MODULE 4

Content:

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, Flat Belt 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.

Mechanical Power Transmission:

Transmission system: The rotational motion can be transmitted from one mechanical element to the other with the help of certain systems known as transmission system (Drive).

Methods of power transmission:

i. Belt drive
ii. Chain drive
iii. Gear drive
iv. Rope drive

Gear drives: The transmission of power or motion from one shaft to another by means of gears is called gear drive. The gear mounted on the shaft to which power source is connected is called driver gear. The gear which is driven by the driver gear called driven gear.

- Possible to drive parallel, intersecting, or neither parallel nor intersecting shafts using gears.
- Due to the continuous engagement between the teeth of driver & driven gears, power is transmitted and possibility of no slip. (Positive drive).
- Preferred for shafts with shorter center distance.

Functions:

1. To increase or decrease speed of motion
2. To move rotational motion to a different axis
3. To reverse the direction of rotation
4. To keep the rotation of two axis synchronized

Types of Gear:

Spur gear:

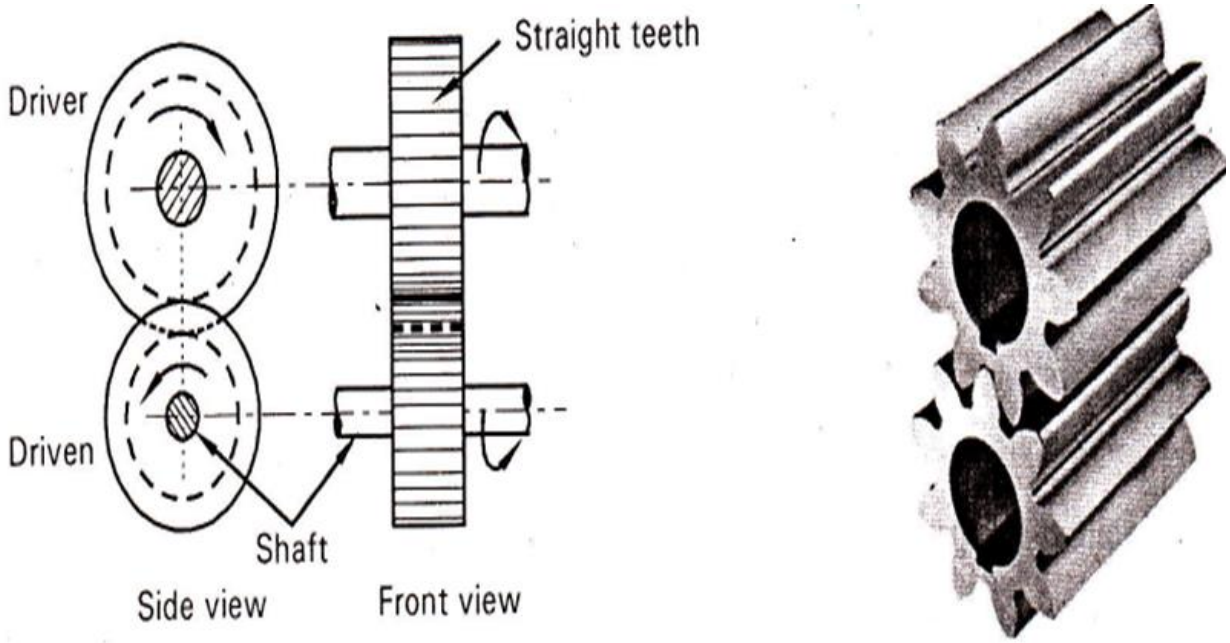

Figure 1. Spur Gear

Spur gears or straight-cut gears are the simplest type of gear. They consist of a cylinder or disk with teeth projecting radially. Spur gears are used in industrial equipment to transfer mechanical motion as well as control speed, power, and torque. Spur gears are used when the axes of the driving and driven shafts are parallel and co-planar. The teeth of the gear wheels are parallel to the axes. The contact between the mating gears will be along a line. Spur gear can transmit higher power. But noise will be very high.

Applications:

- Machine tools, cranes
- Automobile gear boxes
- All general cases of power transmission, where gear drives are preferred.

Helical gear:

- Teeth are cut in the form of the helix around the gear
- Used for transmitting power between two parallel shafts and also between nonparallel, non-intersecting shafts.
- Contact between the mating gears will be along a curvilinear path.
- Preferred to spur gears when smooth and quiet running at higher speeds are necessary.
- Generally used in milling machines, automobile power transmission.

Disadvantage:

- Produces end thrusts on the driving and driven shafts.

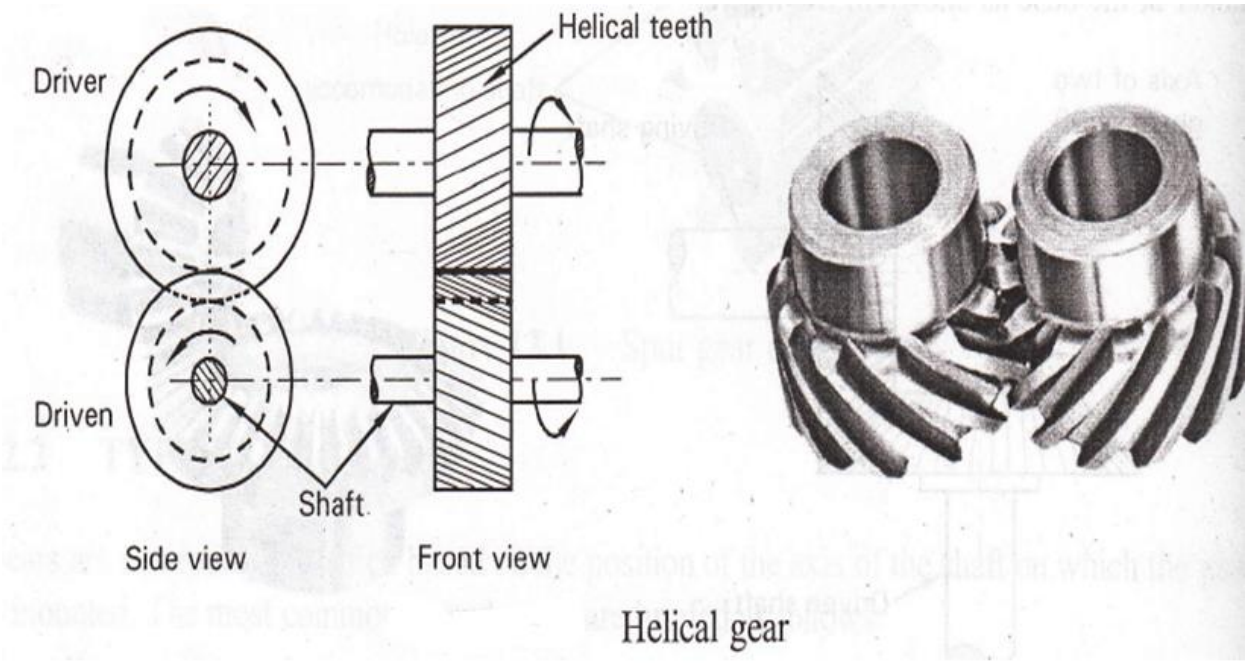

Figure 2. Helical Gear

Bevel gear:

