(4) Drive units

The system composed of electrical, hydraulic and pneumatic drive and the mechanical load is known as the drive system. There are two parts:

-Drive

-mechanical load

Drive motors are required to perform the following functions:

(i) To drive the main spindle (Spindle drive)

(ii) To drive the saddles or carriage (Axis drive)

In addition there may be some more motors in the CNC machine for services such as coolant pumps, swarf removal, etc.

Spindle Drive:

In CNC machines, large variation(10 to 2800 rpm) in cutting speed is required. The cutting speeds are provided by rotation of the main spindle with the help of an electrical motor through suitable gear mechanism. To obtain optimum cutting speeds and feeds, the drive mechanism should be such as to provide infinitely variable speeds between the upper and the lower limits.

It consist of three important components-i)the prime mover, ii) the energy transmitting device and iii) the actual equipment which perform the actual job.

The function of the first two is to impart motion and operate the third one.

So to obtain the correct speed range of spindle and feed rate the CNC machines would be operated by good design:

-Drive based on electrical principles

- Drive based on hydraulic principles

- Drive based on pneumatic principles

Electrical drives :

These are direct current (DC) or alternating current (AC) servo motors. They are small in size and are easy to control.

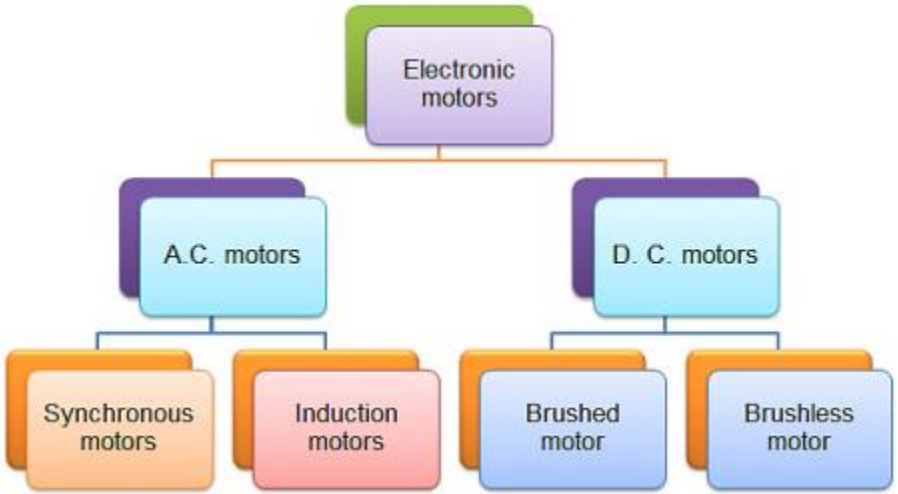
Hydraulic drives :

These drives have large power to size ratio and provide stepless motion with great accuracy. But these are difficult to maintain and are bulky. Generally they employ petroleum based hydraulic oil which may have fire hazards at upper level of working temperatures. Also hydraulic elements need special treatment to protect them against corrosion.

Pneumatic drives :

This drives use air as working medium which is available in abundant and is fire proof. They are simple in construction and are cheaper. However these drives generate low power, have less positioning accuracy and are noisy.

In CNC, usually AC, DC, servo and stepper electrical drives are used.



Axis Drive

All the axis in a CNC machine are controlled by servomotors. The movement along the different axis is required either to move the cutting tool or the work material to the desired positions. In order to accomplish accurate control of position and velocity, stepper motors are used for axis drive. The use of stepper motor considerably simplifies the system as feedback devices are not used. The cost of the machine tool is also less. However stepper motors are suitable only for light duty machines due to low power-output.

Stepper Motor

A stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements. It is designed to accomplish a discrete movement (notion of step) and reach a precise position.The speed of the motor shafts rotation is directly related to the frequency of the input pulses and the length of rotation is directly related to the number of input pulses applied.

Stepper Motor Types

There are three basic stepper motor types. They are :

