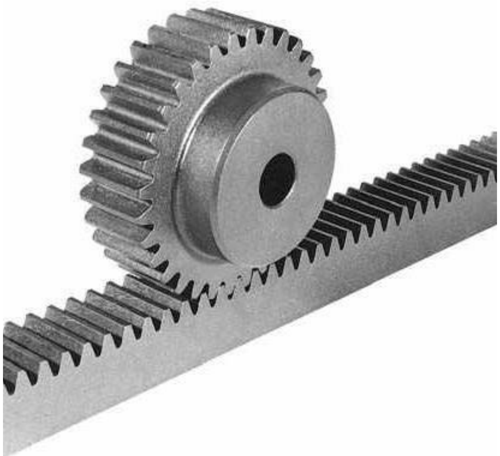
Introduction of Gears

Gears are among the most important power transmission elements. A gear is a rotating machine element having cut teeth which mesh with another toothed part, usually having teeth of similar size and shape, in order to transmit power. Two or more gears working together are called a "*transmission*" (*or gear set*) and can produce "*mechanical advantage*" and thus may be considered a simple machine. The mechanical advantage is a measure of the force or torque amplification that is obtained using mechanical devices.

When two gears mesh with one gear bigger than the other (*the size of the teeth must match thus the bigger gear has more teeth*), a mechanical advantage is obtained where the rotational speeds and the torques of the two gears will be different. Since the input and output power must be equal (*ignoring friction losses*), there is an inverse relationship between the speed and torque ratios (*the small gear will have higher speed and lower torque and the larger gear will have lower speed and higher torque*).

A transmission (*or gear set*) can be used to change the speed, torque, direction of rotation, direction of a power source, or the type of motion. The most common configuration for a gear is to mesh with another gear, however, a gear can also mesh with a non-rotating toothed part, called a "*rack*", thereby producing translation instead of rotation, as shown in the figure. Such arrangement is refered to as "*rack and pinion*" and it is commonly used in the steering systems of automobiles.



Types of Gears

There are four principal types of gears:

- ***Spur gears***: The simplest type of gears. The teeth are parallel to the axis of rotation, as seen in the figure. It transmits rotation between parallel shafts.

Helical gears: The teeth are inclined with respect to the axis of rotation, as seen in the figure. Same as spur gears, it transmits rotation between parallel shafts, but it is less noisy than spur gears because of the more gradual engagement of the teeth during meshing and thus it is more suitable for transmitting motion at higher speeds.

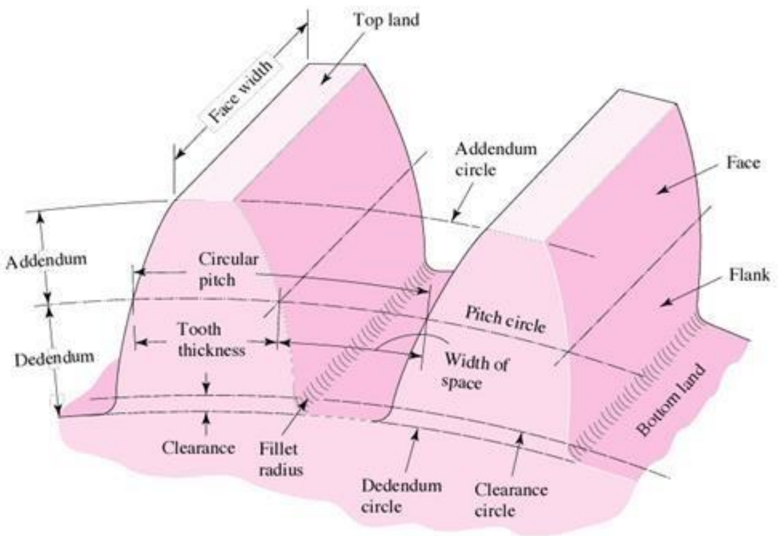
In some cases, helical gears can also be used to transmit rotation between perpendicular shafts, as seen in the figure.

- ***Bevel gears***: The teeth are somehow similar to those of a spur gear but they are formed on conical surfaces instead of cylinders. Bevel gears transmit rotation between intersecting shafts. The gear shown in the figure has straight teeth where this is the simplest type. However, there are other types were the teeth form circular arcs and it is called *spiral bevel gears*, as shown in the figure. With spiral bevel gears, the teeth engagement will be more gradual (*similar to helical gears*) and thus it is less noisy and it is suitable for higher speeds.

