations and noise during operation.

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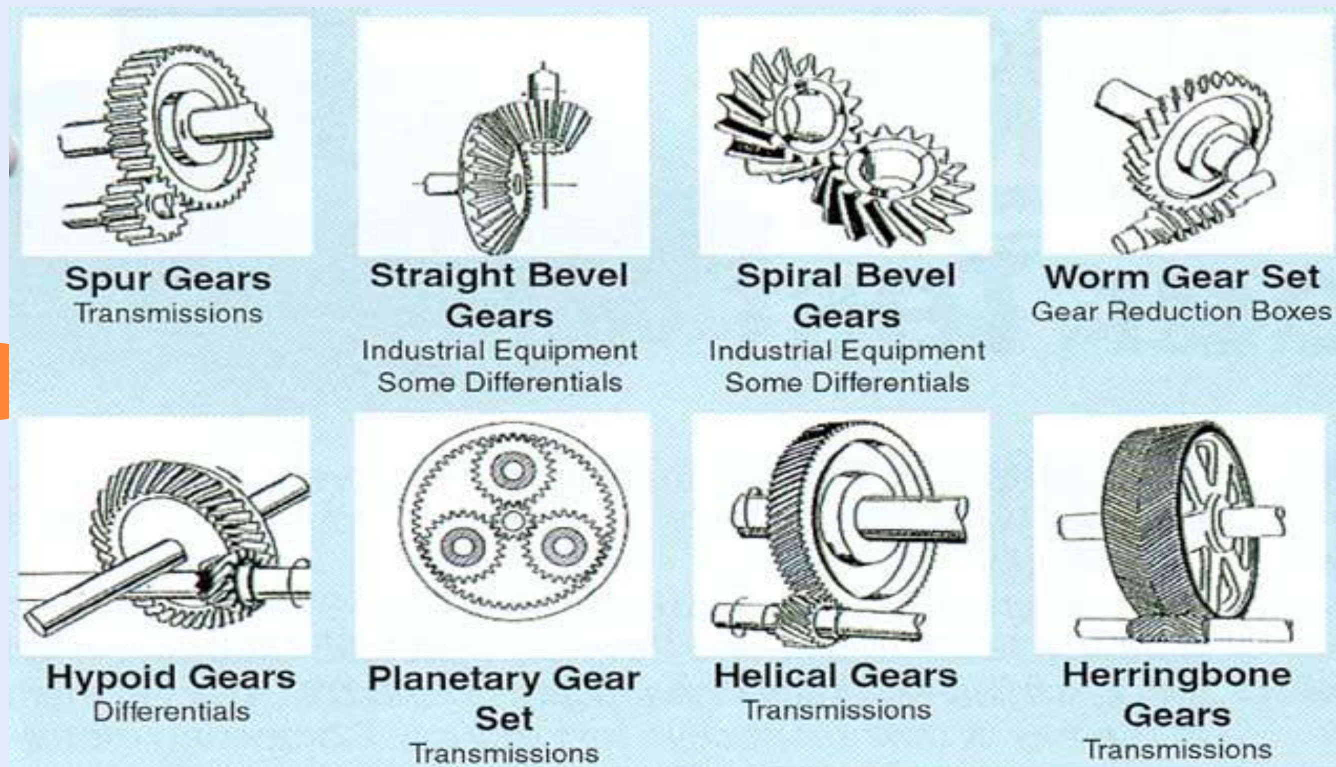
Classific ation of Toothed Wheels

1.According to the position of axes of the shafts. The axes of the two shafts between which the motion is to be transmitted, may be

(a)Parallel, (*b*) Intersecting, and (*c*) Non-intersecting and non-parallel.



