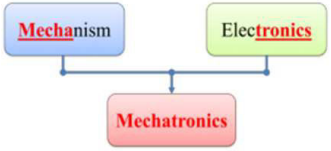
PART-02
Introduction to Mechatronic Systems

Mechatronics

- Mechatronics is a concept of Japanese origin (1969's) and can be defined as the application of electronics and computer technology to control the motions of mechanical systems.



- It is a multidisciplinary approach to product and manufacturing system design. It involves application of electrical, mechanical, control and computer engineering to develop products, processes and systems with greater flexibility, ease in redesign and ability of reprogramming. It concurrently includes all these.

Advantages of Mechatronics

- Mechatronics is important because it enhances functionality and features. It brings more efficiency.
- Mechatronics adds intelligence to design of the system, by which efficiency of the system improves.
- It reduces cost. Mechanical solutions are expensive when compared to mechatronics solutions, which lowers cost.
- A mechatronic solution improves design time, product size and reliability. It is also more user-friendly and safer to use.
- Mechatronic uses microcontroller, by which precision, position, speed, flow rate, and variables can be controlled.
- Using mechatronic solution increases reliability. Mechanical designs get damaged over time whereas mechatronic design is more reliable. An example is the odometer present in the cars

Disadvantages of Mechatronics

1. High initial cost of the system
2. Imperative to have knowledge of different engineering field for design and implementation.
3. Specific problem for various system would have to be addressed separately and properly.
4. It is expensive to incorporate mechatronic approach to an existing/old system.
5. Maintenance and servicing are a costly affaire.

Industrial application

- Mechatronics based automated systems such as automatic inspection and quality assurance, automatic packaging, record making, and automatic dispatch help to expedite the entire manufacturing operation. These systems certainly ensure a supply better quality, well packed and reliable products in the market. Automation in the machine tools has reduced the human intervention in the machining operation and improved the process efficiency and product quality.
- It is widely used in aeronautics engineering for unmanned aerial vehicles and automatic pilots. In the defense industry it is used for automatically guided vehicles and mine detection robots.

Bionics

- Bionics is a field of technology that combines the study of biology in nature and its patterns, with mechatronics, which combines mechanical, electronics and software.
- Bionics consists of many different subject areas, but one of the most eye-catching and popular is bionic implants.
- These implants aim to improve the standard of living for people who have damaged body parts such as arms, legs, eyes, or even ears.

Working of bionic implants

- It's extremely hard to mimic the actions created by regular limbs. It's something that software and hardware engineers have a lot of trouble working with.
- To solve this, all the successful bionics systems use machine learning to mimic physical movements.
- **Myoelectric** *(Myo = muscles)* sensors are used in bionic limbs to generate an electrical signal from muscle contractions.
- This is useful because it can get signals from the still functional nerve endings of the amputated limb. This means that the sensors can pick up when the user wants to move that area.
- In some cases, to improve the accuracy of myoelectric sensors, small incisions are made to place them closer to the muscle/nerve endings.

Autotronics

Definition: Autotronics can be defined as the combination of automobile and electronics or we can say that the use of electronics science in automobile vehicles is called autotronics.

Major Areas:

- The use of electronics in the automobile field makes the system safe, improved and efficient.
- At present, in the new generation automobiles almost 75%-85% of automobile parts are embedded with electronics system.
- The main areas of automobiles using autotronics are engine controlling system, airbags, antilock braking system, lightening interiors, GPS, music systems etc.
- In the autotronics systems the use of control units like sensors, motors and digital equipment establishes a communication between the various essential system and components of the vehicle.

Avionics

Introduction:

Avionics are the electronics systems used on aircraft, artificial satellite, and spacecraft. Avionic systems include communications, navigation, the display and management of multiple systems, and the hundreds of systems that are fitted to aircraft to perform individual functions.

Avionics grew in 1950's and 1960 as electronic devices which replaces the mechanical or analog equipment in the aircraft.

Avionics equipment on a modern military or civil aircraft account for around;

- 30% of the total cost of the aircraft
- 40% in the case of a maritime patrol/antisubmarine aircraft or helicopter.
- Over 75% of the total cost in the case of an airborne early warning aircraft (AWACS).

NEED FOR AVIONICS:

To enable the flight crew to carry out the aircraft mission safely and efficiently. For civil airliner the mission is carrying passengers to their destination. For military aircraft the mission is intercepting a hostile aircraft, attacking a ground target, reconnaissance or maritime patrol.

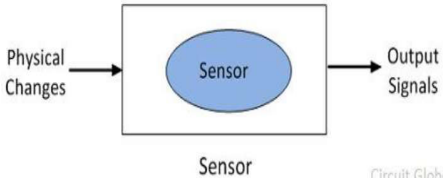
Advantages

- Increased safety
- Air traffic control requirements
- All weather operation
- Reduction in fuel consumption
- Improved aircraft performance and control and handling and reduction in maintenance costs

Sensor and Transducer

Sensor: A sensor is a device that provides usable output in response to change in a specified physical quantity which is measured. A device that receives and responds to a signal or stimulus.