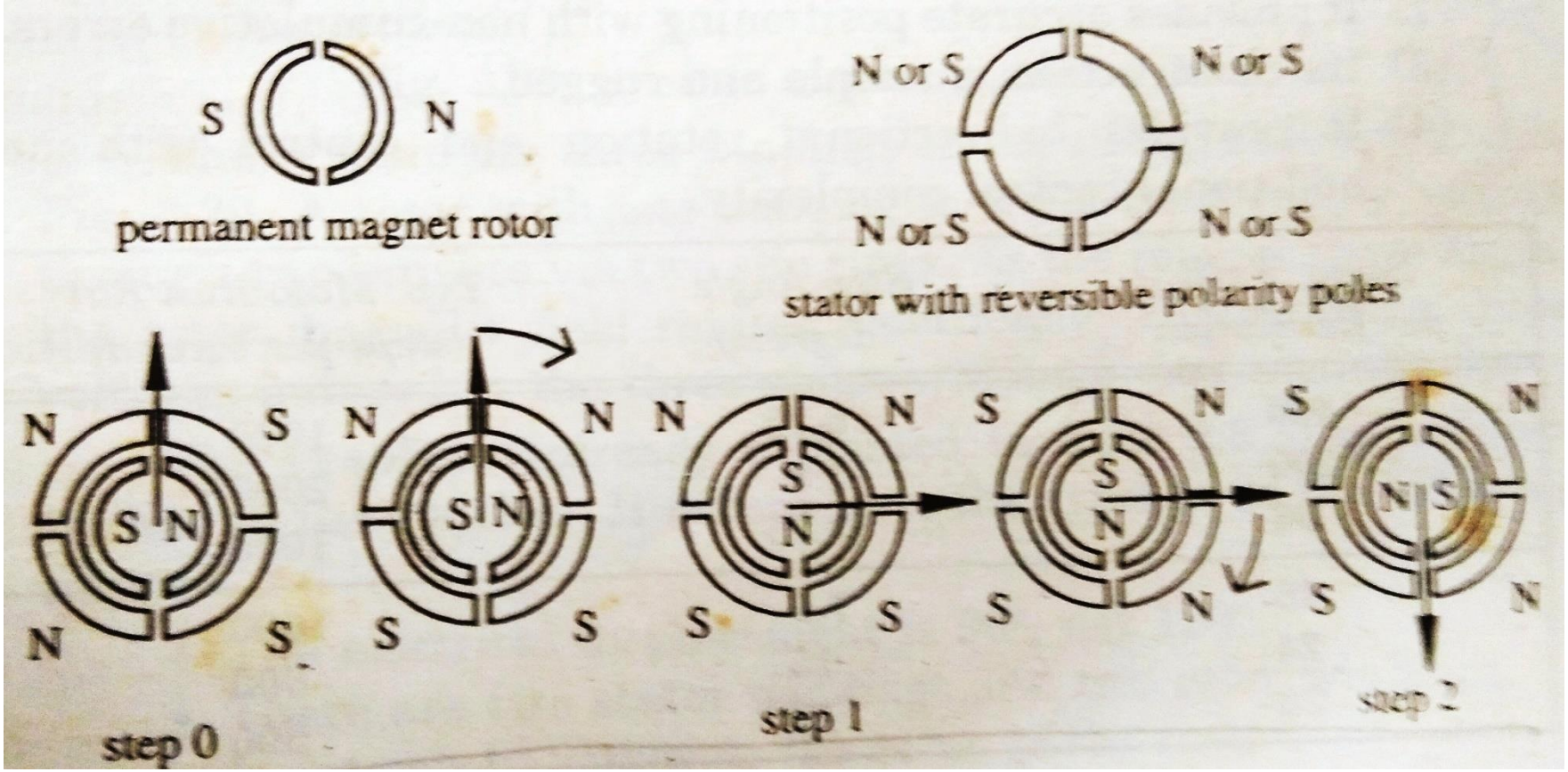
- Variable-reluctance :-Non-magnetic, geared rotor
- Permanent-magnet:– Magnetic rotor
- Hybrid:-Combines characteristics from PM and VR
  - Magnetic, geared rotor

Main **characteristics** of Stepper motors are as -:

- Repetitive positioning tasks with high accelerations (i.e. XYZ of machine tools)
- For back and forth motions.
- Frequent "start/stop" operation.
- Whenever the actual position must be held with high torque.
- Whenever the actual position must be held when no current is applied (thanks to the residual torque).
- Whenever minor speed variation under load are not allowed (peristaltic pumps, XYZ of machine tools)
- Capability for digital control.
- Whenever long life times is required (i.e. using the brushless design).
- Whenever the settling time must be short and with repeatable discrete positions.
- Whenever open loop (absence of electronics) makes sense (e.g. for noise immunity).

The permanent magnet (PM) : A stepper motor using a permanent magnet in the rotor is called a PMSM. The rotor no longer has teeth as with the VRM. Instead the rotor is magnetized with alternating north and south poles situated in a straight line parallel to the rotor shaft. These magnetized rotor poles provide an increased magnetic flux intensity and, because of this the PM motor exhibits improved torque characteristics when compared with the VRM type.

The rotor includes permanent magnets positioned in order to alternatively obtain South and North poles, which can interact with the varying magnetic field of the stator.



Rotation is achieved by alternatively energizing the stator coils A–B–C–D and attracting the North (or South) pole of the rotor to the magnetized stator pole. When no current is applied, a small torque is required to move the rotor from its equilibrium position due to the interaction between the permanent magnets and the stator.

