Rashtreeya Sikshana Samithi Trust

RV Institute of Technology and Management®

(Affiliated to VTU, Belagavi)

JP Nagar, Bengaluru - 560076

Department of Mechanical Engineering

Course Name: Elements of Mechanical Engineering

Course Code: 21ME15/25

I/II Semester
2021 Scheme

MODULE-4

Mechanical Power Transmission:

Gear Drives: Types - spur, helical, bevel, worm and rack and pinion, velocity ratio,

Gear Trains and their application: simple and compound Gear Trains, Simple numerical problems on Gear trains involving velocity ratios

Belt Drives: Components of belt drive and concept of velocity ratio; Types of belt drives, FlatBelt Drive, V-Belt Drive and Application of Belt Drives.

Simple numerical problems on Belt drives involving velocity ratios,

Concept of Chain, Rope drives and their applications

Fundamentals of Mechanical Linkages: Definitions of Machines and Mechanisms.

Applications of linear motion, oscillatory motion, rotary motion, ratchet and latches, clamping, reverse motion, pause and hesitation, loading and unloading Mechanisms.

Introduction to Robotics:

Robot anatomy, Joints & links, common Robot configurations. Applications of Robotics in Material Handling, Processing, Assembly, and Inspection.

Contents

4.1 BELT DRIVES

• Motion (usually rotation) & power from a driving system to a driven system is done with the help of round rods called ***shafts.***

• The transmission system may be classified depending on the distance between the shafts, speeds & power.

• Usually, power is transmitted through;

1. **Belt drives (Flat/V-belt)**
2. **Rope drives**
3. **Chain drives**
4. **Gear drives**

Belt Drives

Belt drives are called flexible machine elements. Flexible machine elements are used for a large number of industrial applications, some of them are as follows: Fig. 4.1 shows the belt drives.

1. Used in conveying systems: Transportation of coal, mineral ores, etc. over a long distance.

2. Used for transmission of power. Mainly used for running of various industrial appliances using prime movers like electric motors, I.C. Engine, etc.

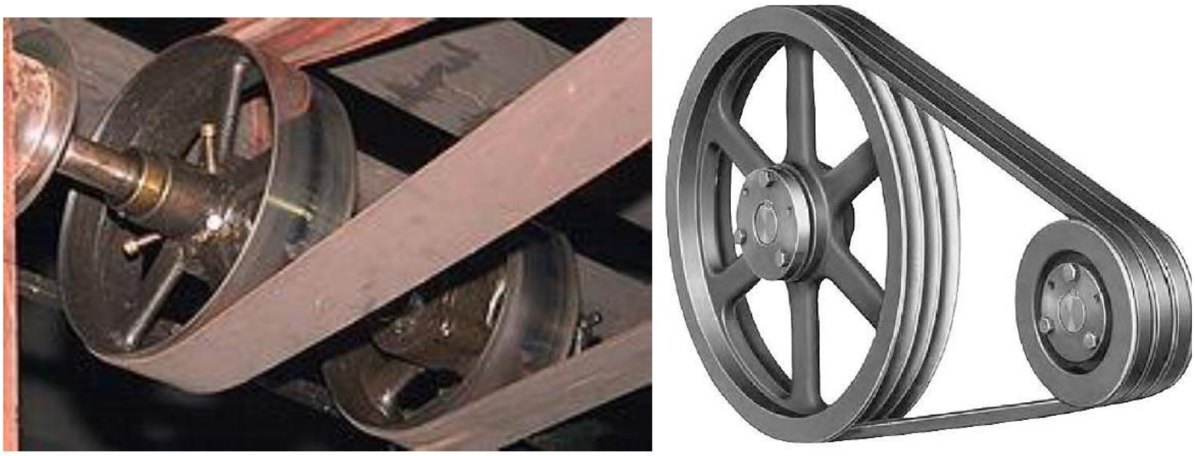

Fig. 4.1 Belt drives

The lower side of the belt will have more tension & is called the **Tight side.** The upper side of the belt will have less tension & is called the **Slack side. Belt Materials:** Leather, rubber, canvas, balata (rubber with cotton). Fig. 4.2 shows line diagram of belt drives.

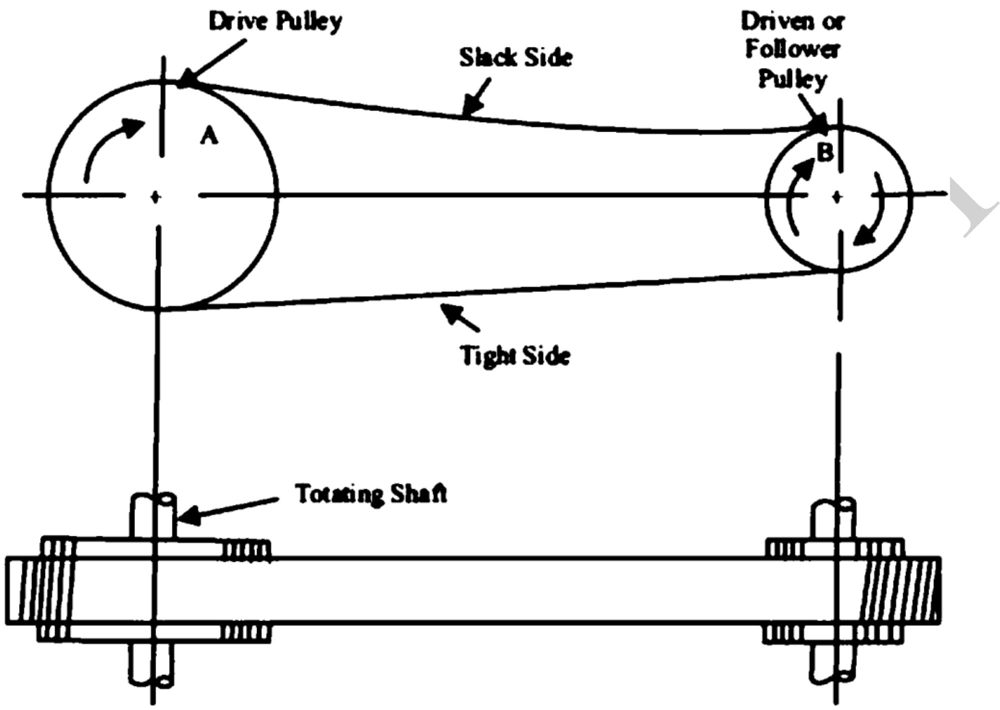

Fig. 4.2 Line diagram of belt drives

• Two types of belt drives, an open belt drive, and a crossed belt drive are shown in Fig. 4.3 Open and crossed belt drive.

