LECTURE NOTES

ON

MECHATRONICS

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UNIT-01 INTRODUCTION TO MECHATRONICS

Mechatronics

Mechatronics is defined as a multidisciplinary field of engineering that includes a combination of systems engineering. It also focuses on designing, manufacturing and maintaining products that have both mechanical and electronics components.

→ Mechatronics involves number of technology.

- mechanical engineering
- electrical engineering
- electronics engineering
- computer engineering
- control engineering

- Evolution level of mechatronics

There are four levels of mechatronics as follows

- Primary level of mechatronics
- Secondary level of mechatronics
- Third level of mechatronics
- Fourth level of mechatronics

➡ Primary level of Mechatronics

This level includes devices such as sensors and actuators that combine (mix) electrical signals with mechanical action at the basic control level.

ex- electrically control fluid valves

➡ Secondary level of Mechatronics

This level combines microelectronics into electrically controlled devices.

ex- cassette player

➡ Third level of Mechatronics

This level includes advanced feedback functi into control strategy thus by enhancing the quality in terms of smoothness.

ex- microelectronics,
micro processors,
application specific integrated circuit (ASIC)

Hard disk, CD drive,
automatic washing machine

➡ **Fourth level of mechatronics**

This level of mechatronics includes intelligent control in mechatronics system. It introduces intelligence and fault detection and isolation (FDI) capability systems.

- **Advantages and Disadvantages of Mechatronics**

Advantages

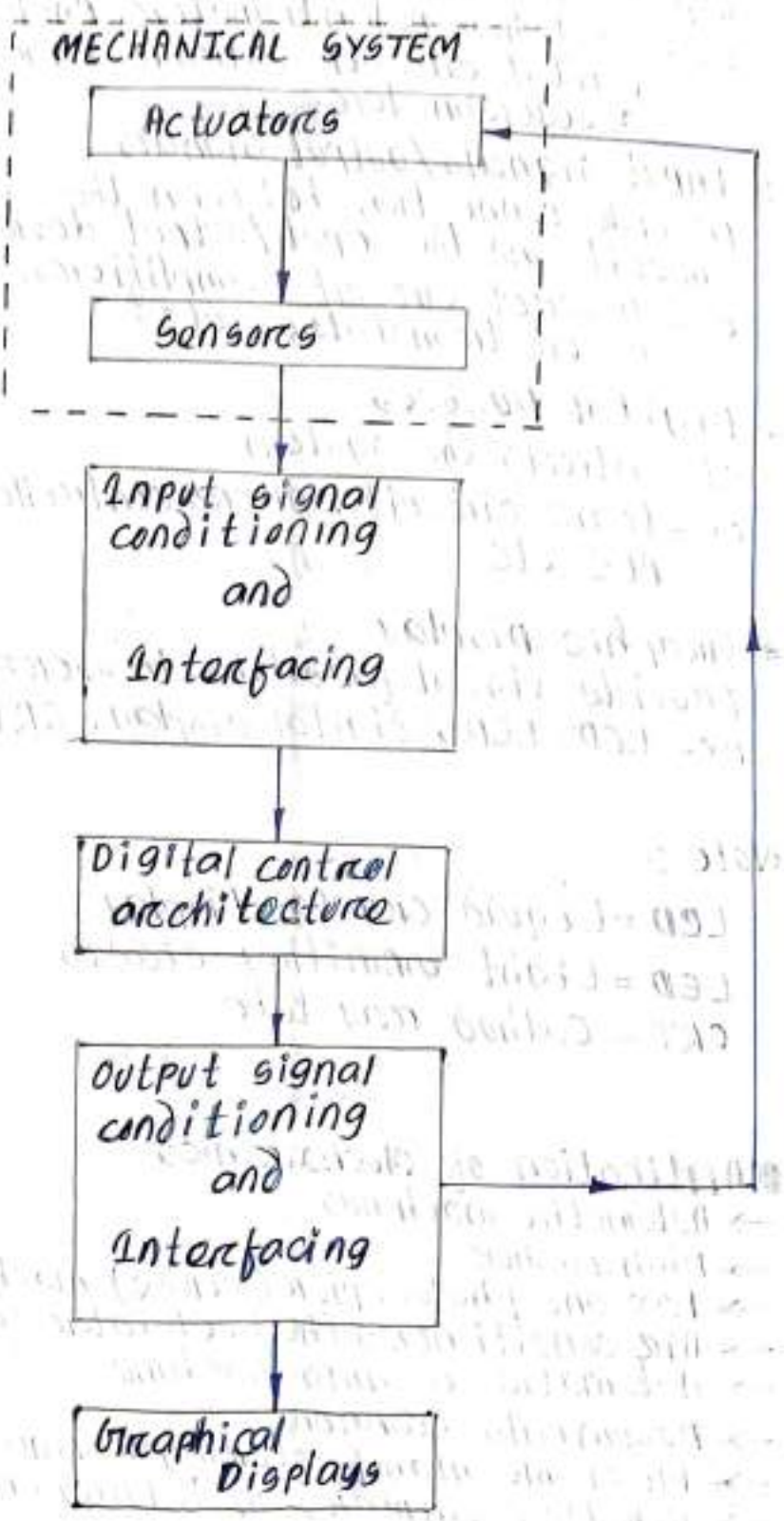
① The product produce are cost effective and very good quality.
② The performance characteristic of mechatronic products are such which are otherwise very difficult to achieve without the synergistic combination.
③ High degree of flexibility.
④ A mechatronics product can be better than just sum of its parts.
⑤ Greater extent of machine utilisation.
⑥ Due to integration of sensors and control system in a complex system, capital expense are reduced.

Disadvantages

① High initial cost of the system.
② Imperative to have knowledge of different engineering field for design and implementation.
③ Specific problems for various system will have to be adressed separately and properly.
④ It is expensive to incorporate mechatronics approach to an existing /old system.

- Components of Mechatronics system

The term mechatronics system (sometime referred to as smart device) encompass a myriad of devices and systems. Increasingly microcontrollers are embedded in the electromechanical devices, creating much more flexibility and control possibilities in system design.



- **Actuators**
  produce motion or cause some action.
  ex- solenoids, voice calls, DC motor, stepper motor, servo motor, hydraulic, pneumatic

- **Sensors**
  Detect the state of the system parameters.
  inputs and outputs.
  ex- switches, potentiometer, photoelectrics, digital encoder, strain gauge, thermocouple accelerometer.

- **Input signals/output signals**
  provide connection between the control system circuit and the input/output devices.
  ex- Discrete circuit, amplifiers, A/D, D/A power transistors etc.

- **Digital Devices**
  It controls the system.
  ex- logic circuit, micro controller, SBC, PLC etc.

- **Graphic Display**
  provide visual feed back to users.
  ex- LCD, LED, digital display, CRT

Note :-

LCD = Liquid crystal Display
LED = Light emmiting diodes
CRT = Cathod ray tube

- **Application of Mechatronics**
  → Automotive machines
  → Dishwasher
  → fax and photocopier (xerox) machines
  → Air conditioners (AC), elevator controls
  → Automatic washing machine.
  → Documents scanner
  → Flexiable manufacturing machine system
  → Robotics employed in buiding, nuclear inspections.
  → home security.

→ Laundry washer - dryer
→ toaster
→ Climate control units
→ Remote control system

- Scope of Mechatronics in Industrial sector
→ Better design of products
→ Better process planning
→ Intelligent process control
→ Reliable and quality oriented manufacturing

- Importance of Mechatronics in automation
➡ Application of mechatronics in health industries
— using robot to perform a surgery/operation
➡ Around the house
— refrigerator that can order milk when you are running low.
➡ For exploration
— The mass robot spirit and opportunity provided a view of the red planet that have never been seen.
➡ In Cars/Bikes
— mechatronics engineering has save a thousands of lives through the discovery of anti-lock breaking system (ABS)

UNIT-02 SENSORS AND TRANSDUCER

Sensors

A sensor is a type of device that senses the condition, state or value of the process variable and produces output which reflects this condition, state or value.

or

Sensor is an element which produces signal relating to the quantity being measured.

or

Sensor can be defined as the device which provides a usable output in response to a specified measurand.

Transducers

The transducers transform the energy of the process variable, output of some other type of energy which is able to operate some control device.

→ A transducer is an electronic device which convert energy from one form to another.

→ A device that converts variations in physical quantity such as pressure or brightness, into an electrical signal or vice versa.

→ It can be broadly defined as a device which convert a non-electrical quantity to electrical quantity.

→ The process of converting energy from one form to another is known as transduction.

• Classification of Transducer

[A] Transducers are broadly classified into two types.

① Active transducer
② passive transducer

Active transducer

They are also known as self generating type transducers. These transducers develop their own voltage or current. The energy required for the production of the output signals is obtained from the physical phenomenon being measured.

ex- thermo couple,
thermo poles,
photo voltaic cell,
piezo electric pickup.

⇨ Passive transducers
They are also known as externally power transducer. These transducers derive the power required from the energy conservation from an external power source.
ex- resistance thermometer,
differential transformer,
potential matric devices,
photo ammision cell.

[B] classification based on type of output
① Analogous transducers
② Digital transducers.

⇨ Analogus transducers
These transducers convert the input physical phenomenon into analogus output which is continuous function of time.
ex- strain gauge,
thermo couple,
thermistor

⇨ Digital transducers
These transducers convert the input physical phenomenon into an electric output which may be in the form of pulse.
ex- shaft encoder,
Limit switch,
Digital tachometer.

[C] classification based on electrical principle involves

⇨ Variable resistance type
ex- strain and pressure gauge,
-thermister, resistance thermister
- photo conductive cell.

⇨ Variable inductance type
ex - Linear voltage differential transformer
- reluctance pickup
- eddy current gauge

⇨ Variable capacitance type
ex - capacitor microphone
- pressure gauge
- Dielectric gauge

⇨ Voltage generating type
ex - thermocouple
- photovoltaic cell
- piezoelectric pickup

⇨ Voltage devidor type
ex - potentiometer position sensor
- pressure actuator voltage devidor

● Electromechanical Transducers
→ Any type of device that either converts an electrical signal into sound waves (as in a loud speaker) or converts a sound waves into an electrical signal (as a microphone).

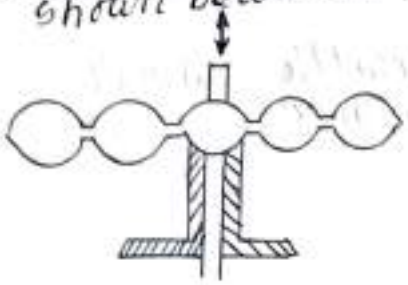
⇨ These days electrical / electronic technic or measurement are being increasingly applied to the measurement in many fields other than electrical engineering. These methods claim the following advantages
① Less power consumption and less loading on the system to be measured.
② Friction and mass inertia effect minimum.
③ More compact instrumentation.
④ possibility of non-contact measurements.
⑤ Good frequency and transient response.
⑥ Feasibility of remote indication and recording.

- Transducers actuating mechanism

Transducers are also known as gauges, pick-ups and signal generators.

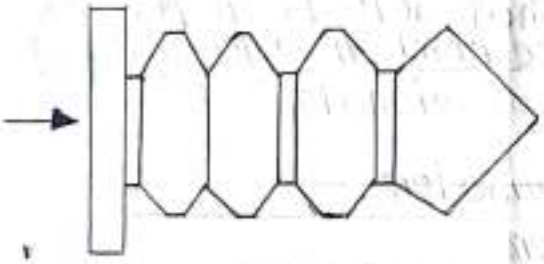
→ An actuating mechanism usually consists of a motor, a transmission and control units, as well as feedback, signalling, interlocking and shutoff units.

→ There are some typical actuating mechanism shown below the figure.



Capsules

Corrugated diaphragms



Bellows

Pressure circular Bourdon tube

- **Displacement and position sensors**

A displacement sensors are the devices used for measuring the position and movement or detect the movement of a given object.

→ The displacement sensors are also known as position sensors.

ex- displacement sensors can be used for steering system on agricultural machinary.
- Electric cart throttle controlled the suspension on bikes.

- **Temp. sensors**

A temperature sensors are the device, typically a thermocouple or resistance temperature detector, that detects or provide temperature measurement in a readable form through an electrical signals.

ex- Digital thermometer
- Thermal scanner
- Automatic water heater
- Automatic iron

- **Light sensors**

It is the type of sensors which are used to measure the intensity of light.

example of light sensors are-
1. photodiodes (fast response to light)
2. phototransistors (greater collector current for a given light intensity)
3. photoresistors (determine the variation of light intensity across the space).

- **Velocity sensors**

The velocity sensors are the type of sensors which are used to measure the value of velocity and speed of a device.

ex - Tachogenerator
↳ used to measure the angular velocity.

- **Pressure sensors**

The pressure sensors are used to measure the pressure in a system or device.

→ In other word the device which helps to measure the pressure difference between two different point

ex - piezoelectric sensor

- **Force sensors**

→ The force sensors are similar as pressure sensors.

→ It is type of tactile sensors.

→ It is used to measure the value of force in a system

ex - Load cells
pneumatic load cell
hydraulic load cell
strain gauges.

→ Load cells are the elastic device which can be used to measure the force through the indirect methods.