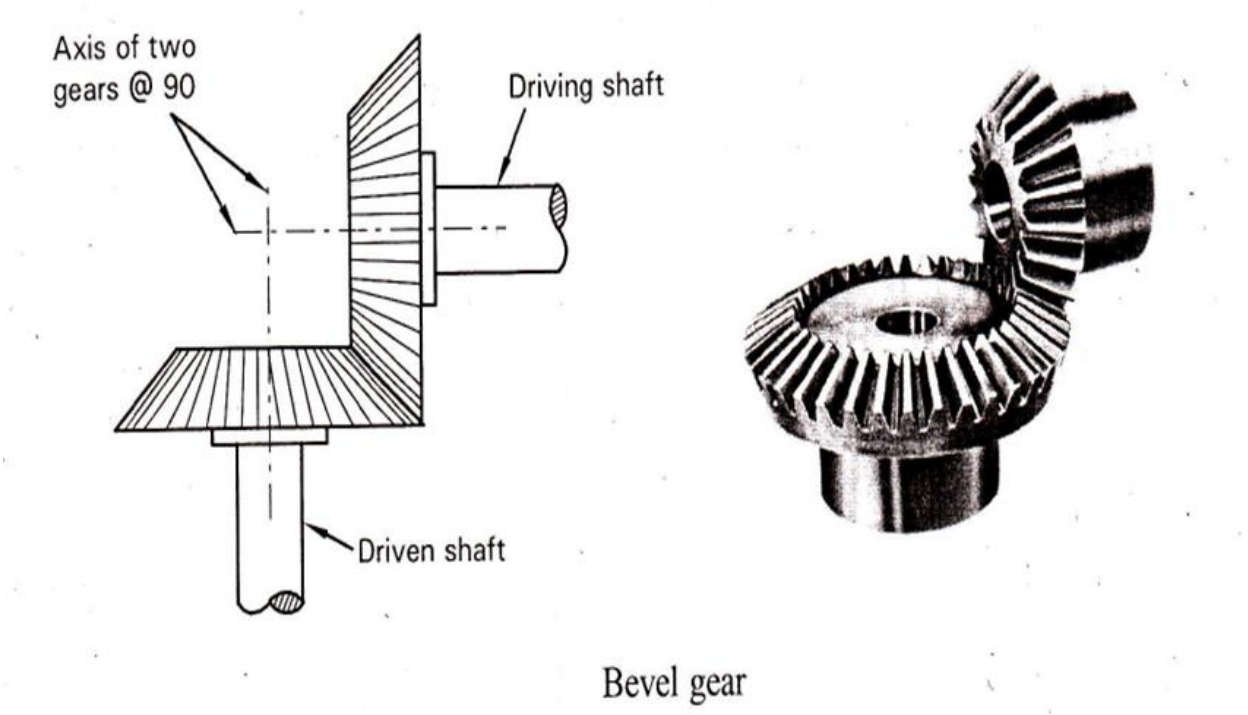

Figure 3. Bevel Gear

- Used when the axes of the two shafts are inclined to one another and intersect when produced.
- Teeth are cut on the conical surfaces.

- The most common examples of power transmission are those in which the axes of the two shafts are at right angles to each other.
- When two bevel gears have their axes at right angles and are of equal sizes, they are called Miter gears.

Worm gear:

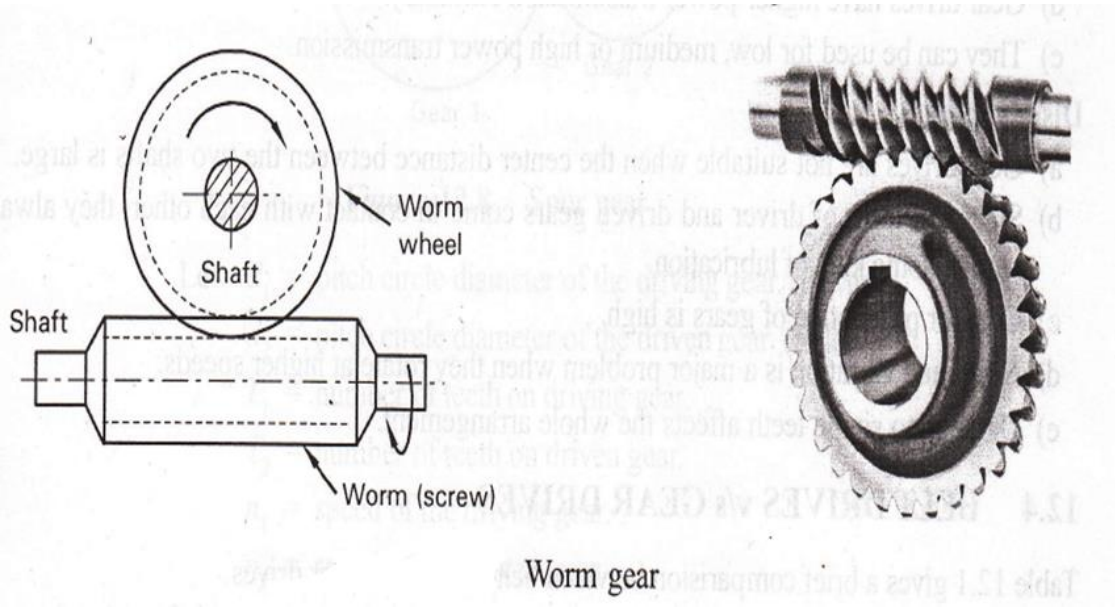

Figure 4. Worm Gear

- Has a screw pinion (worm) which turns along with a spur gear.
- Motion can be transmitted between shafts that are at right angles.

Rack and Pinion:

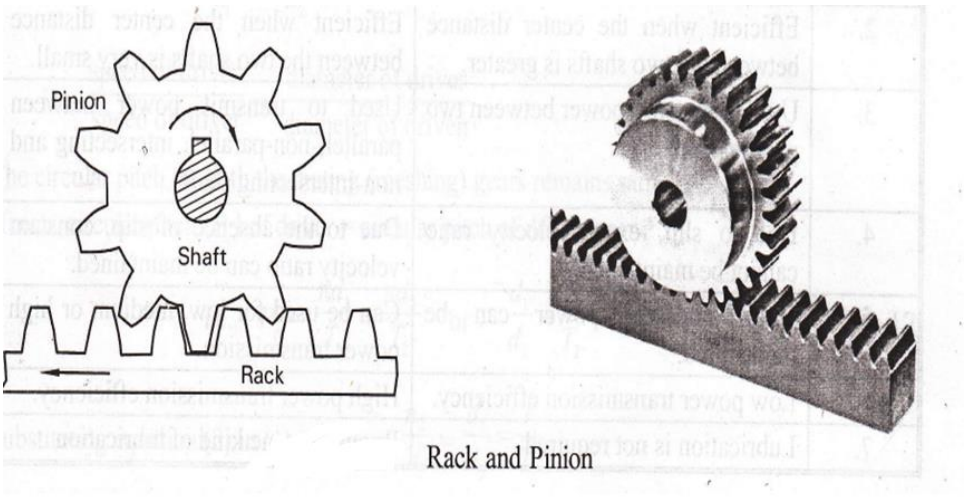

Figure 5. Rack and Pinion

- Used when a rotary motion is to be converted into a linear motion.
- Rack is a rectangular bar with a series of straight teeth cut on it.
- Theoretically rack is a spur gear of infinite diameter.

Applications

- Machine tools, such as, lathe, drilling, planing machines,
- Some steep rail tracks, where the teeth of the locomotive wheel mesh with a rack embedded in the ground, offering the locomotive improved traction.

Advantages of gear drives:

1. Gear drives can be used to transmit power or motion between parallel, non-parallel, intersecting, and non-intersecting shafts.
2. Gear drives preferred when centre distance between the two shafts is very small.
3. Power can be transmitted with a constant speed ratio.
4. Higher power transmission efficiency.
5. Can be used for low, medium, high-power transmission.

Disadvantages of gear drives:

1. Not suitable when centre distance is large.
2. Lubrication is required.
3. Cost of production of gears is high.
4. Noise and vibration are major problem when they rotate at higher speeds.
5. Damage to single-to-single teeth effects the whole arrangement.