• In both the drives, a belt is wrapped around the pulleys.

• Let us consider the larger pulley to be the driving pulley. This pulley will transmit motion to the belt and the motion of the belt, in turn, will give rotation to the smaller driven pulley.

• In an open belt drive system the rotation of both the pulleys is in the same direction, whereas, for the crossed belt drive system, the opposite direction of rotation is observed.

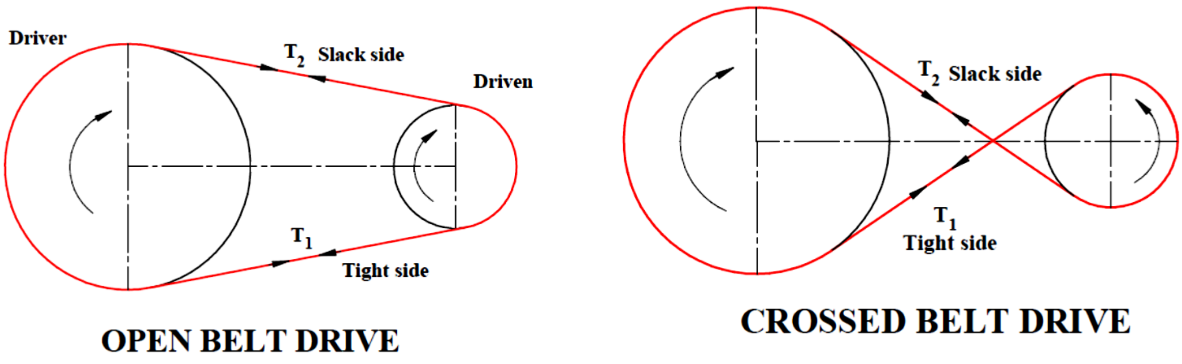

Fig. 4.3 Open and crossed belt drive

Slip in belt drives *Slip* in belt drives is the relative motion between the belt & pulley due to lack of frictional grip between them. This results in the forward motion of the driving pulley without carrying the belt with it and the forward motion of the belt without carrying the driven pulley with it. Slip is expressed as a percentage and it results in a reduction in velocity ratio transmitted by the belt.

Velocity ratio $\frac{n_2}{n_1} = \frac{d_1}{d_2}\left(1 - \frac{S}{100}\right)$ where S=Total % slip on driving & driven pulleys

Creep in belt drives *Creep in* belt drives is the relative motion between the belt & pulley due to elongation and contraction of the belt as it moves from tight side to slack side. Creep occurs when the material of the belt is ***not perfectly elastic*** resulting in slightly more elongation than the contraction of the belt. Creep also results in a reduction in velocity ratio and power transmitted by the belt.

Initial Tension in Belts

• The tension provided in the belt while mounting it on the pulleys when stationary is known as '*Initial Tension'* represented by *To*.

• When the pulleys start rotating, the tension on the tight side increases to T1 & that on the slack side decreases to T2 due to expansion & contraction of the belt.

$$i.e.\text{ if } \alpha = \text{coefficient of expansion or contraction, } \alpha(T_1 - T_0) = \alpha(T_0 - T_2)$$

$$\Rightarrow (T_1 + T_2) = 2T_0 \quad \therefore T_0 = \left(\frac{T_1 + T_2}{2}\right)$$

Advantages of flat belt drives

1. Easy, flexible equipment design, as tolerances are not important.
2. Isolation from shock and vibration between driver and driven system.
3. Belt drives require no lubrication.
4. Maintenance is relatively convenient
5. Very quiet compared to chain drives, and direct spur gear drives.

Disadvantages of flat belt drives

1. Not suitable for short center distances.
2. Exact velocity ratio cannot be maintained.
3. Large power cannot be transmitted effectively.

4.2 V-belt drives

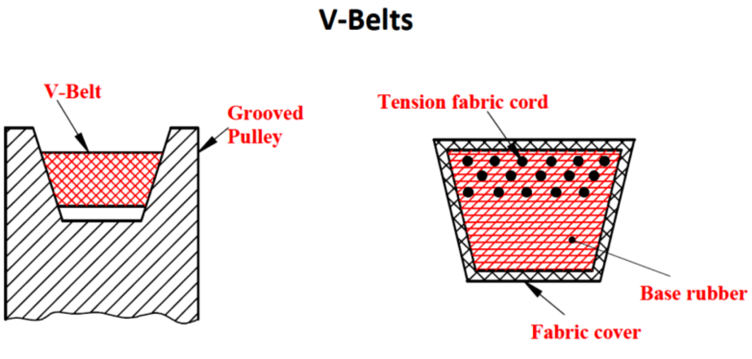

Fig. 4.4 V- belt drives

• V-belts are used in high power transmission due to wedging action between the trapezoidal belt & the grooves on the pulley. Fig. 4.4 shows the V-belt drives.

• They are molded as endless loops from rubber reinforced with fibrous material.

• They run V-grooves on the pulleys and multiple belts can be used for high power transmission up to 150 KW. Fig. 4.5 displays the graphical representation of V-belt drives.

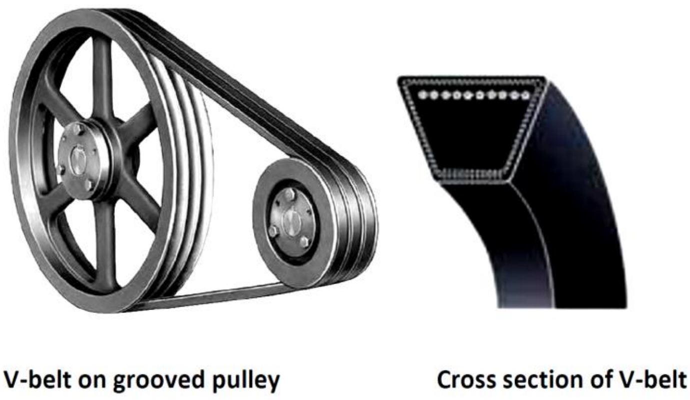

Fig. 4.4 graphical representation of V-belt drives

LENGTH OF BELT FOR OPEN BELT DRIVE

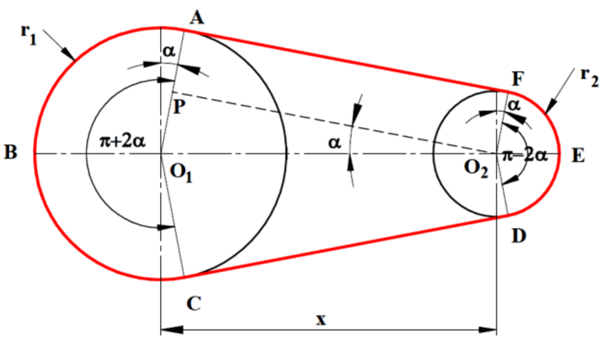

Fig. 4.5 length of belt for open belt drives

Consider an open belt drive as shown in fig.

