DARBHANGA COLLEGE OF ENGINEERING, DARBHANGA

INSTRUMENTATION AND CONTROL
(SEM-IV:ME)

Course Code- PCC-ME 207

MODULE 3

Correction Elements and Actuators

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1.CORRECTION ELEMENTS

- **Introduction:**
- **<u>The correction element or final control element</u>** is the element in a control system which is responsible for transforming the output of a controller into a change in the process which aims to correct the change in the controlled variable. Thus, for example, it might be
- a **valve** which is operated by the output from the controller and used to change the rate at which liquid passes along a pipe and so change the controlled level of the liquid in a cistern.
- It might be a **motor** which takes the electrical output from the controller and transforms it a rotatory motion in order to move a load and so control its position.
- t might be a **switch** which is operated by the controller and so used to switch on a heater to control temperature.

2.Actuators

- The term **actuator** is used for the part of a correction/final control element that provides the power, i.e. the bit which moves, grips or applies forces to an object, to carry out the control action.
- Thus a **valve** might have an input from the controller and be used to vary the flow of a fluid along a pipe and so make a piston move in a cylinder and result in linear motion. The piston-cylinder system is termed an actuator. In this session pneumatic/hydraulic and electric correction control elements, along with actuators, are discussed.

3.Pneumatic and hydraulic systems

- Process control systems frequently require control of the flow of a fluid. The valves used as the correction elements in such situations are frequently **pneumatically** operated, even when the control system is otherwise electrical. This is because such pneumatic devices tend to be cheaper and more easily capable of controlling large rates of flow.
- The main drawback with pneumatic systems is, however, the compressibility of air. This makes it necessary to have a storage reservoir to avoid changes in pressure occurring as a result of loads being applied.
- **Hydraulic signals** do not have this problem and can be used for even higher power control devices. They are, however, expensive and there are hazards associated with oil leaks which do not occur with air leaks

3.1Current to pressure converter

- Figure

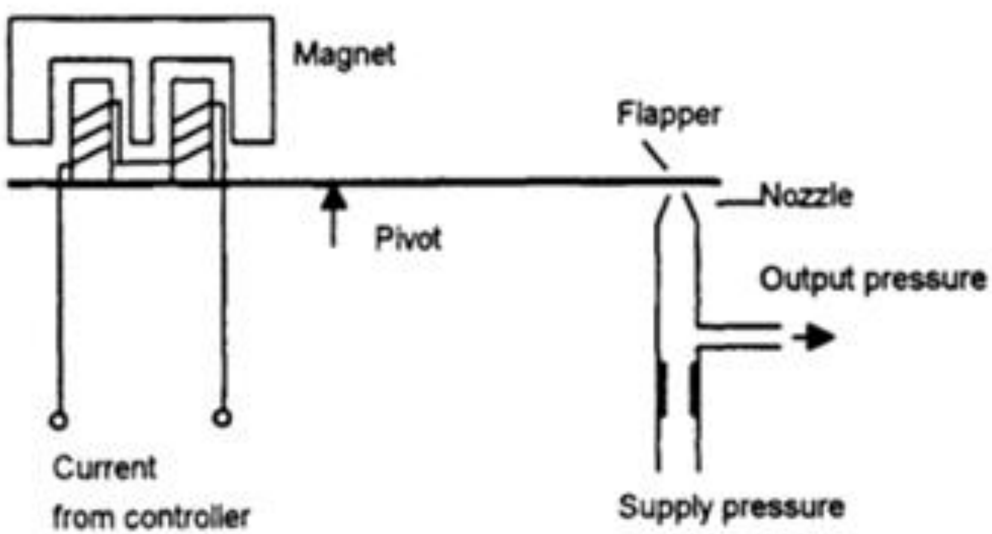

Figure 6.1 *Current to pressure converter*

Current to pressure converter

- Figure shows the principle of one form of a current to pressure converter that can be used to convert a current output from a controller, typically in the range 4 to 20 mA, to a pneumatic pressure signal of 20 to 100 kPa to operate a final control element.
- current from the controller passes through coils mounted on a pivoted beam. As a consequence, the coils are then attracted towards a magnet, the extent of the attraction depending on the size of the current.
- The movement of the coils cause the lever to rotate about its pivot and so change the separation of a flapper from a nozzle. The position of the flapper in relation to the nozzle determines the size of the output pressure in the system.

