“Robot Sensor and Drive”

1

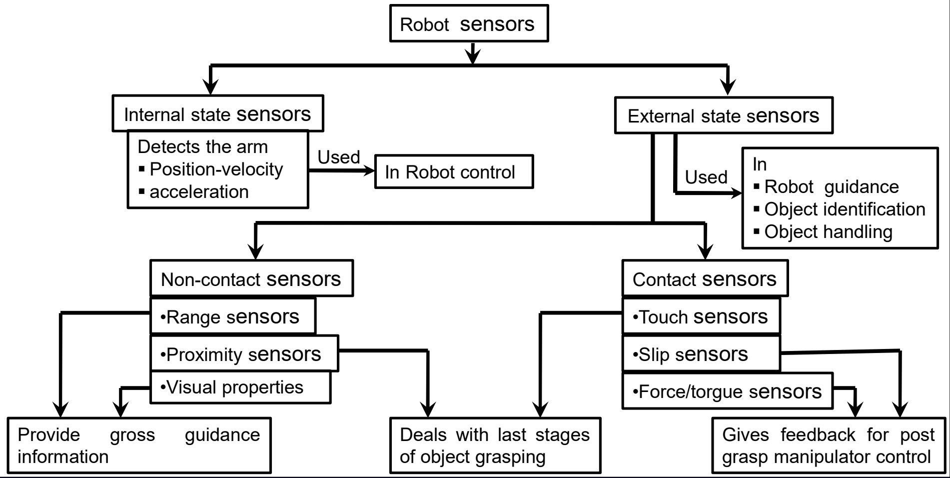
Robotic Sensor

- ‘A robotic sensor is a device that detects information about the robot and its surroundings, and at the same time transmits it to the robot’s controller’.
- In robotics, sensors are used for both internal feedback control and external interaction with the outside environment.
- Sensors are used for a variety of functions in robotic systems such as:
  a) for detecting positions and orientation of parts.
  b) to ensure consistent product quality.
  c) to discover variations of shape and dimensions of parts.
  d) To identify unknown obstacles and
  e) To determine system malfunctions and to analyze it.

2

Robotic Sensor

Classification of Sensor and Their functions.



Robotic Sensor

Sensor Classification:

Sensors that are of interest in manufacturing may be classified as:

1. Mechanical- for manufacturing quantities such as position, shape, velocity, force, torque, pressure, vibration, strain and mass.
2. Electrical-for measuring voltage, current, charge, and conductivity.
3. Magnetic-for measuring magnetic field, flux and permeability.
4. Thermal-for measuring temperature, flux conductivity and specific heat.
5. Others-such as acoustic, proximity, chemical, photoelectric, radiation, lasers, optical systems (fiber optics and light-emitting diodes), tactile, voice and visual sensing.

Robotic Sensor

Sensors also are grouped into three main categories:

1. Function performed
2. Location and type of detection
3. Physical activation

Function Performed:

- According to their function performed, sensors can be categorized under manipulation or acquisition.
- **Manipulation:**
  - Those that allow the robot to interact with its surroundings, like tactile and force sensors attached to the manipulator are grouped under manipulation.
  - Tactile sensors are devices that indicate contact between themselves and another solid object.
  - Tactile sensing devices can be divided into two classes: touch sensors and force sensors.

Robotic Sensor

Acquisition:

- Those sensors that let the robot know its own present state are grouped under acquisition.
- These devices measure the distance to the nearest object within a zone of information-collection space.
- An example of a point measuring device may be found in the distance measuring ultrasound devices.

Location and type of Detection:

- According to their location and type of detection, sensors are categorized as internal, external or interlock.

Robotic Sensor

Location and type of Detection:

- According to their location and type of detection, sensors are categorized as internal, external or interlock.
- **Internal:**
  - Internal sensors use feedback information internally to ascertain their present condition.
  - The first complex sensors used by industrial robots is known as haptic perception.
  - This is the robotic equivalent of the human sense of kinesthesia, which is sensing information that comes from the joints and muscles without locating them visually.
  - Presently, an industrial robot's internal sensors use mechanical, electrical, electronic, and hydraulic devices to obtain feedback information. These devices are called closed-loop and servo-controlled systems.
- **External:**
  - The four most common external sensors are the microswitches, the simple touch or tactile sensors, the photoelectric devices, and the proximity sensors.