Velocity ratio of gear drives:

Velocity ratio of gear drive is defined as the ratio between the speed of the driven gear and speed of the driving gear.

d = Diameter of the wheel

N =Speed of the wheel

ω = Angular speed

$$Velocity\ Ratio = \frac{\omega_2}{\omega_1} = \frac{N_2}{N_1} = \frac{d_1}{d_2}$$

Gear trains:

A gear train is a combination of two or more gears in assembly, through which motion and power are transmitted from one shaft to the other.

Gear trains are used to get the desired velocity ratio between the driver and driven shafts, and to get the desired direction of rotation for the driven shaft.

The different types of gear trains commonly used are

- Simple gear trains.
- Compound gear trains.
- Reverted gear trains, and
- Epicyclic gear trains.

Simple gear trains:

In a simple gear train, each gear wheel is mounted on an independent shaft, and no two gears are on the same shaft.

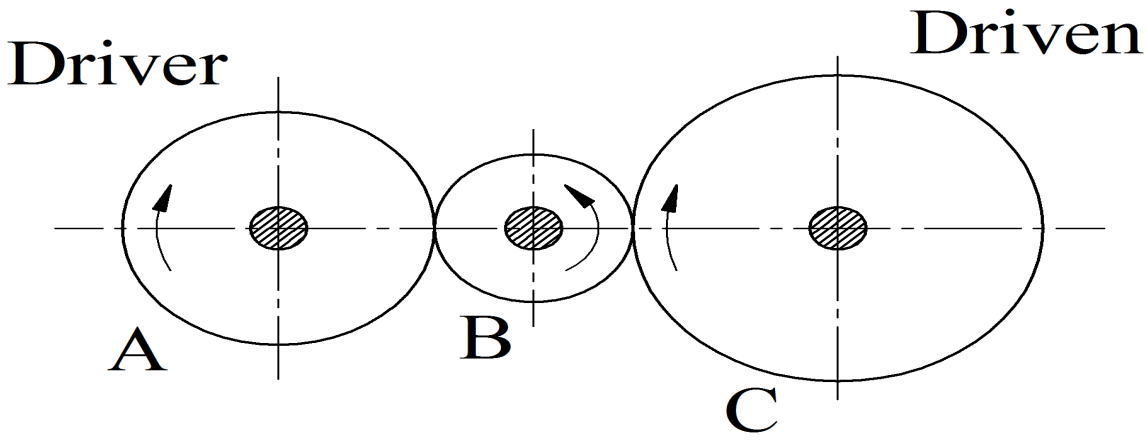

Figure 6. Simple Gear Train

Velocity ratio of simple gear trains:

Velocity ratio is the ratio of speed of driven gear to driver gear.

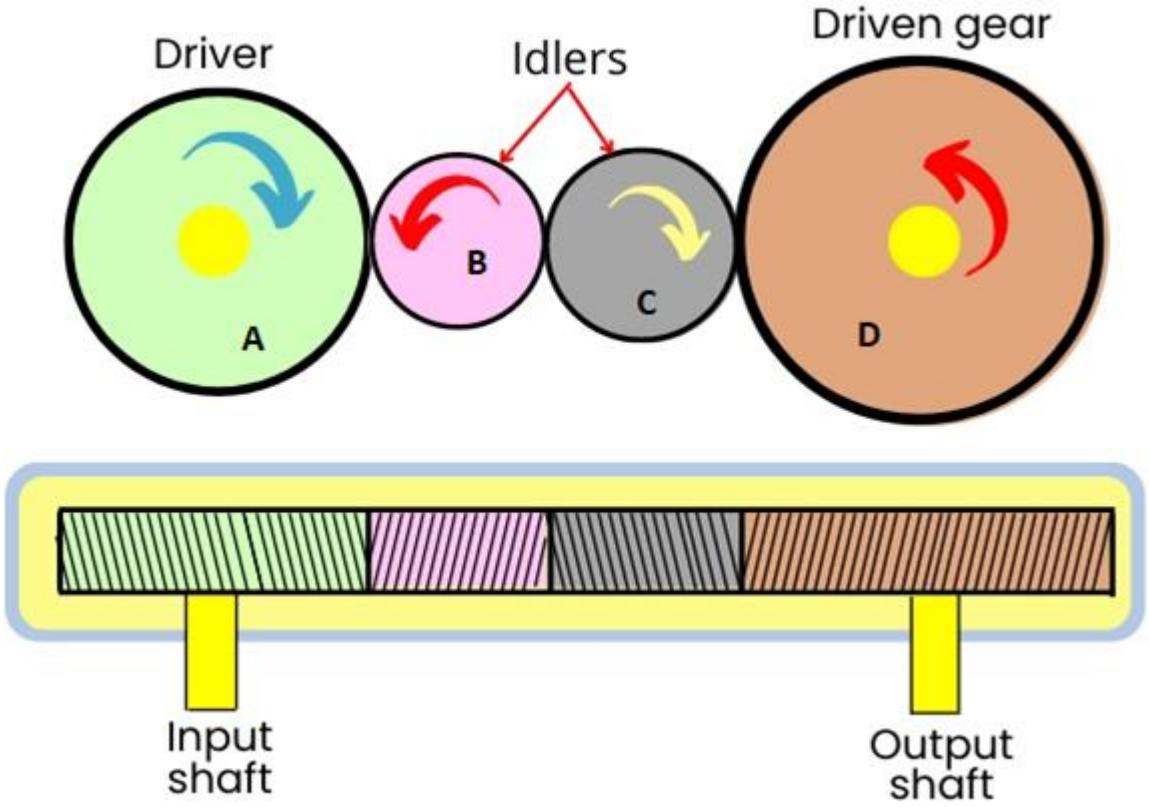

Figure 7. Simple Gear Train

A drives B,

$$\frac{N_B}{N_A} = \frac{T_A}{T_B} \qquad (i)$$

B drives C,

$$\frac{N_C}{N_B} = \frac{T_B}{T_C} \qquad (ii)$$

C drives D,

$$\frac{N_D}{N_C} = \frac{T_C}{T_D} \qquad (iii)$$

Multiplying (i), (ii) and (iii),

$$\frac{N_B}{N_A} * \frac{N_C}{N_B} * \frac{N_D}{N_C} = \frac{T_A}{T_B} * \frac{T_B}{T_C} * \frac{T_C}{T_D}$$

$$Velocity\ Ration, \qquad \frac{N_D}{N_A} = \frac{T_A}{T_D}$$

Numerical on simple gear trains:

1.

Compound gear trains:

In this type of arrangement, more than one gear is mounted on the same shaft.

Gear A is the driver and gear D is the driven gear.

The intermediate gears B and C are mounted on the same shaft.

Gear A meshes with gear B, and gear D meshes with gear C.