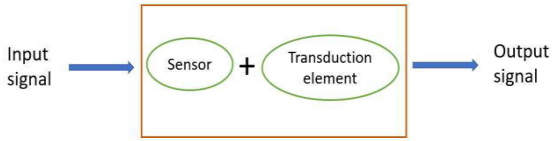
- The physical quantity may be temperature, force, pressure, displacement, flow etc.
- For example, the bulb of a thermometer senses the temperature of the body in contact



Transducers:

The transducer is a device that changes the physical attributes of the non-electrical signal into an electrical signal which is easily measurable. The process of energy conversion in the transducer is known as the transduction(figure). It consists of two parts:

1. Sensing element/detector
2. Transduction element



Types of sensors:

The following is a list of different types of sensors that are commonly used in various applications.

- Temperature Sensor
- Proximity Sensor
- Accelerometer
- IR Sensor (Infrared Sensor)
- Pressure Sensor
- Light Sensor
- Ultrasonic Sensor
- Smoke, Gas and Alcohol Sensor
- Touch Sensor, colour sensor
- Humidity Sensor
- Flow and Level Sensor

Types of transducers:

There are of many different types of transducer, they can be classified based on various criteria as:

1. Transducer based on Quantity to be Measured

- Temperature Transducers (e.g thermocouple)
- Pressure transducers (e.g. a diaphragm)
- Displacement transducers (e.g. LVDT)
- Oscillator transducers
- Flow transducers

2. Transducer based on the Principle of Operation

- Capacitive
- Inductive
- Resistive
- Photoelectric
- chemical

3. Transducer based on need of an External Power Source

- **Active Transducer:** Active transducers are those which do not require any power source for their operation. For example, a thermocouple, thermometer etc.
- **Passive Transducer:** Transducers which require an external power source for their operation is called as a passive transducer**.** For example, a strain gauge, thermistor etc.

Characteristics

The performance characteristics are mainly divided into two categories: i) Static characteristics ii) Dynamic characteristics

Static characteristics:

Static characteristics refer to the characteristics of the system when the input is either held constant or varying very slowly. Range, sensitivity, linearity, resolution, accuracy, precision, response time etc are important static characteristics.

Dynamic characteristics:

Dynamic characteristics refer to the performance of the instrument when the input variable is changing rapidly with time. For example, human eye cannot detect any event whose duration is more than one-tenth of a second; thus, the dynamic performance of human eye cannot be said to be very satisfactory.

Few important dynamics characteristics are dynamic error, speed of response, fidelity and lag.

PART-03
Overview of Mechanical actuation system

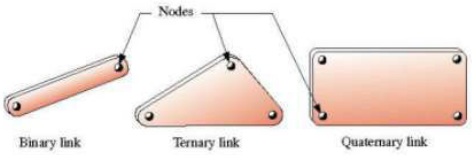
Kinematic chain

- A kinematic chain is a group of links either joined together or arranged in a manner that permits them to move relative to one another. If the links are connected in such a way that no motion is possible, it results in a locked chain or structure.

Important terms:

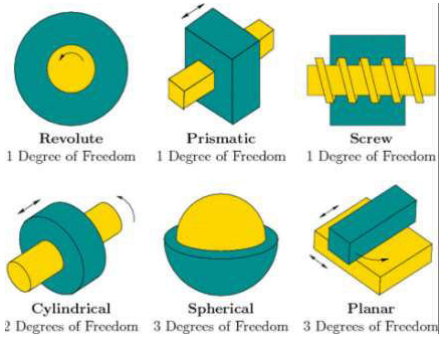
A] Kinematic link (or element): It is defined as a resistant body which has relative motion with some other element. e.g. crank, Piston, cylinder, frame.

b] Kinematic pair: When two links are connected in such a manner that relative motion between them take place in a definite way then it is called kinematic pair.



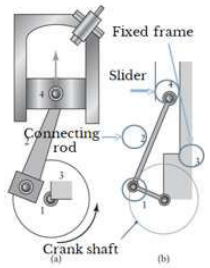
Kinematic link

kinematic pairs / types of kinematic pairs

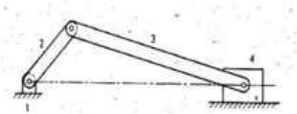


Mechanism: A mechanism is a constrained kinematic chain. This means that the motion of any one link in the kinematic chain will give a definite and predictable motion relative to each of the others. Usually one of the links of the kinematic chain is fixed in a mechanism.

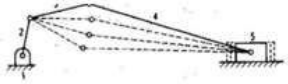
- If, for a particular position of a link of the chain, the positions of each of the other links of the chain cannot be predicted, then it is called as unconstrained kinematic chain and it is not mechanism.
- For example, the crankshaft of an engine forms a kinematic pair with the bearings which are fixed in a pair, the connecting rod with the crank forms a second kinematic pair, the piston with the connecting rod forms a third pair and the piston with the cylinder forms a fourth pair. The total combination of these links is a kinematic chain.



All mechanisms are Kinematic chains but *not* vice versa.



Kinematic Chain and a mechanism

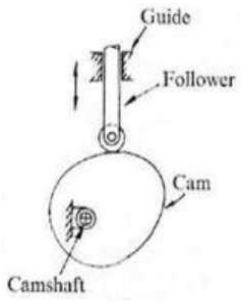


Unconstrained kinematic chain

Kinematic Chain and not a mechanism

CAM

A cam is a mechanical member used to impart desired motion to follower by direct contact.