Robotic Sensor

- **Interlock:**
  - Interlock sensors are devices that do not allow an operation to be performed until certain conditions exist.
  - They are very old devices that are used to protect from harmful conditions.
  - Some interlock devices may sound an alarm or stop the motion without switching its power off in an emergency.
  - An interlock sensor may also be used to protect a robot.
  - Examples include the airflow in the robot's controller that can reach the level before power is applied to the controller's system; hydraulic pressure that can reach some minimum level before hydraulic actuators are allowed to move, the temperature of the hydraulic fluid, which can remain below a certain level if the hydraulic systems is to be used.

Robotic Sensor

- **Physical activation**
- According to their physical activation, sensors are categorized as contact or non-contact.
- **Contact:**
  - Contact sensors, must physically touch an object before the sensor is activated.
  - Contact sensors include microswitches and all tactile-sensing devices.
- **Non-contact:**
  - Non-contact sensors measure the condition of an object without physically touching the part.
  - Most frequently, non-contact sensors are those that measure point of response and others that give a spatial array of measurements at neighboring points of information.
  - A vision system is the most common example of a device that measure spatial information.
  - By point of response, non-contact sensors includes devices that measure spectral range such as infrared, visible and X-ray.

Robotic Sensor

Sensor Characteristics:

1. To choose an approximate sensor for a particular need, one has to consider a number of different following characteristics:
   - **Cost:** The cost must be balanced with other requirements of the design, such as reliability, importance of the data they provide, accuracy, and life.
   - **Size:** For example, the joint displacement sensors have to be adapted into the design of the joints and move with the robot's body elements. The available space around the joint may be limited. In addition, a large sensor may limit joint ranges. Thus, it is important to ensure that there is enough room for the joint sensors.
   - **Weight:** Since robots are dynamic machines, a heavy sensor adds to the inertia of the arm, as well as reduces its overall payload.

Robotic Sensor

- **Type of output (digital or analog):** For example, the output of a potentiometer is analog, whereas that of an encoder is digital. If an encoder is used in conjunction with a microprocessor, the output may be directly routed to the input port of the processor, while the output of a potentiometer will have to be converted to digital signal with an analog-to-digital converter (ADC). The appropriateness of the type of output must be balanced with other requirements.
- **Interfacing:** The interfacing between the sensor and the device can become an important issue if they do not match or if other add-on circuits become necessary.
- **Sensitivity:** Sensitivity is the ratio of a change in output in response to a change in input. Highly sensitive sensors will show larger fluctuations in output as a result of fluctuations in input, including noise.

Robotic Sensor

- **Resolution:** Resolution is the minimum step size within the range of measurement of the sensor. In a wire-wound potentiometer, it will be equal to the resistance of one turn of the wire. In a digital device with n bits, the resolution will be,

$$\mathrm{Resolution} = \frac{Full\ Range}{2^n}$$

- **Range:** Range is the difference between the smallest and the largest outputs the sensor can produce, or the difference between the smallest and largest inputs with which it can operate properly.

Robotic Sensor

- **Linearity:** Linearity represents the relationship between input variations and output variations. This means that in a sensor with linear output, the same change in input at any level within the range will produce the same change in output. Almost all devices in nature are somewhat nonlinear, with varying degrees of nonlinearity.

  For example, suppose that a displacement sensor has an output that is varying with the sine of an angle. Then to use the sensor, the designer may divide the output by the sine of the angle, either in programming or through addition of a simple electronic circuit that divides the signal by the sine of the angle. Thus, the output will be as if the sensor were linear.

Robotic Sensor

- **Response time:** Response time is the time that a sensor's output requires to reach a certain percentage of the total change. It is usually expressed on percentage of total change, such as 95%. For example, the response time of a simple mercury thermometer is long, whereas a digital thermometer's response time, which measures temperature based on radiated heat, is short.

Robotic Sensor

- **Frequency response:** Suppose that you attach a very-high-quality radio tuner to a small, cheap speaker. Although the speaker will reproduce the sound, its quality will be very low, whereas a high-quality speaker system with woofer and tweeter can reproduce the same signal with much better quality. This is because the frequency response of the two-speaker system is very different from the small, cheap speaker. The frequency response is the range in which the system's ability to resonate (respond) to the inputs remains relatively high. The larger the range of the frequency response, the better the ability of the system to respond to varying input. Similarly, it is important to consider the frequency response of a sensor and determine whether the sensor's response is fast enough under all operating conditions.