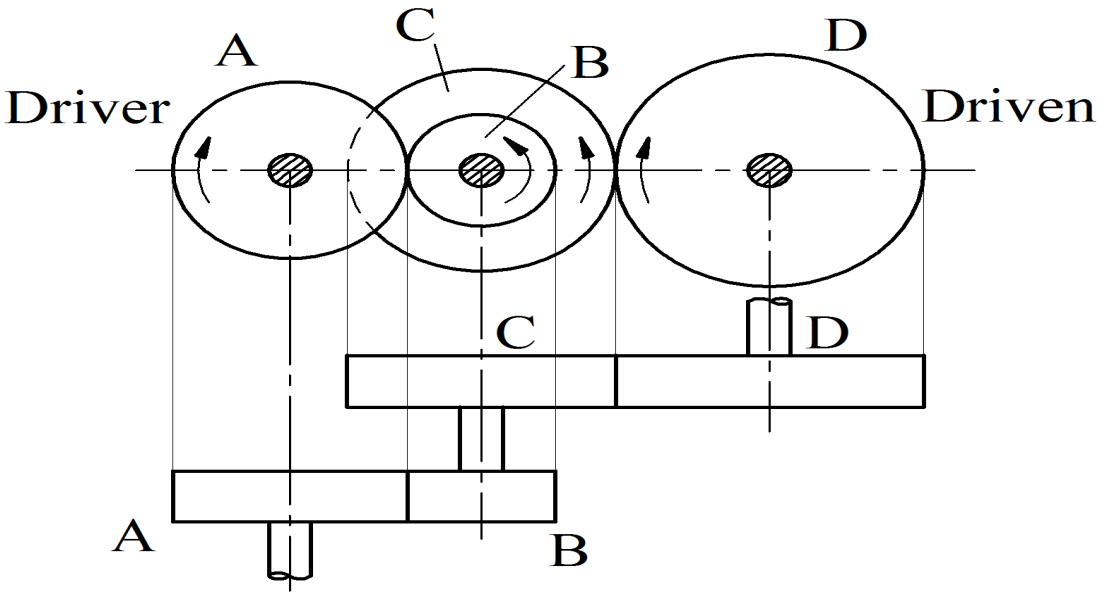

Figure 8. Compound Gear Train

Velocity ratio of compound gear trains:

Referring to above figure,

A drives B,

$$\frac{N_B}{N_A} = \frac{T_A}{T_B} \qquad (i)$$

Since B and C are keyed to the same shaft, they rotate at speed,

C drives D,

$$\frac{N_D}{N_C} = \frac{T_C}{T_D} \qquad (ii)$$

Since B and C are keyed to the same shaft, they rotate at speed,

$$N_B = N_C$$

Multiplying (i) and (ii),

$$\frac{N_B}{N_A} * \frac{N_D}{N_C} = \frac{T_A}{T_B} * \frac{T_C}{T_D}$$

$$\frac{N_D}{N_A} = \frac{T_A}{T_B} * \frac{T_C}{T_D}$$

Numerical on compound gear trains:

1.

Belt drives:

- Belt drive, in machinery, are a pair of pulleys attached to usually parallel shafts and connected by an encircling flexible belt (band) that can serve to transmit and modify rotary motion from one shaft to the other.
- Most belt drives consist of flat leather, rubber, or fabric belts running on cylindrical pulleys.

Types of belt drives:

- Open belt drive
- Crossed belt drive

Open belt drive:

- It is employed when the two parallel shafts must rotate in the same direction.
- When the shafts are placed far apart, the lower side of the belt should be the tight side and the upper side must be the slack side.

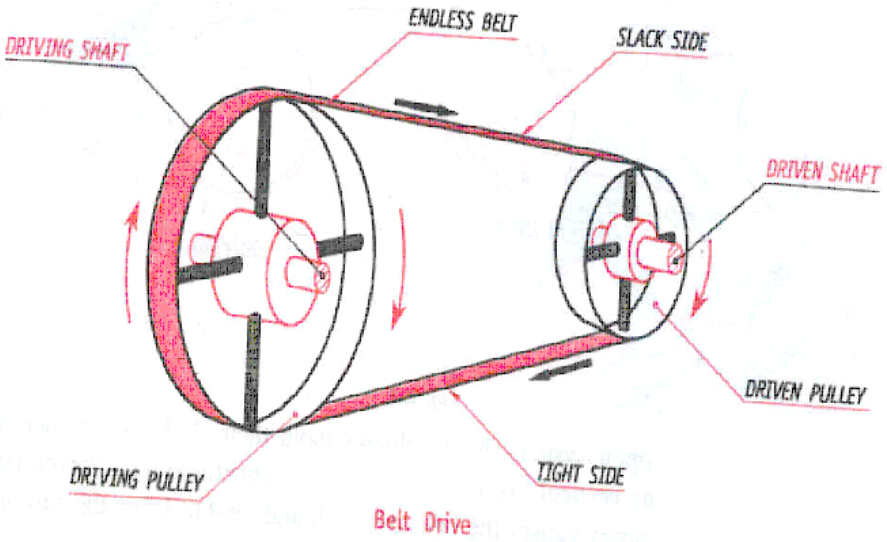

Figure 9. Open Belt Drive

Crossed belt drive

- Employed when two parallel shafts must rotate in the opposite direction.
- At the junction where the belt crosses, it rubs against itself and wears off. To avoid excessive wear, the shafts must be placed at a maximum distance from each other and operated at very low speeds.

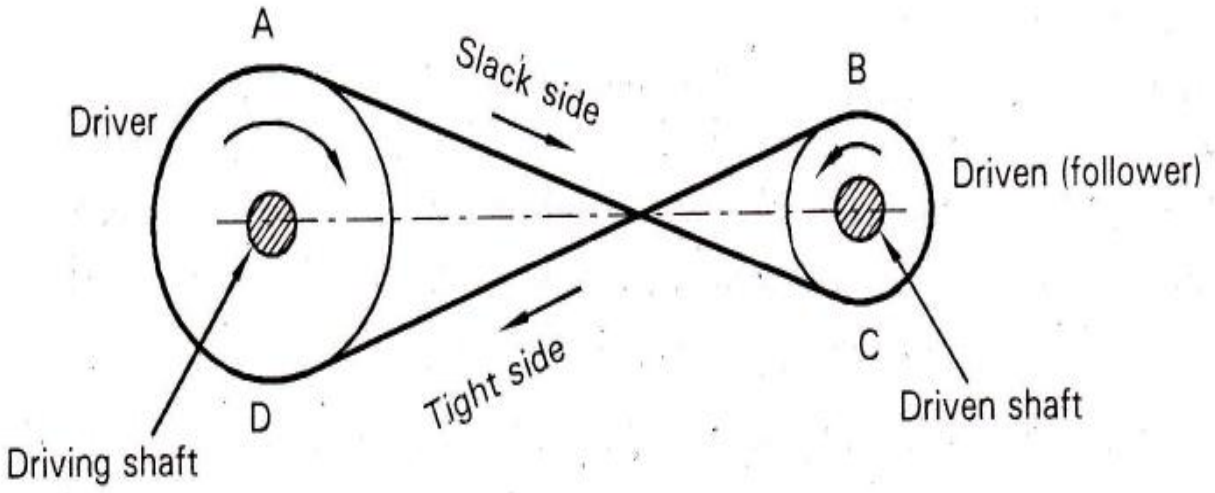

Figure 10. Cross Belt Drive

Components of belt drives:

- Driving shaft
- Driven shaft
- Belt

Velocity ratio of belt drives:

The velocity ratio of the belt drive is the ratio between the velocities of the follower or driven (N_2) and the driver (N_1).

Velocity Ratio = Speed of Follower (driven) in rpm/Speed of Driver in rpm.

The circumferential speeds of the driving and driven pulleys and the linear speed of the belt are equal.

Linear speed of the belt = Circumferential speed of the driving pulley = circumferential speed of the driven pulley

Let,

N_1 = speed of the driver pulley

d_1 = diameter of the driver pulley

N_2 = speed of the driver pulley

d_2 = diameter of the driver pulley

$$\pi d_1 N_1 = \pi d_2 N_2$$

$$d_1N_1 = d_2N_2$$

$$Therefore, Velocity\ Ratio = \frac{N_2}{N_1} = \frac{d_1}{d_2}$$

Types of belt:

Flat belt drive- Flat belt drives are suitable to transmit power from one place to another place when the distance between the two places or pulleys or shafts is larger.