Necessary members of cam and follower mechanism are

1. A driver member known as cam
2. A driven member known as follower
3. A frame which supports the cam and guides the follower

Example: A radial cam is shown in fig along with its important elements

Classification of CAM

Disk or plate cam: The disk (or plate) cam has not regular contour to transmit a specific motion to the follower.

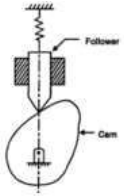


Fig. Plate cam

Cylindrical cam: The cylindrical cam has a groove in a cylindrical surface and the follower runs on the cylindrical surface parallel to the axis of the cylinder.

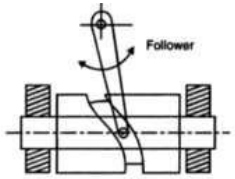


Fig. Cylindrical cam

Wedge cam: The wedge cam has an angled flat regular contour to impart a specific motion of the follower.

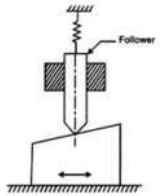
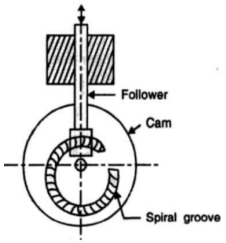
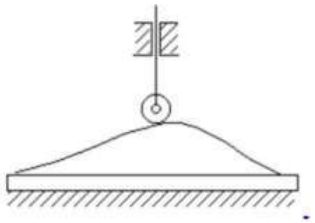


Fig. Wedge cam

Spiral cam: The spiral cam has a half-circular or a spiral shaping grooved contour, the cam moves in reciprocating motion and the follower moves vertically to the axis of the cam.



Translating cam: Translating cam has a grooved or contoured plate and its follower oscillate in the face of the plate. The groove or the contour has specified the motion of the follower.



Cam systems can also be classified according to the basic shape of the follower:

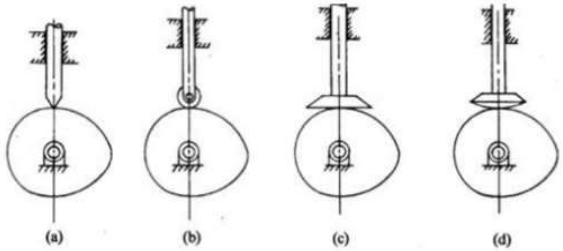
Figure shows plate cams actuating four different types of followers:

(a) A knife-edge follower.

(b) A roller follower

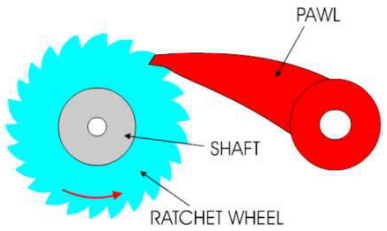
(c) A flat-face follower

(d) A spheric-face or curved-shoe follower



Ratchet Mechanisms

A ratchet mechanism is based on a wheel that has teeth cut out of it and a pawl that follows as the wheel turns. The diagram shows that as the ratchet wheel turns and the pawl falls into the 'dip' between the teeth. The ratchet wheel can only turn in one direction - in this case anticlockwise.



Construction and working:

A ratchet consists of a round gear or a linear rack with teeth, and a pivoting, spring-loaded finger called a pawl that engages the teeth. The teeth are uniform but asymmetrical, with each tooth having a moderate slope on one edge and a much steeper slope on the other edge.

When the teeth are moving in the unrestricted (i.e. forward) direction, the pawl easily slides up and over the gently sloped edges of the teeth, with a spring forcing it (often with an audible 'click') into the depression between the teeth as it passes the tip of each tooth. When the teeth move in the opposite (backward) direction, however, the pawl will catch against the steeply sloped edge of the first tooth it encounters, thereby locking it against the tooth and preventing any further motion in that direction.

Advantages:

- Simplicity is one of the big advantages of the ratchet.
- low cost and reliability.
- The ratchet is noted for its ability to carry a large load in relation to its size.
- It is a versatile device and is used in an amazing number of applications ranging from moderately heavy-duty machinery to high-speed instruments.

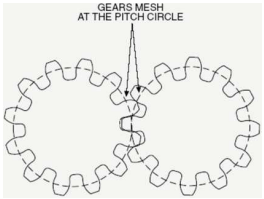
Disadvantages:

- It is an impacting mechanism. The impacts can lead to wear, control, and stability problems unless the rest of the system is properly designed. The basic problem of course, is that impacts produce forces throughout the mechanism that are well in excess of the subsequent drive forces.
- Impact also results in noise, which is very undesirable in most applications.

Applications: The ratchet and pawl mechanism is used wherever rotation is required in one direction only, e.g. in yacht winches, fishing reels, mechanical clocks. They are also very useful when using a system, such as the one seen in the figure, to lift heavy weights.

Gears

Definition: A gear is a kind of machine element in which teeth are cut around cylindrical or cone shaped surfaces with equal spacing. By meshing a pair of these elements, they are used to transmit rotations and forces from the driving shaft to the driven shaft.



Function: A gear drive has three main functions: to increase torque from the driving equipment (motor) to the driven equipment, to reduce the speed generated by the motor, and/or to change the direction of the rotating shafts.