Let r_1 be the radius of the larger pulley & r_2 be the radius of the smaller pulley

x=Center distance between the pulleys. From the fig, Length of open belt

$$L_{open} = Arc\ ABC + 2(AF) + Arc\ DEF = r_1(\pi + 2\alpha) + 2(AF) + r_2(\pi - 2\alpha)$$

$$From\ triangle\ O_1O_2P,\ O_2P = \left\{(O_1O_2)^2 - (O_1P)^2\right\}^{\frac{1}{2}}$$

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$$O_2P = \left\{(x)^2 - (r_1 - r_2)^2\right\}^{\frac{1}{2}} = x\left\{1 - \left(\frac{r_1 - r_2}{x}\right)^2\right\}^{\frac{1}{2}}$$

Expanding using binomial theorem & negelcting higher order terms,

$$O_2P = AF = x\left\{1 - \frac{1}{2}\left(\frac{r_1 - r_2}{x}\right)^2\right\} = x - \frac{1}{2x}(r_1 - r_2)^2\ From\ fig, \sin\alpha \approx \alpha = \left(\frac{r_1 - r_2}{x}\right)$$

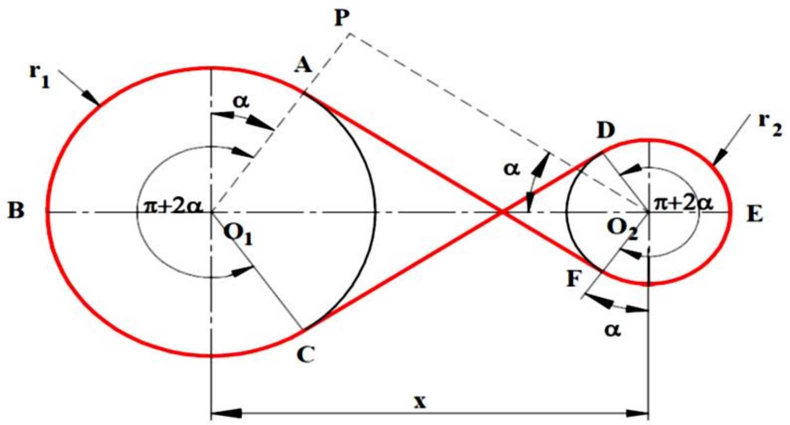
$$\Rightarrow L_{open} = r_1(\pi + 2\alpha) + 2\left(x - \frac{1}{2x}(r_1 - r_2)^2\right) + r_2(\pi - 2\alpha)$$

$$L_{open} = \pi(r_1 + r_2) + 2\alpha(r_1 - r_2) + 2x - \frac{(r_1 - r_2)^2}{x}$$

$$L_{open} = \pi(r_1 + r_2) + 2(r_1 - r_2)\left(\frac{r_1 - r_2}{x}\right) + 2x - \frac{(r_1 - r_2)^2}{x}$$

$$\therefore L_{open} = \pi(r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x}$$

LENGTH OF BELT FOR CROSSED BELT DRIVE



Consider an crossed belt drive as shown in fig.

Let r_1 be the radius of the larger pulley & r_2 be the radius of the smaller pulley

x=Center distance between the pulleys. From the fig, Length of crossed belt

$$L_{crossed} = Arc\ ABC + 2(AF) + Arc\ DEF = r_1(\pi + 2\alpha) + 2(AF) + r_2(\pi + 2\alpha)$$

$$From\ triangle\ O_1O_2P,\ O_2P = \left\{(O_1O_2)^2 - (O_1P)^2\right\}^{\frac{1}{2}}$$

$$O_2P = \left\{(x)^2 - (r_1 + r_2)^2\right\}^{\frac{1}{2}} = x\left\{1 - \left(\frac{r_1 + r_2}{x}\right)^2\right\}^{\frac{1}{2}}$$

Expanding using binomial theorem & negelcting higher order terms,

$$O_2P = AF = x\left\{1 - \frac{1}{2}\left(\frac{r_1 + r_2}{x}\right)^2\right\} = x - \frac{1}{2x}(r_1 + r_2)^2$$

$$From\ fig,\ \sin\alpha \approx \alpha = \left(\frac{r_1 + r_2}{x}\right)$$

$$\Rightarrow L_{crossed} = r_1(\pi + 2\alpha) + 2\left(x - \frac{1}{2x}(r_1 + r_2)^2\right) + r_2(\pi + 2\alpha)$$

$$L_{crossed} = \pi(r_1 + r_2) + 2\alpha(r_1 + r_2) + 2x - \frac{(r_1 + r_2)^2}{x}$$

$$L_{crossed} = \pi(r_1 + r_2) + 2(r_1 + r_2)\left(\frac{r_1 + r_2}{x}\right) + 2x - \frac{(r_1 + r_2)^2}{x}$$

$$\therefore L_{crossed} = \pi(r_1 + r_2) + 2x + \frac{(r_1 + r_2)^2}{x}$$

Ratio of Tensions in a flat belt drive

$$\log_e\left(\frac{T_1}{T_2}\right)=\mu\theta \quad \text{OR} \quad \left(\frac{T_1}{T_2}\right)=e^{\mu\theta}$$

where T_1 and T_2 are the tensions on tight & slack sides of the belt

$\mu=$ Coefficeint of friction between the belt & pulley.

Note :

(1) *The angle θ must be in radians*

(2) *For open belt drive,* $\theta=\theta_s=\pi-2\sin^{-1}\left(\frac{r_1-r_2}{x}\right)$

(3) *For crossed belt drive,* $\theta=\pi+2\sin^{-1}\left(\frac{r_1+r_2}{x}\right)$

Power Transmitted by Belt Drive :

The net driving tension on the pulley $=(T_1-T_2)$

$\therefore$ Torque on the pulley $=(T_1-T_2)\times r$ where r=radius of the pulley.