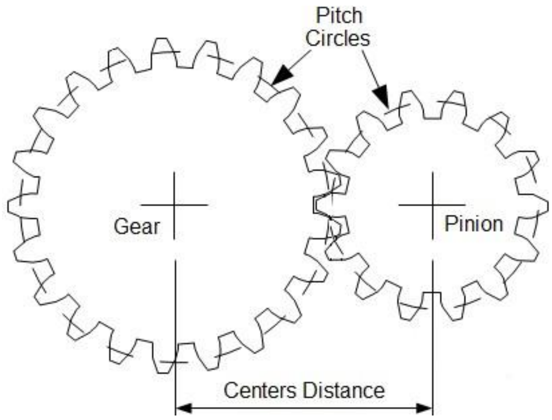
- ***Worms and worm gears***: Transmit rotation between perpendicular shafts (*not intersecting, there is an offset between them*). The worm resembles a screw which can be right handed or left handed. Worm gear sets are usually used when high reduction in speed is desired (*speed ratios of 3 or higher*). It transmits rotation from the worm to the worm gear, but not the opposite.

Nomenclature

Since spur gears are the simplest type, it will be used for illustration and to define the primary parameters of gears and their relations. The figure illustrates the terminology of spur gears.

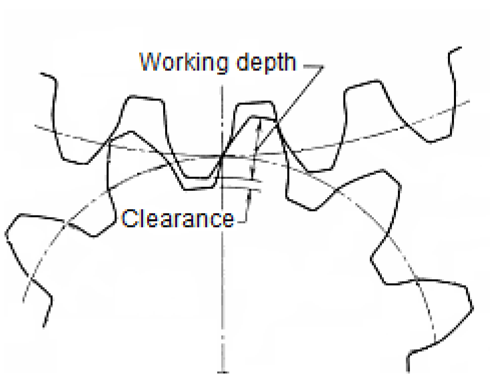


- ***Pitch circle***: the theoretical circle upon which all gear calculations are based and its diameter is called the "***pitch diameter***".



- Pitch circles of mating gears are tangent to each other.
- The "***centers distance***" between two mating gears is the sum of the pitch radiuses of the two gears.
- The smaller of two mating gears is called the "***pinion***" and the larger is called the gear.

- ***Addendum and Dedendum circles***: the circles defining the top and bottom faces of the teeth.
- ***Addendum*** *"a"*: the radial distance from the pitch circle to the top surface of the teeth.
- ***Dedendum*** *"b"*: the radial distance from the pitch circle to the bottom surface of the teeth.
- ***Clearance circle*** (or *working depth circle*): the circle tangent to the addendum circle of the mating gear. The radial distance between the addendum circle and the clearance circle is called the "*working depth*".
- ***Clearance*** *"c"*: the distance between the tooth top surface and the bottom surface of a mating gear.



- ***Circular pitch*** *"p"*: the distance measured on the pitch circle from a point on one tooth to the corresponding point on an adjacent tooth. The circular pitch is equal to the sum of "*tooth thickness*" and "*width of space*". The width of space is slightly larger than the tooth thickness such that mating teeth can engage easily without obstruction.
- ***Module*** *"m"*: is the ratio of pitch diameter to the number of teeth of a gear.

Module (*mm per tooth*) → $\boxed{m = \frac{d}{N}}$ ← Pitch diameter (d), Number of teeth (N)

Circular pitch → $\boxed{p = \frac{\pi d}{N} = \pi m}$

- ***Diametral pitch*** *"P"*: the ratio of the number of teeth of a gear to the pitch diameter *(it is the inverse of the module and it is used with gears sized in inches; its unit is "teeth per inch").*

$$\boxed{P = \frac{N}{d} = \frac{1}{m} \quad \rightarrow \quad p = \frac{\pi}{P}}$$

Important Notes:

- The module (or the diametral pitch) determines the size of gear teeth.
- In order for gears to be able to mesh (*work together*), they ***must have the same module*** (or diametral pitch).
- The pitch diameter of a gear (*i.e., its size*) is determined based on its module (or diametral pitch) and the number of teeth: $\boxed{d = m\,N}$