Types of Gear

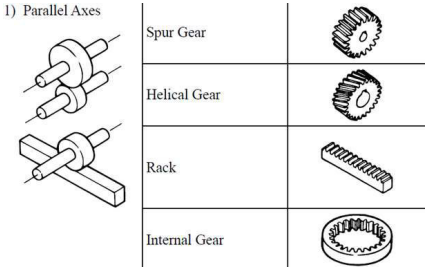
The gear has been classified through a lot of methods. The classification that is most popular is through the different position of the gear axis. Another way is through method of manufacturing, material and Tooth profile.

Classifications by the position of gear axis: There are three principal axes configurations employed by gears:

- Parallel
- Intersecting
- Non-parallel, non-intersecting

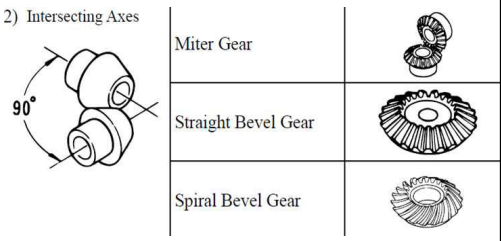
Parallel Axes Gear Configurations:

- Parallel configurations involve gears connected to rotating shafts on parallel axes within the same plane.
- The rotation of the driving shaft (and the driving gear) is in the opposite direction to that of the driven shaft (and driven gear), and the efficiency of power and motion transmission is typically high.
- Some of the types of gears which employ parallel configurations include spur gears, helical gears, internal gears, and some variants of rack and pinion gears.



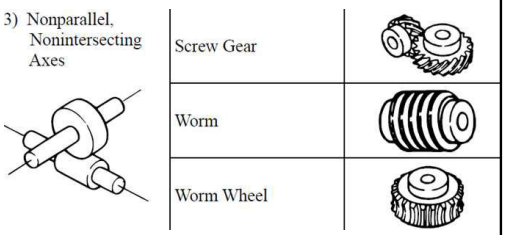
Intersecting Axes Gear Configurations:

- In intersecting configurations, the gear shafts are on intersecting axes within the same plane.
- Like the parallel configuration, this configuration generally has high transmission efficiencies. Bevel gears—including miter, straight bevel, and spiral bevel gears—are among the group of gears which employ intersecting configurations.
- Typical applications for intersecting gear pairs include changing the direction of motion within power transmission systems.



Non-parallel, Non-intersecting Gear Configurations:

- Gear pairs with a non-parallel, non-intersecting configuration have shafts existing on axes which cross (i.e., are not parallel) but not on the same plane (i.e., do not intersect).
- Unlike parallel and intersecting configurations, this configuration generally has low motion and power transmission efficiencies.
- Some examples of non-parallel, non-intersecting gears include screw gears, worm gears, and hypoid gears.



Applications:

Gears are devices used throughout industry for a variety of mechanical machines and systems. Several types of gears are available and employed in a wide range of residential, commercial, and industrial applications, including:

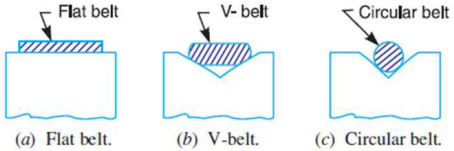
- Aircrafts
- Automobiles
- Clocks
- Marin Systems
- Material handling equipment
- Measuring instrumentation
- Power plants
- Pumps

Belt

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

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

Types of Belts
(a) Flat belt.
(b) V-belt.
(c) Circular belt.



(*a*) Flat belt. (*b*) V-belt. (*c*) Circular belt.

1. Flat belt: The flat belt, as shown in Figure (a), is mostly used in the factories and workshops, where a moderate amount of power is to be transmitted from one pulley to another pulley when the two pulleys are not more than 8 meter apart.
2. V-belt: The V-belt, as shown in Figure (b), is mostly used where a great amount of power is to be transmitted from one pulley to another when the two pulleys are very near to each other.
3. Circular belt or rope: The circular belt or rope, as shown in Figure (c), is mostly used where a great amount of power is to be transmitted. from one pulley to another pulley when the two pulleys are more than 8 meters apart.

Types of Flat Belt Drives:

1. *Open belt drive* - The open belt drive, as shown in Figure, is used with shafts arranged parallel and rotating in the same direction. The lower side belt (because of more tension) is known as ***tight side*** whereas the upper side belt (because of less tension) is known as ***slack side***, as shown in Figure.

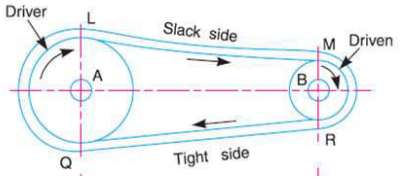


Figure: Open belt drive.

2. Crossed or twist belt drive - The crossed or twist belt drive, as shown in Figure, is used with shafts arranged parallel and rotating in the opposite directions.

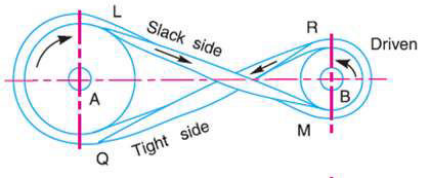


Figure: Crossed or twist belt drive.

Advantages of belt drives:

- Belt drives are simple are economical.
- They don't need parallel shafts.
- Noise and vibration are damped out. Machinery life is increased because load fluctuations are shock-absorbed.
- They are lubrication-free. They require less maintenance cost.
- Belt drives are highly efficient in use (up to 98%, usually 95%).
- They are very economical when the distance between shafts is very large.