- **Motion sensors**

A motion sensors are the device which detect the nearby motion.
→ It is also known as motion detectors.

ex - Microwave
Dual Tech / Hybrid
Passive infrared (PIR)

UNIT-03 ACTUATORS - MECHANICAL, ELECTRICAL

Definition

Actuators are defined as a type of device there produced physical changes such as linear and angular displacement. They also modulate the rate and power associated with those changes

→ There are following type of actuators

- Mechanical actuator
- Electrical actuator
- Hydraulic actuator
- Pneumatic actuator

- Mechanical Actuators

Mechanical actuators are the devices which can be consider to be motion convertors. In that they transform motion from one form to another form

For example

- transform the linear motion into rotational motion.
- A linear recoprocating motion into rotational motion.

ex- IC (Internal combustion) Engine

Note :-

→ Mechanical elements include the use of cams, Linkage, gears, chains, belt drive etc.

Role of mechanical actuators in mechatronics system

→ change of speed that is given by gears

→ specific type of motion, that is given by quick return mechanism.

→ Transfer of rotation about one axis to rotation about another.

- **Machine**

➡ Machine may be defined as an apparatus for applying mechanical power, consisting of a number of interrelated parts, each having a definite function.

(or) It is a device by means of which available energy can be converted into desired forum of useful work.

→ A machine is the assembly of resistant bodies or links whose relative motions are successfully constrained so that available energy can be converted into useful work.

→ Machines are used to transmit both the motion and force.

→ A body is said to be resistant if it can transmit the required force with negligible deformation.

→ These bodies are the parts of machine which are employed for transmitting motion and force.

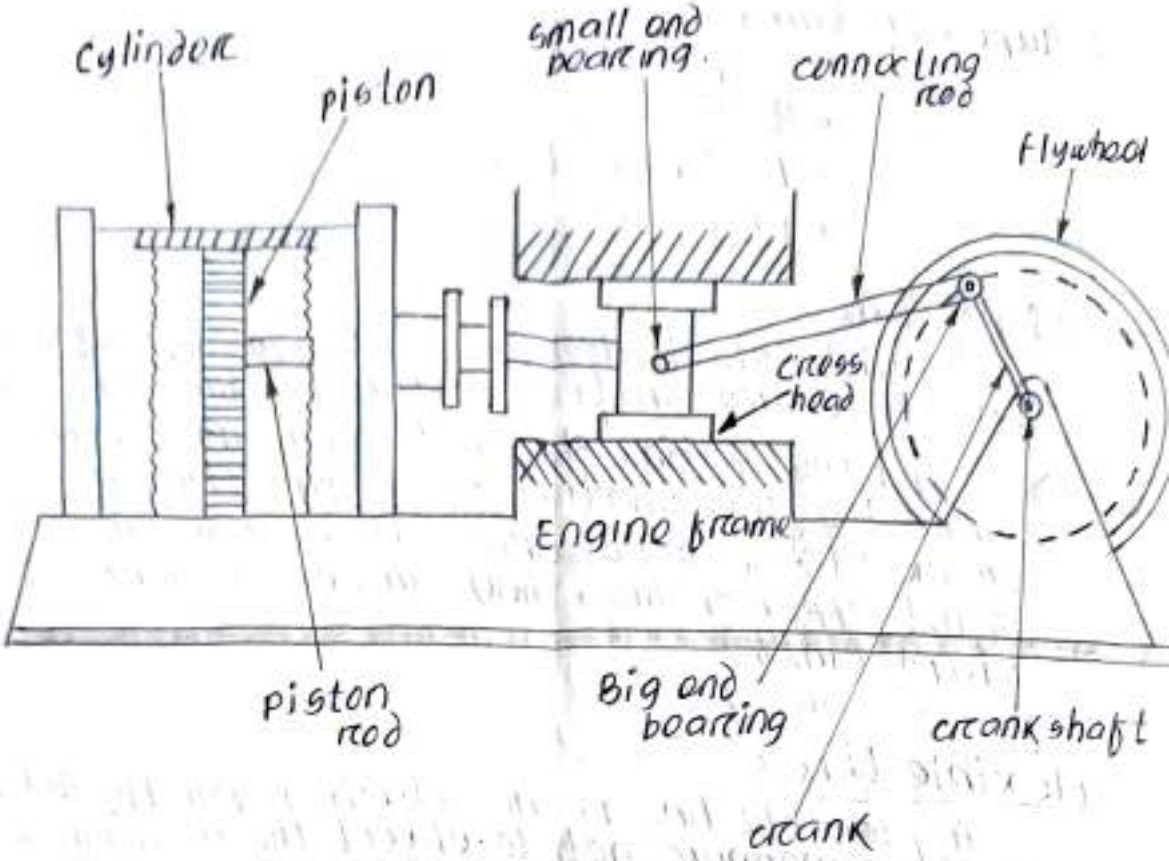
➡ A machine is a mechanism or combination of of mechanism which not only imparts definite motion but also transmit and modifies the available mechanical energy into some kind of useful work.

- **Kinametic Link**

A kinametic elemonts is a resistant body or an assembly of resistant body which go to make a part or parts of a machine connecting other parts which have motion relative to it.

➡ A kinametic link is a resistance body that constitutes part of the machine connecting other parts which have motion relative to it. A kinametic link is assumed to be completly rigid.

➡ A kinametic link is defined as a member or combination of member, connecting other member and having motion relative to them.



Reciprocating Steam Engine

① [piston, piston rod, Cross head] → Link 1
② [connecting rod with big and small end bearing] → Link 2
③ [Crankshaft and flywheel] → Link 3
④ [Cylinder, engine frame and main bearing] → Link 4

- Characteristics of Links

A Link should have two characteristics.

→ It should have relative motion
→ It must be a resistant body (need not be rigid only):
(Zero deformation)

- Types of Links

The various types of links are

- Rigid link
- Flexiable link
- Fluid link

Rigid Link :-

A link which does not undergo any deformation while transmitting motion is called rigid link

→ Such type of link does not exist. However since the deformation of a connecting rod, crank etc. of a reciprocating steam engine is not appreciable, they can be considered as rigid links.

Flexible link :-

A flexible link is one which is partly deformed in a manner not to effect the transmission of motion.

ex - Bolts, ropes, chains and wires.
(these links transmit tensile force only)

Fluid Link

A fluid link is one which is formed by having a fluid in receptacle and the motion transmitted through the fluid by pressure or compression only.

ex - hydraulic presses
Disk Brakes.

- Kinametic Pair

➡ A kinametic pair is a joint of two links that permits relative motion.

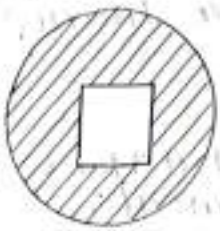
➡ A joint of two links having relative motion between them is known as kinametic pair.

→ The relative motion between the elements or links that form a pair is required to be completly constrained or successfully constrained.

Completely Constrained motion

when the motion between a pair is limited to a definite direction irrespective of the direction of force applied, then the motion is said to be completely constrained motion

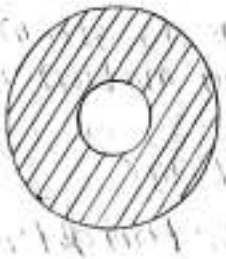
ex- the motion of a square bar in a square hole.
- The motion of piston and cylinder in a steam engine.



Incompletely Constrained motion

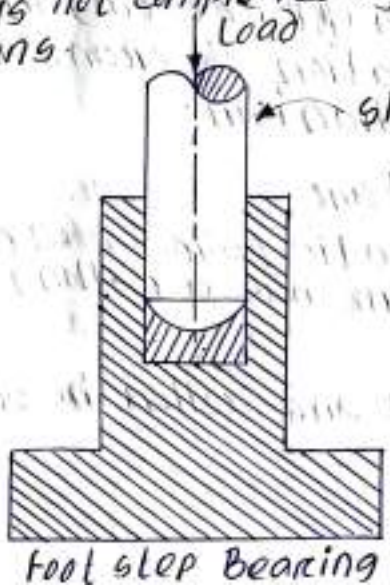
when the motion between a pair can take place in more than one direction then the motion is said to be incompletely constrained motion.

ex- a circular bar or shaft in a circular round role.



Successfully Constrained motion

The motion is said to be successfully constrained motion when the motion between the element forming a pair is such that constrained motion is not completed by itself but by some means



- Classification of Kinametic Pairs

The kinametic pairs may be classified on the following considerations.

1. Nature of relative motion between the elements
2. Nature of contact between the element
3. Nature of mechanical arrangement for complete or successful constrained between the elements.

➡ Classification based on nature of relative motion between the elements

- Sliding Pair
- Turning Pair
- Rolling Pair
- Screw Pair
- Spherical pair

Sliding Pair :-

A kinamatic pair is known as sliding pair, if the two links have a sliding motion relative to each other.

ex - piston and cylinder pair
- Rectangular rod in rectangular hole.

Turning Pair :-

A kinametic pair is known as turning pair, if one link has turning or revolving motion relative to each other.

ex - a shaft rotating in a bearing
- rotation of crank in a slider crank mechanism.

Rolling Pair :-

A kinametic pair is known as rolling pair if one link has a rolling motion relative to other.

ex - Ball and roller bearing

Screw pair :-
A kinametic pair is known as screw pair if the two links have a turning as well as sliding motion between them.
ex- nut and bolt arrangement.

Spherical pair :-
A kinametic pair is known as spherical pair if one link of the pair in the form of a sphere turn inside a fixed link.
ex- Ball and socket joints
attachment of a car mirror.

➡ Classification based on nature of contact between the elements
- Lower Pair
- Higher Pair

Lower Pair :-
A kinametic pair is known as lower pair, if the two links has a surface contact or area contact between them. Also the contact surface of the two links are similer.
ex - shaft rotating in a bearing
- Nut turning on a screw
- piston cylinder arrangement

Higher Pair :-
A kinametic pair is said to be higher pair, if the two links has a point or line contact between them. The contact surface of the two links are not similer.
ex - Ball and roller bearing
- Cam and followers

➡ Classification based on the nature of mechanical constraint:

- Closed pair
- Unclosed pair

Closed pair :-

If the elements of the pair are held together mechanically, they constitute a closed pair.

ex - all lower pair are closed pair

Unclosed pair :-

When two elements are not held together mechanically, it forms an unclosed pair. The two elements are connected together by sprung or by sprung force.

ex - cam and followers.

- Kinematic chain

➡ A kinematic chain is defined as the combination of kinematic pairs, joined in such a way that each links forms a part of two pairs and the motion of each relative to other is definite.

➡ When a number of links are connected in a a such a way that the relative motion of any point on a link with respect to any other point on the other link follows a law the chain, is called kinematic chain.

(OR) Kinematic chain is a combination of kinematic pair joined in a such a way that each kinematic link forms two kinematic pairs having completely or successfully constrained motion between them.

→ In a kinematic link no fixed links.

Mathematically we have two equation to varify the pair form a kinametic chain or not.

equation no-01

$$L = 2P - 4$$

equation-02

$$L = \frac{2}{3}(J+2)$$

where,
L = no. of Links
P = no. of pairs
J = no. of joints

If L.H.S = R.H.S (Chain is possible)
L.H.S ≠ R.H.S (chain is not possible)

Note:-
when there is no relative motion between the members (In case of Δ), it forms a structure. It can not be change.

- Mechanism
when one of the link of a kinamatic chain is fixed then the chain is known as mechanism

→ It may be used for transmitting of motion
ex- engine indicators
typewrighters

→ Mechanism are of two types

① Simple mechanism
② Compound mechanism.

Simple mechanism :-
A mechanism with four links is known as simple mechanism.

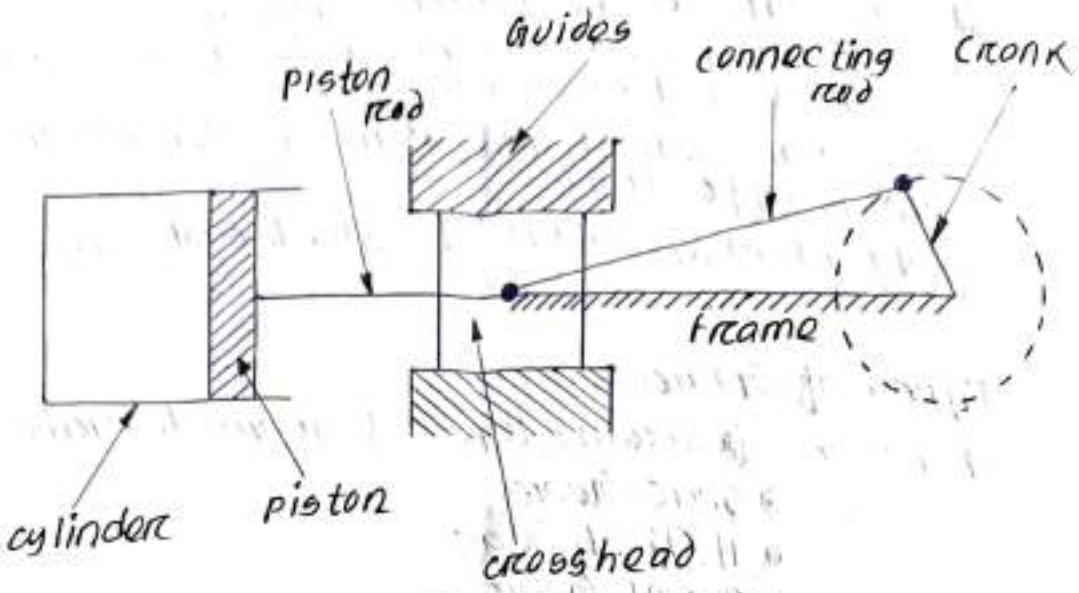
Compound mechanism :-
The mechanism with more than four links is known as compound mechanism.

