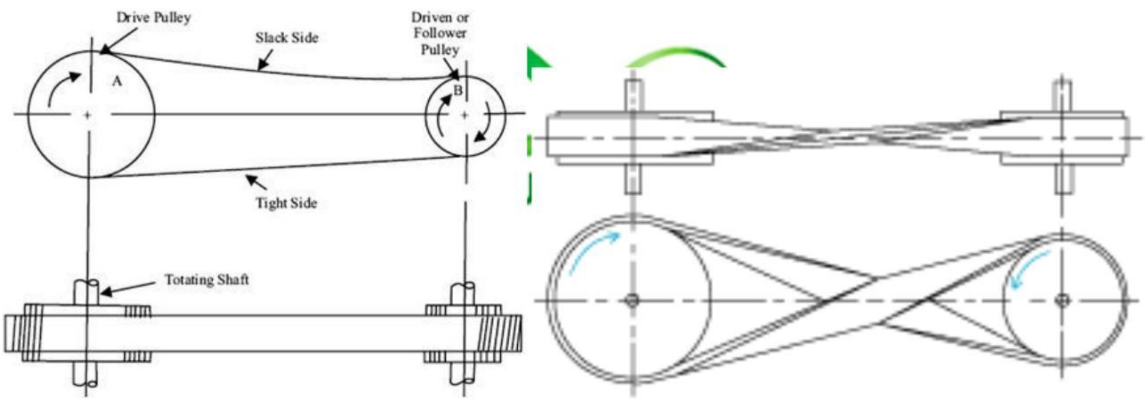
Power transmission systems

In mechanical industries, power from the engines or electric motor are transmitted to the machines using the following drives

1. belt drive
2. chain drive
3. gear drive

Belt drives

A belt is a loop of flexible material used to link two or more rotating shafts mechanically. Belts are looped over pulleys. In a two pulley system, the belt can either drive the pulleys in the same direction, or the belt may be crossed, so that the direction of the shafts is opposite. The shaft from which power is transmitted is called driver shaft and the shaft to which power is transmitted is called driven shaft.



Types of belts

Based on arrangement of shafts and belt

Open belt drive: in this the direction of rotation is same for both driver and driven shaft. See the fig. Above. The driver pulley pulls the belt from one side and delivers the same belt to the other side . hence the tension on the former side will be greater than the later side. The side where tension is more is called tight side and the other side is called slack side.

Cross belt drive: in this driver and driven pulley have different direction of rotation. At the point where belt crosses, it rubs against itself and wears. In order to reduce this shaft should be placed at a minimum distance of 20 d, where 'd' is the width of belt.

Based on shape of cross section

Flat belt- it used to transmit moderate amount of power for a long distane between shafts(upto 10m). Flat belts are again classifie as open belt drive and cross belt drive

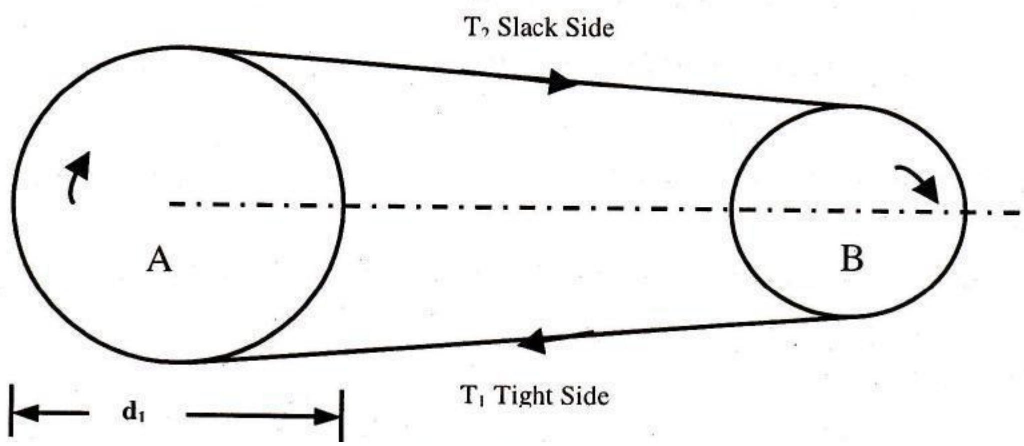
Vee/ V- belt- these are used to transmit large amout of power between two shafts for a short distance

Circular belt/rope- these belts are used to transmit large amount of power for large distance(>8m)
Flat-belt drives are simple and convenient. They permit the use of ordinary pulleys with smooth surfaces, and they can be operated at speeds as high as 40–50 m/sec and more. However, they are bulky in design and low in strength. V-belt drives provide improved attachment of the belt to the pulleys, permit shortening of the centre distances, and allow a decrease in the size of the drive. Round-belt drives are now rare and are used only in mechanisms of low power, such as those in sewing machines.

The advantages of belt drives are their simplicity of design, relative low cost, capacity to transmit power over significant distances (up to 10 m and more), and smooth and noiseless operation. It can be used with very high speed drives. In addition, the elastic properties of the belt and its ability to slip on the pulleys help prevent overload. The disadvantages include the short lifetime of the belts, relatively large size, heavy stress on the shafts and bearings, and variation in the tension ratio caused by the inevitable slipping of the belt.