Power transmitted by the belt drive $P=\dfrac{2\pi n(T_1-T_2)\times r}{60000}KW$

$\Rightarrow P=\dfrac{(T_1-T_2)\times v}{1000}KW$ where v=velocity of belt= $\dfrac{2\pi rn}{60}=\dfrac{\pi dn}{60}$ m/sec

Velocity ratio Transmitted by Belt Drive :

It is the ratio of speed of the driven pulley to the speed of the driving pulley.

If the driving pulley is suffixed as 1 & driven pulley as 2,

Velocity ratio $=\dfrac{n_2}{n_1}=\dfrac{d_1}{d_2}$ (neglecting slip & belt thickness)

Velocity ratio $=\dfrac{n_2}{n_1}=\left(\dfrac{d_1+t}{d_2+t}\right)$ (neglecting slip &considering belt thickness)

Velocity ratio $\dfrac{n_2}{n_1}=\dfrac{d_1}{d_2}\left(1-\dfrac{S}{100}\right)$ where S=Total % slip on driving & driven pulleys

4.3 GEARS

Gears are toothed wheels used to transmit power from one shaft to another when a constant velocity ratio is desired and the distance between shafts is relatively small.

Gears are classified as follows:

(i) According to the relative position of shaft axes:

Parallel axes: Spur gear, helical gear

Intersecting axes: Bevel gears Nonparallel,

Non intersecting: Worm gears

(ii) According to peripheral velocity (v) of gears:

V< 3 m/sec: Low velocity gears

3<V< 15 m/sec: Medium velocity gears

V>15 m/sec: High-velocity gears

(iii) According to the type of gearing:

Gears mesh externally & hence rotate in opposite directions: External gearing Gears mesh internally & hence rotate in same directions: Internal gearing

(iv) According to the position of the teeth on the gear surface:

Straight teeth: Spur gears

Inclined teeth: Helical gears

Skewed (curved) teeth: Spiral gear

i) Spur Gears

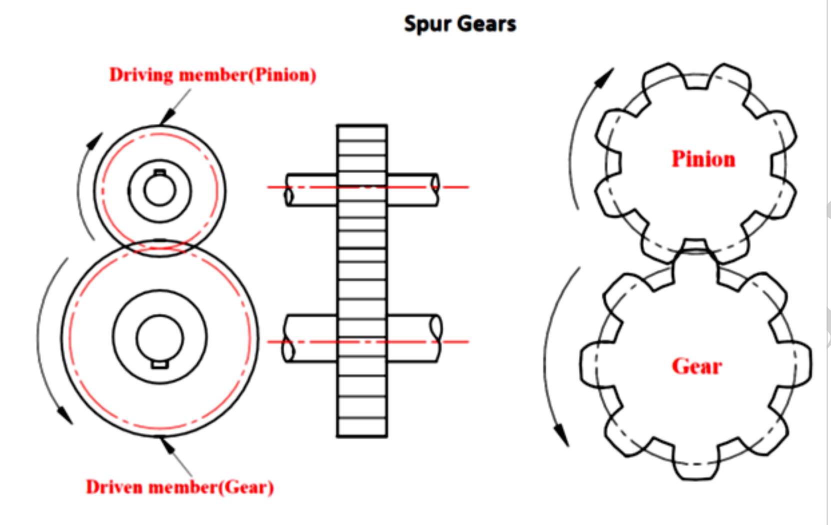


Fig. 4.6 Spur gears

- This is the simplest form of gears for transmitting power between two parallel shafts. The teeth are straight & parallel to the axis. Fig. 4.6 shows the spur gears.
- Spur gears impose only radial loads on bearings.
- Because of the instantaneous line contact during meshing, the drive will be noisy.
- Spur gear drive is widely used in machine tools, automobile gearboxes, etc.

ii) Helical Gears

- Helical gears are used to transmit power between parallel shafts. Fig. 4.7 shows the Helical gears.
- In these gears, the teeth are inclined to the axis of the shaft at an angle known as ***Helix angle (15°to 45°)***.
- Helical gears are preferred to spur gears as their operation is quiet due to the progressive engagement of teeth.
- The disadvantage of helical gears is it produces an axial thrust. Hence double-helical gears (herringbone gears) are used.

elevators, conveyors

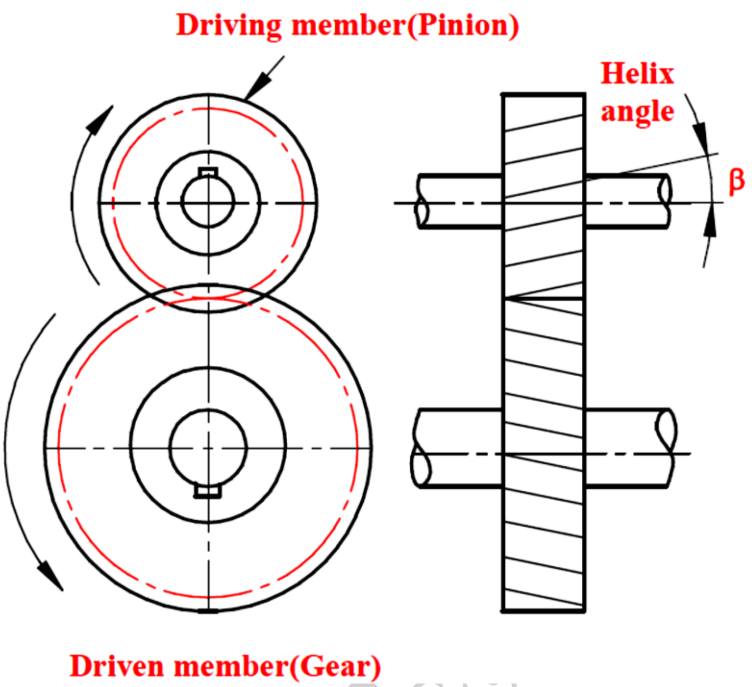


Fig. 4.7 Helical gears

iii) Bevel gears

• Bevel gears are most commonly used for transmitting power between intersecting shafts. Fig. 4.8 bevel gears.

• The pitch surfaces of bevel gears are rolling cones. The tooth section becomes gradually smaller as the apex of the cone is approached.

• They impose thrust as well as radial loads on the bearings supporting the shaft.