Disadvantages of belt drives:

- In Belt drives, angular velocity ratio is not necessarily constant or equal to the ratio of pulley diameters, because of slipping and stretching.
- Heat buildup occurs. Speed is limited to usually 35 meters per second. Power transmission is limited to 370 kilowatts.
- Operating temperatures are usually restricted to –35 to 85°C.
- Some adjustment of center distance or use of an idler pulley is necessary for wearing and stretching of belt drive compensation.

Bearings

Bearings are machine elements which are used to support a rotating member viz., a shaft. They transmit the load from a rotating member to a stationary member known as frame or housing.

Classification of Bearings:

On the basis of the contact between the rotating and the stationary member:
a. Sliding contact
b. Rolling contact

a. **Sliding contact:** In sliding contact bearings, the sliding takes place along the surfaces of contact between the moving element and the fixed element as shown in figure (a). The sliding contact bearings are also known as plain bearings.

b. **Rolling contact:** The contact between the bearing surfaces is rolling instead of sliding as in sliding contact bearings as shown in figure (b). Due to this low friction offered by rolling contact bearings, these are called antifriction bearings.

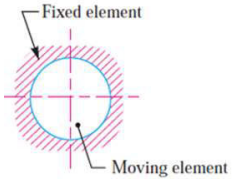


Fig. (a)

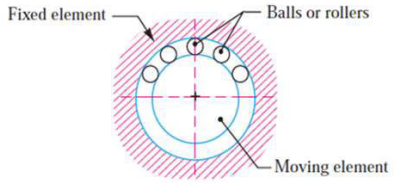
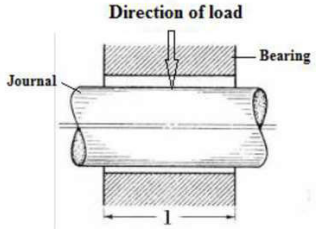


Fig. (b)

Bearing classification based on type of load carried:

a. Radial bearings
b. Thrust bearings or axial bearings
c. Radial – thrust bearings

a. Radial Bearing: These bearings carry only radial loads as shown in figure. The load acts perpendicular to the axis of the shaft or journal.



b. Thrust Bearing: Such type of bearings carries only axial loads as shown in fig 2. A collar is provided to restrict the axial movement of the shaft or journal. The collar present in the bearing tends to arrest the movement of the shaft in the axial direction. The collar is accommodated and thus correspondingly engages with the surfaces in the thrust block.

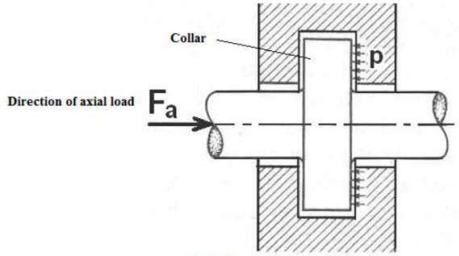
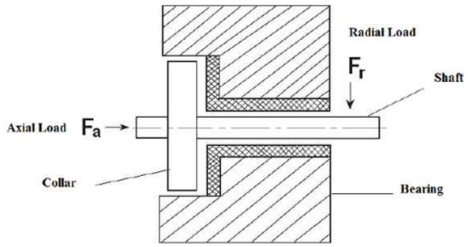


Fig 2: Single Collar Thrust Bearing

c. Radial Thrust Bearing: These bearings carry both radial and thrust Loads as shown in figure.



Advantages and disadvantages of rolling contact bearings over sliding contact bearings:

Advantages

1. Low starting and running friction except at very high speeds.
2. Ability to withstand momentary shock loads.
3. Accuracy of shaft alignment.
4. Low cost of maintenance, as no lubrication is required while in service.
5. Small overall dimensions.
6. Reliability of service.
7. Easy to mount and erect.
8. Cleanliness.

Disadvantages

1. Noisier at very high speeds.
2. Low resistance to shock loading.
3. More initial cost.
4. Design of bearing housing complicated

PART-4

Hydraulic and Pneumatic actuation system

Actuator:

Actuators are output devices which convert energy from pressurized hydraulic oil or compressed air into the required type of action or motion. In general, hydraulic or pneumatic systems are used for gripping and/or moving operations in industry. These operations are carried out by using actuators.

Actuators can be classified into two types.

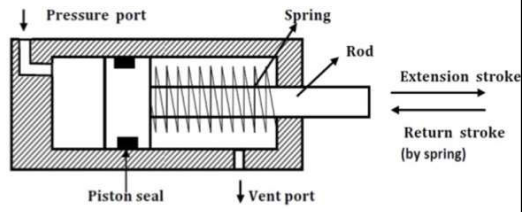
1. Linear actuators: These devices convert hydraulic/pneumatic energy into linear motion.
2. Rotary actuators: These devices convert hydraulic/pneumatic energy into rotary motion.

Linear actuators(cylinders)

All hydraulic cylinders create linear movement, but there are different varieties which have their own unique effects. Below we will outline some of the most common types of hydraulic cylinders.