Note :-
When a mechanism is required to transmit power or to do some particulerc type of work, it become a machine

● Inversion of mechanism
when we obtained different mechanism by fixing different links in a kinametic chain, It is known as inversion of the mechanism.

➡ Slider crank mechanism
A slider crank chain is a modification of the basic four bar chain. It consists of one sliding pair and three turning pairs.
ex- Reciprocating steam engine mechanism

Some important inversion of slider crank chain are -
① pendulum pump
② oscilating cylinder engine
③ Rotary IC engine
④ Crank and slotted lever quick return mechanism.
⑤ whitworth quick return motion mechanism.



Single slider crank chain

- **Gear Drives**

A gear is a wheel provide with tooth which mess with the tooth on another wheel or on to a rack, so as to give a positive transmission of motion from one component to other.

➡ The gear is defined as the toothed element which is used for transmitting rotary motion from one shaft to another.

→ Gears are used for power transmission or for changing the power-speed ratio.

→ They are used for transmitting motion and power from one shaft to another when they are not too far apart and when a constant velocity ratio is desired.

Advantages of toothed gearing

① High efficiency
② Long service life
③ High reliability
④ More compact
⑤ Can operate at high speed
⑥ Large power can be transmitted

Disadvantages of toothed Gearing

① special equipment and tools are required to manufacture the gears.
② When one wheel gets damaged the whole set up is affected.
③ Noisy in operation at considerable speeds.

Types of Gears

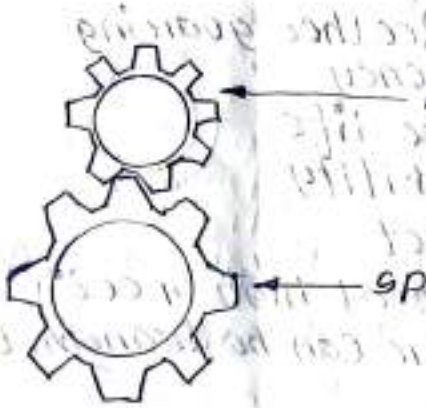
There are following types of gears described below.

- Spur Gear
- Helical Gear
- Bevel Gear
- Worm Gear
- Rack and pinion Gear

- **Spur Gear :-**

A spur gear is a gear wheel or pinion for transmitting motion between two parallel shafts.

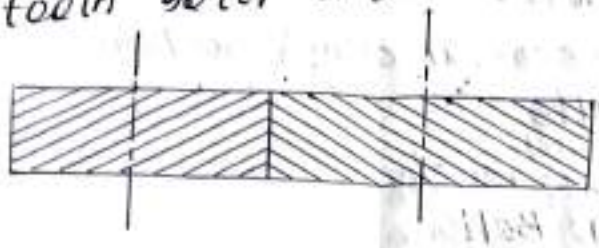
→ This is the simplest form of gear drive.
→ The efficiency of power transmission by these gears are very high.
→ The disadvantages of these gears are that they are more noisy in operation.



- **Helical Gear :-**

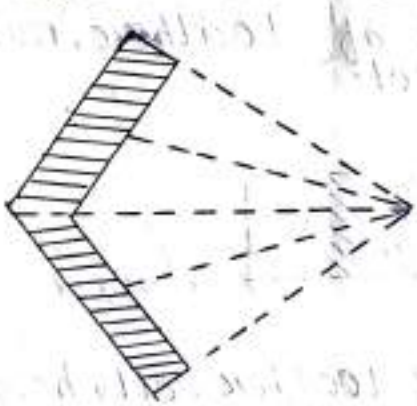
The helical gear is one which tooth instead of being parallel with shaft as in ordinary spur gear, are inclined. This ensures smooth action and more accurate maintainance of velocity ratio.

→ A disadvantages is that the inclination of the tooth setup a lateral thrust.



- **Bevel Gear :-**

A bevel gear transmit motion between two shafts which intersheped. If the shafts are at right angles and wheels are equal in size, they are called mistre gears. If the shafts are not at right angles they are called angled bevel gears.



- **Worm Gear :-**

Worm gears connect two non-parallel, non-intersecting shafts which are usually at right angles. One of the gears is called the worm. It is machined with the teeth on a gear wheel, called the worm wheel.

→ The advantages of worm gearing, there is high gear ratios (it is the ratio of rotational speed of the work to that of worm wheel)

→ worm gearing is smooth and quite.

Belt and Belt Drives

A belt is a continuous band of flexible material passing over pulleys to transmit motion from one shaft to another.

There are various type of belts.

① with a narrow rectangular cross-section
Flat Belts

② with a trapezodial cross-section
V belts

③ Round cross-section
Round Belts

→ Flat Belts

Flat belts are used for their simplicity and because they are subjected to minimum bending stress on the pulleys. The load capacity of flat belts varies with their width.

→ They are made off leather, rubber, textile balata and steel.

→ **Leather Belts** :- Leather belts have the best pulling capacity. Because of the high cost of leather they are used very rarely.

→ **Rubber Belts** :- Rubber belts are made of rubber on a cotton-duck base are used where the belts is exposed to weather or steam, as they do not absorb moisture so easily as leather.

→ **Textile Belts** :- Textile belts are made of cotton and are used for rough and short service.

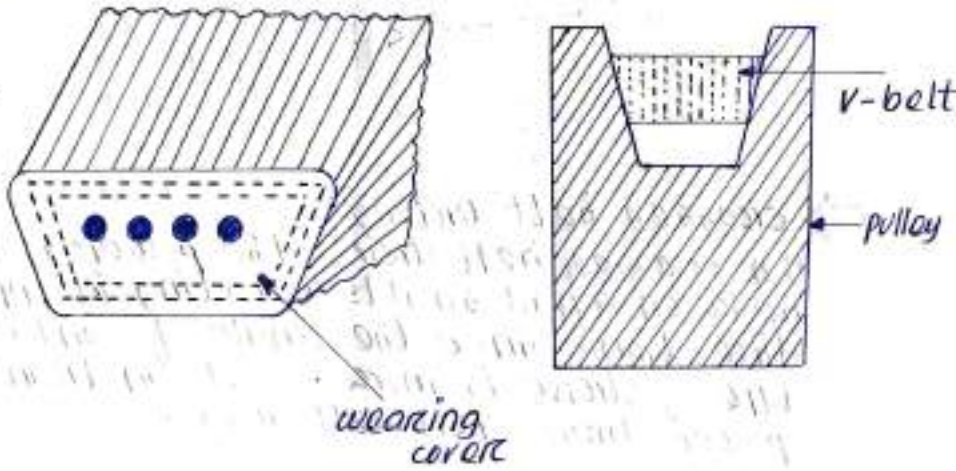
→ **Balata Belts** :- Balata belts are acid and water proof and can not withstand temperature higher than 100°C.

➡ Steel Belts :- Steel belts are claimed to transmit more horse power per cm width and to remain unaffected by heat and immune from stretching and slipping.

➡ V-Belts

A v-belts is a belt of trapezodial section running on a pulleys with grooves cut to match the belt. The normal angle between the sides of the groove is 40 degree.

→ V-belts are usually made of fabric coated rubber.
→ They are used when the distance between the shafts is too short for flat belt drives.
→ V-belts are less likely to slip, hence more power can be transmitted for the same belt tension.



➡ Round Belts

Round belts are employed to transmit low power. mainly in instruments, table type machine tools, machinary of clothing industry and house hold appliances.

→ They are made off leather, canvas and rubbers.
→ The diameter ranges from (3-12) mm

• Belt Drives

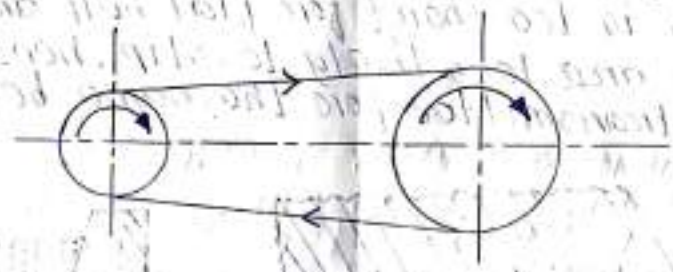
A belt drives consists of the driving and driven pulleys and the belt which is mounted on the pulleys with a certain amount of tension and transmits peripheral force by friction.

→ Belts drives are of two types

- open belt drive
- cross belt drive

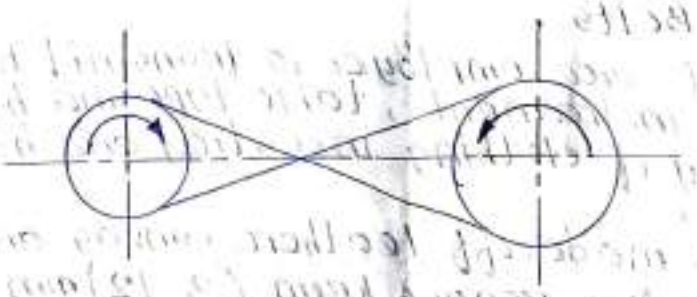
⇨ open belt Drives

open belt drives are applied between parallel shafts which rotates in the same direction. Here the belt is subjected to tension and bending.



⇨ crossed belt Drives

In crossed belt drives the power is transmitted between small shafts rotating in opposite direction. Since the angle of contact in this type of drive is more, so it can transmit more power than open belt drives.



Application of Belt Drives

① To transmit power from low or medium capacity electric motors to operative machines.
② To transmit power from small prime movers (IC engines).
③ The electrical generators, agricultural and other machinary.

• Bearings

→ A bearing is a device which supports, guids and restrains moving elements.
→ The material used for bearing is commonly castiron for low speeds or slow speeds, bronze or brass lining being fitted or higher speed.
→ The main function of the bearing is it reduces the friction between the moving parts.

➡ classification of Bearing

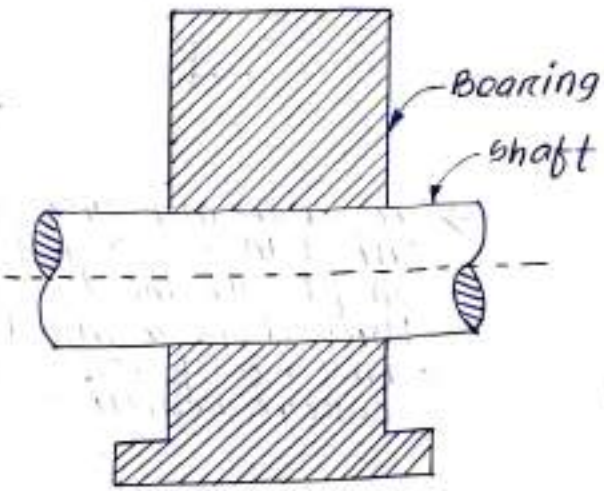
Bearing may be classified as
- Plain Bearing
- Ball and roller Bearing

• Plain Bearing

The plain bearings are classified as three catagories
(i) Journal Bearing
(ii) Pivot Bearing
(iii) Collar and thrust Bearing

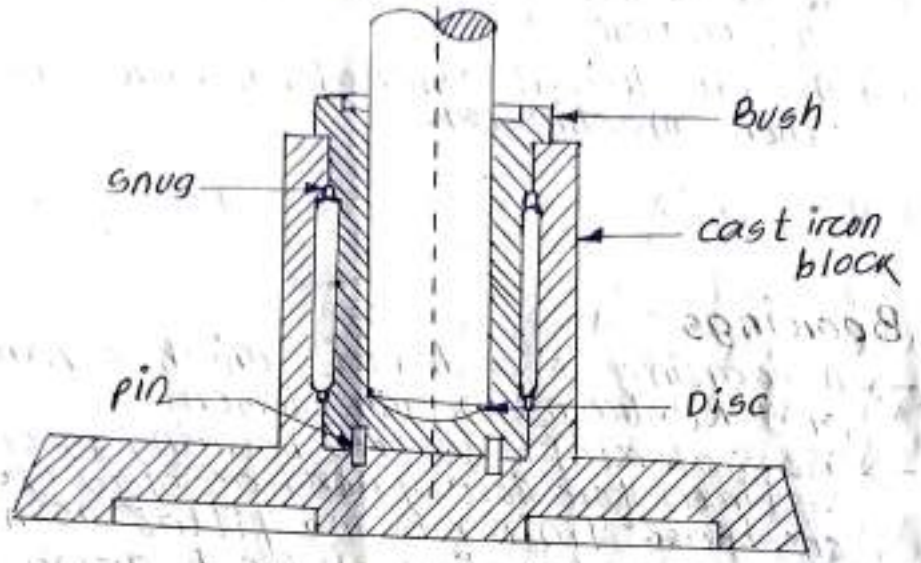
(i) Journal Bearing

A journal bearing in which the bearing pressure is perpendicular to the axis of the shaft. The portion of the rotating elements which is in contact within the bearing is called as journal.