Robotic Sensor

- **Reliability:** Reliability is the ratio of how many times a system operates properly divided by how many times it is tired. For continuous, satisfactory operation, it is necessary to choose reliable sensors that last a long time, while considering the cost, as well as other requirements.
- **Accuracy:** Accuracy is defined as how close the output of the sensor is to the expected value. If for a given input, the output is expected to be a certain value, the accuracy is related to how close the sensor's output is to this value.
- **Repeatability:** If the sensor's output is measured a number of times in response to the same input, the output may be different each time. Repeatability is a measure of how varied the different outputs are relative to each other.

Robotic Sensor

1. Microswitches:

Microswitches are electromechanical devices actuated either by some part or motion of a robot or machine to alter the electrical circuit. This event is indicated by means of opening or closing the switch contacts.

- **Mechanical Contact Switches**
- It must pass an electrical current with a virtual short circuit in the ON state, and break that current flow in the OFF state.
- The location at which current is interrupted in a mechanical switch is known as the contacts.
- The basic problem with mechanical contact switches is an arc, or spark, jumping from one contact to that other as the contacts separate.
- The greater the amount of current flowing through the contacts, and the higher the voltage across the open contact pair, the greater the tendency to arc.
- As the contacts are opened, arcing across the air gap results in spark erosion of the contact surfaces as well as contact oxidation.

Robotic Sensor

- When the contacts are closed again, the arc-eroded contact surfaces offer slightly higher resistance than they did on the previous closing.
- All mechanical switch contacts will fail sooner or later by virtue of the degradation inherent in the switching operation itself.
- To maximize contact attempt to minimize contact resistance (thus heating) by using oxidation-resistant metals (gold, platinum) and by providing contact pressure in the ON state to squeeze the contact interface, increasing the contact area and breaking through any oxide film.
Switching Resistive and Inductive Loads
- There are two basic types of electrical loads that must be switched by machine-control systems: resistive and inductive.
- Resistive loads include lights and heaters Inductive loads include motors and solenoids.
- Contacts carrying DC current to purely resistive loads have a tendency to are when the circuit is broken, which is proportional to the open-circuit voltage and the amount of current being carried through the circuit.

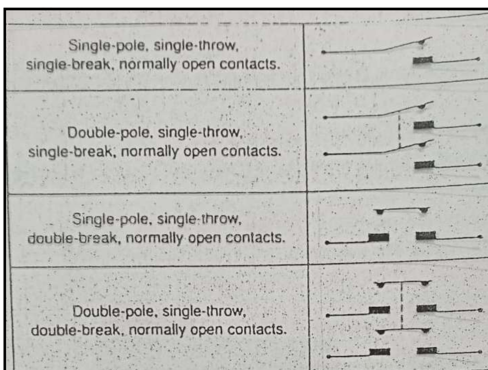
Robotic Sensor

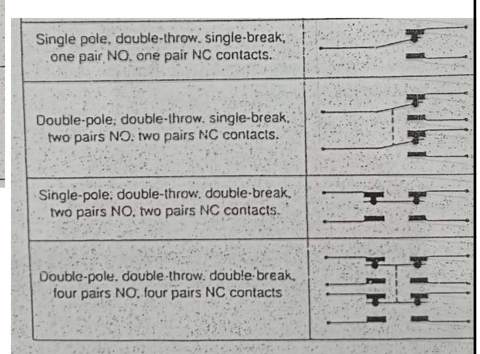
- The problem with switching inductive loads carrying LC power is that an abrupt opening of the circuit results in a very high voltage surge, which not only aggravates arcing but also is potentially damaging to any other electronic components in the same circuit.
- Another problem associated with switching motors, relays, and solenoids is that they exhibit high inrush currents upon start-up.
- These initial high currents can result in contact welding.
- Contact arcing in DC inductive load circuits can also be suppressed by inserting resistors, capacitors, and/or diodes in parallel with the contacts and the inductive load.

Robotic Sensor

Control Arrangements:

- The state of a switch's contacts in the un-actuated mode determines whether a switch is normally open (NO) or normally closed (NC) with respect to a single circuit. An NO contact pair will close (stop current flow) or break upon switch actuation.
- The number of poles associated with a switch is the number of independent circuits that the switch makes or breaks at one actuator position.
- The throw of the switch is the number of circuits that can be switched by a single pole. For example, a single-throw switch might make a circuit in one switch position and break that same circuit in another position.
- A double-throw switch might have circuit A closed and circuit B open in one switch position, and vice versa in the other switch position.
- Switch break is the number of contact pairs that are opened or closed in each independent circuit as the switch moves from one position to the other.