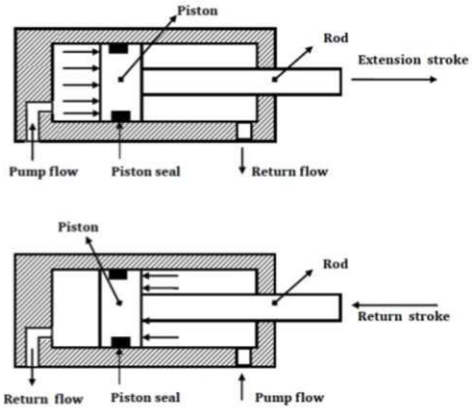
1. Single acting hydraulic cylinder

Single acting cylinders operate in one direction only. They have a single port at one end of the cylinder, so when the fluid is pumped into the port it pushes the rod, causing it to extend. The rod returns because of an external force such as the load or a spring.



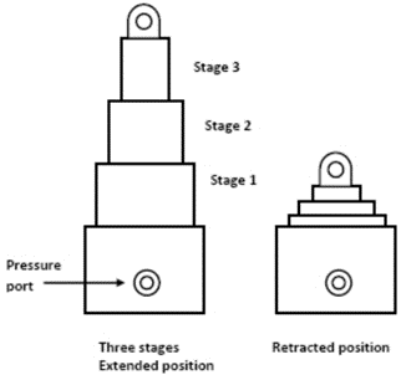
2. Double acting hydraulic cylinder:

Unlike single acting cylinders which can only push or pull, double acting cylinders do both. They have ports both ends of the cylinder so that when oil is pumped into the head port, the piston moves and extends the rod. Oil in the rod end of the cylinder is pushed out into a reservoir. To achieve the opposite movement and retract the rod, the oil flow is reversed.



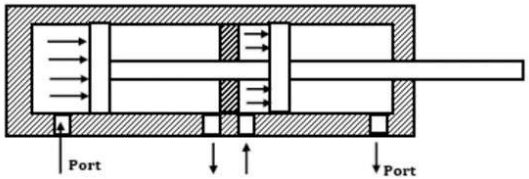
3. Telescopic hydraulic cylinder:

Telescopic cylinders are, as their name suggests, a series of rams inside one another like a telescope. This means they can achieve a comparatively long stroke when all the rams are extended. These types of cylinders can be single or double acting.



4. Tandem hydraulic cylinder:

In a tandem hydraulic cylinder, two interconnected cylinders operate together to generate a greater force than one cylinder would be able to create on its own. The two cylinders are supplied by different hydraulic systems, but they are connected mechanically so that the rod of the first cylinder enters the second cylinder, pushing its base.

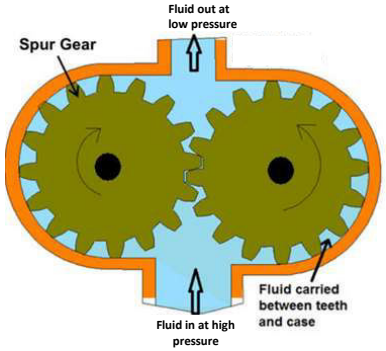


Rotary actuator:

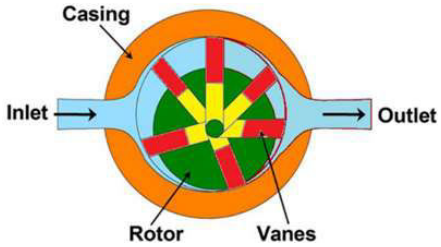
Rotary actuators convert energy of pressurized fluid into rotary motion. Rotary actuators are similar to electric motors but are run on hydraulic or pneumatic power.

Gear motor:

It consists of two inter meshing gears inside a housing with one gear attached to the drive shaft. Figure shows a schematic diagram of Gear motor. The air enters from the inlet, causes the rotation of the meshing gear due to difference in the pressure and produces the torque. The air exits from the exhaust port. Gear motors tend to leak at low speed, hence are generally used for medium speed applications.

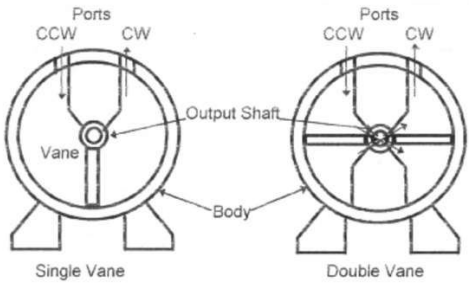


Vane motor:
A rotary vane motor consists of a rotor with sliding vanes in the slots provided on the rotor (Fig.). The rotor is placed eccentrically with the housing. Air enters from the inlet port, rotates the rotor and thus torque is produced. Air is then released from the exhaust port (outlet).

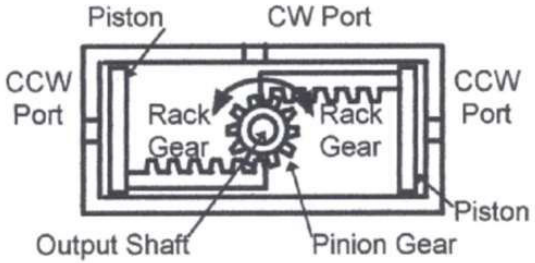


Limited rotation actuators:

A. Vane type:
Figure provides simplified cutaway views of vane-type rotary actuators. The figure depicts both single- and double-vane-types. The vanes attach to an output shaft and have seals around their periphery. When fluid pressure on a given vane area pushes it through the body cavity, the output shaft turns with a given torque. The maximum rotation of vane rotary actuators is limited to approximately 280° in a single-vane model and approximately 100° in the double-vane configuration. These are generally used to actuate dampers in robotics and material handling applications.