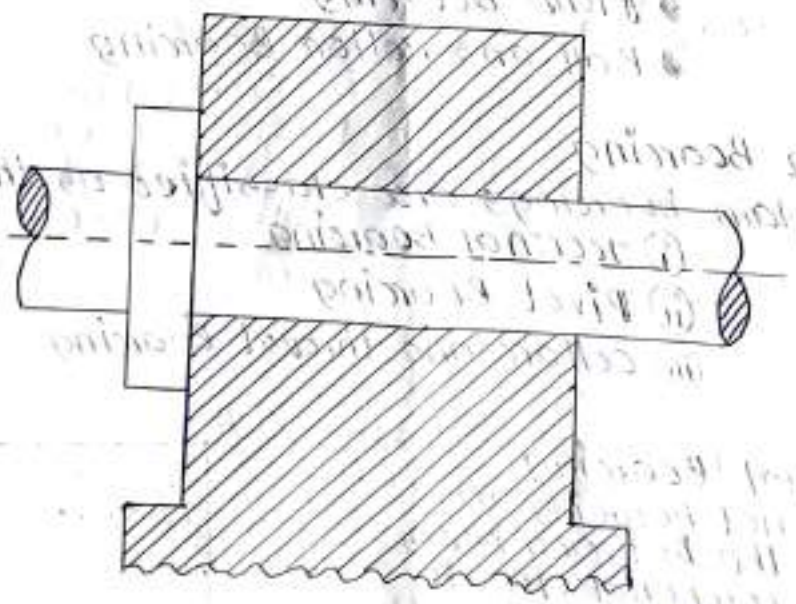
(ii) Pivot Bearing

A pivot bearing is one in which the pressure is parallel to the axis of shaft and the end of the shafts rests on the bearing surface.



(iii) Collar Bearing or thrust Bearing

In collar bearing the pressure is parallel to the axis of shaft, which is passed and extended through the bearing.



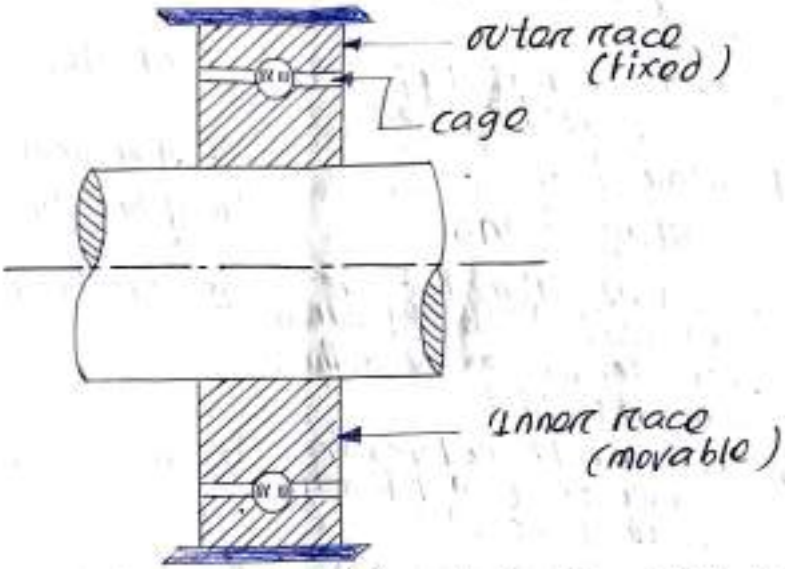
→ The bearings are employed are used to take unbalanced axial loads on the horizontal shafts. If the load is light, a single collar thrust bearing is used.

→ In case of large / heavy loads multiple collar bearings are used.

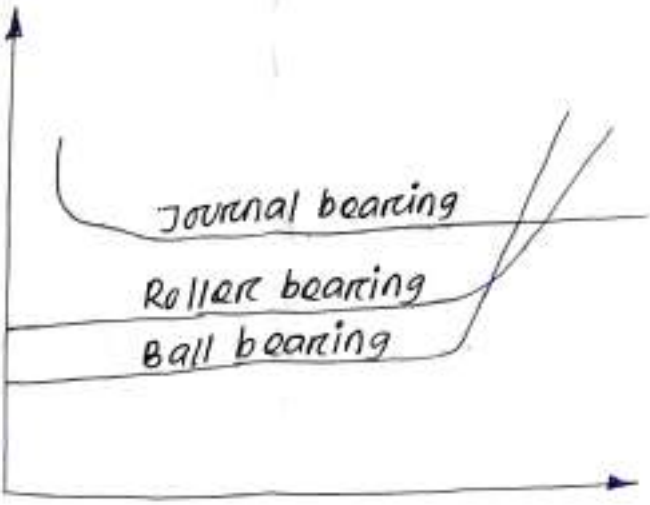
- **Ball and Roller Bearing**

→ Ball and roller bearings are also known as rolling contact bearings or rolling element bearing or antifriction bearings. This is because the bearing elements are act as an rolling contact.

→ The ball and roller bearings are suitable at moderate speed but at high speed it is found that a properly designed and lubricated journal bearing has less friction.



→ In case of ball and roller bearing the coefficient of friction varies little with loads and speeds, except at extreme values, this property makes the ball and roller bearings extremely suitable for machines that are started and stoped frequently.



Uses of Bearings

Sl No	Equipment	Bearings
01.	High HP motors, generators and alternators whose shaft are horizontal and have no thrust (end pressure)	Journal Bearings
02.	High HP electrical machines with horizontal shafts and having end thrust.	Thrust or roller bearings
03.	Turbo generator sets with vertical shaft.	Foot step or pivot bearing
04.	Table fans	Ball bearing (radial type)
05.	Ceiling fans	Ball bearing (thrust type)
06.	Medium HP motors or generator (shaft with horizontal axis without end thrust)	Roller bearing (radial type)
07.	Medium HP motors or generators (shaft with vertical axis)	Roller bearing (thrust type)
08.	Medium HP motors and generators (shaft with horizontal axis and having end thrust or shafts placed in an inclined position)	Roller bearing (tapered type)

- **Electrical Actuator**
  An actuator receiving electrical energy for motion is called electrical actuators.

Electrical actuators systems include the following

→ Switching Devices → Drive system

Switching Device
- ① Mechanical switches
  - solenoids
  - Relays
- ② solid state switches
  - Diodes
  - Tyristor
  - Transistors

① Mechanical switches

→ Mechanical switches are the lolements which are often use as sensors to give input to the system.

ex- Keyboard.

→ Mechanical switches are those where in switching action is by the application of force on the switch and during switching action mechanical elements move with the switch.

→ The switches consists of one or more pair of contacts which are mechanically closed or opened.

• Solenoids

A solenoids is a type of electromagnet which purpose is to generate a controlled magnetic field through a coil wound into a tightly packed helix.

→ The coil can be arranged to produce a uniform magnetic field when a electric current is passed through it.

→ A solenoids consists of a coil and a movable iron core called the armature.

→ When the current is passed through the coil it gets energized and consequently (or ultimately) the core moves to increase the flux linkage by closing the air gap between the cores.

→ The force generated is approximately proportional to square of the current and inversely proportional to square of the width of the air gap.

Mathematically,

$$F \propto I^2$$

$$F \propto \frac{1}{w^2}$$

$$\Rightarrow F \propto \frac{I^2}{w^2}$$

$$\Rightarrow F = K \frac{I^2}{w^2}$$

where, F = force
I = current
w = width of the air gap
K = constant

- Advantages:
→ Solenoids are inexpensive
→ Solenoids are easily available.

- Uses:
→ Solenoids are used as electrically operated actuators.
ex- It is used to control fluid flow in hydraulic or pneumatic system.
- used in home appliances that is washing machine valves.
- Automobiles
- factory automation
- pinball machine.

- Relays
Relays are electrically operated switches in which changing circuit in one electricall circuit switches a current on or off in another circuit.
→ Relays are often used in control system.
→ Relays are used in power switches and electromechanical control elements.
→ A relay performs a function similar to a power transistor switch circuit but has the capability to switch much larger currents.

- Disadvantages
→ The disadvantages of relay is that they have slower switching timing than transistor.

- DC motor
→ DC stands for direct current.
→ DC motors find wide applications in a large number of mechatronics design because of the torque-speed characteristics achievable with different electrical configurations.
→ The speeds of the DC motor can be smoothly controlled and in most cases are reversible.
→ These motor can respond quickly since they have a high ratio of torque to rotor inertia

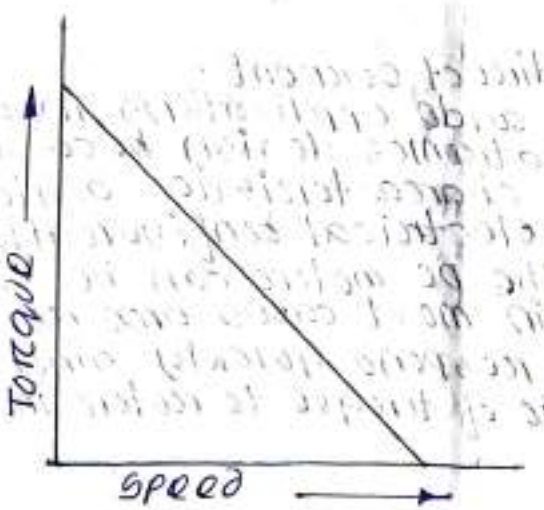
Note:-
→ torque
unit = N-m

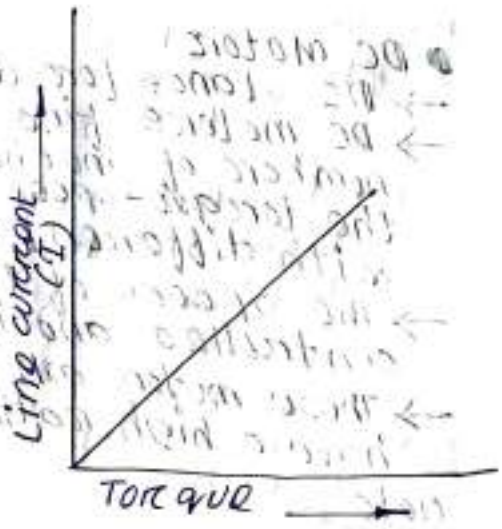
→ rotor inertia
The tendancy of a body to resists changes in rotational speed for a given torque.

→ Dynamic breaking and regenerative breaking can be implemented in applications where quick stops and high efficiency are desired.

Note :-
- Dynamic breaking – when the motor generated energy is fed to a resistor dissipater.
- Regenerative breaking – where the motor generated energy is fed back to the DC power supply.

*permanent magnet DC motor
→ It is the type of DC motor that uses a permanent magnet to create the magnetic field required for the operation of a DC motor.
→ A PMDC motor is lighter in weight and smaller than others equivalat DC motor, because the field strength of permanent magnet is high.
→ PMDC motor has easily reversed by switching the direction of the applied voltage, because the current and the field (magnetic field) can change direction only in the rotor.





- Application of PMDC motor

① The PMDC motor is ideal in computer control application because of the linearity of its torque-speed relation.

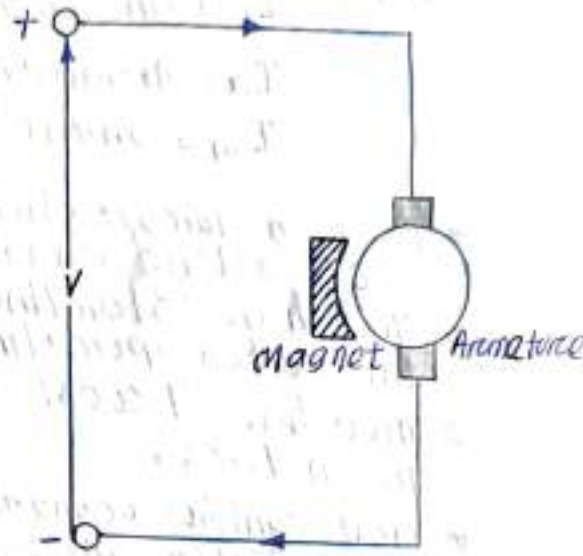
② When a motor is used in a position or speed control application with sensor, feedback to a controller, it is referred as a 'servo motor'.

③ They are commonly used in automobiles, windshield wipers, washers, blower used in heater and air conditioners, to raise an lower window etc.

- Advantages

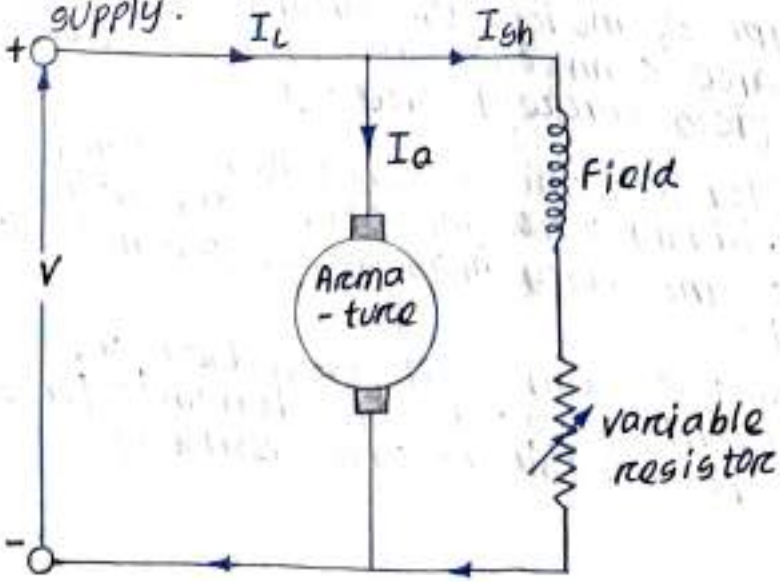
As compared to rest of motors the PMDC motor is

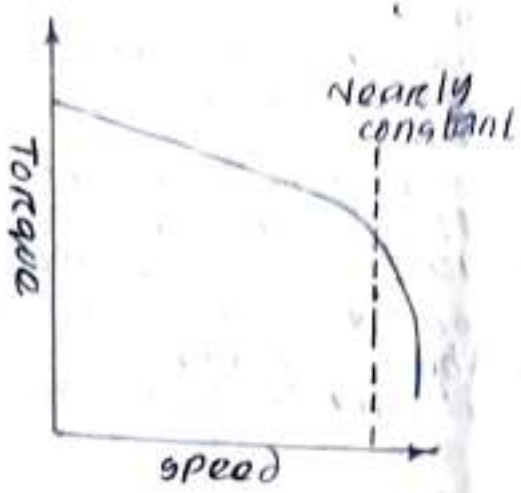
(i) more efficient.
(ii) more reliable.
(iii) more compact.