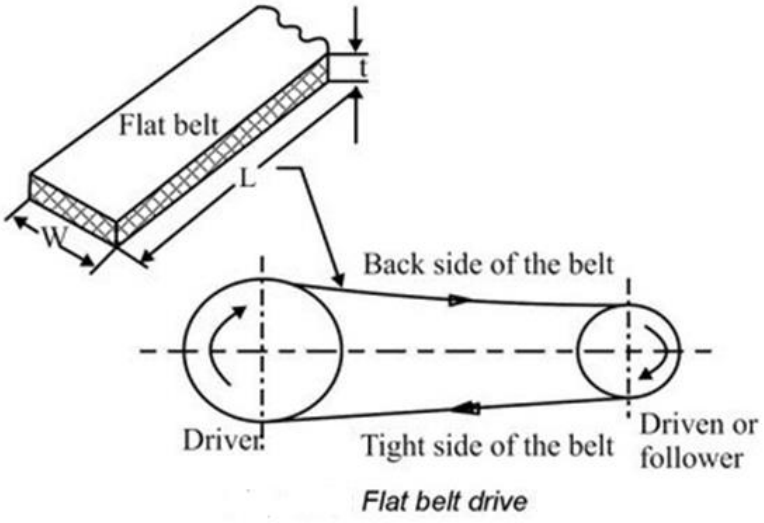

Figure 11. Flat Belt Drive

V belt drive- It is used when the distance between the shafts are shorter. The V-belt drive technology is based on the belt tracking in a mating groove in the belt pulley. The more power that is transmitted, the more belts and grooves in a row.

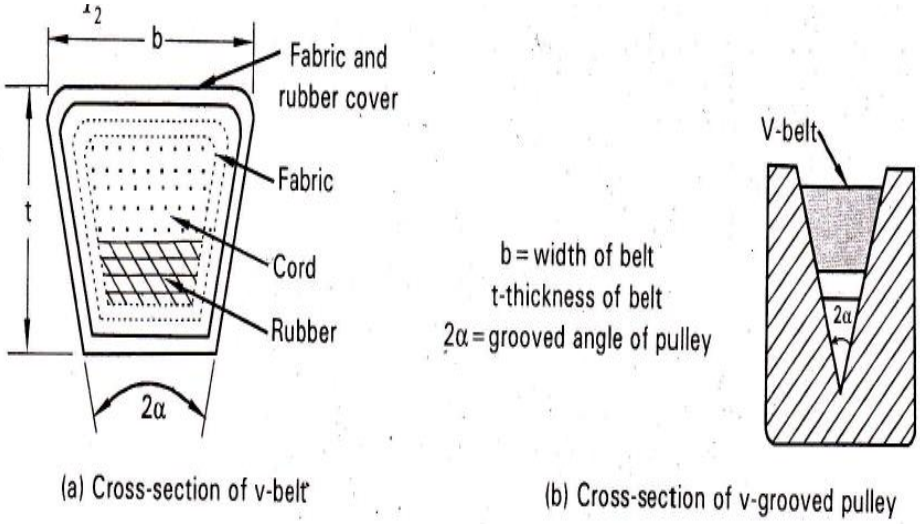

Figure 12. V- Belt Drive

Application of belt drives:

- In washing machines to transfer power from the motor shaft to the drum shaft.
- Alternators in automobiles.
- Flour mills.
- Lathe Machine, Milling Machines, Drilling machine, etc.
- Paper mills.
- Conveyors

Chain drive:

- Chain drives are most used to transmit power between two components that are at a greater distance, but they may also be used for short distances.
- It is often used to convey power to the wheels of a vehicle.

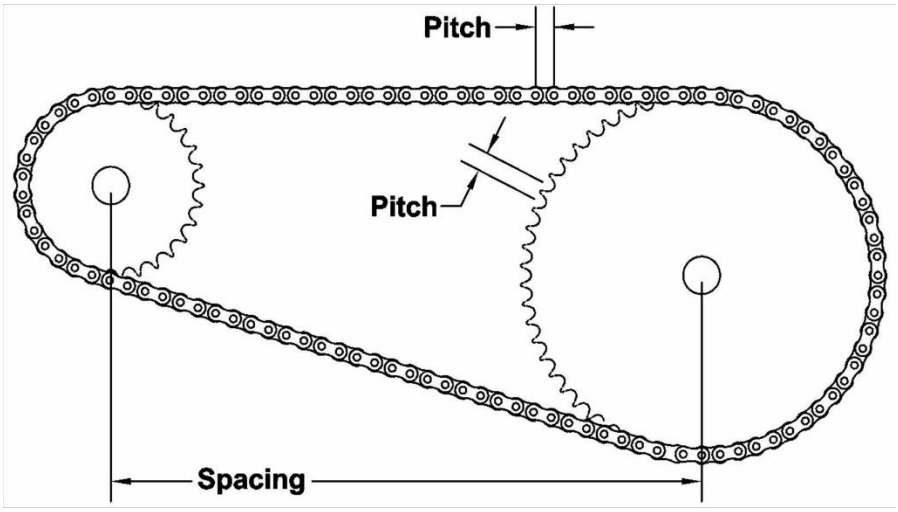

Figure 13. Chain Drive

Advantages of chain drive:

- They can be used for both long and short distances.
- Several shafts can be driven from a single chain.
- They are compact and have small overall dimensions.
- They do not present fire hazard.
- Temperature and environmental conditions do not affect their working.
- They do not require initial tension.

Application of chain drive:

Chain drives are employed for a wide range of power transmission applications.

- In bicycles
- Motorcycles
- rolling mills
- agricultural machinery
- machine tools
- Conveyors

- Coal cutters etc.

Rope drive:

The rope drives (wire ropes) are widely used where a large amount of power is to be transmitted from one pulley to another over a considerable distance (i.e., when the pulleys are up to 150 metres apart).

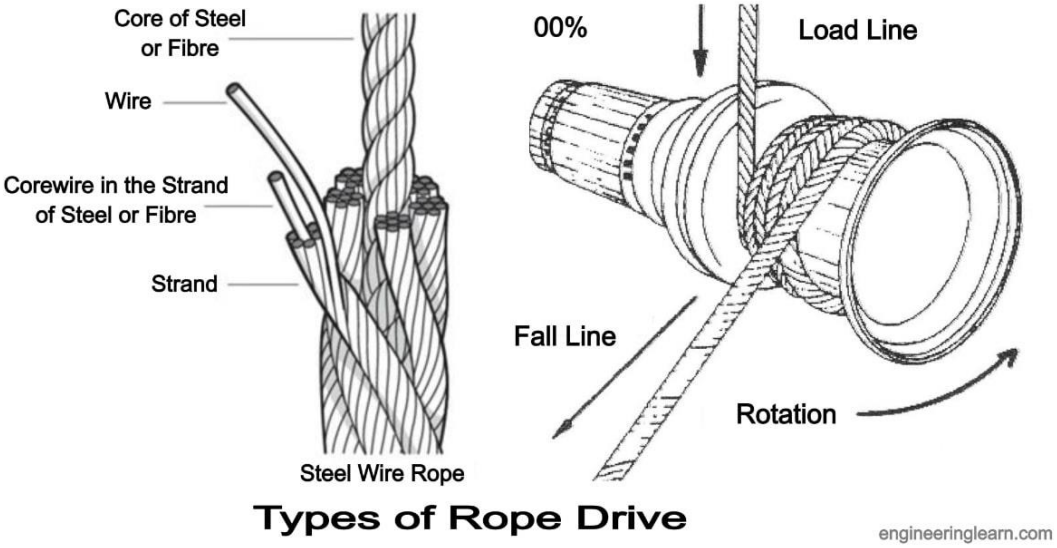

Figure 14. Rope Drive

Application of rope drive:

The wire ropes are widely used in

- Elevators
- mine hoists
- Cranes
- Conveyors
- hauling devices and
- suspension bridges.