• When two **equal** bevel gears have their axes **at right angles**, they are called **Miter bevel** gears.

automobiles, printing presses

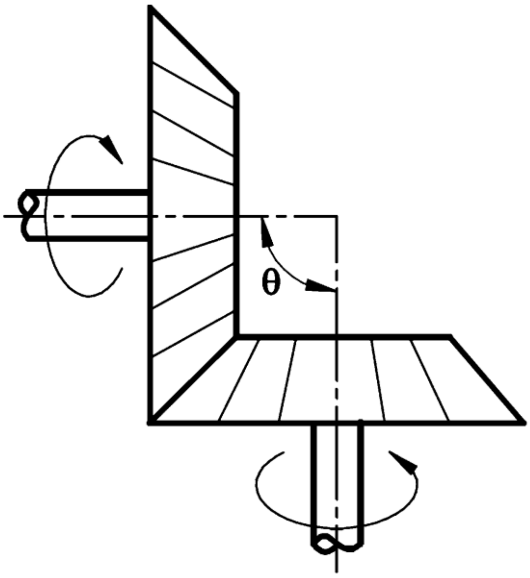


Fig. 4.8 Bevel gears

iv) Worm gears

• Worm gears are used to transmit power between two non-parallel, non-intersecting shafts. Fig. 4.9 worm gears.

• A worm drive consists of a **worm shaft** with helical grooves which meshes with a gear called

v) worm wheel.

• Worm gear drives are used for high-speed reduction as high as 60:1.

• The worm gear drive may be made self-**locking,** i.e. does not allow the reversal in the direction of the drive.

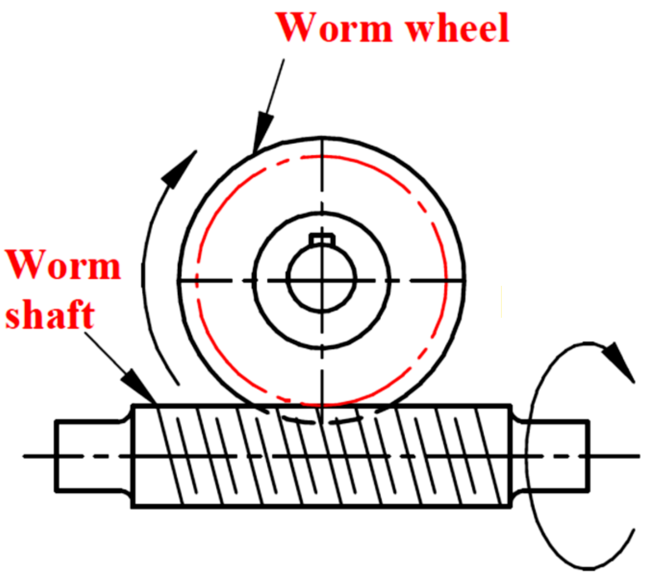


Fig. 4.9 Worm gears

vi) Rack & Pinion

• When a rotary motion is to be converted into a linear motion, rack & pinion arrangement is used. Fig. 4.10 shows the Rack & Pinion.

• Theoretically, the rack is a straight gear of infinite diameter.

• Elliptical gears are used when there is a need for varying speeds of the driven gear in each revolution.

• In each revolution of the driven shaft, there are four different speeds, two maximum & two minimum.

• They are used in printing machines, packaging machines, quick return motion mechanisms, etc. Gear tooth profiles.

• Gears are mainly used for transmission of motion & power and must be of accurate profile to obtain exact velocity ratio.

• Two commonly used profiles of gear teeth are the Involute profile & the Cycloidal profile.

• Involute is defined as the path described by a point on an inextensible cord which is unwound from a stationary cylinder.

• A cycloid is defined as the curve traced by a point on the rim of a circle which rolls without slipping on a fixed straight line.

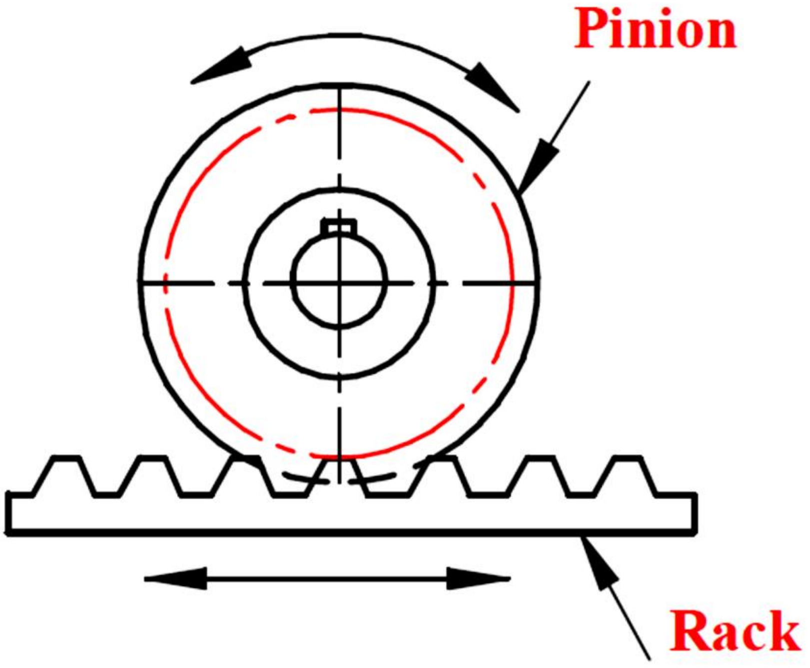


Fig. 4.10 Rack & Pinion

Advantages of Gear drives

1. They are positive drives and used to connect closely-spaced shafts.

2. High efficiency, compactness, reliability, longer life, less maintenance.

3. They can transmit heavier loads.

Disadvantages of Gear drives

1. Not suitable for large center distances.

2. High production cost.

3. Due to errors and inaccuracies in the manufacture, the drive may become noisy and produce vibrations at high speeds.

Velocity ratio in Gear Drives :

$$\frac{n_2}{n_1} = \frac{d_1}{d_2} = \frac{z_1}{z_2}, \text{ where } n_1 = \text{Speed of driving pulley}, n_2 = \text{Speed of driven pulley}$$

d_1 = Pitch circle diameter (PCD) of driver gear, d_2 = PCD of of driven gear

z_1 = No of teeth on driver gear, z_2 = No of teeth on driven gear

4.4 Robotics and Automation

4.4.1 Introduction

Robots are devices that are programmed to move parts, or to do work with a tool. Robotics is a multidisciplinary engineering field dedicated to the development of autonomous devices, including manipulators and mobile vehicles.