When the windings are excited in the sequence the rotor will be driven in a clockwise direction. The step length is 90 degree in this machine.

step angle =360/number of steps per revolution=90

Stepper Motor Advantages

1. The rotation angle of the motor is proportional to the input pulse.
2. The motor has full torque at standstill (if the windings are energized)
3. Precise positioning and repeatability of movement since good stepper motors have an accuracy of 3 – 5% of a step and this error is non cumulative from one step to the next.
4. Excellent response to starting/stopping/reversing.
5. Very reliable since there are no contact brushes in the motor. Therefore the life of the motor is simply dependant on the life of the bearing.
6. The motors response to digital input pulses provides open-loop control, making the motor simpler and less costly to control.
7. It is possible to achieve very low speed synchronous rotation with a load that is directly coupled to the shaft.
8. A wide range of rotational speeds can be realized as the speed is proportional to the frequency of the input pulses.

One of the most significant advantages of a stepper motor is its ability to be accurately controlled in an open loop system. This type of control eliminates the need for expensive sensing and feedback devices such as optical encoders. Your position is known simply by keeping track of the input step pulses.

Disadvantages

- Resonances can occur if not properly controlled.
- Not easy to operate at extremely high speeds.
- They are not suitable for heavy loads.
- During overloading, the synchronization will be broken. Vibration and noise occur when running at high speed.

Applications:-For most small consumer electronic devices, such as hard disc drives, ink jet printers, cameras, paper feed, tape drives, andplotters.

- Optical systems (e.g. zoom, focus, pan/tilt, and filter positioning, microscope stages)
- Photonics (e.g. laser tuning, laser scanner)
- Telecommunications (e.g. variable optical amplifiers (VOA))
- Medical (e.g. pumps, DNA analyzers)
- Instrumentation (e.g. gas analyzer)
- Aerospace & Defense (e.g. UAVs)

servo motors

A servo motor is a rotary actuator or a motor that allows for a precise control in terms of the angular position, acceleration, and velocity. Basically it has certain capabilities that a regular motor does not have. Consequently it makes use of a regular motor and pairs it with a sensor for position feedback . A typical servo motor comprises of three wires namely- power, control, and ground. The shape and size of these motors depends on their applications.

Servomotors are special electromechanical devices that produce precise degrees of rotation. A servo motor is a DC or AC or brushless DC motor combined with a position sensing device. Servomotors are also called control motors as they are involved in controlling a mechanical system. The servomotors are used in a closed-loop servo system.

Types of servo motors –

Servo motors can be of different types on the basis of their applications. The most important amongst them are :

AC servo motor, DC servo motor, brushless DC servo motor, positional rotation servo motor, continuous rotation servo motor, and linear servo motor.

Servo Mechanism : It consists of three parts:

Controlled device
Output sensor
Feedback system

The servomotors are used in a closed-loop servo system as shown in Figure A reference input is sent to the servo amplifier, which controls the speed of the servomotor.

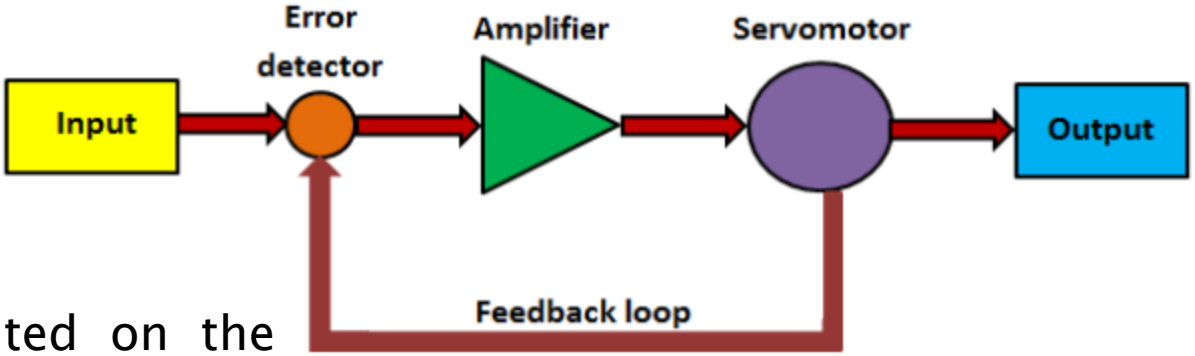


Fig. 4.2.4 Servo system block diagram

A feedback device is mounted on the machine, which is either an encoder or resolver.

This device changes mechanical motion into electrical signals and is used as a feedback.