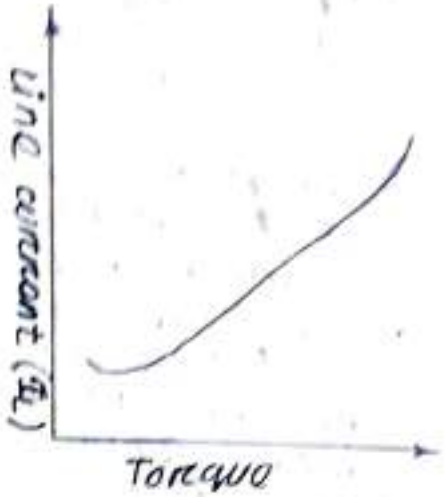


* DC shunt motor

In this motors the armature and field windings are connected parallel and powered by the same supply.







where. I_L = line current ($I_a + I_{sh}$)

I_a = Armature current

I_{sh} = shunt current

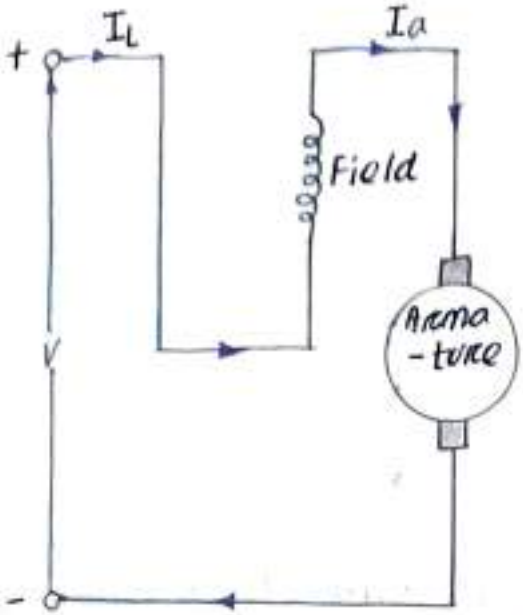
- These motors exhibit nearly constant speed over a long range of loading.
- They have starting torques about 1.5 times the rated operating torque.
- They have lowest starting torque of any of DC motors.
- They can be economically converted to allow adjustable speed by placing a potentiometer in series with the field winding.

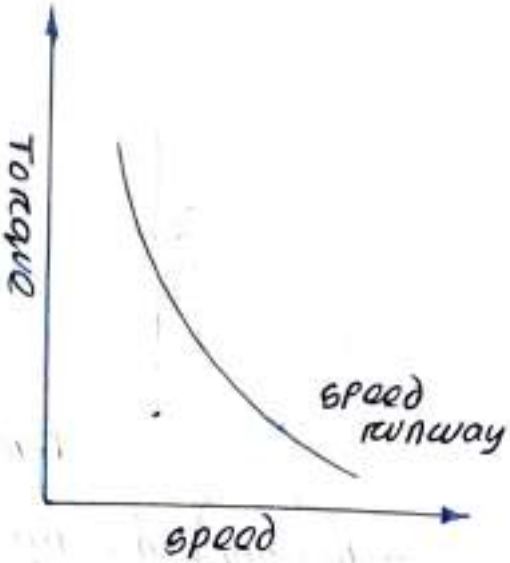
* DC series motor

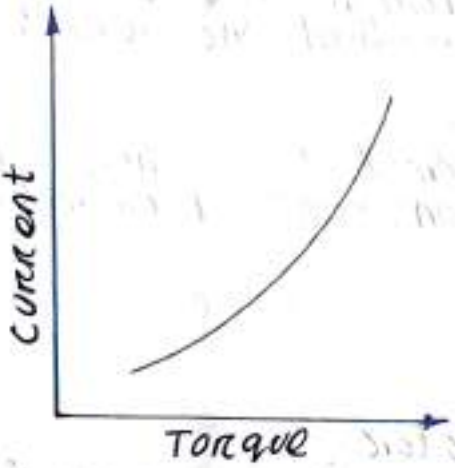
In this type of motor the armature and field winding are connected in series so the armature and field current are equal.

→ These motors exhibit very high starting torque, highly variable speed depending on the load and very high speed when the load is small.

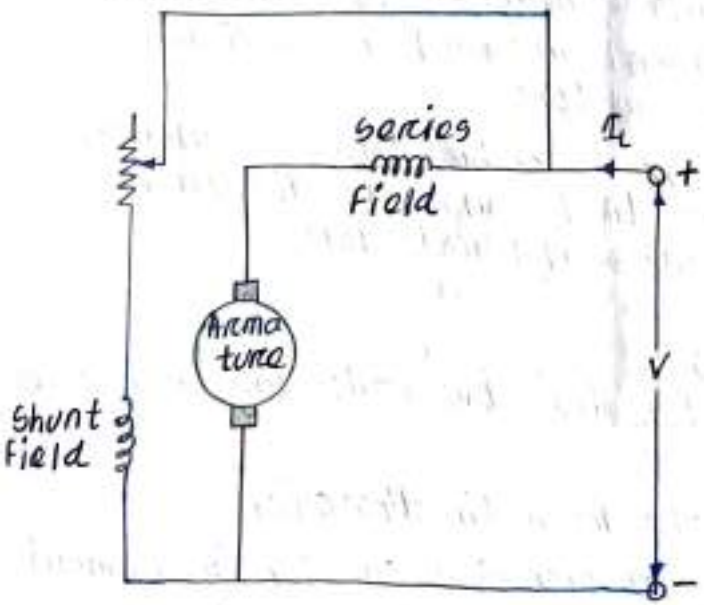
→ These motors can fail when they are suddenly unloaded, due to dynamic forces at high speed, this is called runway

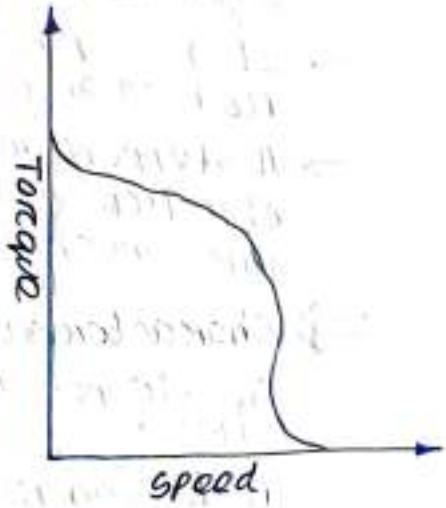


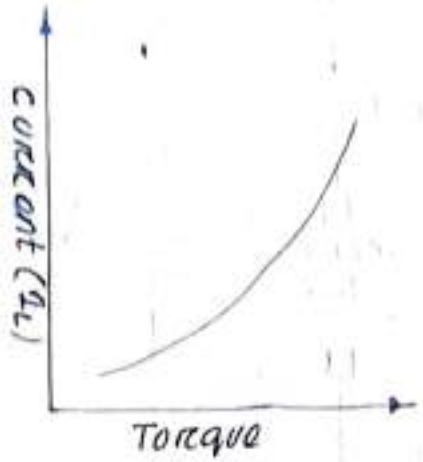




* DC compound motors







→ A compound D.C motor connects the armature and fields windings in a shunt and series combination to give it the characteristics of both a shunt and series DC motor.

Advantages

→ This motor is good when both a high starting torque and good speed regulation is needed.

- stepper motor

→ A stepper motor is a special type of DC motor, which converts electrical power into mechanical power.

→ It is also defined as the motor that divides a full rotation into a number of equal steps.

→ It is a permanent magnet or variable reluctance DC motor.

→ A stepper motor is a brushless, synchronous electric motor that converts digital pluses into mechanical shaft rotation.

⇨ characteristics

The stepper motor has the following characteristics.

(i) It can rotate in both direction.

(ii) It can more in precise angular increments.

(iii) It can sustain a holding torque at zero speeds.

(iv) It can be controlled with digital circuit.

→ A stepper motor moves in accurate equal angular increments, known as steps, in response to the application of digital pulse to an electric drive circuit. The number and rate of the pulse control the position and speed of the motor.

→ Generally stepper motors are manufactured with steps per revolution of 12, 24, 72, 144, 180 and 200, resulting shaft increment of 30°, 15°, 5°, 2.5°, 2° and 1.8° per steps. Special micro-stepping circuitry can be designed to allow many more steps per revolution, often 10000 steps/revolution or more.

→ The stepper motor is used in digitally controlled position control system in open loop mode. The input command is in the form of train of pules to turn a shaft through a specified angle.

→ stepper motors are either bipolar, requiring two power source of a switchable polarity power source, or unipolar, requiring only one power source. They are powered by DC sources and requires digital circuitry to produce coil energising sequences for rotation of the motor.

→ Feedback is not always required for control but the use of an encoder or other position sensor can ensure accuracy when exact position control is critical.

→ Generally, steper motors produce less than 1HP and are therefore used only in low power position control application.

⇨ Construction and working

→ A stepper motor consists of a slotted stator having multiple-pole, multiphase winding and a rotor structure carrying no winding.

→ The typical use of three and four phase winding, the number of poles depends upon the required angular change per input pulse.

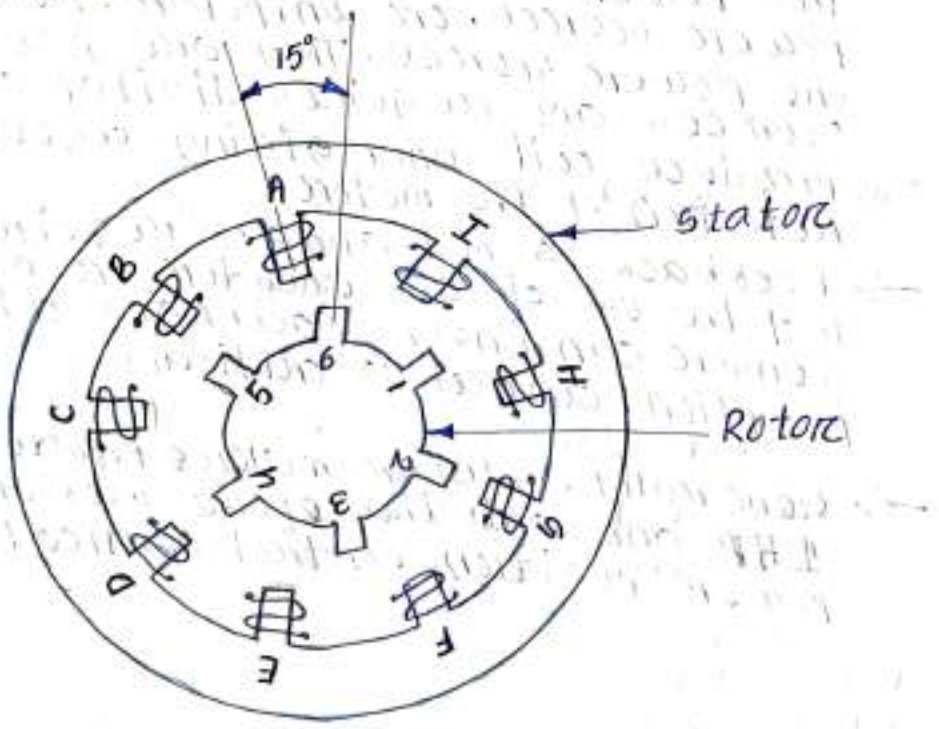
→ The rotor may be of the permanent magent or variable reluctance type.

→ stepper motors operates with an external drive logic circuit.

→ when a train of pulse is applied to the input of the drive circuit, the circuit supplies current to the stator winding of the motor to make the axis of the air-gap field around in coincidence with the input pulses.

→ The rotor follows the axis of the air-gap magnetic field by virtue of the permanent magnet torque.

→ A magnet interaction takes place in between the rotor and the sensor, which makes the rotor more.



Servo Motor

The term servo motor refers to the feedback control system which the controlled variable is
- mechanical position
- Time derivatives (velocity and acceleration)

→ There are two types of servo motors.
1. DC servo motor
2. AC servo motor

DC servo motor

→ These motors are performed for very high power systems, since they operate more efficiently as compared to AC servo motors.

→ These motors are of the following types.
- (a) series motors
- (b) split series motors
- (c) shunt control motors
- (d) permanent shunt magnet motors.

➡ Series motors

→ These motors have high starting torque.
→ It draws a large current (I).
→ The speed regulation is poor.
→ Reversal can be obtained by reversing field voltage polarity.

➡ Split series motor

→ The DC series motor with split field may be operated as a separately excited field control motor.
→ The armature may be supplied from a constant current source.