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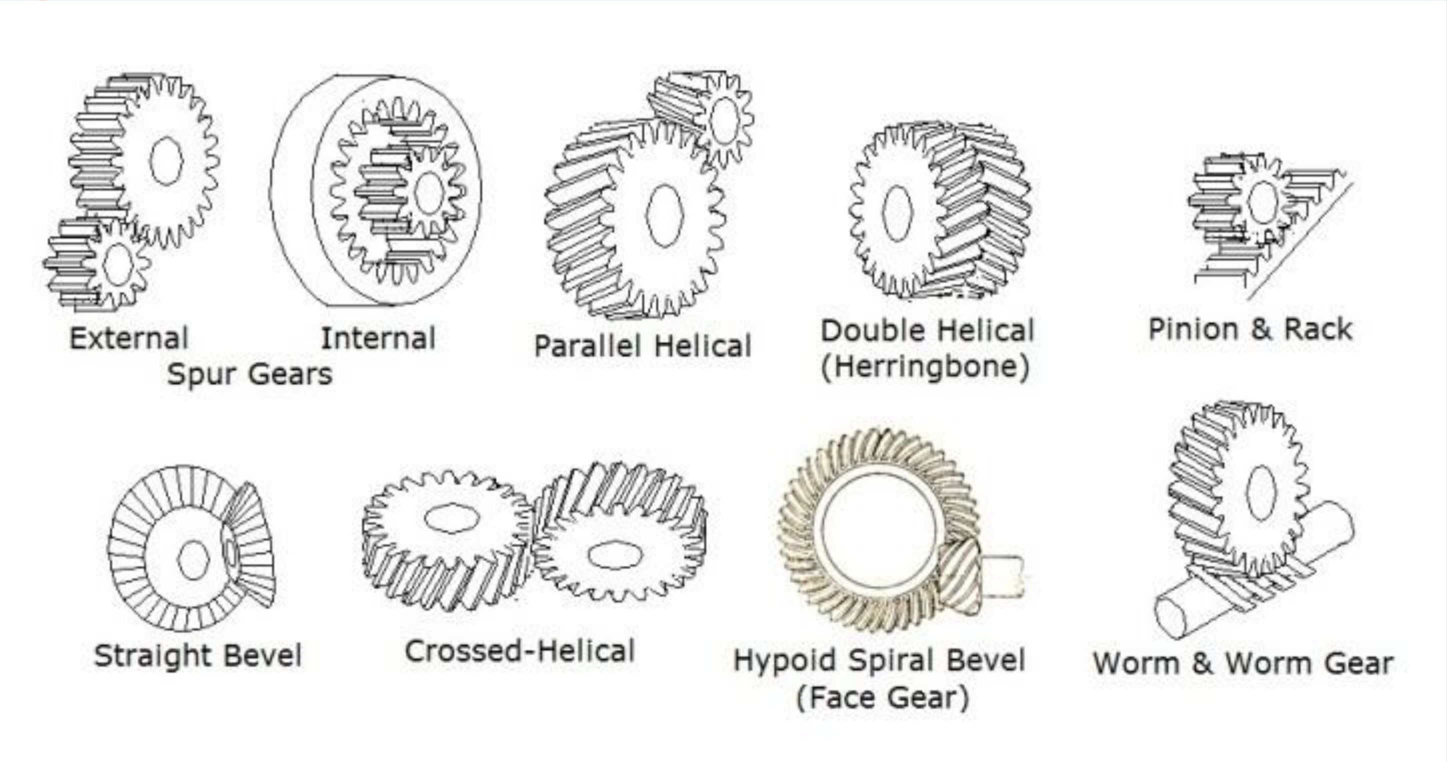
2. ***According to the peripheral velocity of the gears.***

(*a*) Low velocity, (*b*) Medium velocity, and (*c*) High velocity.

The gears having velocity less than 3 m/s are termed as *low velocity* gears and gears having velocity between 3 and 15 m/s are known as *medium velocity gears*. If the velocity of gears is more than 15 m/s, then these are called *high speed gears*.

3. ***According to the type of gearing.***

(a)External gearing, (*b*) Internal gearing, and (*c*) Rack and pinion.



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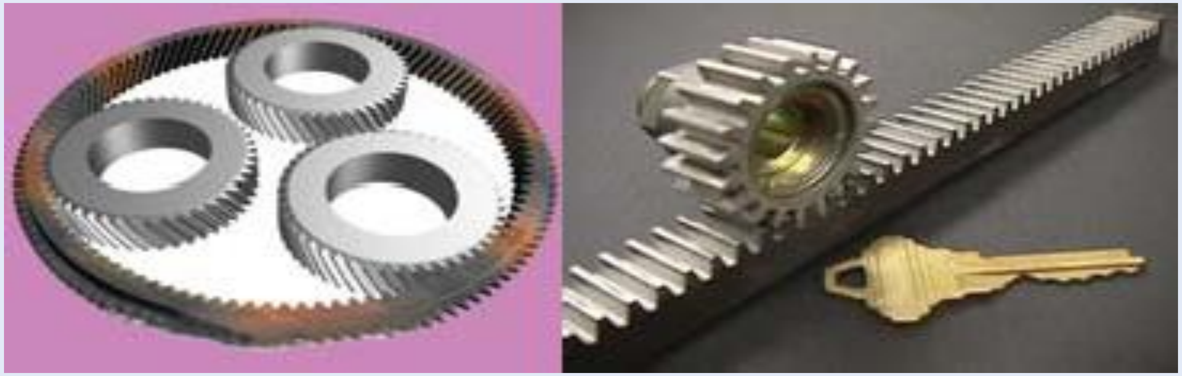
__4.According to position of teeth on the gear surface__. The teeth on the gear surface may be