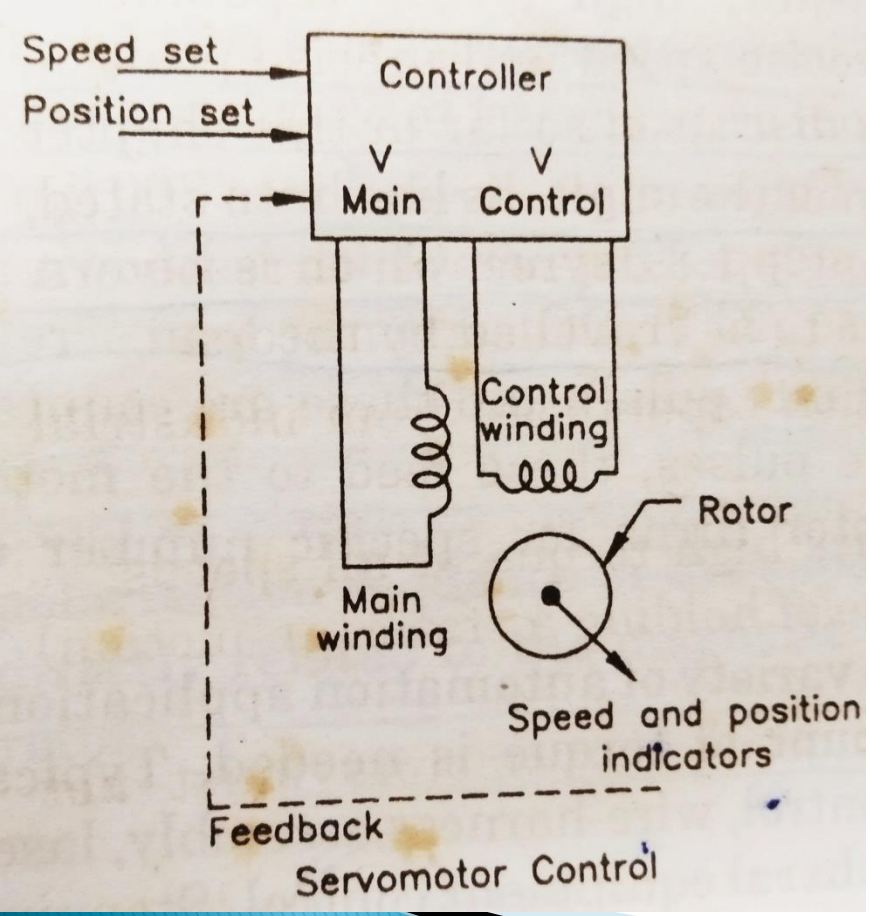
This feedback is sent to the error detector , which compares the actual operation with that of the reference input.

If there is an error, that error is fed directly to the amplifier, which will be used to make necessary corrections in control action.

Servomotors provide accurate speed, torque, and have ability of direction control.

Main characteristics-

- It must produce higher torque at all speeds
- It must be capable of holding a static position.
- At lower speeds or at standstill, servomotors must not overheat.
- It should be able to reverse directions quickly
- It must be able to accelerate and decelerate quickly.
- It must return to a given position time after time and not drift.



Magnetic field or force rotates around the stator as a result of the ac voltages and the arrangement of coils around the stator housing.

Rotor have no external voltage applied, rather voltages are induced in the rotor windings due to the rotating fields around the stator.

Causing fields to rotates around the rotor windings at the same rate as the fields rotate around the stator. Due to to interaction of these fields, the rotor rotates at the same speed as the stator fields.

It has no brushes so there is little noise/vibration. This motor provides high precision control with the help of high resolution encoder.

The stator is composed of a core and a winding. The rotor part comprises of shaft, rotor core and a permanent magnet.

Digital encoder can be of optical or magnetic type. It gives digital signals, which are in proportion of rotation of the shaft.

Advantages of servo motors –

- Provides high intermittent torque, high torque to inertia ratio, and high speeds
- Work well for velocity control
- Available in all sizes
- Quiet in operation, it has no brushes so there is little noise/vibration.
- Smoother rotation at lower speeds

Disadvantages of servo motors–

- More expensive than stepper motors
- Require tuning of control loop parameters
- Not suitable for hazardous environments or in vacuum
- Excessive current can result in partial demagnetization of DC type servo motor

Applications :

1. **Robotics** : At every joint of the robot, we connect a servomotor. Thus giving the robot arm its precise angle.
2. **Conveyor belts** : servo motors move , stop , and start conveyor belts carrying product along to various stages , for example , in product packaging/ bottling, and labelling .
3. **Camera auto focus** : A highly precise servo motor build into the camera corrects a camera lens to sharpen out of focus images.
4. **Solar tracking system** : Servo motors adjust the angle of solar panels throughout the day and hence each panel continues to face the sun which results in harnessing maximum energy from sunup to sundown .