3.2Pressure sources

3.2.1Pneumatic system

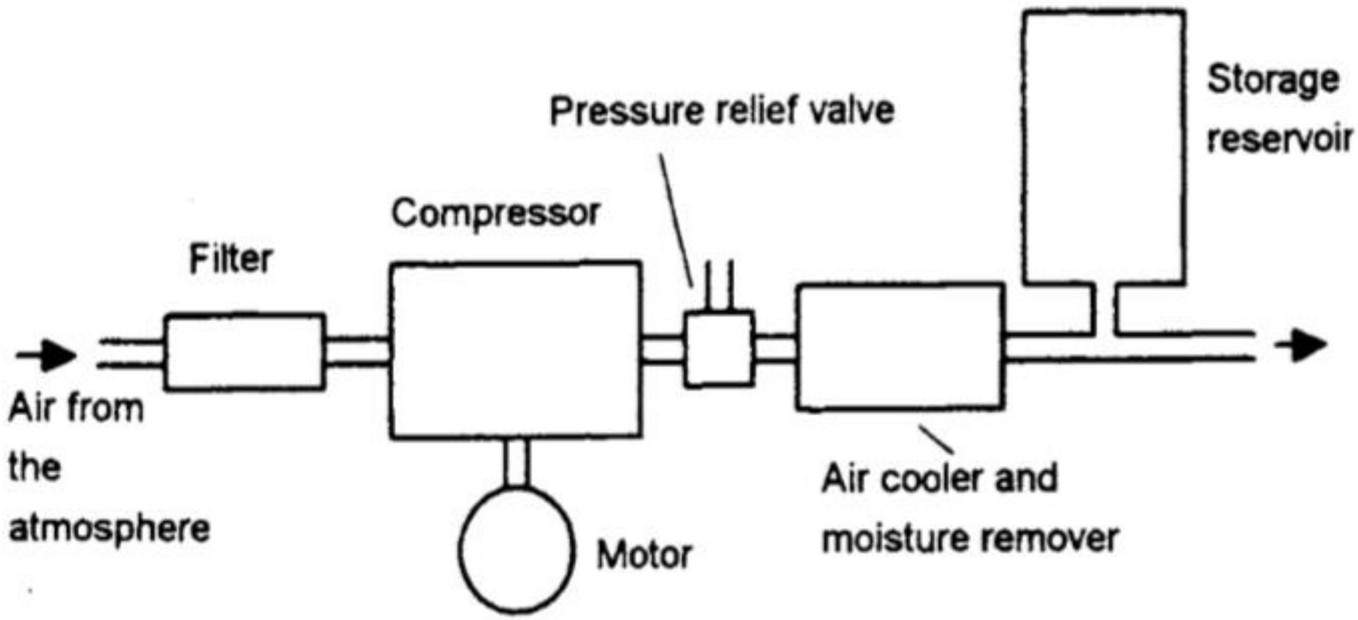

Figure 6.2 *A pressurised air source*

3.2Pressure sources

- With a pneumatic system a source of pressurized air is required. This can be provided by an electric motor driving an air compressor (Figure 6.2).
- The air is drawn from the atmosphere via a filter. Since the air compressor increases the temperature of the air, a cooling system is likely to follow and, since air also contains a significant amount of moisture, a moisture separator to remove the moisture from the air.
- A storage reservoir is used to smooth out any pressure fluctuations due to the compressibility of air. A pressure relief valve provides protection against the pressure in the system rising above a safe level.