Electromagnetic contact arrangements

Robotic Sensor

Types of Microswitches

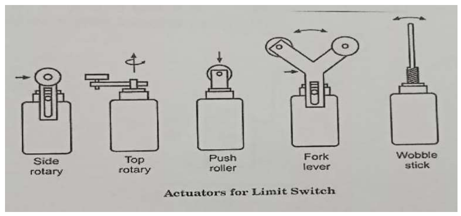
- There are five types of microswitches used in workcells:
    1. Manual switches
    2. Limit switches
    3. Impulse limit switches
    4. Reed switches
    5. Pressure switches.
- **Manual switches** are manually actuated and classified as momentary or maintained contact types. Momentary contact switches include push-button and toggle switches, and this type of action is widely used to start and stop machine operations. Maintained contact switches include push-button, toggle, sliding, and rotary types. The contacts are transferred by the actuator and remain transferred after the operator's hand is removed.

Robotic Sensor

- Industrial **limit switches** are usually enclosed in cases in order to protect the switch from dust, water, and human abuse. Heavy-duty limit switches are available as oil-tight, corrosion-resistant, and generally more rugged enclosures. Figure shows the common limit switch actuators used in workcells. Actuator types are selected primarily on the basis of where the limit switch might be located with respect to the controlled machine member.
- It is important to install the limit switch in a location and position such that:
    1. The moving member will not destroy the limit switch.
    2. The limit switch is accessible for maintenance.
    3. The limit switch is protected from accidental actuation (such as an over-hanging workpiece, etc.)
    4. Chips, moisture, grease, or oil accumulation does not take place on the actuator.
-

Robotic Sensor

- A limit switch is designed to be mechanically actuated when a machine member of te reaches a particular position. The machine member physically contact the limit switch actuator and switches the contacts. The limit switch can be used to control machine operation sequencing or to provide machine protection functions by shutting down the machine when machine members or workers are at a prohibited location.

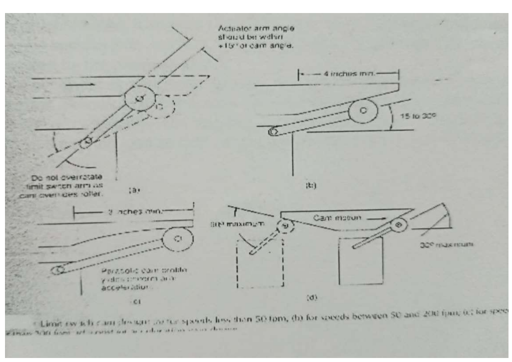


Actuators for Limit Switch.

Limit switches can come with momentary contacts (standard signal) or impulse (spontaneous signal)

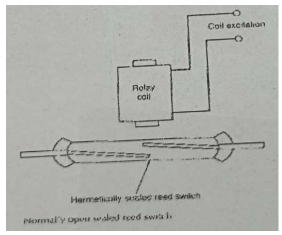
Robotic Sensor

- Impulse limit switches produce a switching signal only while the plunger travels inward. The contacts switch back when the end of the plunger travel is reached and remain OFF during return travel of the plunger. This switching action overcomes some control system design problems where an actuator sitting on a limit switch will not allow subsequent operations to take place.



Robotic Sensor

- Reed switches consist of two or more thin metal strips (reeds) enclosed in an evacuated hermetically sealed glass capsule.
- The reeds overlap and can be closed by moving a magnet close to the reeds, and opened by moving the magnet away.
- Alternatively, the reeds can be closed by energizing a nearly coil (reed relay).
- Figure shows an NO reed switch. Reed switches are not generally used to switch large inductive loads directly i.e. motors) but often are used to switch power to another control source.



"Robot Drive"

Robot Drive

- The links of the robots move about the prescribed axis by receiving power through the drive system also known as actuator.
- Actuator are the muscles of the robots which move or rotate the links to change the configuration of the robots.
- Actuators are the devices which provide actual motive force for the robot joints.
- Source of power for the actuators can be through:
  i. Electricity
  ii. Pressurized fluid
  iii. Compressed air

  based on which they are classified.