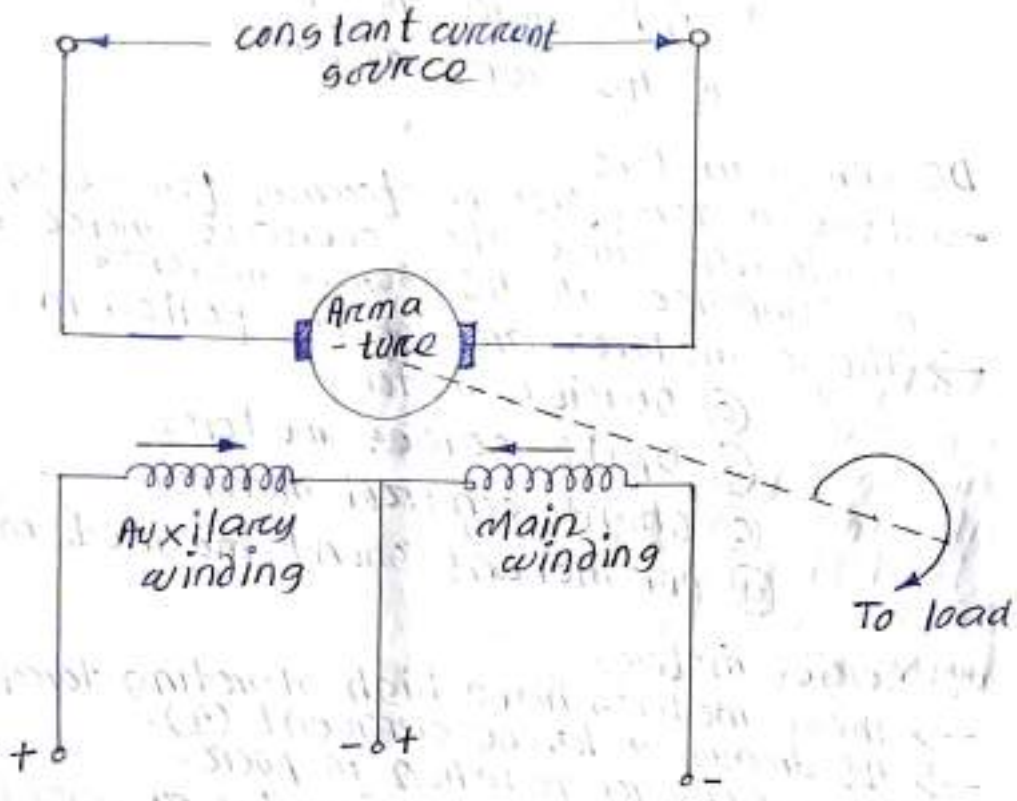
➡ Shunt control motors

→ The type of motor has two separate windings. field winding placed on the stator and the armature winding placed on the rotor of the machine. Both the windings are connected to a DC supply source.
→ where as in a conventional DC shunt motor two windings are connected in parallel across the DC supply mains.

➡ Permanent magnet shunt motor

→ It is a fixed exitation shunt motor where the field is actually supplied by a permanent magnet.

→ Its performance is similar to that of the armature controlled fixed field motor.



AC servo motors

Application :-

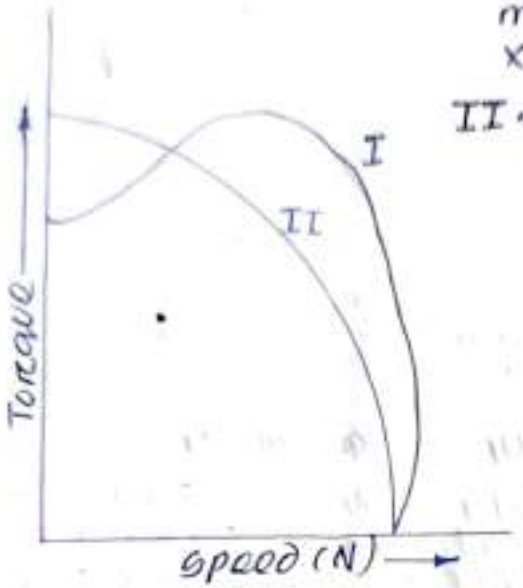
→ These motors are best suited for low power applications.

→ PRECISION servo-motors are used in
- instrument servos
- computers
- Inertial guidance system etc.

→ The mechanical output power of AC servomotor varies from 2 watts to a few hundred watts.

→ An A.C servomotor is basically a two-phase induction motor except for certain special design features. The main important difference between a standard split phase motor and AC servo motor is that the latter has thinner conducting bars in the squirrel cage motor.

so that the motor resistance is higher. The torque-speed characteristics should be linear



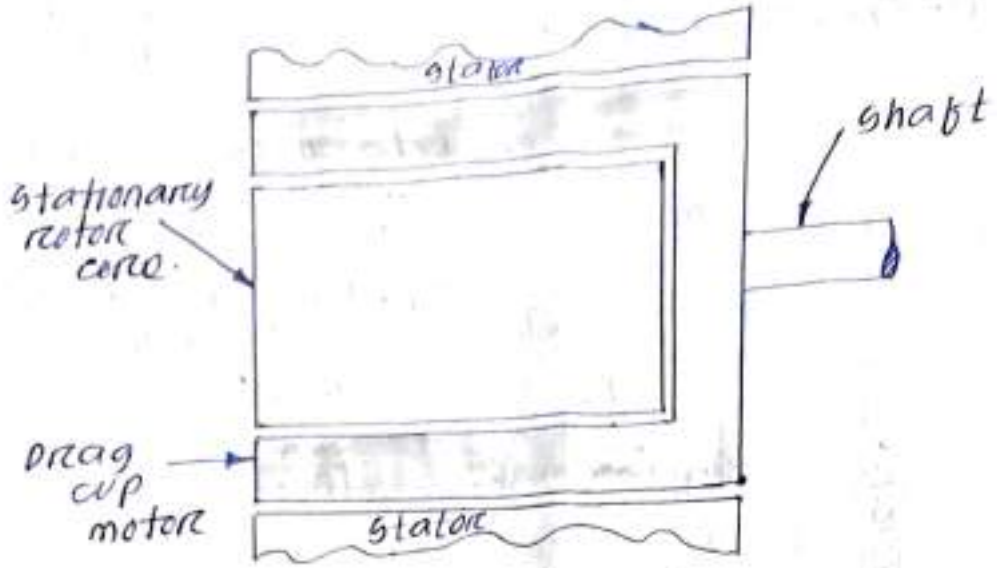
I. For normal-split phase motor or with large X/R ratio.

II. For servo motor or with small X/R ratio.

Description of A.C servo motor

1. Drag Cup rotor servo motor

- Drag-cup construction is used for very low inertia application.
- In this type of motor the rotor construction is usually of squirrel cage or drag cage type: here only a light cup rotates while the rotor core is stationary.
- The servo motor contains two winding namely main winding (sometimes called fixed or reference winding) and control winding. The voltage applied to the winding are right angles to the one another. Usually one winding is excited with a fixed voltage while the other one is excited by the control voltage.
- While the operation, the output torque of the motor is roughly proportional to the applied control voltage and the direction of the torque is determined by the polarity of the control voltage.



2. Shaded pole type servo motor

- The type of motor employes a phase-sensitive relay to activate those contacts which produce a short circuit of the shaded-pole winding to produce rotation in the desired direction.
- The main short coming of this motor is that is responds only when the amplifier error signals is of adequate to cause the relay to operate.

UNIT-05 ELEMENTS OF CNC MACHINES

- **Introduction**

→ Now a machine tools have been built to absorb new machining technology.

→ The new technology includes
- ultrasonic machining (USM)
- electro chemical machining (ECM)
- laser beam machining (LBM)

→ Numerically controlled (NC) machine tools are highly flexible and are economical for producing a large number of parts.

→ Numerical control. NC can be simply controlled by numbers.

→ A machine tool having a dedicated computer to help prepare the program and control some or all of the machine tool operation is called computer numerical control (CNC) machine tool.

⇨ **N.C machines**

'A system in which actions are controlled by the direct insertion of numerical data at some point. The system must automatically interpret at least some portion of this data.'

→ In NC machines, the input information for controlling the machine tool motion is provided by means of punched tape or magnetic tapes in a coded language.

Working of NC machine tool

→ The first two steps, component drawing and process planning are similar in both operator controlled and NC machine tools.

→ In the operator controlled machine tools, the operator controls the cutter position during manufacture and also makes necessary adjustments and corrections to produce the desired component.

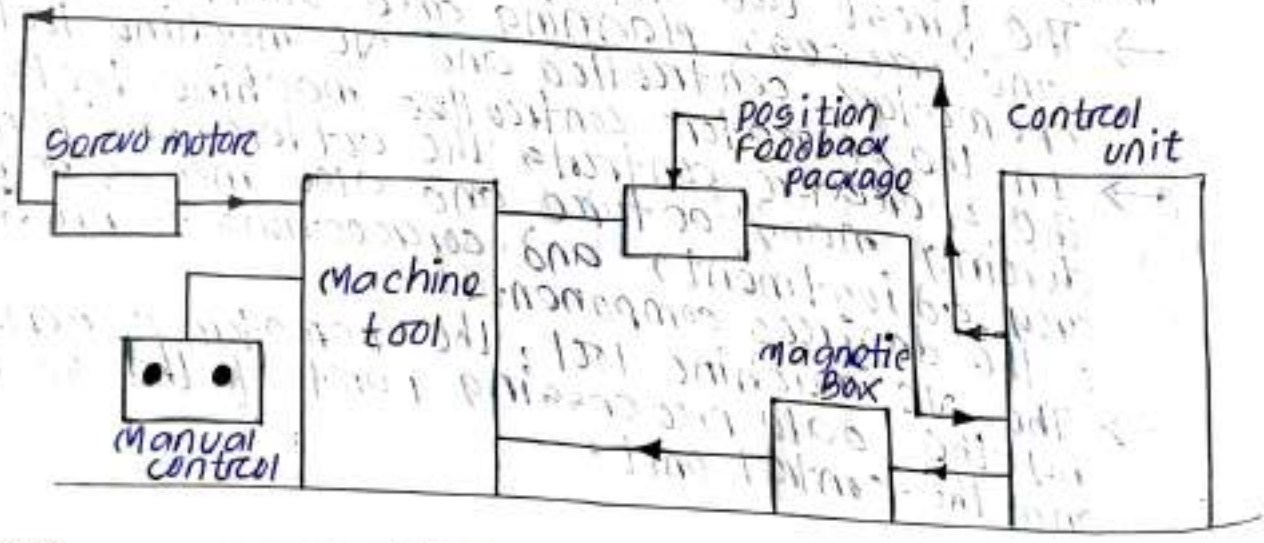
→ The NC machine tool, the operator is replaced by the data processing part of the system and the control unit.

→ In the data processing unit, the co-ordinate information regarding the component is recorded on a tape by means of a tele printer.
→ Tape is fed to the control unit which sends the position command signals to slideway transmission elements of the machine.
→ At the same time, time command signal is constantly compared with the actual position achieved, with the help of position feedback signal derived from automatic monitoring of the machine tool slide position.
→ The difference in two signals, if any, is corrected until the desired component is produced.

Elements of NC machine tool

The main elements of a NC machine tool are:

1. The control unit
2. The drive units
3. The position feedback package
4. Magnetic Box
5. Manual control.



- The Control unit
  → In the control unit, a tap recorder reads the instruction (written in a coded language) for manufacturing the components.

- The Drive unit
  → The instruction under the electronic processing and the control units sends command signals to the drive units of the machine tool and also to the magnetic box (Electrical control cabinate). Command signals sent to the drive unit of the machine tool, control the length of the travel and feed rates, while the command signals sent to the magnetic box control other functions such as spindle motor starting and stoping, selecting spinde speeds, actuation of tool change, coolant supply etc.

- The position feedback package
  → A feedback transducers provided in the machine tool checks whether the required lengths of travell have been obtained. It sends the information of the actual position achieved to the control unit. In case there is any difference between the input command signals and the actual position achieved.

- Manual Control
  → The main control provided in the machine tool asists the operator to perform some function manually such as motor start-stop, speed change, feed change, suitable axes movements, coolant supply etc.

Classification of NC machine
The NC machines are classified as follows.
A. According to control system
① point to point system
The machining is done at specific positions
ex - Drilling machine operations.
② straight line system
It is an extension of point to point system.
ex - speed turning on lathe
pocket milling etc.

③ Contour system
There are continuous, simultaneous and co-ordinated motions of the tool and workpiece along different coordinate axes.
ex- machining of profiles
contours and curved surface.

B. According to feedback
① Open loop system
There is no 'feedback' and no return signals to indicate whether the tool has reached the correct position or at the end of the operation or not.
ex- co-ordinate drilling machine.

② Closed loop system
A feedback is built into the system, which automatically monitors the position of the tool.
→ It is more expensive than an open loop system.

Application of NC machines

The major applications of NC machine are.
① Complex parts
② parts which are frequently subjected to design changes.
③ Repetitive and precision quality parts which are to be produced in low to medium batch quantity.
④ To cut down lead time manufacture.
⑤ widely use in press working, Automatic drafting, metal cutting, spot welding etc.

UNIT-06 ROBOTICS

- Definition

Robotics is the art knowledge and known how of designing, applying and using robots in the human endeavors.

'or'

"Robotics is the science of designing and building robots suitable for real-life applications in automated manufacturing and other non-manufacturing environment".

→ Robotics is the interdisciplinary subject that benifits from number of engineering fields
- mechanical engineering.
- electrical engineering.
- electronics engineering
- computer engineering
- and several other engineering fields

→ The main advantages of Robots are
* Reliability
* Increased flexibility
* Low cost in the long run.