B. Rack and pinion type:
The rack-and-pinion design rotary actuators shown in Figure are available with a second rack gear and pistons mounted on the opposite side of the pinion. This double-piston setup produces twice the torque in both directions of rotation.



Control valves

One of the most important functions in any fluid power system is control. If control components are not properly selected, the entire system will fail to deliver the required output. Elements for the control of energy and other control in fluid power system are generally called “Valves”.

There are 3 basic types of valves
1. Directional control valves
2. Pressure control valves
3. Flow control valves

Directional control valves:

Directional control valves perform only three functions:

- stop fluid flow
- allow fluid flow, and
- change direction of fluid flow.

These three functions usually operate in combination.

Directional control valves can be classified in a number of ways:

1. According to type of construction:
   - Poppet valves
   - Spool valves
2. According to number of working ports:
   - Two- way valves
   - Three – way valves
   - Four- way valves.
3. According to number of Switching position:
   - Two – position
   - Three – position

1. Poppet Valves: Directional poppet valves consists of a housing bore in which one or more suitably formed seating elements (moveable) in the form of balls, cones are situated. When the operating pressure increases the valve becomes more tightly seated in this design.

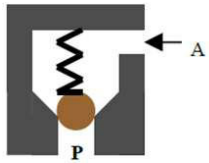
Advantage

- No Leakage as it provides absolute sealing.
- Long useful life, as there are no leakage of oil flows.
- May be used with even the highest pressures, as no hydraulic sticking (pressure dependent deformation) and leakages occurs in the valve.

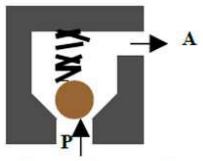
Disadvantages

- Large pressure losses due to short strokes
- Pressure collapse during switching phase due to negative overlap (connection of pump, actuator and tank at the same time).

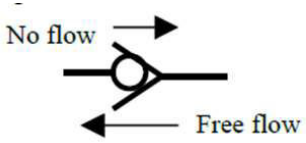
2 / 2 DCV (Poppet design) :-



a. Valve Closed

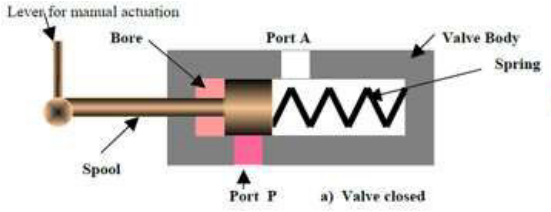


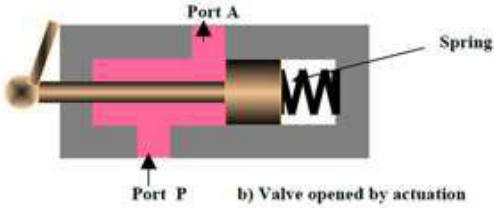
b. Valve Opened



C. Symbol of 2/2 DCV

2. Spool valves: The spool valve consists of a spool which is a cylindrical member. The spool valves are sealed along the clearance between the moving spool and the housing. The grooves between the lands provide the flow passage between ports.

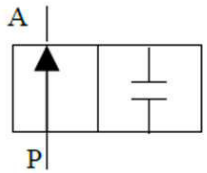




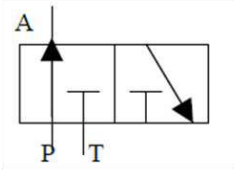
According to the number of ports and switching position:

The number of ports on a directional control valve (DCV) is usually identified by the term " way".

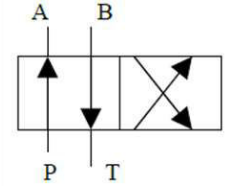
- A valve with 2 service ports and 2 switching positions is designated as 2 / 2 way valve.
- A valve with 3 service ports and 2 position is designated as 2 / 3 way valve.
- A valve with 4 service ports and 2 position is designated as 2 / 4 way valve



2/2 way valve



2/3 way valve



2/4 way valve

Pressure control valve

These are the units ensuring the control of pressure. A throttling orifice is present in the valve and by variation of orifice, the pressure level can be controlled or at a particular pressure, a switching action can be influenced.
The most common valves for controlling pressure include relief, reducing, sequence, counterbalance, and unloading valves.

Pressure relief valve: The pressure relief valve is an important type of safety valve. A pressure relief valve protects motors, pumps and actuators from becoming damaged from high pressure. The valve remains closed for normal operation. And no water passes through the valve. When the pressure in the loop exceeds the limit the valve opens, and the relief the excess pressure. Thus, protects the expensive machinery.

Pressure-relief valves limit the maximum pressure in a hydraulic circuit by providing an alternate path for fluid flow when the pressure reaches a preset level.