(a) straight, (*b*) inclined, and (*c*) curved



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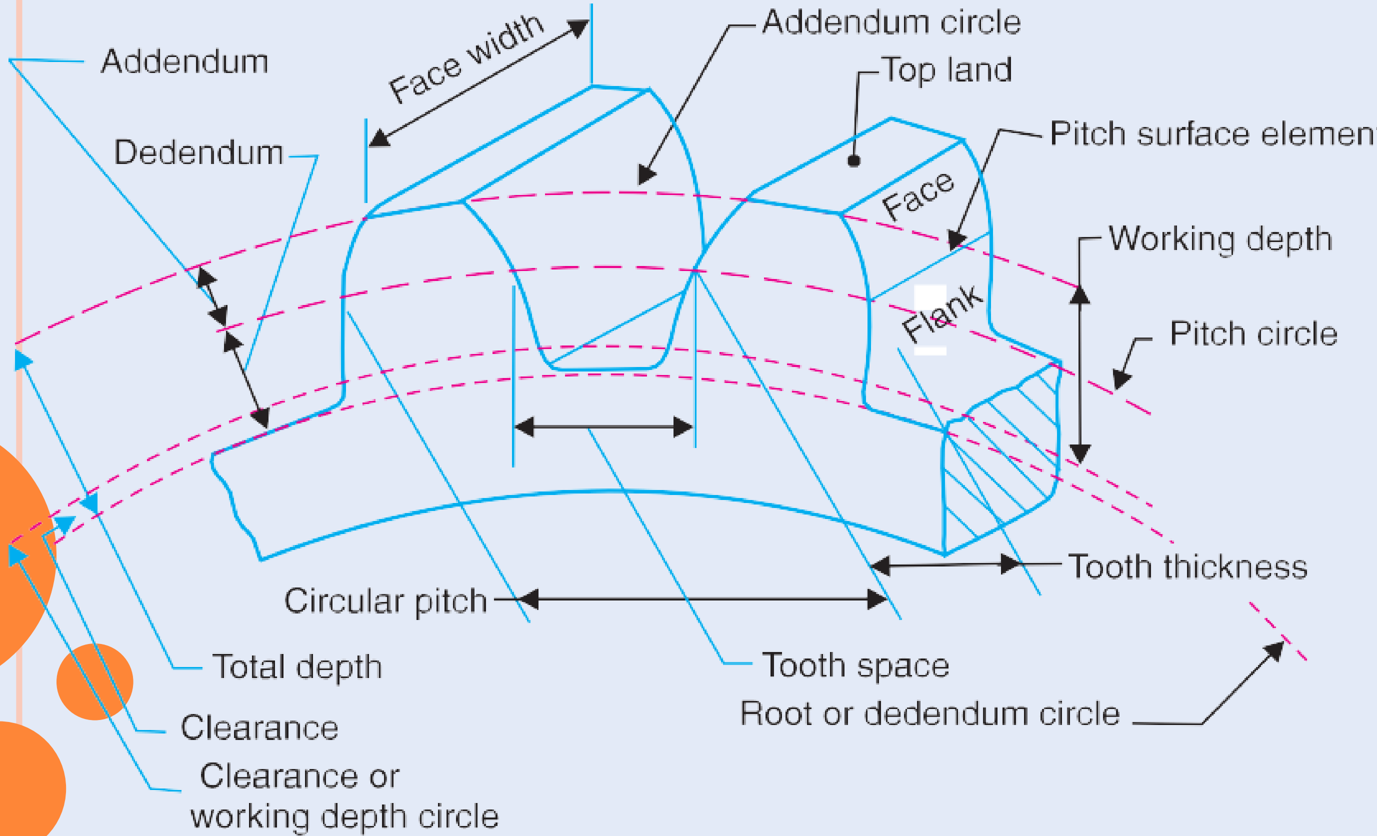
Terms Used in Gears/ Gear tooth terminology :



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

2. 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 known as ***pitch diameter***.

3.***Pitch point***. It is a common point of contact between two pitch circles.

4.Pitch surface. It is the surface of the rolling discs which the meshing gears have replaced at the pitch circle.

5.*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 14 1/2° and 20°.

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

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

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

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

10.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= p * *D/T*

Where *D*= Diameter of the pitch circle, and

***T*= Number of teeth on the wheel.**

A little consideration will show that the two gears will mesh together correctly, if the two wheels have the same circular pitch.

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

12. ***Module:*** It is the ratio of the pitch circle diameter in millimeters to the number of teeth. It is usually denoted by *m*. Mathematically, Module, $m = D / T$

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13.*Clearance*. It is the radial distance from the top of the tooth to the bottom of the tooth, in a meshing gear. A circle passing through the top of the meshing gear is known as ***clearance circle***.

14.Total depth. It is the radial distance between the addendum and the dedendum circles of a gear. It is equal to the sum of the addendum and dedendum.

15.Working depth. It is the radial distance from the addendum circle to the clearance circle. It is equal to the sum of the addendum of the two meshing gears.

16.Tooth thickness. It is the width of the tooth measured along the pitch circle.

17.Tooth space . It is the width of space between the two adjacent teeth measured along the pitch circle.

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18.Backlash. It is the difference between the tooth space and the tooth thickness, as mea-sured along the pitch circle. Theoretically, the backlash should be zero, but in actual practice some backlash must be allowed to prevent jamming of the teeth due to tooth errors and thermal expansion.