- Laws of Robotics

There are four laws of robotics.

① zeroth law
A robot must not harm humanity, or through inaction, allow humanity to come to harm.

② 1st law of Robotics
A robot must not harm a human being or through inaction allow one to come to harm.

③ 2nd law of Robotics
A robot must always obey human being unless it is in conflict with a higher order law.

④ 3rd law of Robotics
A robot must protect itself from harm unless that is in conflicts with a higher order law.

- Robot

→ Robot is an automatic device that performs functions normally ascribed to humans or a machine in the form of a human.

→ A robot is a software control level mechanical device that uses sensors, to guide one or more end effectors through preprogrammed motion in a workpiece.

- Types of Industrial Robot

There are two types of industrial robot.

① General purpose robot

② special purpose robot.

① General purpose robot

→ These robots carry standard design and parts and are readily available.

→ They can be easily adapted to the users requirement by attaching suitable end effectors or fingers to them according to the requirement of the work, such as a part picking operation, welding operation, spray painting etc.

→ since such robots are mass produced they are cheaper.

② special purpose robot

→ These robots are made to specific job requirements.

→ The ultimate user has to feed his requirement and based on them, these robots are specially designed and built to fulfil the specific needs.

→ The designing and manufacturing of these robots consumes a lot of time, therefore they can not be readily available in the market.

→ since they can not be manufactured on a mass scale, the price of these robots are bound to be higher.

- Advantages and Disadvantages of Robots

➡ Advantages

① Lifting and moving heavy objects
② working in hostile environments.
③ providing repeatability and consistency.
④ working during unfavourable hours.
⑤ performing dull or monotonous jobs.
⑥ Increasing productivity, safety, efficiency, and quality of products.
⑦ Achieving more accuracy than human being

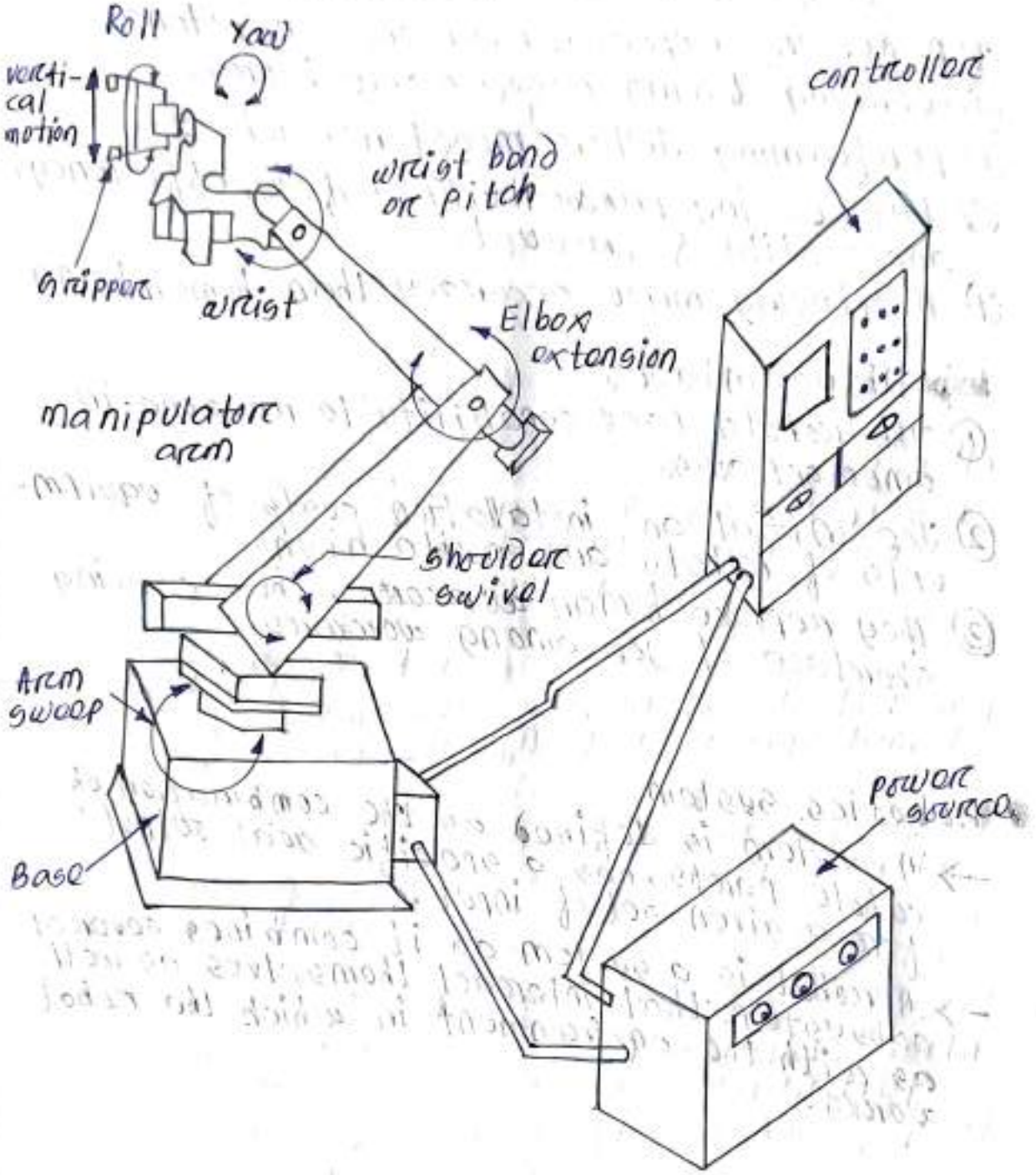
➡ Disadvantages

① The robots lack capability to respond in emergencies.
② The initial and installation costs of equipments of robots are quite high.
③ They replace human workers, thus causing shortage of job among workers.

- Robotics system

→ A system is defined as the combination of whole parts, has a specific goal output for a given set of input.

→ A robot is a system as it combines several subsystem that interact themselves as well as with the environment in which the robot works.


Roll
Yaw
vertical motion
wrist band or pitch
controller
gripper
wrist
Elbow extension
manipulator arm
shoulder swivel
Arm swoop
Base
power source

Component of Robots

There are many components of robot. Those are listed below.

① Base
② Manipulator arm
③ End-effector
④ Actuators and transmissions
⑤ Controller
⑥ Sensors.

① Base

→ The base may be fixed or moveable.

② manipulator arm

→ The most obvious mechanical configuration of the robot is the manipulator arm.

→ There are several design of the arm to facilitate movement within the work envelope with maximum possible load and speed with high precision and repeatability

→ The simplest robot may be a good two or three-axes arm. The axis is meant to understand independent movement or degree of freedom.

→ A robot manipulator arm consists of several separate links making a chain. The arm is located relative to the ground on either a fixed base or a moveable base. It has a free end where an end deflector or gripper or sometimes a specialised tool holder or any powered device is attached.

③ End deflector

→ Robot end deflector is the grooper or the end of arm tooling mounted on the wrist of the robot manipulator arm.

→ A robot performs a variety of tasks for which various tooling and special grippers are required to be designed.

→ Robot manupulator is flexible and adaptable but its end deflector is task-specific.

④ Actuators and transmissions

➡ Actuators

→ The robot arm can be put to a desired motion with its payload if actuator modules are fitted into provide power drives to the system.

→ Basically there are three types of power drives.

① Pneumatic drives

→ Those system used compressed air to move the robot arm.

→ The pneumatic system may employ a linear actuator i.e. double acting cushioned cylinders or it may employ rotary actuator like vane motors.

② Hydraulic drives

→ In a hydraulic system, the electric motors pump fluid (oil) from a reserve tank to the hydraulic actuators.

→ The hydraulic drives have high payload capacities and are relatively easy to maintain.

③ Electrical drives.

→ Those drives are clean and quite with high degree of accuracy and reliability.

→ They also offer a wide range of payload capacity.

→ Some of the important electrical drives are, DC servo motors, reversible AC servo motors, and stepper motor

➡ Transmission

→ Transmissions are the elements between the actuators and the joint of the mechanical linkage.

⑤ Controller

The controller provides the intelligence that is necessary to control the manipulator system.

→ It generally includes

① memory to store the control programme
② Hardware for a user interface.
③ The appropriate hardware to interface with the external world.

⑥ Sensors

→ The sensors performs the following functions
(i) To act as feedback device to direct further actions of the manipulator arm and the end effector (gripper)
(ii) To interact with the robot's working environment.

→ Usually there are two types of sensors.

- Tactile sensors
- Non-tactile sensors.

Tactile sensor

These are contact sensor that must be brought in contact with the object to be obtain signals to measure the necessary qualities.

→ There are four types of contact sensors. that are

ⓐ Force sensors
ⓑ Torque sensors
ⓒ Touch sensors
ⓓ position sensors.

Non-tactile sensors

→ Those are contactless sensors which senso the signals remotely by-I only within the specified range of distance from the object

→ They detect and measure magnetic fields, infrared, ultraviolet light, x-ray, electrical fields etc.

→ Types of non-tactile sensors that a robot includes are

ⓐ Proximity sensors
ⓑ Electro-optical sensors
ⓒ Range imaging sensors

UNIT-04 PROGRAMMABLE LOGIC CONTROLLERS (PLC)

Introduction

→ A programmable logic control (PLC) is an industrial grade computer that is capable of being programmed to performed control functions.

→ The PLC has elemenated much of the hard-wiring associated with conventional relay control circuits.

→ other benifits include easy programming and installation, high control speed, network compatibility, troubleshooting and testing convenience and high reliability.

→ The PLC is designed for multiple input and output arrangements, extended temperature ranges, immunity to electrical noise and resistance to vibration and impact.

→ programs for the control and operation of manufacturing process equipment and machinary are typically stored in battery-backed or nonvolatile memory.

→ A PLC is an example of real-time system since the output of the system controlled by the PLC depends on the input conditions.

→ The PLC is then basically a digital computer designed for use in machine control.

→ unlike a personal computer, it has been designed to operate in the industrial environment and is equipped with special input and output interface and control programming language.

→ It is capable not only of performing relay switches tasks but also of performing other applications such as timing, counting, calculating, comparing and processing a analogue signals.

- Advantages of PLC
  1. Increased Reliability.
  2. Lower cost.
  3. Good communications capability.
  4. More flexibility.
  5. Faster response time.
  6. Easier to troubleshoot.
  7. Resistance to environment.
  8. Easy programming.
  9. Less wiring.
  10. Large quantity of contact.
  11. Fault can be easily detect.

→ PLC = programmable logical control.
→ PLC is a industrial digital computer or relay circuit that is capable of being programmed to control the function.
→ The PLC is a combination of multiple no. of input and output device.
→ The device is also easily fault detector and noise cancellation.
→ The PLC are resistance to vibration.
→ PLC can be used as personal computer.
→ The PLC are controls the machines and applications of other.
→ PLC have replaced hardware device such as relay and contacts.
→ The PLC is an electronics device which is a programmed before and use to control other device.

- Selection of PLC

① System requirements

- The starting point of determining any solution must be understand what is to be achieved.
- The program design starts with breaking down the task into a number of simple understandable elements, each of which can be easily described.

② Application requirements

- Input and output device requirements. After determing of the system, the next step is to determine what input and output device the system requires.
- List the function required and identify a specific type of device.
- The need of special operation in addition to discret (on/off) logic.
- List the advance function required beside simple discret circuit.

③ Electrical Requirements

The electrical requirements for inputs, outputs and system power, when determining the electrical requirements of system, consider three items.

- Incoming power (power for the control system)
- Input device voltage.
- output voltage and current.

④ speed of operation

How fast the control system must operate (speed of operation)

when determining speed of operation, consider those points

- How fast does the process occus or machine operates.
- Are their 'time circle' operations or events that must be detected.
- In what time frame must the fastest action occers.

- Does the control system need to count pulse from an encoder of flow meter and respond quickly.

⑤ communication

- If the application requires sharing data outside the process i.e communication. communication involves sharing application data or status with another electronic device, such as a computer or a monitor in an operator's station.
- communication can take place locally through a twisted-pair wire or remotely via tele phone or radio modern.

⑥ operator Interface

If the system needs operator control or interaction. In order to convey information about machine or process status or to allow an operator to input data, many applications requires operator interface.

⑦ physical Environment

The physical environment in which the control system will be located. Consider the environment where the control system will be located. In harsh environments house the control system in an appropriate IP-rated enclosure.