An industrial robot is a general purpose, programmable machine possessing certain anthropomorphic characteristics. The most obvious anthropomorphic characteristic of an industrial robot is its mechanical arm, which is used to perform various industrial tasks. Other human like characteristics are the robot's capabilities to respond to sensory inputs, communicate with other machines, and make decisions. These capabilities permit robots to perform a variety of useful tasks. Some of the qualities that make industrial robots commercially and technologically important are listed

- Hazardous work environments
- Repetitive work cycle
- Consistency and accuracy
- Difficult handling task for humans
- Multi shift operations
- Reprogrammable, flexible

- Interfaced to other computer systems

Classification based on robots configuration:

- Polar Coordinate
- Cylindrical Coordinate
- Cartesian Coordinate

Polar Coordinate: This configuration Consists of a sliding arm (L joint) actuated relative to the body, which can rotate about both a vertical axis (T joint) and horizontal axis (R joint)

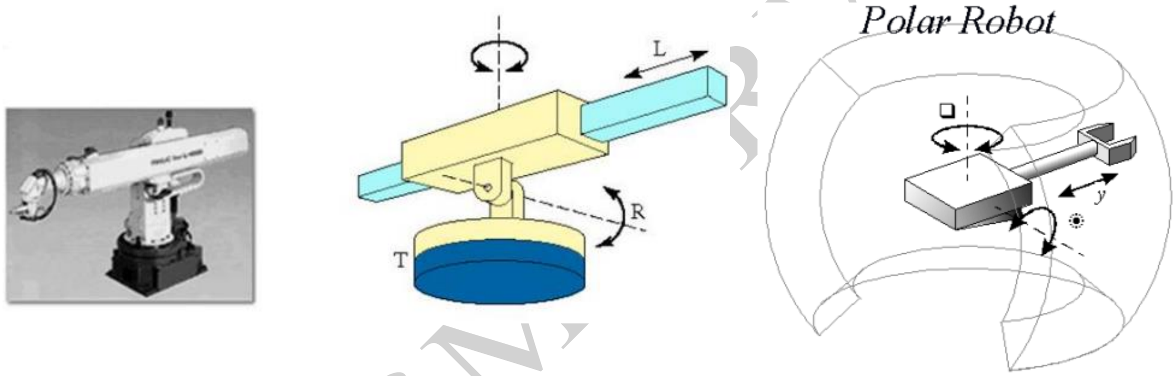


Fig. 4.11 Polar Coordinate

Cylindrical Coordinate: This configuration Consists of a vertical column, relative to which an arm assembly is moved up or down. The arm can be moved in or out relative to the axis of the column

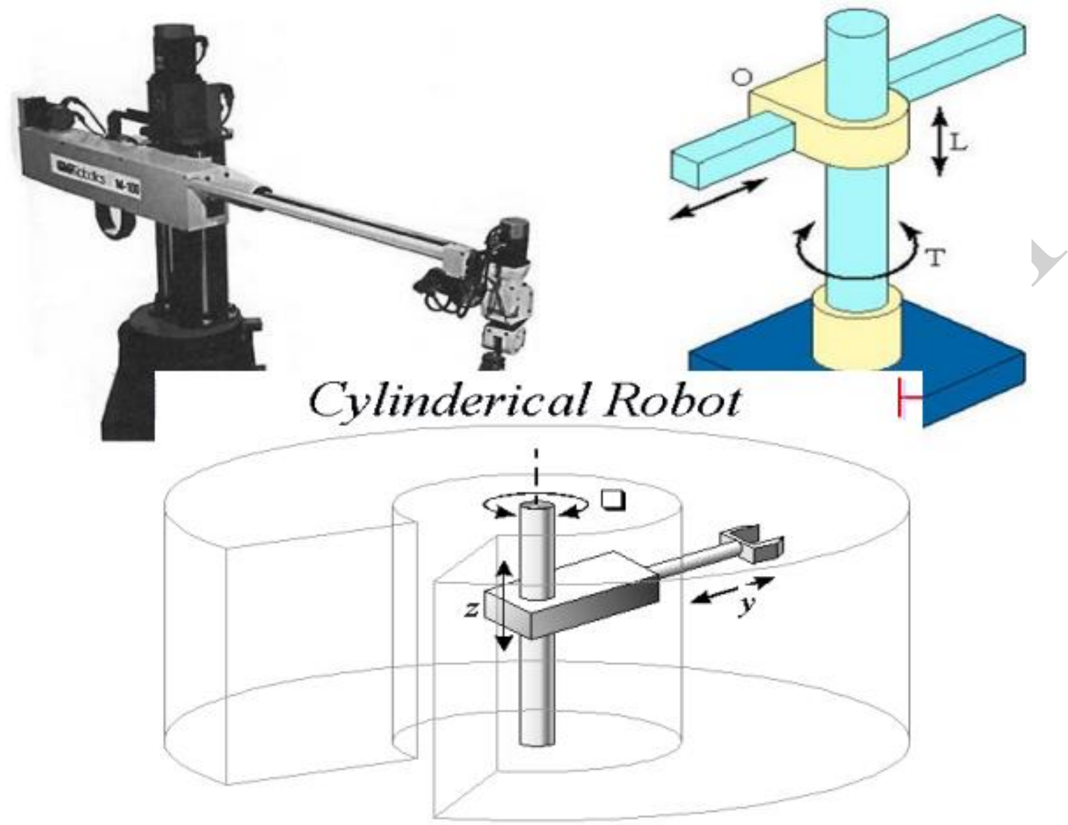


Fig. 4.12 Cylindrical Robot

Cartesian coordinate: Other names for this configuration include rectilinear robot and x-y-z robot. It is composed of three sliding joints, two of which are orthogonal.