3.2Pressure sources

Hydraulic system

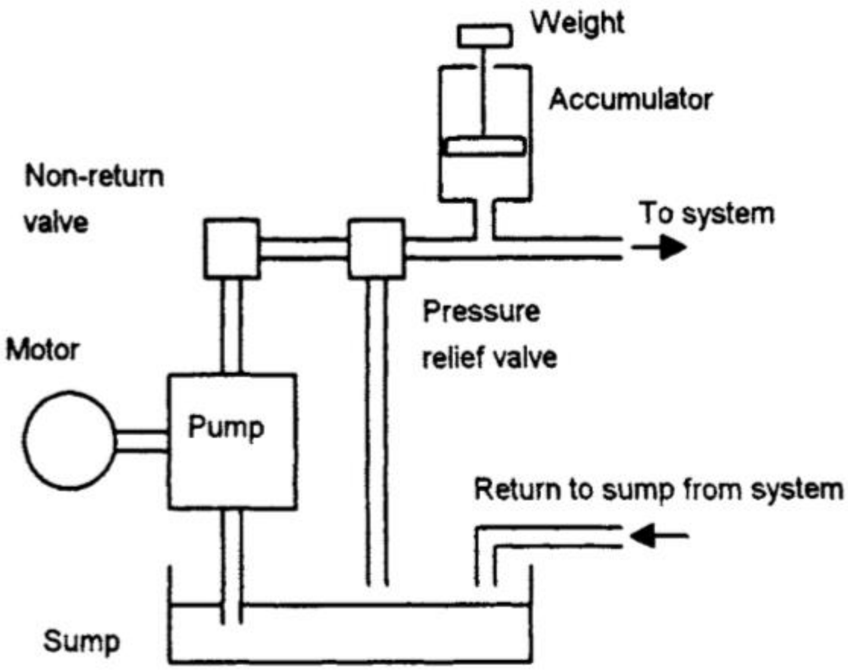

Figure 6.3 *A source of pressurised oil*

3.2Pressure sources

Hydraulic system

- With a hydraulic system a source of pressurized oil is required. This can be provided by a pump driven by an electric motor. The pump pumps oil from a sump through a non-return valve and an accumulator and back to the sump (Figure 6.3).
- The non-return valve is to prevent the oil being back-driven to the pump. A pressure relief valve is included so that the pressure is released if it rises above a safe level.
- The accumulator is essentially just a container in which the oil is held under pressure against an external force and is there to smooth out any short-term fluctuations in the output oil pressure. If the oil pressure rises then the piston moves to increase the volume the oil can occupy and so reduces the pressure. If the oil pressure falls then the piston moves in to reduce the volume occupied by the oil and so increase its pressure.

3.3Control valves

- Pneumatic and hydraulic systems use control valves to give direction to the flow of fluid through a system, control its pressure and control the rate of flow.
- These types of valve can be termed directional control valves, pressure control valves and flow control valves.
- Directional control valves, sometimes finite position valves because they are either completely open or completely closed, i.e. they are on/ofif devices, are used to direct fluid along one path or another. They are equivalent to electric switches which are either on or off. Pressure control valves, often termed pressure regulator valves, react to changes in pressure in switching a flow on or off, or varying it.
- Flow control valves, sometimes termed infinite position valves, vary the rate at which a fluid passes through a pipe and are used to regulate tlie flow of material in process control systems.

3.4 Actuators

- Fluid power actuators can be classified in two groups: **linear** actuators which are used to move an object or apply a force in a straight line and
- **rotary** actuators which are used to move an object in a circular path.
- The hydraulic or pneumatic cylinder is a linear actuator, the principles and form being the same for both versions with the differences being purely a matter of size as a consequence of the higher pressures used with hydraulics. The hydraulic/pneumatic cylinder consists of a hollow cylindrical tube along which a piston can slide.
- Figure 6.4(a) shows the single acting form and Figure 6.4(b) the double acting form. The single acting form has the control pressure applied to just one side of the piston, a spring often being used to provide the opposition to the movement of the piston.
- The piston can only be moved in one direction along the cylinder by the signal from the controller. The double acting form has control pressures that can be applied to each side of the piston. When there is a difference in pressure between the two sides the piston moves, the piston being able to move in either direction along the cylinder

3.4 Actuators

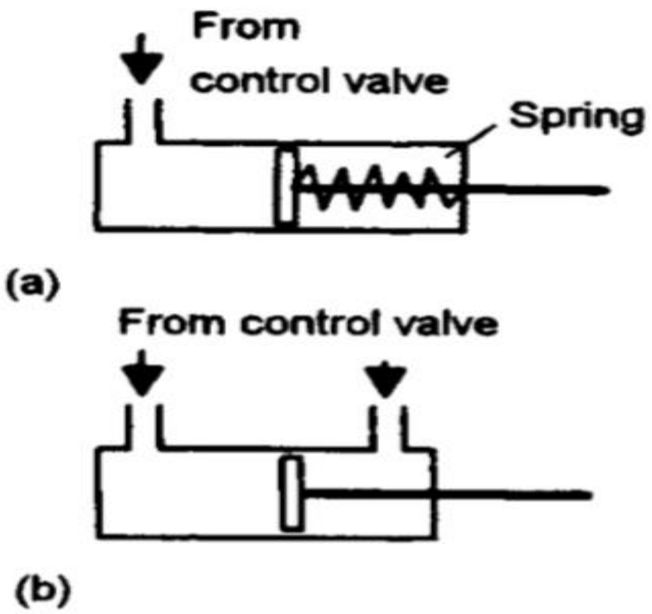

Figure 6.4 *(a) Single acting, (b) double acting cylinder*

3.4.1 The choice of a cylinder

- The choice of cylinder is determined by the force required to move the load and the speed required. Hydraulic cylinders are capable of much larger forces than pneumatic cylinders. However, pneumatic cylinders are capable of greater speeds. Since pressure is force per unit area, the force produced by a piston in a cylinder is equal to the cross-sectional area of the piston, this being effectively the same as the internal cross-sectional area of the cylinder, multiplied by the difference in pressure between the two sides of the piston. Thus for a pneumatic cylinder with a pressure difference of 500 kPa and having an internal diameter of 50 mm.