- Application of PLC

① Industrial Applications of PLC

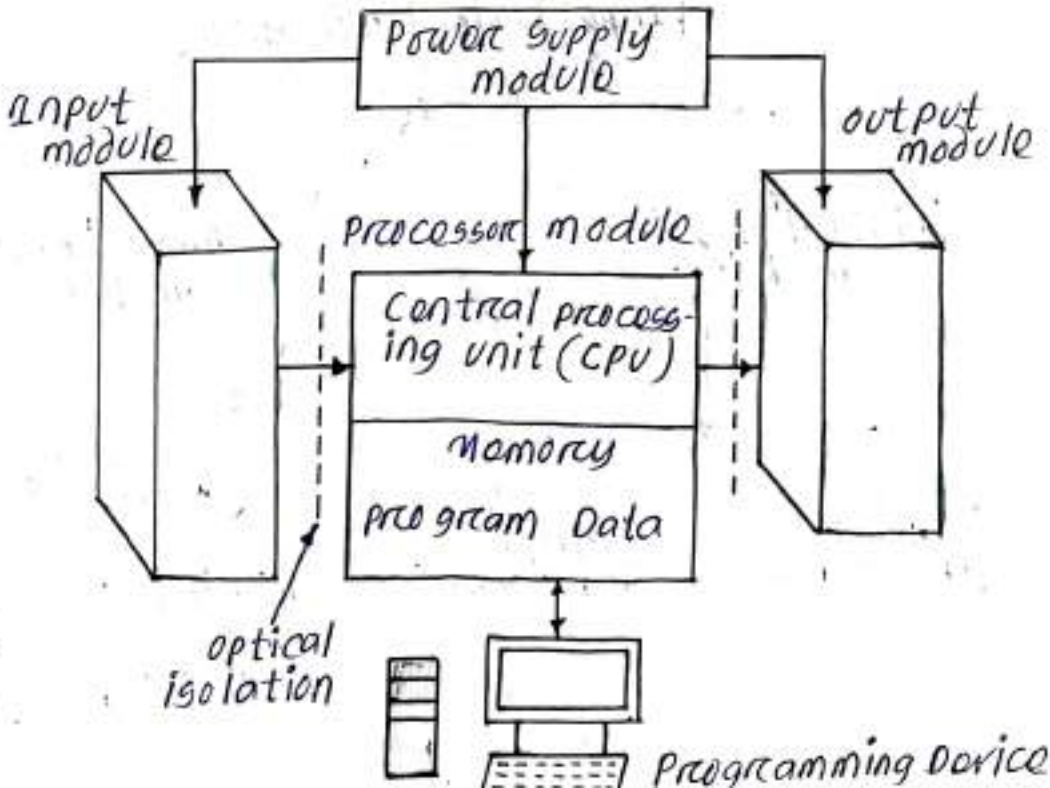
→ Transportation system like conveyor belt system.
→ packing and labeling system in food and Beverage.
→ Automatic Bottle or liquid filling system
→ packing and labelling system in pharma industries.
→ Transportation system like escalator and elevator.

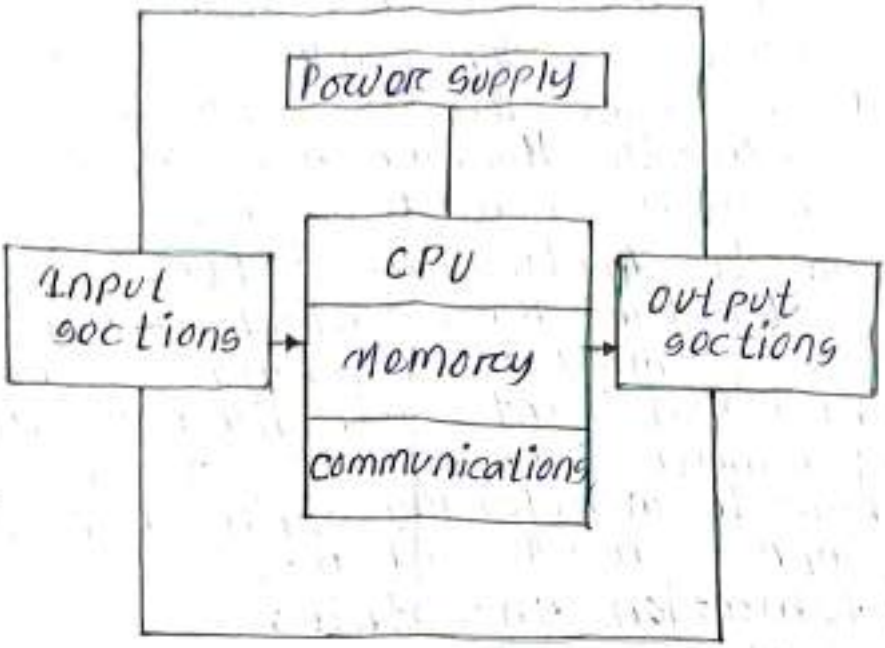
② commercial application of PLC
→ smart trafic control signals system.
→ smart elevator control system
→ fire Detection and alarm system.
→ Automatic Machine handling system.
→ Automatic, vehicle washer system.

③ Domestic Application of PLC
→ water tank level control system.
→ Car washing and parking system.
→ flashing light controlling system.
→ Automatic Door opening/closing system.
→ Remote monitoring application like air compressor (AC), fan.

④ Automation Industries
→ steel industries
→ Glass industries
→ paper industries
→ Textile industries
→ cement industries
→ Automobile industries
→ Food processing system.

• Architecture of PLC

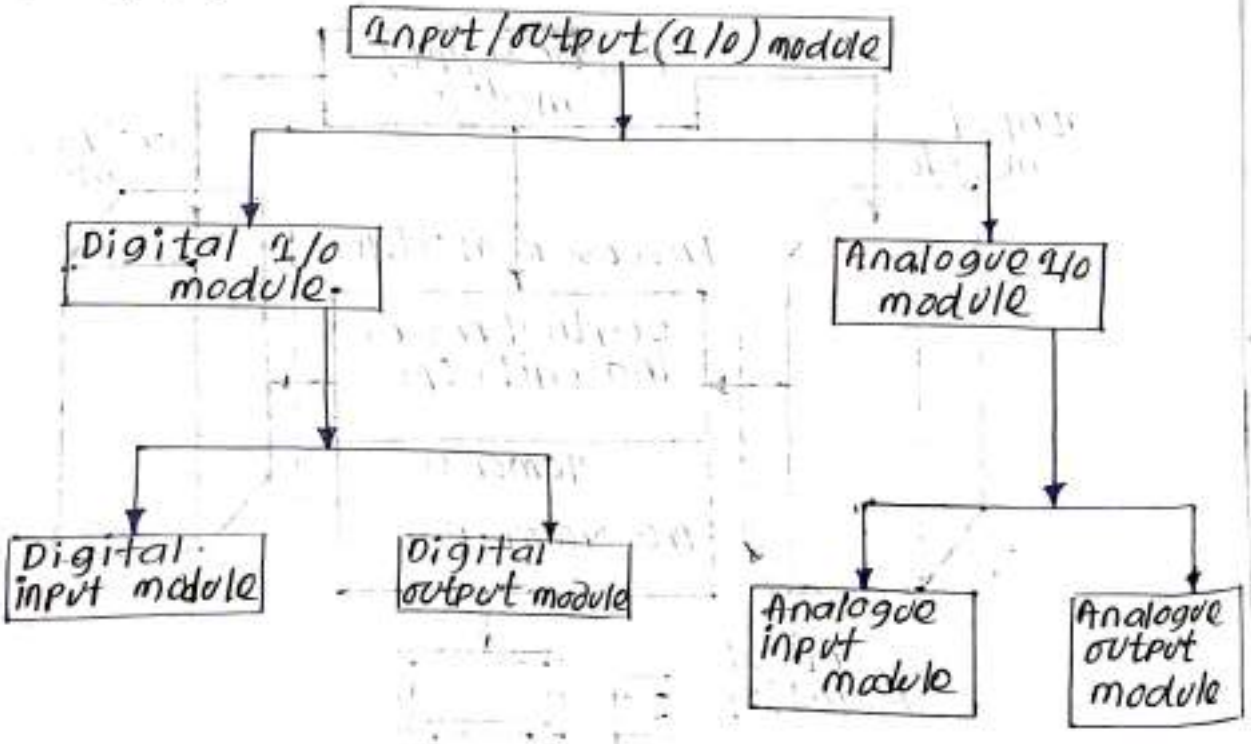




- Power supply module

→ This module is used to provide the power to the whole PLC systems.
→ It converts the available AC power to DC power which is required by the CPU and I/O module.
→ PLC generally works on a 24V DC supply.
→ Few PLC uses an isolated power supply.

- Input and output modules



⇨ Digital I/O module

→ The digital module is also called Discrel module.

→ In this module the input and output module works on the binary system (i.e 0,1)

→ It is useful in the on or off condition.

→ Based on input and output the digital module is of two types.

- Digital input module
- Digital output module

→ The digital I/O signals gives status in the different form.

- High / Low, True/false and I/O general status
- on/off for load condition
- Activated and deactivated for switching mechanism.
- close / open for the switching contact status.

→ example of Digital input signals are

- push switch
- Rocker switch
- selector switch
- proximity switch
- Limit switch.

→ example of Digital output signals are

- Lamp
- coil
- Buzzer
- Relay
- motor
- fan
- heater
- actuator
- solonoid valves.

⇨ Analog I/O module.

→ The analogue module is called continuous module.

→ usually the voltage and current is given to the input module in the form of a analog signals.

→ Generally analog input signals operated in the range of (4-20) mA, (0-20) mA, 1.5 V etc.

→ This analog signals provide any intermittent value between two extreme limits for the analog input module.

→ The analog modules are of two types
- Analog input module
- Analog output module.

→ example of analog input signals are
- temperature detection switch
- pressure detection switch
- flow detection switch
- Limit detection switch
- position detection switch
- PH level detection switch.

→ example of analog output signals are
- temperature transmitter
- Thermo couples
- Thermo couples
- pressure transmitters
- flow transmitters
- level transmitters.

• Central processing unit (CPU)

→ The CPU acts as the brain of PLC.

→ Basically, CPU performs arithimatic, logic, controling operation specified by the programming instructions.

→ when we talk about PLC system, the CPU has different type of operating mode.
- In programming mode (download)
- In running mode (execute)

→ The CPU is classified into three important subparts
  ① processor
  ② memory
  ③ power supply.
→ The communication processor is an optional module, it can be used for providing an additional communication port for communication protocols.
→ The communication processor is used for networking communication between multiple PLC, also helps in exchange of data.

• PLC memory
→ The PLC memory consists of two types.
  ① RAM
  ② ROM

RAM
→ RAM stands for Random Access memory.
→ It is the type of PLC memory where programms and data are stored.
→ All the users programs and data variables are stored in RAM.
→ The RAM memory location can be written and read.
→ RAM can be further classified into two types.
  ⓐ volatile memory (non-retaintive)
  ⓑ Non-volatile memory (retaintive)

ROM
→ The ROM stands for Read only memory.
→ In this memory the data can be only read.
→ The data can not be stored.

→ Types of PLC are
① compact PLC (fixed PLC)
② Modular PLC (flexible PLC)

- Input/output processing
→ ladder programming is the basic form of programming commonly used with PLC.
→ Each looks of input/output processing being specified through a rung of a ladder.
→ The rung specified the two switches A and B, the inputs.
→ If the A and B are both closed Then a solenoid, the output.

Sequence of carrying out a program
① Scanning the input associated with a rung of the ladder.
② Solving the logical operation involving those inputs
③ setting/Resting the output for that rung.
④ Moving to the next rung and repeating operation 1, 2, 3.
⑤ Moving to the next rung and repeating operation 1, 2, 3
⑥ Moving on the next rung and repeating 1, 2, 3. continuing until the end of the program.

For input/output processing the following two methods are used.
① Continuous updating
→ In this method the CPU scans the input channel as they occurs in the programme instructions.
→ Each input point is examined individually and its effect on the program determined.
→ There will be built in delay typically about 3ms.

② Mass input / output copying

→ In case of continuous updating methods since there has to be a 3ms delay in each point, therefore the time taken for examining several hundreds input and output can become comparatively long.

→ In order to have more rapid execution the mass input/output copying methods is used.

- **Programming**

→ When a PLC programming carried out using ladder diagram, a program is written in a similar manner to drawing a switching circuit.

→ The ladder diagram consists of two vertical line representing the power rails.

→ Circuits are connected as horizontal lines i.e the rungs of the ladder between those two vertical.

→ While drawing the circuits line for a rung, inputs must always precede outputs and there must be atleast one output on each time.

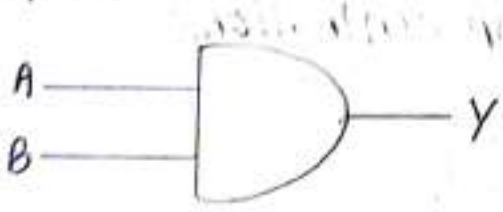
→ Each rung must starts with an input or a series of inputs and end with an output.

→ The inputs and outputs are numbered, the notation used depending upon the manufacture of PLC.

- **Logical function**

AND, OR, NOR, NAND, EXCLUSIVE-OR (XOR)

example:



AND gate

Truth Table

Inputs		output
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

- Latching
→ Sometimes there are situation where it is necessary to hold a coil energised, even when the input which energises it ceases
→ The circuit which is used to carry out such an operation is termed as latch circuit.
→ It is a self manufacturing circuits.

- Sequencing
→ Sometimes there are control situation where sequence of output is required.
→ It is done by sensors.

- Mnemonics
→ In a ladder program each horizontal line rung on the ladder represents the line in program and entire ladder gives complete program in ladder language.
→ The program can entered on the PLC by keyboard with graphical symbols or computer
→ Then it can be translated into machine language that can be stored in the PLC memory.
→ A program can also be entered by translating the ladder program into mnemonics.
→ Then it translated into machine language.
→ Different mnemonics used for different PLC.

- Master and Jump controllers

Master :-
→ A master controls can be thoughts of 'emergency switches'
→ It is an alternative of way of programming to achieve the same switching effect as use a master relay.

Jumps :-

→ A function which is often provided with PLC s is the conditional Jump

→ Jump instruction in ladder logic is used to skips some process or rungs according to our requirement.