Belts made of highly elastic, strong synthetic materials like leather, cotton and rubber. Belt drives are widely used in agricultural machines, electric generators, certain machine tools, and textile machines. They are ordinarily used for transmitting power up to 30–50 kilowatts.

Power transmitted by belt drive



Here the driving pulley pulls the belt from the lower side to the upper side. Thus the tension in the lower side will be greater than the tension in the upper side. The upper side is called the slack side and lower side is the tight side.

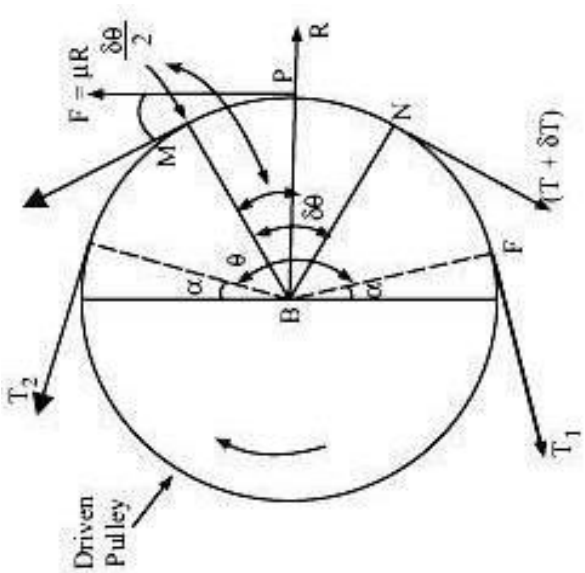
T_1 - tension in the tight side of the belt is Newton
T_2 – Tension in the slack side of the belt is Newton
d_1 – diameter of the driving pulley
d_2 – diameter of the follower
v = linear velocity of the belt in m/sec
The driven pulley rotates because of the difference in tensions in the tight and slack side of the belt. Therefore the force causing the rotation is the difference between the two tensions the belt exerts a force on the pulley.

Let F is the net force acting on the belt
So F = (T_1-T_2)

P = F X V= (T_1-T_2) X V

P = (T_1-T_2) X V =(T_1-T_2)*r* 2.π.N/60.

Relation between belt tension and friction:



In the picture angle of contact between belt and pulley is θ. Let the tight side tension be T1 and slack side tension T2. Consider a short length MN of belt, which subtends an angle δθ at pulley centre. Let T be tension at M and (T + δT) be the tension at N. The frictional force depends normal reaction R. Suppose the belt is in equilibrium. Then ∑X=0 and ∑Y=0. Here x direction is horizontal(radial direction) and y direction is tangential at point P.

$(T + \delta T) \cos (\delta\theta / 2)- T \cos (\delta\theta / 2) - \mu R =0$

Since δθ is very small,

$\cos (\delta\theta / 2) = 1$

$(T + \delta T) + T-\mu R = 0$

$\mu R = \delta T$ ………………………………… (1)

and resolving the force is radial reaction.

$T \sin(\delta\theta / 2) + (T + \delta T) \sin(\delta\theta/2) - R = 0$

Since, $\delta\theta$ is very small, $\sin(\delta\theta/2) = (\delta\theta/2)$

$T\, \delta\theta/2 + (T + \delta T)\, \delta\theta/2\ R = 0$ ($\delta T.\ \delta\theta / 2$ is neglected)

From equations (1) and (2)
$\mu(T\, \delta\theta) = \delta T$
$\delta T / T = \mu\, \delta\theta$
On integration, we get
$\int_{T1}^{T_2} \delta T/T = \int_o^\theta \mu d\theta$
$\log T_1 / T_2 = \mu\theta$
$T_1 / T_2 = (e)^{\mu\theta}$

Gears and gear train

Toothed wheels are known as gears. A gear is a rotating machine part having cut *teeth*, which *mesh* with another toothed part in order to transmit torque. Gears having high efficiency and high accuracy. It is having less maintenance cost.

There are different types of gears. Gears may be classified according to the relative position of the axis of revolution. The axis may be

1. spur,
2. helical
3. bevel gear
4. worm and worm wheel
5. Rack and pinion.