Fundamentals of Mechanical Linkages:

Machine:

- Machine is an assemblage of parts that transmit forces, motion, and energy in a predetermined manner.
- A machine is a combination of rigid or resistant bodies, formed and connected so that they move with definite relative motions and transmit force from the source of power to the resistance to be overcome.
- A machine has two functions: transmitting definite relative motion and transmitting force. These functions require strength and rigidity to transmit the forces.

Mechanism:

- Mechanism is a means of transmitting, controlling, or constraining relative movement.
- Movements which are electrically, magnetically, pneumatically operated are excluded from the concept of mechanism.
- The central theme for mechanisms is rigid bodies connected by joints.

Machine and Mechanism:

The similarity between machines and mechanisms is that

- they are both combinations of rigid bodies
- the relative motion among the rigid bodies is definite.

Difference between machine and mechanism:

Mechanism	Machine
It transmits and modifies Motion	Machine modifies mechanical work
It is the skeleton outline of the machine to produce definite motion between various links	Machine may have many mechanisms for transmitting mechanical work or power
E.g., Clock work, Typewriter	E.g., Shaper Machine in a Workshop.

Linear motion:

When a body moves either in a straight line or along a curved path, then we say that body is executing linear motion.

Linear motions are of two types: rectilinear motion and curvilinear motion.

In rectilinear motion the object moves in a straight line for example a stone falling freely from the top of the building.

In curvilinear motion objects move in a circular path for example motion of earth around the sun.

Applications of linear motion:

- TV Lifts.
- Standing Desks.
- Adjustable Beds.
- Car Customization.
- Automated Window Openers.
- Automated Doors.
- Boatsheds.
- Solar Trackers.

Applications of rotary motion:

The ability to provide accurate rotary motion is critical in a wide range of applications in the

- automation equipment
- medical device
- machine tool
- energy
- welding
- robotics
- automotive
- aerospace
- semiconductor and
- heavy equipment industries, as well as many others.

Ratchet and latch mechanism:

A ratchet is a mechanical device that allows continuous linear or rotary motion in only one direction while preventing motion in the opposite direction. Ratchets are widely used in machinery and tools. The word ratchet is also used informally to refer to a ratcheting socket wrench.

Application of Ratchet and latch mechanism:

It is used in application where one sided power transmission is required or to permit shaft to rotate in one direction but not the other. They are used in many applications like gain wheel, clocks, shaping machines.

Clamping mechanism:

Clamping device are used to minimize the distortion during the machining process. Once the workpiece is located, it is necessary to hold it against the machining force. The mechanism used for this is known clamps. They are work holding devices usually positioned above the supporting surfaces.

Reverse motion mechanism:

Reverse motion linkages change the direction of input so that the output goes the opposite way. A fixed pivot forces the change in direction. These are often used on foldable clothes horses.

Linkages can be used to make things move in opposite directions. The movement is reversed by using a lever to form the linkage. If the pivot point (fulcrum) is at the centre of the connecting lever, then the output movement will be the same as the input movement, but it will act in the opposite direction.

Pause and hesitation mechanism:

In this mechanism a pause is given at the end of the movement. Observed in the slider crank mechanism used in machine tools.

Loading and unloading mechanism:
These are used to load and unload materials. Finds wide application in industry and construction field.

Introduction To Robotics:

Robot:
A Robot is a reprogrammable, multifunctional, manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions of performance of a variety of tasks.
Robotics:
Robotics can be defined "as a field of technology that deals with the conception, design, construction, and application of robots.

Why is a robot required?
1. Robots can work in hazardous or dangerous environments such as a nuclear reactor, behind enemy lines, outside earth's atmosphere, etc. They can substitute humans in such environment.
2. Robots can consistently work as per the program with great repeatability and accuracy that is unmatched by the humans.
3. At the end of a task, robots can be programmed to take up a different task altogether.
4. Robot parts can be replaced when damaged.
5. In industries, Computer Integrated Manufacturing can be realized by connecting robots to computer systems and carrying out the different tasks.

Industrial Robot terminology:

1. Manipulator: Manipulator is an arm-like mechanism which is designed to manipulate or move material, parts, or tools without direct human contact.
2. Joint: A joint is the one that integrates two or more links to provide controlled relative movement between input link and the output link.
3. Link: The link is a rigid member that connects the joints. Link can be an input link and an output link. The movement of the input link causes various motions of the output link.
4. Degree of freedom (d.o.f): The degrees of freedom describe a robot's freedom of motion in the three-dimensional space.

5. End effector: End effector or end-of-arm tool is the device at the end of the robotic arm which is shaped like a hand or special tool depending upon the application.
6. Base: The support for the robot arm is called as the base.

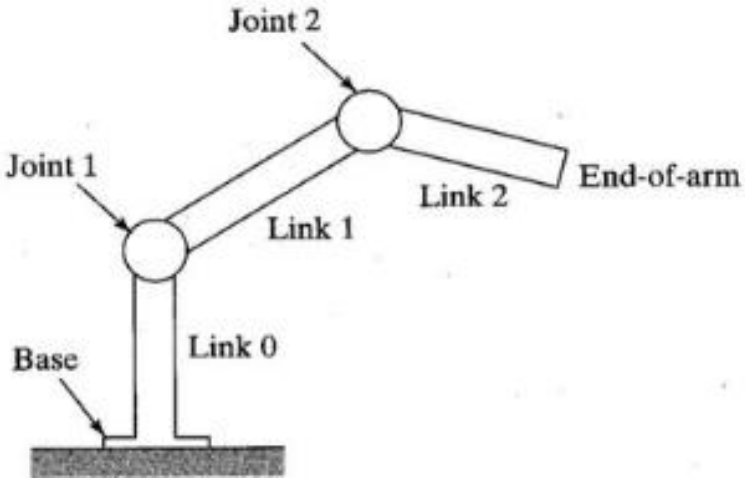

Figure 15Robot Terminology

Robot anatomy:

Robot anatomy deals with the study of different joints and links and other aspects of the manipulator's physical construction. A robotic joint provides relative motion between two links of the robot. Each joint, or axis, provides a certain degree-of-freedom (dof) of motion.

Robots consist of joints and links.

- Joints provide relative motion.
- Links are rigid members between joints.
- Joints are linear or rotary.
- Each joint provides degree of freedom.
- Most robots have five or six degrees of freedom.

Elements of a Robotic system:

1. The Robot: this consists of

a. The manipulator which included the base and the arm assembly.
b. End-of-arm tooling which is the end effector.
c. Actuators which convert stored energy into movement. Common actuators include electric motors and linear actuators.
d. Transmission elements such as ball screws, pulleys, belts, gears etc.,

2. Control system: The control system generates the required signal to coordinate and execute the robot movements. The control system consists of

a. Controls such as mechanical control, hydraulic control, pneumatic control, electrical or electronic control. The control techniques can be open loop control, feedback control, feed forward control and adaptive control.

b. Sensors that allow robots to collect information about a certain measurement of the environment or internal components. The sensor may be touch sensor or vision sensor.
c. Equipment interfaces.

3. Computer system: The computer system is used to program the robots according to the tasks required to be performed. The necessary software must be installed in the computer to develop robot programs.
4. Power source: Power source supplies electrical energy for the robot. The commonly used power source is the battery which can be a lead acid battery or a silver-cadmium battery.