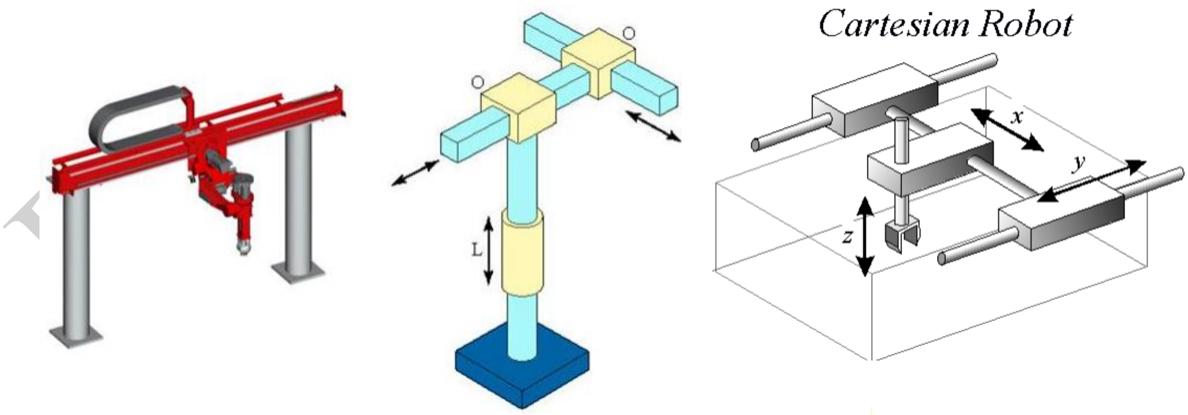


Fig. 4.12 Cartesian Robot

Jointed-arm configuration: is combination of cylindrical and articulated configurations. This is similar in appearance to the human arm, as shown in fig. the arm consists of several straight members connected by joints which are analogous to the human shoulder, elbow, and wrist. The robot arm is mounted to a base which can be rotated to provide the robot with the capacity to work within a quasi-spherical space.

4.5 Automation:

Automated manufacturing is a manufacturing method that relies on the use of computerized control systems to run equipment in a facility where products are produced. Human operators are not needed on the assembly line or manufacturing floor because the system is able to handle both the mechanical work and the scheduling of manufacturing tasks. The development of fully automated manufacturing systems dates to the later half of the 20th century, and this manufacturing technique is used in facilities of varying scale all over the world.

Automation of production systems can be classified into three basic types:

1. Fixed automation (Hard Automation)

2. Programmable automation (Soft Automation)

3. Flexible automation.

1. Fixed automation (Hard automation): Fixed automation refers to the use of special purpose equipment to automate a fixed sequence of processing or assembly operations. Each of the operation in the sequence is usually simple, involving perhaps a plain linear or rotational motion or an uncomplicated combination of two. It is relatively difficult to accomodate changes in the product design. This is called hard automation.

Advantages:

1. Low unit cost

2. Automated material handling

3. High production rate.

Disadvantages:

1. High initial Investment

2. Relatively inflexible in accommodating product changes,

2. **Programmable automation:** In programmable automation, the production equipment is designed with the capability to change the sequence of operations to accomodate different product configurations. The operation sequence is controlled by a program, which is a set of instructions coded. So that they can be read and interpreted by the system. New programs can be prepared and entered into the equipment to produce new products.

Advantages:

1. Flexible to deal with design variations.

2. Suitable for batch production.

Disadvantages:

1. High investment in general purpose equipment

2. Lower production rate than fixed automation.

Example: Numerical controlled machine tools, industrial robots and programmable logic controller

3. **Fixed Automation:** (Soft automation): Flexible automation is an extension of programmable automation. A flexible automation system is capable of producing a variety of parts with virtually no time lost for changeovers from one part style to the next. There is no lost production time while reprogramming the system and altering the physical set up.

Advantages:

1. Continuous production of variable mixtures of product.
2. Flexible to deal with product design variation.

Disadvantages:

1. Medium production rate
2. High investment.
3. High ‘unit cost relative to fixed automation.

Basic Robot Motions

Whatever the configuration, the purpose of the robot is to perform a useful task. To accomplish the task, an end effector, or hand, is attached to the end of the robots arm. It is the end effector which adapts the general purpose robot to a particular task. To do the task, the robot arm must be capable of moving the end effectors through a sequence of motions and positions. There are six basic motions or degrees of freedom, which provide the robot with the capability to move the end effectors through the required sequences of motions. These six degree of freedom are intended to emulate the versatility of movement possessed by the human arm. Not all robots are equipped with the ability to move in all sex degrees. The six basic motions consist of three arm and body motions and three wrist motions.

Arm and body motions

1. Vertical traverse: Up and down motion of the arm, caused by pivoting the entire arm about a horizontal axis or moving the arm along a vertical slide

2. Radial traverse: extension and retraction of the arm (in and out movement) 3. Rotational traverse: rotation about the vertical axis (right or left swivel of the robot arm)

Wrist Motion

• Wrist swivel: Rotation of the wrist

• Wrist bend: Up or down movement of the wrist, this also involves rotation movement.

• Wrist yaw: Right or left swivel of the wrist.

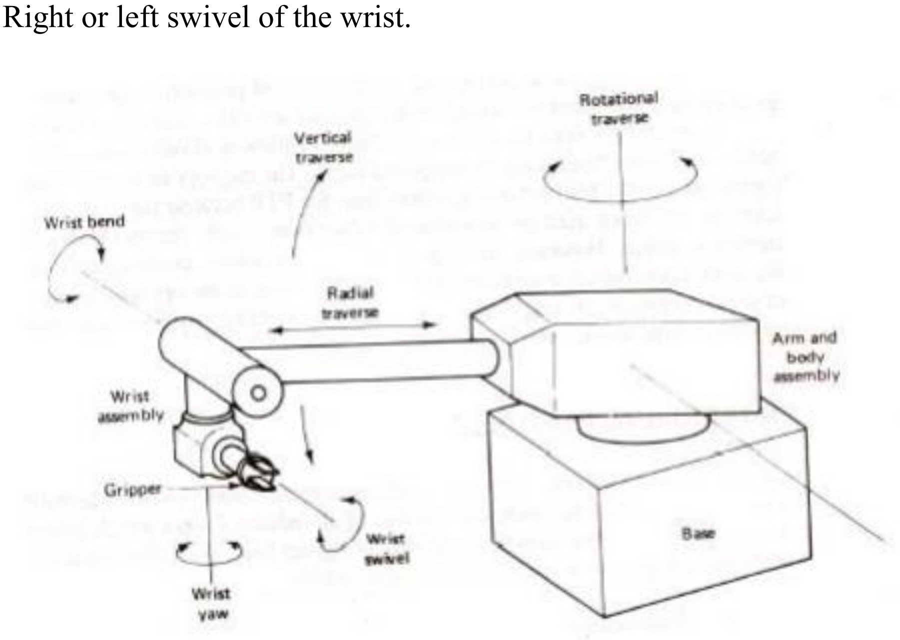


Fig. 4.13 Arm and body motion

4.6 Concept of Chain, and Rope drives

Introduction

The belts or ropes are used to transmit power from one shaft to another by means of pulleys which rotate at the same speed or at different speeds. The amount of power transmitted depends upon the following factors :

1. The velocity of the belt.
2. The tension under which the belt is placed on the pulleys.
3. The arc of contact between the belt and the smaller pulley.
4. The conditions under which the belt is used.