19.Face of tooth. It is the surface of the gear tooth above the pitch surface.

20.Flank of tooth. It is the surface of the gear tooth below the pitch surface.

21.Top land. It is the surface of the top of the tooth.

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

23.Profile. It is the curve formed by the face and flank of the tooth.

24.Fillet radius. It is the radius that connects the root circle to the profile of the tooth.

25.Path of contact. It is the path traced by the point of contact of two teeth from the beginning to the end of engagement.

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25.Path of contact. It is the path traced by the point of contact of two teeth from the beginning to the end of engagement.

26.Length of the path of contact. It is the length of the common normal cut-off by the addendum circles of the wheel and pinion.

27. ***Arc of contact***. It is the path traced by a point on the pitch circle from the beginning to the end of engagement of a given pair of teeth. The arc of contact consists of two parts, *i.e.*

Arc of approach. **It is the portion of the path of contact from the beginning of the engagement to the pitch point.**

Arc of recess. **It is the portion of the path of contact from the pitch point to the end of the engagement of a pair of teeth.**

Note : The ratio of the length of arc of contact to the circular pitch is known as *contact ratio* *i.e.* number of pairs of teeth in contact.

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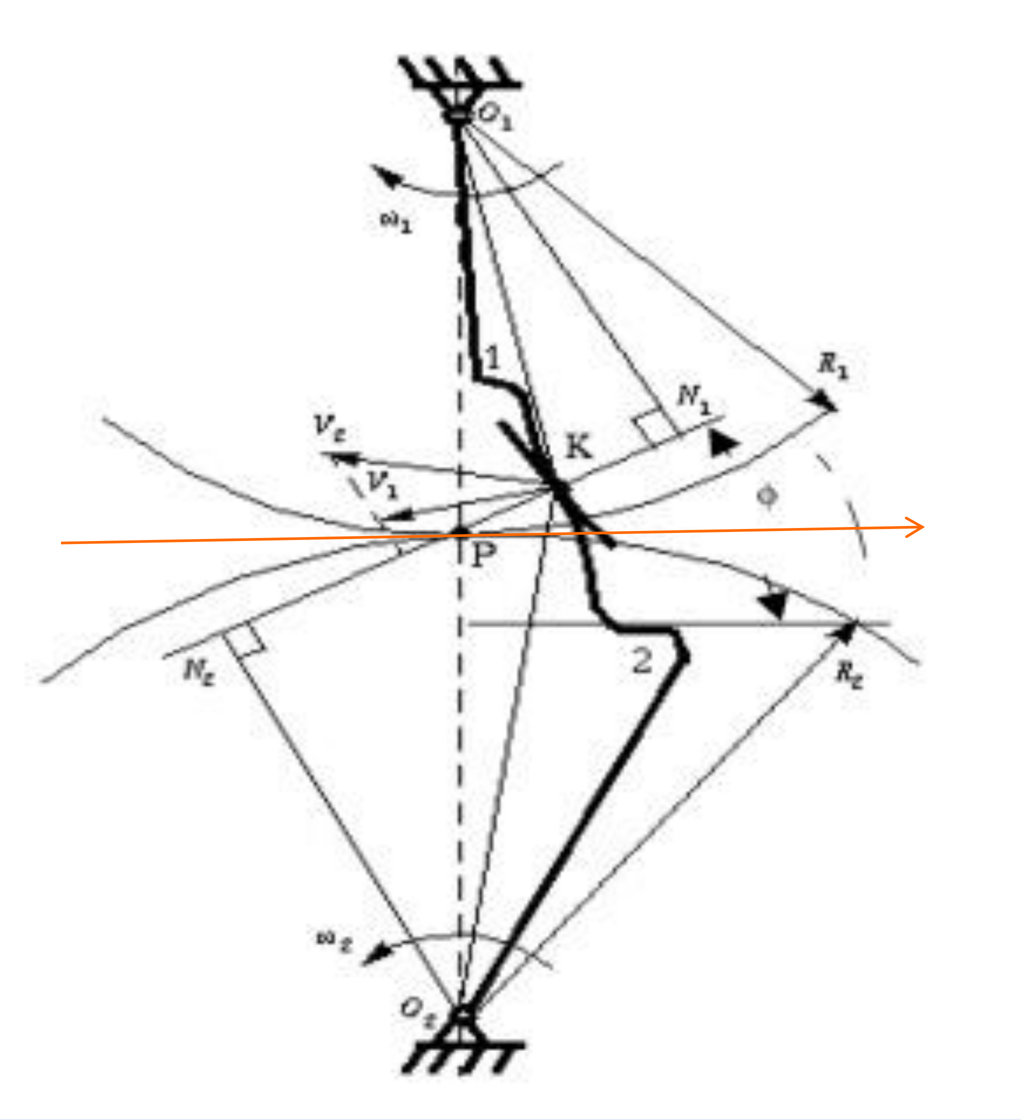