Important terms:

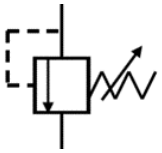
- **Cracking pressure:** The pressure at which a relief valve first opens to allow fluid to flow through is known as cracking pressure.
- **Flow pressure:** When the valve is bypassing its full rated flow, it is in a state of full-flow pressure.
- **Pressure override:** The difference between full-flow and cracking pressure is sometimes known as *pressure differential,* also known as *pressure override.*

There are two different designs of relief valves in use:

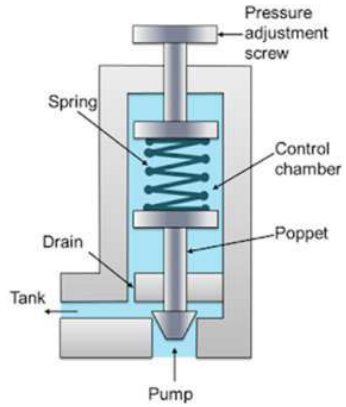
- Direct-acting
- Pilot-operated

Both types have advantages and work better in certain applications.

Direct-acting relief valves: Schematic diagram of simple relief valve is shown in Figure. It is normally a closed valve whose function is to limit the pressure to a specified maximum value by diverting pump flow back to the tank. A poppet is held seated inside the valve by a heavy spring. When the system pressure reaches a high enough value, the poppet is forced off its seat. This permits flow through the outlet to the tank as long as this high pressure level is maintained



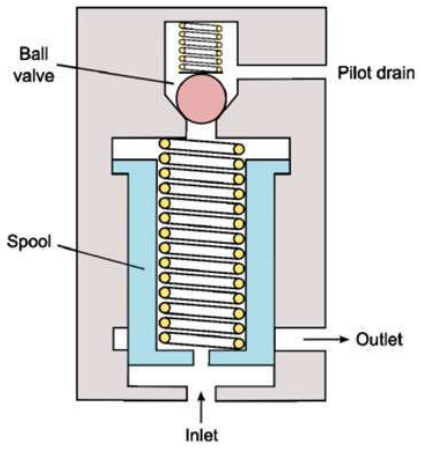
Symbol



Pilot-operated relief valves: A pilot-operated pressure-relief valve consists of a small pilot relief valve and main relief valve as shown in Figure. The main relief valve consists of a piston and a stem. The main relief piston has an orifice drilled through it. The piston has equal areas exposed to pressure on top and bottom and is in a balanced condition due to equal force acting on both the sides. It remains stationary in the closed position.

It operates in a two-stage process:

- The pilot relief valve opens when a preset maximum pressure is reached.
- When the pilot relief valve opens, it makes the main relief valve open.



Accumulator:

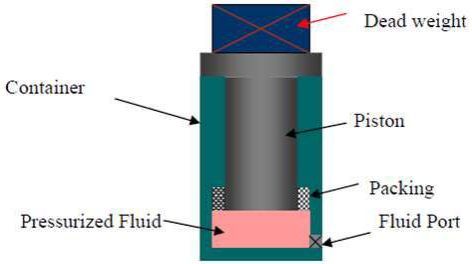
- A hydraulic accumulator is a device that stores the potential energy of an incompressible fluid held under pressure by an external source against some dynamic force.
- The stored potential energy in the accumulator is a quick secondary source of fluid power capable of doing useful work as required by the system.

There are three basic types of accumulator used in hydraulic system. They are:

1. Weight – Loaded, or gravity, type
2. Spring -Loaded type
3. Gas – Loaded type

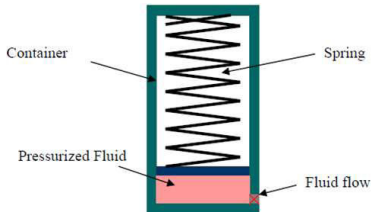
1. Weight – Loaded Accumulator :

- This type consists of a vertical, heavy- wall steel cylinder, which incorporates a piston with packing to pressure leakage as shown in figure. A dead weight is attached to the top of the piston. The force of gravity of the dead weight provides the potential energy in the accumulator.
- This type of accumulator creates a constant fluid pressure throughout the full volume output of the unit regardless of the rate and quantity of output. The main disadvantage of this type of accumulator is extremely large size and heavy weight which makes it unsuitable for mobile equipment



2. Spring – Loaded Accumulator:

- A spring loaded accumulator is similar to the weight – loaded type except that the piston is preloaded with a spring as shown in figure. The spring is the source of energy that acts against the piston, forcing the fluid into hydraulic system. The pressure generated by this type of accumulator depends on the size and pre-loading of the spring. In addition, the pressure exerted on the fluid is not a constant.
- The spring- loaded accumulator typically delivers a relatively small volume of oil at low pressures. Thus, they tend to be heavy and large for high- pressure, large – volume systems. This type of accumulator should not be used for applications requiring high cycle rates because the spring will fatigue and lose its elasticity. The result is an inoperative accumulator.



Application:

1. Accumulator as a auxiliary power source: The accumulator then releases this stored oil on demand to complete the cycle, thereby serving as a secondary power source to assist the pump.
2. Accumulator as an emergency power source: In some hydraulic system, safety dictates that a cylinder be retracted even though the normal supply of oil pressure is lost due to a pump or electrical power failure. Such an application requires the use of an accumulator as an emergency power source.
3. Accumulator as a hydraulic shock absorber: One of the most important industrial application of accumulator is the elimination or reduction of high pressure pulsation or hydraulic shock Hydraulic shock is caused by the sudden stoppage, sudden impact load, or reversal with heavy loads.