Types of Robotic joints:

1. Rotational joint or the R- joint: It allows rotary relative motion where the axis of the rotation is perpendicular to the axes of the input link and the output link.
2. Linear joint or the L- Joint: It allows a translational sliding motion between the input and the output links parallel as shown in fig.
3. Orthogonal joint or the O- joint: It allows a translational sliding motion between the input link and the output link with the axis of the output link perpendicular to the input link as show in fig.
4. Twisting joint or the T- joint: It allows rotary motion where the axis of rotation is parallel to the axes of the input and output links as shown in fig.
5. Revolving joint or the V- joint: In this the input link axis is parallel to the rotational axis of the joint whereas the output link axis is perpendicular to the rotational axis of the joint as shown in fig.

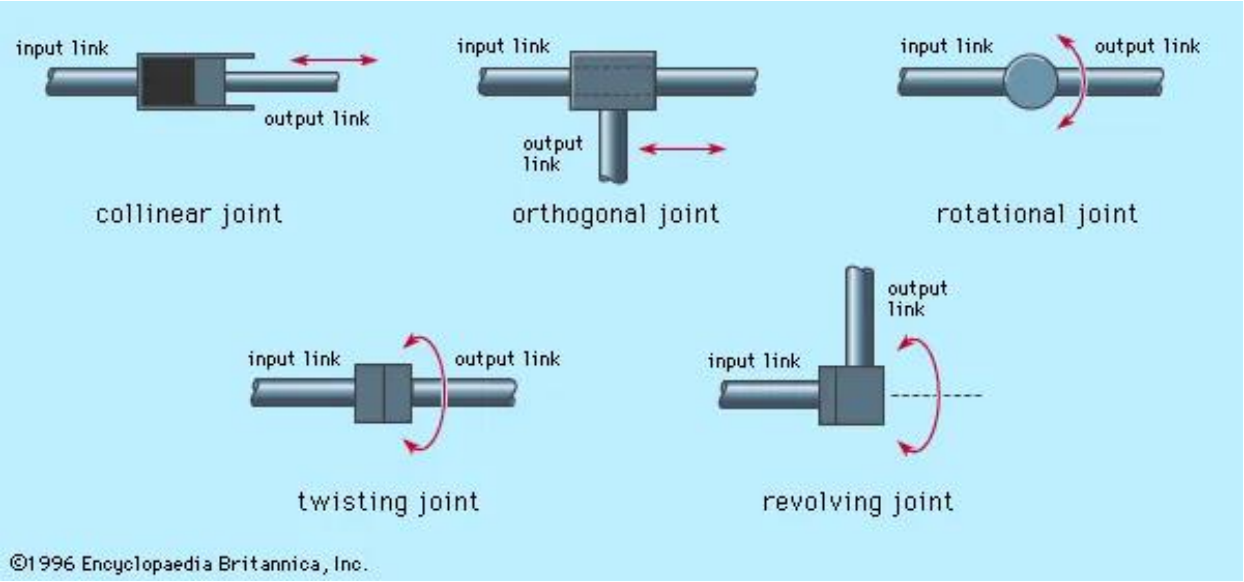

Figure 16. Robot Joints

Robotic configurations:

1. **Polar or Spherical configuration:** It consists of a sliding arm (L- joint) that is actuated relative to the body and the rotational base along with a pivot, which can rotate about a horizontal axis (R joint) and vertical axis (T joint).

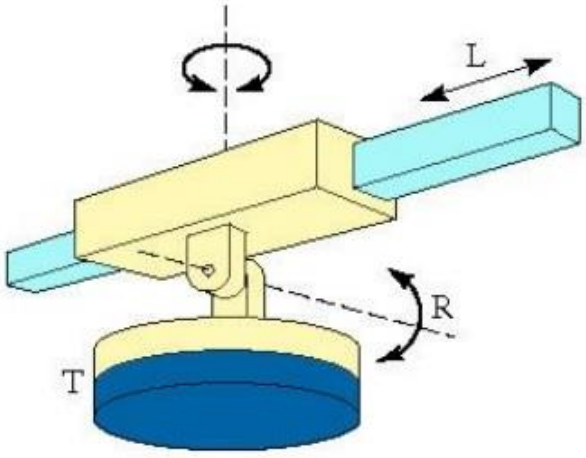

Figure 17. Polar Robot Configuration

Advantage:

- Long reach capability is realized in the horizontal position.
- Disadvantages:
- The vertical reach is low.

Applications:

- Die casting, forging, injection moulding, dip coating, cleaning if parts etc.,

2. **Cylindrical configuration:** It consists of a slide in the horizontal position and a column in the vertical position. The arm assembly moves up and down relative to the column using a L-joint. The column is rotated about its axis using the T-joint. The radial movement of the arm is achieved using the O-joint as shown in fig.

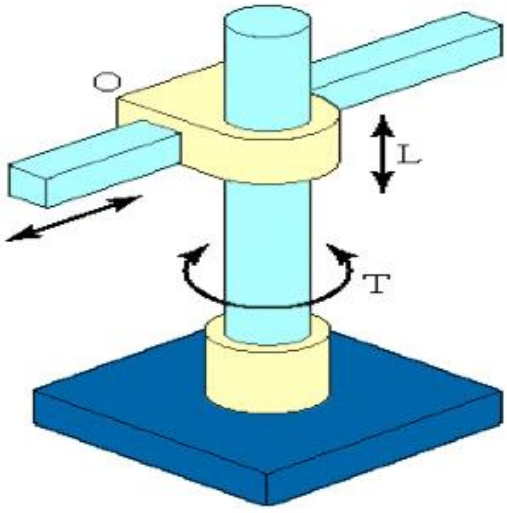

Figure 18. Cylindrical Robot Configuration

Advantage:

- Rigidity is increased and is quite robust.
- Has the capacity to carry high pay loads.
- Disadvantages:
- Work volume is less.
- Occupies more floor space.

Applications:

- Foundry and forging, investment casting, conveyor pallet transfers, machine loading and unloading.

3. **Cartesian coordination robot:** It is also called rectilinear robot or XYZ robot. It consists of three sliding joints along the X Y and Z directions in three-dimensional space. There are two orthogonal joints. Since the motion can stop and start simultaneously along the X, Y and Z axes, the motion of the tool tip is smoother.

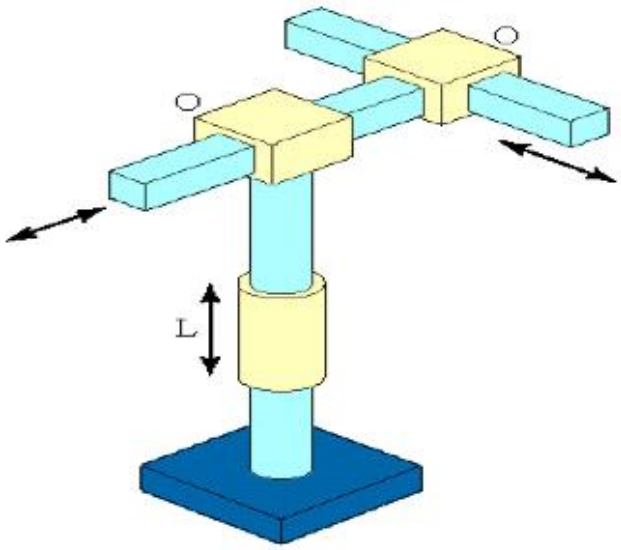

Figure 19. Cartesian Robot Configuration

Advantage:

- Allows for simpler controls.
- Possess high degree of mechanical rigidity, accuracy, and repeatability.
- They can carry heavy loads and the weightlifting capacity do not vary within the work envelope.

Disadvantages:

- Limited in their movement to a small and rectangular workspace.
- Reduced flexibility.

Applications:

- To perform pick and place tasks, material handling, loading/ unloading, and machining operations.