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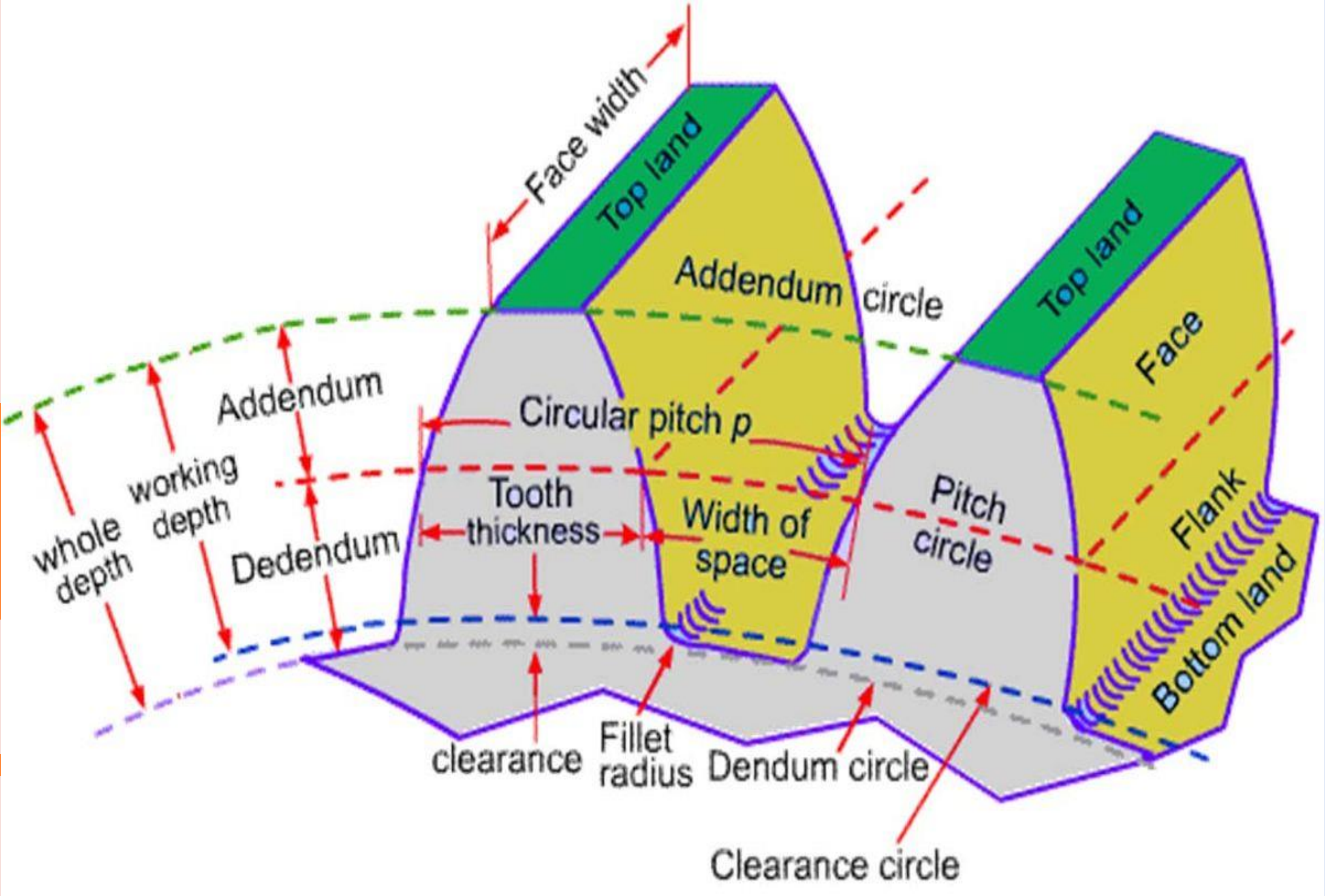

Face width
Top land
Addendum circle
Top land
Face
Addendum
Circular pitch p
working depth
whole depth
Tooth thickness
Width of space
Pitch circle
Flank
Bottom land
Dedendum
clearance
Fillet radius
Dendum circle
Clearance circle

GEAR TRAINS

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Sometimes, two or more gears are made to mesh with each other to transmit power from one shaft to another. Such a combination is called ***gear train*** or ***train of toothed wheels.***

Different types of gear trains : (based on arrangement of wheels)

1.Simple gear train,

2. Compound gear train,

3. Re- verted gear train, and

4. Epicyclic gear train

1. SIMPLE GEAR TRAIN :

When there is only one gear on each shaft it is known as ***simple gear train.***

Since the gear 1 drives the gear 2, therefore gear 1 is called the ***driver*** and the gear 2 is called the ***driven*** or ***follower.***