Robot Drive

- Actuators chosen (would depends upon) should be
  i. Light
  ii. Economical
  iii. Accurate
  iv. Responsive
  v. Reliable
  vi. Easy to maintain

Robot Drive

- **Classification of Actuators:**

  - **Electric Motors:**

    Electric Motors Produce rotational movement.

    Translatory movement are produced by transmission devices.

    a) Servomotor
       i. AC
       ii. DC

    b) Stepper motor

    c) Direct drive motor

Robot Drive

- **Classification of Actuators**: contd…

  - **Hydraulic Actuators:**

    Hydraulic actuators use pressurised fluid.

    a) Linear actuators

    Hydraulic cylinder produce translatory motion in joints.
       i. Single acting
       ii. Double acting

    b) Rotary actuators

    Hydraulic motors produce rotation motion joints.
       i. Gear
       ii. Vane
       iii. Piston
       iv. Rack and pinion

Robot Drive

- **Classification of Actuators: contd…**
  - **Pneumatic Actuators:**

    Pneumatic actuators use compressed air.

    a) Air cylinders

    Air cylinders produce translatory motion in joints.

    i. Single acting

    ii. Double acting

    b) Air motors

    Air motors produce rotation motion joints.

    i. Vane

    ii. Piston
  - **Shape Memory Metal Actuators**
  - **Magneto Restrictive Actuators**

Robot Drive

There are many types of electric motors that are used in robotics. They include the following:

1. DC motors
2. Reversible AC motors
3. Brushless DC motors

i. Except for stepper motors, all other types of motors can be used as a servo- motor.

ii. In each case, the torque or power output of the motor is a function of the strength of the magnetic fields and the current in the windings. Some motors have permanent magnets (PMs).

iii. These motors generate less heat, since the field is always present and no current is needed to build them.

iv. Others have a soft iron core and windings, where an electric current creates the magnetic field.

Robot Drive

v. In this case, more heat is generated, but when needed, the magnetic field can be varied by changing the current, whereas in permanent magnet motors, the field is constant.
vi. Additionally, under certain conditions, it is possible that the permanent magnet may get damaged and loses its field strength, in which case the motor becomes useless.
vii. For example, you should never take a motor apart, as the permanent magnet will become significantly weaker.
viii. This is because the iron mass around the magnet holds the field intact until they are separated.
ix. To increase the strength of the permanent magnets in motors, most manufacturers magnetize the magnets after assembling the motor. Motors without permanent magnets do not have this problem.

Robot Drive

Advantages of DC Motor Provide :

i. Excellent speed regulation
ii. high torque and high efficiency

Disadvantages of DC Motor:

a) The operation of DC motor must take place within its thermal range.
b) Maintenance owing to carbon deposits on brushes.
c) Used in positioning systems where slower response can be tolerated in comparison to hydraulic systems.

Robot Drive

AC Motor:

a) Unlike DC motors, AC motors operate without brushes this eliminating one of the main maintenance problems associated with the DC motors.

b) The velocity of the AC motor is regulated by voltage frequency rather than voltage magnitude as in the case of DC motors.

c) The frequency manipulation requires use of an electrical inverter (The inverter contains a DC power supply and a circuit that invert the resultant DC voltage into AC voltage with a continuously controllable frequency.)

d) The use of AC motors was limited earlier because intervals were expensive huge in size compared to DC power amplifiers which are required to control the voltage magnitude applied to the DC motor drives.

e) Nowadays cost-effective, small size inverters are used, thus enabling prominence of AC motors in CNC machines.

Robot Drive

AC And DC:

i. One important issue in the design and operation of all motors is the dissipation of heat.

ii. The heat is generated primarily from the resistance of the wiring to electric current (load related), but includes heat due to iron losses, including eddy current losses and hysteresis losses, friction losses, brush losses, and short-out circuit losses (speed related) as well.

iii. The higher the current, the more heat is generated, as $W = RI^2$.

iv. Thicker wires generate less heat, but are more expensive, are heavier (more inertia), and require more space.

v. However, what is important is the path that the heat must take to leave the motor since if the heat is dissipated faster, more generated heat can be dissipated before damage occurs.