Spur Gears

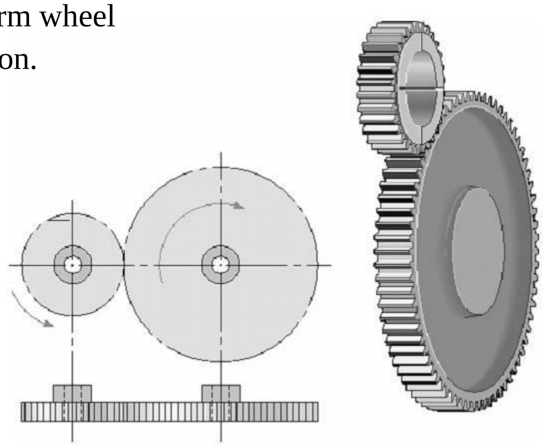


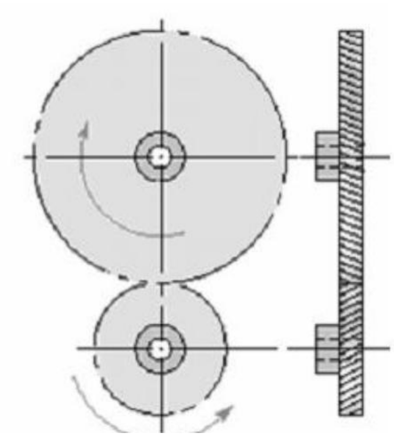
Figure 1: Spur Gear

Spur gears are the most commonly used gear type. They are characterized by teeth which are perpendicular to the face of the gear or teeth are parallel to the axis of rotation. Spur gears are by far the most commonly available, and are generally the least expensive. The basic descriptive geometry for a spur gear is shown in the figure.

Limitations: Spur gears generally cannot be used when a direction change between the two

shafts is required. Advantages: Spur gears are easy to find, inexpensive, and efficient.

Helical Gears



Helical gears are similar to the spur gear except that the teeth are at an angle to the shaft/axis of rotation. The resulting teeth are longer than the teeth on a spur gear of equivalent pitch diameter. The longer teeth cause helical gears to have the following differences from spur gears of the same size :

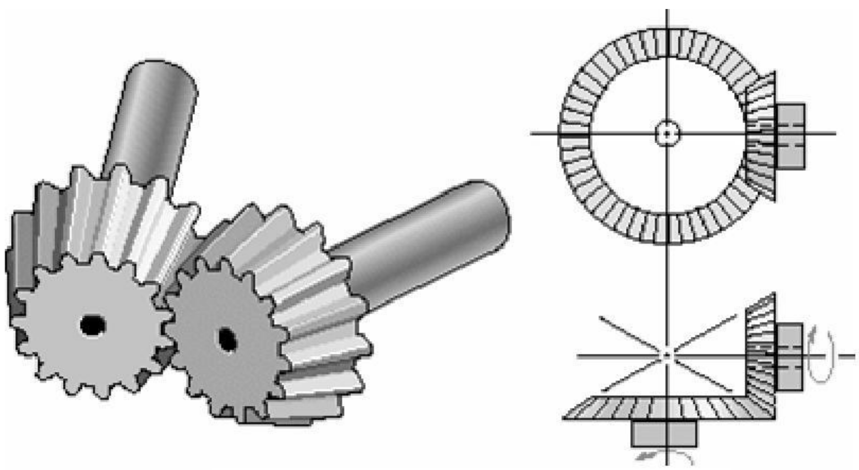
1. Tooth strength is greater because the teeth are longer,
2. Greater surface contact on the teeth allows a helical gear to carry more load than a spur gear
3. The longer surface of contact reduces the efficiency of a helical gear relative to a spur gear

Helical gears may be used to mesh two shafts that are parallel.the angle between tooth and axis of rotation is called helix angle.

Limitations: Helical gears have the major disadvantage that they are expensive . Helical gears are also slightly less efficient than a spur gear of the same size

Advantages: Helical gears can be used on non parallel and even perpendicular shafts, and can carry higher loads than spur gears.

Bevel Gears:



Bevel gears are primarily used to transfer power between intersecting shafts. The teeth of these gears are formed on a conical surface. Standard bevel gears have teeth which are cut straight and are all parallel to the line pointing the apex of the cone on which the teeth are based. One of the most common applications of bevel gears is the automobile differential system,

Limitations: Limited availability. Cannot be used for parallel shafts. Can become noisy at high speeds.
Advantages: Excellent choice for intersecting shaft systems.

Worm Gears

Worm gears are special gears that resemble screws, and can be used to drive spur gears or helical gears. Worm gears, like helical gears, allow two non-intersecting , non parallel shafts to mesh. Normally, the two shafts are at right angles to each other. A worm gear is equivalent to a V-type screw thread. Another way of looking at a worm gear is that it is a helical gear with a very high helix angle. Worm gears are normally used when a high gear ratio is desired, or again when the shafts are perpendicular to each other. One very important feature of worm gear meshes that is often of use is their irreversibility: when a worm gear is turned, the meshing spur gear will turn, but turning the spur gear will not turn the worm gear. The resulting mesh is 'self locking', and is useful in ratcheting mechanisms.

Limitations: Low efficiency. The worm drives the drive gear primarily with slipping motion, thus there are high friction losses.

Advantages: Will tolerate large loads and high speed ratios. Meshes are self locking (which can be either an advantage or a disadvantage).

Racks (straight gears

Racks are straight gears that are used to convert rotational motion to translational motion by means of a gear mesh. (They are in theory a gear with an infinite pitch diameter). In theory, the torque and angular velocity of the pinion gear are related to the Force and the velocity of the rack by the radius of the pinion gear, as is shown below:

Perhaps the most well-known application of a rack is the rack and pinion steering system used on many cars in the past.

Limitations: Limited usefulness. Difficult to find.

Advantages: The only gearing component that converts rotational motion to translational motion. Efficiently transmits power. Generally offers better precision than other conversion methods.