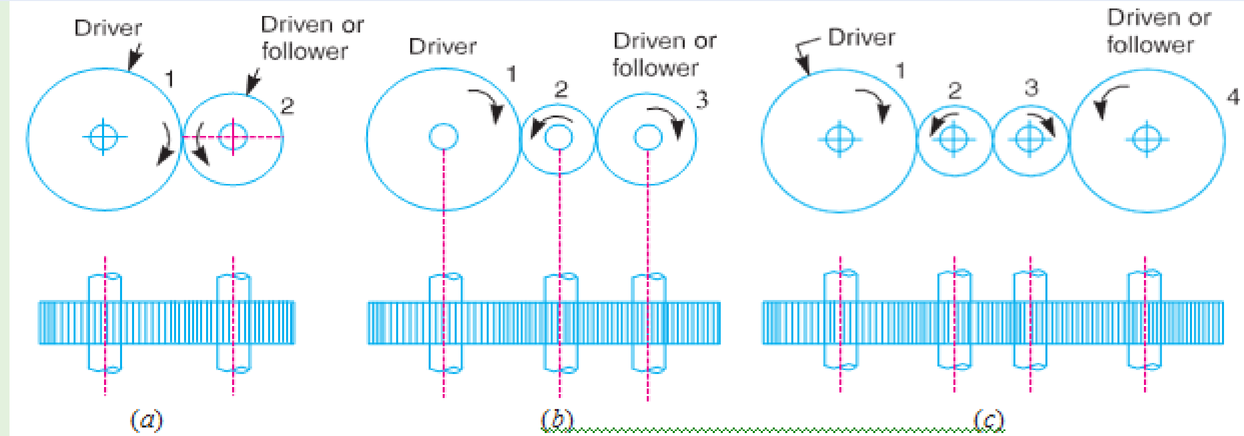


Fig. 13.1. Simple gear train.

Let N_1 = Speed of gear 1(or driver) in r.p.m.,

N_2 = Speed of gear 2 (or driven or follower) in r.p.m.,

T_1 = Number of teeth on gear 1, and

T_2 = Number of teeth on gear 2.

For fig (a): Velocity ratio OR Speed ratio = N1 / N2 = T2 / T1

Train value = N2 / N1 = T1 / T2.

T_3 = Number of teeth on driven or follower.

Since the driving gear 1 is in mesh with the intermediate gear 2, therefore speed ratio for these two gears is

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} \quad \text{...(i)}$$

Similarly, as the intermediate gear 2 is in mesh with the driven gear 3, therefore speed ratio for these two gears is

$$\frac{N_2}{N_3} = \frac{T_3}{T_2} \quad \text{...(ii)}$$

The speed ratio of the gear train as shown in Fig. 13.1 (*b*) is obtained by multiplying the equations (*i*) and (*ii*).

$$\therefore \quad \frac{N_1}{N_2} \times \frac{N_2}{N_3} = \frac{T_2}{T_1} \times \frac{T_3}{T_2} \quad \text{or} \quad \frac{N_1}{N_3} = \frac{T_3}{T_1}$$

i.e. $$\text{Speed ratio} = \frac{\text{Speed of driver}}{\text{Speed of driven}} = \frac{\text{No. of teeth on driven}}{\text{No. of teeth on driver}}$$

and $$\text{Train value} = \frac{\text{Speed of driven}}{\text{Speed of driver}} = \frac{\text{No. of teeth on driver}}{\text{No. of teeth on driven}}$$

2.COMPOUND GEAR TRAIN :

When there are more than one gear on a shaft, it is called a ***compound train of gear.***

whenever the distance between the driver and the driven or follower has to be bridged over by intermediate gears and at the same time a great (or much less) speed ratio is required, then the advantage of intermediate gears is intensified by providing compound gears on intermediate shafts.

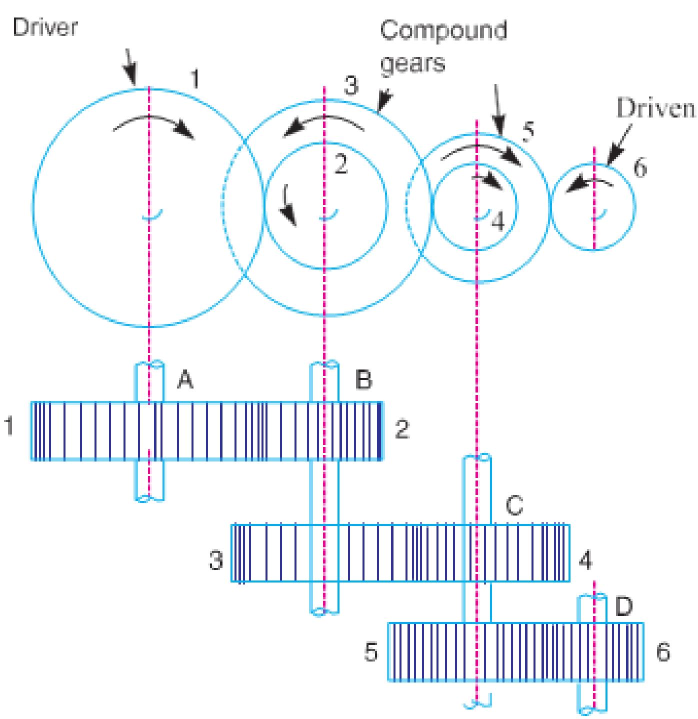


Fig. 13.2. Compound gear train.