4. **Jointed-arm configuration robot:** This resembles human arm where the column swivels about a base (the column and the base forms a T- joint), the column top connects to the shoulder through a shoulder joint (R- joint) and the shoulder connecting to the elbow through an elbow joint (which is also R- joint). Thus, this configuration has the capability to be controlled at any adjustments in the workspace.

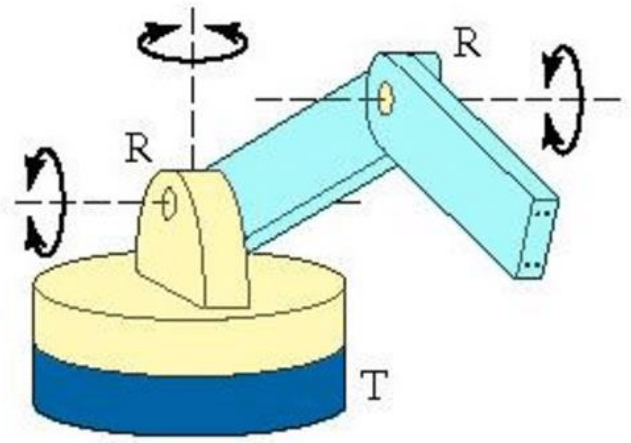

Figure 20. Jointed- arm Robot Configuration

Advantages:

- The work volume available is large.
- Operation is quick. Flexibility is increased.

Disadvantages:

- Operation procedures are difficult. Quite expensive type of configuration.
- Number of components involved are more.

Applications:

- To perform arc welding, spot welding and spray-painting operations.

Application of Robots:

1. Material Handling:

Typical applications of robots include welding, painting, assembly, disassembly, pick and place for printed circuit boards, packaging and labelling, palletizing, product inspection, and testing; all accomplished with high endurance, speed, and precision. They can assist in material handling.

i. Pick and Place application: Here the objects are picked from one location and placed to another location.

ii. Palletizing application: A robotic palletizer can handle one or more units at a time according to pallet configuration, and forms multiple layers on a pallet after picking the products off a conveyor. Robotic palletizing solutions can easily accommodate different pallet patterns and product types.

iii. Depalletizing application: Palletizing refers to the operation of loading an object such as a corrugated carton on a pallet or a similar device in a defined pattern. Depalletizing refers to the operation of unloading the loaded object in the reverse pattern.

Figure 21. Palletizing Operation

Figure 22. Depalletizing Operation

iv. Stacking application: Here the robots are used to stack parts one upon another. After each placement, the vertical position is re-calculated, and the new stacking height is determined.

v. Insertion application: Here the robots are used to insert parts into the compartments

2. Machine loading/ unloading:

i. Machine loading: Robotic machine loading is commonly used to feed parts to and from CNC machines, injection machines, transfer machines, and press

machines. Machine loading robots can be fitted with end of arm tooling to customize them to the specific requirements to complete the loading application.

ii. Machine unloading: In the unloading operation, a robot is used to unload the finished parts that comes out of a production machine, but the loading of the parts on to the production machine is done by means other than the use of robot.

iii. Machine loading and unloading: In this operation, a robot is used to both load raw parts into the production machine and unload finished parts from the production machine.

3. Processing operations: In robotic processing operations, the robot manipulates a tool to perform a process on the work part. Examples of such applications include spot welding, continuous arc welding, and spray painting. Spot welding of automobile bodies is one of the most common applications of industrial robots in the United States.

i. Spot welding: The robots used for spot welding are articulate robots which are also called as six-axis robots. Articulate robots consist of three rigid members connected by two revolute joints and mounted on a rotary base. Robotic welding is a highly advanced version of automated welding, in which machines conduct the welding, but welders still control and supervise the process. The use of robotic technology allows for precise and quick results, less waste, and greater safety.

Figure 23. Spot Welding

ii. Arc welding: Robotic welding is the use of mechanized programmable tools (robots), which completely automate a welding process by both performing the weld and handling. Arc welding applications are typically automated with a six-axis industrial robot. The robot's main purpose is to position the torch and workpiece while energy is supplied to the articulated robot from the power supply. The primary benefit of robotic arc welding is the production of high-

quality welds in a shorter cycle time, with manufacturing flexibility another major advantage. Through extensive application in many manufacturing industries sectors; robotic welding has been developed to a mature production method.

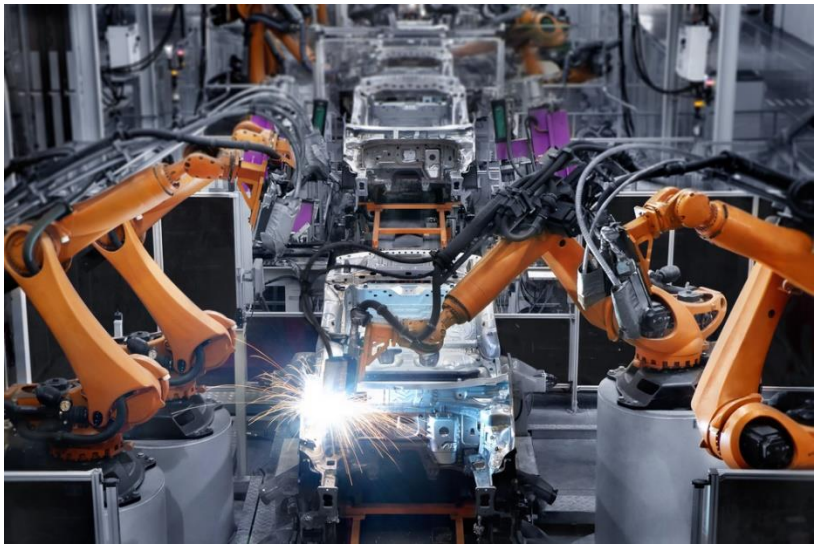

Figure 24. Arc Welding

iii. Spray painting: Industrial paint robots are designed to help standardize the distance and path the automatic sprayer takes, thus eliminating the risk of human error caused by manual spraying. Paint robots are often paired with other automatic painting equipment to maximize the efficiency and consistency of the paint finish. A robot must have several necessities such as two or more program storage, continuous path control, manual lead through programming method, and hydraulic drive system for carrying out this process. Since robots are precise, they don't leave behind drips or other imperfections. Instead, each piece of equipment is sprayed evenly with just the right amount of paint for a flawless finish. Industrial robots can recognize what areas to paint by using software, algorithms, sensors, and cameras.

Figure 25. Spray Painting

4. Assembly and inspection:

Assembly robots are used for lean industrial processes and have expanded production capabilities in the manufacturing world. An assembly line robot can dramatically increase production speed and consistency. They also save workers from tedious and dull assembly line jobs. The robotic form of "go/no go" inspection utilizes a camera mounted on the robot's arm, which is moved around to check the presence of different features on a part. Robots are also used to measure items.

Advantages of Industrial Robots:

1. Robots can be substituted for human work in hazardous work environment.
2. Better productivity and accuracy.
3. Robot can work at constant speed without any break.
4. Robots can lift heavy loads.
5. Robot can work in spaces where human reach is not possible.
6. Robots can be re-programmed with changed tooling to take up a different task.
7. Accidents are avoided as robots can perform risky jobs.
8. Robot can be integrated to Computer Integrated Manufacturing (CIM).
9. Robot produces lesser or no defective parts, hence saving in time and money.

Disadvantages of Industrial Robots:

1. Huge investments to introduce robots in the workplace.
2. Maintenance cost is high as replacement of parts which are precise are costly.
3. Highly skilled technical engineers and programmers.
4. Highly sophisticated level of artificial intelligence is required for robots to respond properly during times of emergency, during times of accidents or when as unexpected variance occurs.