It may be noted that

(*a*) The shafts should be properly in line to insure uniform tension across the belt section.

(*b*) The pulleys should not be too close together, in order that the arc of contact on the smaller pulley may be as large as possible.

(*c*) The pulleys should not be so far apart as to cause the belt to weigh heavily on the shafts, thus increasing the friction load on the bearings.

(*d*) A long belt tends to swing from side to side, causing the belt to run out of the pulleys, which in turn develops crooked spots in the belt.

(*e*) The tight side of the belt should be at the bottom, so that whatever sag is present on the loose side will increase the arc of contact at the pulleys.

(*f*) In order to obtain good results with flat belts, the maximum distance between the shafts should not exceed 10 metres and the minimum should not be less than 3.5 times the diameter of the larger pulley.

Chain Drives

We have seen in belt and rope drives that slipping may occur. In order to avoid slipping, steel chains are used. The chains are made up of rigid links which are hinged together in order to provide the necessary flexibility for warping around the driving and driven wheels. The wheels have projecting teeth and fit into the corresponding recesses, in the links of the chain as shown in Fig. 11.23. The wheels and the chain are thus constrained to move together without slipping and ensures perfect velocity ratio. The toothed wheels are known as ***sprocket wheels*** or simply ***sprockets.*** These wheels resemble to spur gears.

The chains are mostly used to transmit motion and power from one shaft to another, when the distance between the centres of the shafts is short such as in bicycles, motor cycles, agricultural machinery, road rollers, etc.

Advantages and Disadvantages of Chain Drive Over Belt or Rope Drive

Following are the advantages and disadvantages of chain drive over belt or rope drive :

Advantages

1. As no slip takes place during chain drive, hence perfect velocity ratio is obtained.
2. Since the chains are made of metal, therefore they occupy less space in width than a belt or rope drive.
3. The chain drives may be used when the distance between the shafts is less.
4. The chain drive gives a high transmission efficiency (upto 98 per cent).
5. The chain drive gives less load on the shafts.
6. The chain drive has the ability of transmitting motion to several shafts by one chain only.

Disadvantages

1. The production cost of chains is relatively high.
2. The chain drive needs accurate mounting and careful maintenance.
3. The chain drive has velocity fluctuations especially when unduly stretched.

Rope Drive

The rope drives are widely used where a large amount of power is to be transmitted, from one pulley to another, over a considerable distance. It may be noted that the use of flat belts is limited for the transmission of moderate power from one pulley to another when the two pulleys are not more than 8 metres apart. If large amounts of power are to be transmitted by the flat belt, then it would result in excessive belt cross-section. It may be noted that frictional grip in case of rope drives is more than that in V-drive. One of the main advantage of rope drives is that a number of separate drives may be taken from the one driving pulley. For example, in many spinning mills, the line shaft on each floor is driven by ropes passing directly from the main engine pulley on the ground floor.

The rope drives use the following two types of ropes :

1. Fibre ropes, and 2. Wire ropes.

The fibre ropes operate successfully when the pulleys are about 60 metres apart, while the wire ropes are used when the pulleys are upto 150 metres apart.

4.7 Fundamentals of Mechanical Linkages:

A **mechanism** is a group of link connected to each other by joints, to form a kinematic chain with one link fixed, to transmit force and motion. It is design to do a specific motion.

A **machine** is assemblage of link that transmits/ and/or transforms forces, motion and energy in a predetermined manner, to do work. The term machine is generally applied to a complete product.

Motion:

The free movement of a body with respect to time is known as motion. For example- the fan, the dust falling from the carpet, the water that flows from the tap, a ball rolling around, a moving car etc. There are mainly 4 types of motion, i.e.

1. **Rotary Motion**: A special type of motion in which the object is on rotation around a fixed axis like, a figure skater rotating on an ice rink. Example; Rotation of earth, Wheels of a moving vehicle, blades of a fan, blades of a windmill, Helicopter rotary blades etc.
2. **Oscillatory Motion**: A repeating motion in which an object continuously repeats in the same motion again and again like a swing. The motion of the spring is regularly repeated in equal periods of time at the two sides of its rest position. The velocity of the oscillatory body (spring) is very high when it passes its rest position. The velocity of the oscillating body (spring) decreases when it goes far from its rest position until it reaches zero at the maximum displacement. Some of the best examples of Oscillatory Motion are: A swinging swing, The motion of a pendulum, A boat tossing up and down a river, The tuning fork.
3. **Linear Motion**: A one-dimensional motion on a straight line, like an athlete running on a straight track. Important examples of linear motion are: An athlete running on a straight track of a park, a bullet shot from a pistol always moves in a straight line, etc.
4. **Reciprocating Motions**: A repetitive and continuous up and down or back and forth motion like a needle in a sewing machine.

<u>Reverse Motion Linkage:</u>

- Reverse Motion Linkages are used to change the direction of motion.
- Single lever with a pivot at its centre reverses an input motion without affecting the input force.

- Another way of describing this linkage is the direction of movement in one rod is reversed in the other rod.

Stop and Dwell Mechanism:

The most obvious example of this type of mechanism is that used to control the valves on and internal combustion engine. The valve has to open, remain open for a fixed part of the cycle, close, and remain close for a fixed part of the cycle. The solution for this type of mechanism is to use of cam controlling the motion of the valve stem. Indexing mechanisms as described in the indexing section can often provide stop and dwell motions.

Ratchet Mechanism:

There are many forms of ratchets often requiring some ingenuity in their derivation. Ratchets are used widely in lifting equipment to lock the motion and prevent reverse rotation when the input force is removed. Ratchets can also be used to drive a motion in one direction and allow free-wheeling in the reverse direction. The best example of this application is the bicycle chain drive.

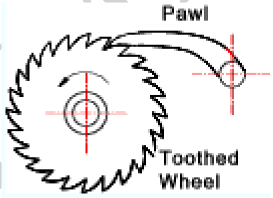


Fig. 4.14 Pawl Ratchet