Let N_1 = Speed of driving gear 1,

T_1 = Number of teeth on driving gear 1,

$N_2, N_3 ..., N_6$ = Speed of respective gears in r.p.m., and

$T_2, T_3 ..., T_6$ = Number of teeth on respective gears.

Since gear 1 is in mesh with gear 2, therefore its speed ratio is

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} \quad ...(i)$$

Similarly, for gears 3 and 4, speed ratio is

$$\frac{N_3}{N_4} = \frac{T_4}{T_3} \quad ...(ii)$$

and for gears 5 and 6, speed ratio is

$$\frac{N_5}{N_6} = \frac{T_6}{T_5} \quad ...(iii)$$

The speed ratio of compound gear train is obtained by multiplying the equations (i), (ii) and (iii),

$$\frac{N_1}{N_2} \times \frac{N_3}{N_4} \times \frac{N_5}{N_6} = \frac{T_2}{T_1} \times \frac{T_4}{T_3} \times \frac{T_6}{T_5} \quad \text{or} \quad {}^*\frac{N_1}{N_6} = \frac{T_2 \times T_4 \times T_6}{T_1 \times T_3 \times T_5}$$

i.e. Speed ratio = $\dfrac{\text{Speed of the first driver}}{\text{Speed of the last driven or follower}}$

$= \dfrac{\text{Product of the number of teeth on the drivens}}{\text{Product of the number of teeth on the drivers}}$

and Train value = $\dfrac{\text{Speed of the last driven or follower}}{\text{Speed of the first driver}}$

$= \dfrac{\text{Product of the number of teeth on the drivers}}{\text{Product of the number of teeth on the drivens}}$

The advantage of a compound train over a simple gear train is that a much larger speed reduction from the first shaft to the last shaft can be obtained with small gears. If a simple gear train is used to give a large speed reduction, the last gear has to be very large. Usually for a speed reduction in excess of 7 to 1, a simple train is not used and a compound train or worm gearing is employed.

same module as they mesh together. Similarly gears 3 and 4, and gears 5 and 6 must have the same module.

Example 13.1. *The gearing of a machine tool is shown in Fig. 13.3. The motor shaft is connected to gear A and rotates at 975 r.p.m. The gear wheels B, C, D and E are fixed to parallel shafts rotating together. The final gear F is fixed on the output shaft. What is the speed of gear F ? The number of teeth on each gear are as given below :*

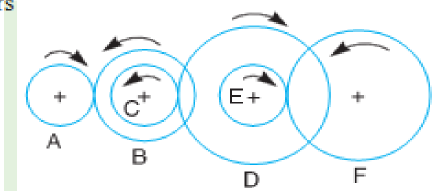


Fig. 13.3

Gear	*A*	*B*	*C*	*D*	*E*	*F*
No. of teeth	*20*	*50*	*25*	*75*	*26*	*65*

Solution. Given : $N_A = 975$ r.p.m. ; $T_A = 20$; $T_B = 50$; $T_C = 25$; $T_D = 75$; $T_E = 26$; $T_F = 65$

$$\frac{N_A}{N_F} = \frac{T_B \times T_D \times T_F}{T_A \times T_C \times T_E} = \frac{50 \times 75 \times 65}{20 \times 25 \times 26} = 18.75$$

$$N_F = \frac{N_A}{18.75} = \frac{975}{18.75} = 52 \text{ r.p.m.}$$ **Ans.**

Design of Spur Gears

Sometimes, the spur gears (*i.e.* driver and driven) are to be designed for the given velocity ratio and distance between the centres of their shafts.

Let x = Distance between the centres of two shafts,

N_1 = Speed of the driver,

T_1 = Number of teeth on the driver,

d_1 = Pitch circle diameter of the driver,

N_2, T_2 and d_2 = Corresponding values for the driven or follower, and

p_c = Circular pitch.

We know that the distance between the centres of two shafts,

$$x = \frac{d_1 + d_2}{2} \quad \text{...(i)}$$

and speed ratio or velocity ratio,

$$\frac{N_1}{N_2} = \frac{d_2}{d_1} = \frac{T_2}{T_1} \quad \text{...(ii)}$$

From the above equations, we can conveniently find out the values of d_1 and d_2 (or T_1 and T_2) and the circular pitch (p_c). The values of T_1 and T_2, as obtained above, may or may not be whole numbers. But in a gear since the number of its teeth is always a whole number, therefore a slight alterations must be made in the values of x, d_1 and d_2, so that the number of teeth in the two gears may be a complete number.