$$\text{force} = \text{pressure} \times \text{area} = 500 \times 10^3 \times \tfrac{1}{4}\pi \times 0.050^2 = 982\ \text{N}$$

3.4.1 The choice of a cylinder

- A hydraulic cylinder with the same diameter and a pressure difference of 15 000 kPa, hydraulic cylinders being able to operate with higher pressures than pneumatic cylinders, will give a force of 29.5 kN.
- Note that the maximum force available is not related to the flow rate of hydraulic fluid or air into a cylinder but is determined solely by the pressure and piston area. The speed with which the piston moves in a cylinder is determined by the rate at which fluid enters the cylinder. If tlie flow rate of hydraulic liquid into a cylinder is a volume of Q per second, then the piston must sweep out a volume oiQ. If a piston moves with a velocitv v then, in one second, it moves a distance of v
- See(Figure 6.5).

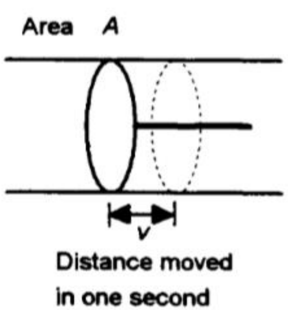

Figure 6.5 *Movement of a piston in a cylinder*

3.4.1 The choice of a cylinder

- But for a piston of cross-sectional area A this must mean that the volume swept out by the piston in 1 s is *Av*. Thus we must have:
- Q = Av
- Thus the speed v of a hydraulic cylinder is equal to the flow rate of liquid Q through the cylinder divided by the cross-sectional area A of the cylinder.
- The speed is determined by just tlie piston area and the flow rate. For example, for a hydraulic cylinder of diameter 50 mm and a hydraulic fluid flow of 7.5 x 10(^-3) m^3/sec:

$$\text{speed } v = \frac{Q}{A} = \frac{7.5 \times 10^{-3}}{\frac{1}{4}\pi \times 0.050^2} = 3.8 \text{ m/s}$$

3.4.2 Rotary Actuators

Rotary actuators give rotary motion as a result of the applied fluid pressure. Figure 6.6 shows a rotary actuator which gives partial rotary movement. Continuous rotation is possible with some forms and then they are the equivalent of electric motors. Figure 6.7 shows one form, known as a vane motor. The vanes are held out against the walls of the motor by springs or hydraulic pressure. Thus, when there is a pressure difference between the inlet and outlets of the motor, rotation occurs.

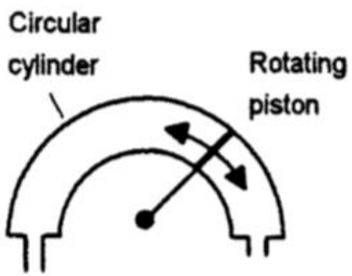

Figure 6.6 *Rotary actuator*

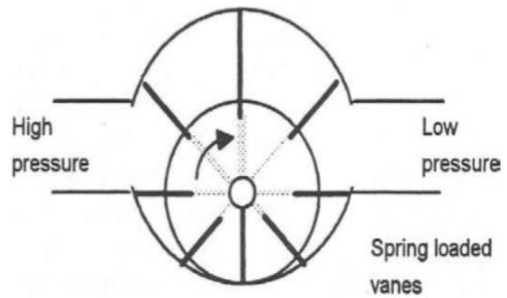

Figure 6.7 *Vane motor*

Example:

A hydraulic cylinder is to be used in a manufacturing operation to move a workpiece through a distance of 250 mm in 20 s. If a force of 50 kN is required to move the workpiece, what is the required pressure difference and hydraulic liquid flow rate if a cylinder with a piston diameter of 150 mm is to be used?

As derived above, the force produced by the cylinder is equal to the product of the cross-sectional area of the cylinder and the working pressure. Thus the required pressure is:

$$\text{pressure} = \frac{F}{A} = \frac{50 \times 10^3}{\frac{1}{4}\pi \times 0.150^2} = 2.8 \times 10^6 \text{ Pa} = 2.8 \text{ MPa}$$

The average speed required is 250/20 = 12.5 mm/s. As derived above, the speed of a hydraulic cylinder is equal to the flow rate of liquid through the cylinder divided by the cross-sectional area of the cylinder. Thus the required flow rate is:

$$\text{flow rate} = \text{speed} \times \text{area}$$

$$= 0.0125 \times \tfrac{1}{4}\pi \times 0.150^2 = 2.2 \times 10^{-4} \text{ m/s}$$

Thank you..