Example 13.2. *Two parallel shafts, about 600 mm apart are to be connected by spur gears. One shaft is to run at 360 r.p.m. and the other at 120 r.p.m. Design the gears, if the circular pitch is to be 25 mm.*

Solution. Given : $x = 600$ mm ; $N_1 = 360$ r.p.m. ; $N_2 = 120$ r.p.m. ; $p_c = 25$ mm

Let d_1 = Pitch circle diameter of the first gear, and

d_2 = Pitch circle diameter of the second gear.

We know that speed ratio,

$$\frac{N_1}{N_2} = \frac{d_2}{d_1} = \frac{360}{120} = 3 \quad \text{or} \quad d_2 = 3d_1 \qquad \ldots(i)$$

and centre distance between the shafts (x),

$$600 = \frac{1}{2}(d_1 + d_2) \quad \text{or} \quad d_1 + d_2 = 1200 \qquad \ldots(ii)$$

From equations *(i)* and *(ii)*, we find that

$$d_1 = 300 \text{ mm, and } d_2 = 900 \text{ mm}$$

∴ Number of teeth on the first gear,

$$T_1 = \frac{\pi\, d_2}{p_c} = \frac{\pi \times 300}{25} = 37.7$$

and number of teeth on the second gear,

$$T_2 = \frac{\pi\, d_2}{p_c} = \frac{\pi \times 900}{25} = 113.1$$

Since the number of teeth on both the gears are to be in complete numbers, therefore let us make the number of teeth on the first gear as 38. Therefore for a speed ratio of 3, the number of teeth on the second gear should be 38 × 3 = 114.

Now the exact pitch circle diameter of the first gear,

$$d_1' = \frac{T_1 \times p_c}{\pi} = \frac{38 \times 25}{\pi} = 302.36 \text{ mm}$$

and the exact pitch circle diameter of the second gear,

$$d_2' = \frac{T_2 \times p_c}{\pi} = \frac{114 \times 25}{\pi} = 907.1 \text{ mm}$$

∴ Exact distance between the two shafts,

$$x' = \frac{d_1' + d_2'}{2} = \frac{302.36 + 907.1}{2} = 604.73 \text{ mm}$$

Hence the number of teeth on the first and second gear must be 38 and 114 and their pitch circle diameters must be 302.36 mm and 907.1 mm respectively. The exact distance between the two shafts must be 604.73 mm. **Ans.**

3.REVERTED GEAR TRAIN :

When the axes of the first gear (*i.e.* first driver) and the last gear (*i.e.* last driven or follower) are co-axial, then the gear train is known as ***reverted gear* train** as shown

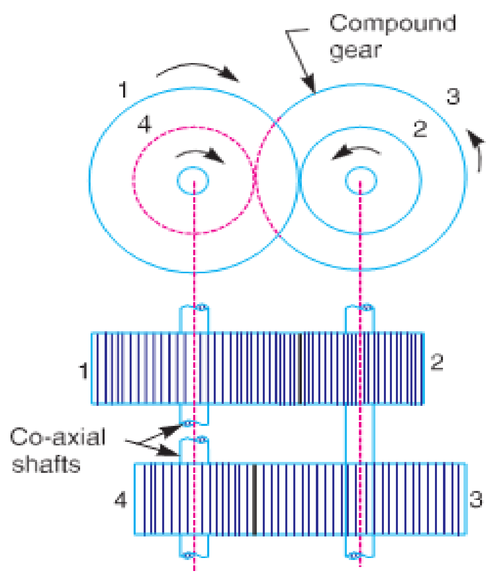


Fig. 13.4. Reverted gear train.

Here T1,T2,T3 and T4 are no.of teeth on gears
r1, r2,r3 and r4 are pitch circle radii of respective gears
N1,N2,N3,and N4 are speeds of the respective gears.

From fig :
r1 + r2 = r3 + r4 since module (m = d /T) is being same for the each of the two pairs. Here r α T ,
We have T1 + T2 = T3 + T4.

$$r_1 + r_2 = r_3 + r_4 \quad \text{...}(i)$$

Also, the circular pitch or module of all the gears is assumed to be same, therefore number of teeth on each gear is directly proportional to its circumference or radius.

$$\therefore \quad {}^*T_1 + T_2 = T_3 + T_4 \quad \text{...}(ii)$$

and

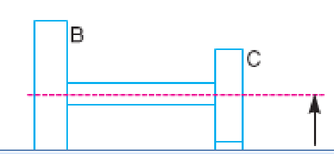
$$\text{Speed ratio} = \frac{\text{Product of number of teeth on drivens}}{\text{Product of number of teeth on drivers}}$$

or

$$\frac{N_1}{N_4} = \frac{T_2 \times T_4}{T_1 \times T_3} \quad \text{...}(iii)$$

From equations (*i*), (*ii*) and (*iii*), we can determine the number of teeth on each gear for the given centre distance, speed ratio and module only when the number of teeth on one gear is chosen arbitrarily.

The reverted gear trains are used in automotive transmissions, lathe back gears, industrial speed reducers, and in clocks (where the minute and hour hand shafts are co-axial).



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