Robot Drive

In hydraulic system:

Hydraulic systems comprise of the following:

1. A hydraulic power supply,
2. A servo valve for each axis of motion to effect power amplification,
3. A hydraulic actuator cylinder / motor for each axis of motion,
4. A sump.

i. Hydraulic Power Supply:

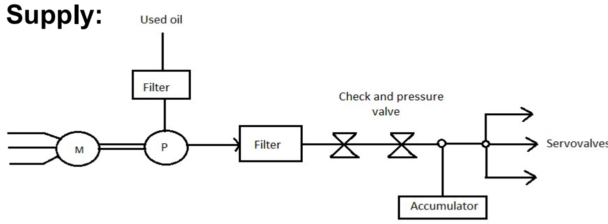


Fig. Hydraulic Power supply

Robot Drive

i. The power source for hydraulic actuation system (cylinder/ Motor/ servo valves) wall is high pressure oil supplied by an oil pump.

ii. The main components of the hydraulic power supply are:

   a. A pump(P), either gear pump vane pump for piston pump (radial or axial type) is used for supplying high-pressure oil.
   b. An electric motor (M) for driving the pump usually three phase induction motor.
   c. A fine filter for protecting the servo system for a dirt or chips.
   d. A coarse filter for protecting the pump.
   e. A check valve for eliminating a reverse flow from the accumulator to the pump.
   f. A pressure regulating valve for controlling supply pressure to the servo system.

Robot Drive

g. An accumulator for storing hydraulic energy and smoothing the pulsating flow.

Accumulators:

- Can provide large amount of energy in a short period of time and a smooth the pulsations carried by the pump.
- In hydraulic actuator systems the oil undergoes a considerable amount of temperature change (rise) therefore a necessary part of all high pressure hydraulic systems in an cooling device which would maintain a relatively stable oil temperature, so that properties of hydraulic fluid are maintained.

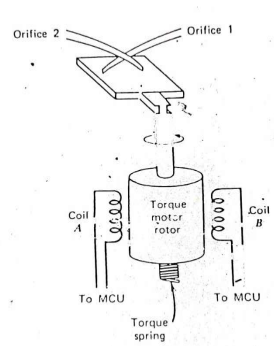
Robot Drive

2. Servo Valve:

i. The electro hydraulic servo valve controls the flow of high pressure oil to the hydraulic motor.

ii. That is, power amplification in a hydraulic system requires that an electrical signal processed in MCU be converted to appropriate hydraulic pressure.

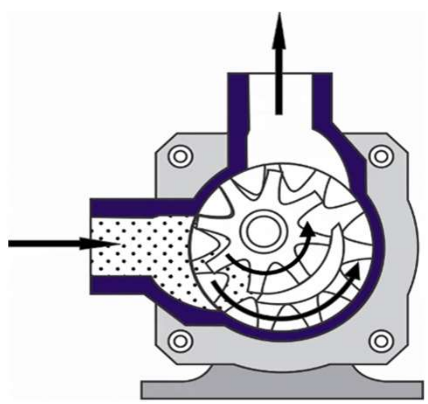
iii. In NC machines the common hydraulic power amplification device is 4-way proportional servo valve.

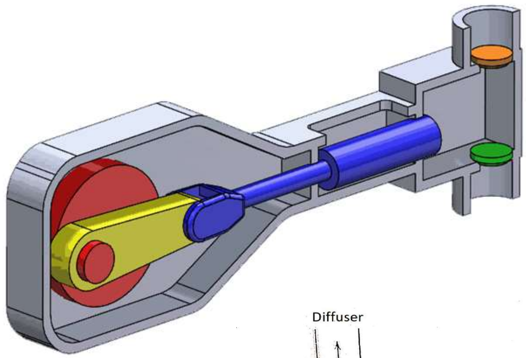


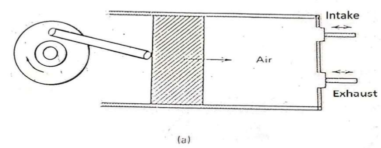
Four-way proportional servo valve and flapper control

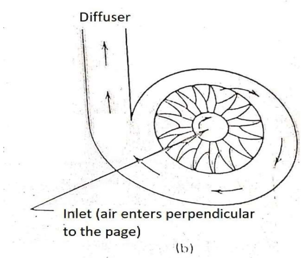
Robot Drive

3. **Hydraulic Actuator:**
   i. The hydraulic actuator is either a hydraulic cylinder for linear motion or a rotary type motor for angular motion
   ii. The hydraulic cylinder due to large quantity of high pressure oil which contains is limited for short throw applications, 0.6mm or less.
   iii. The rotary hydraulic motor is used in large power servo systems and is preferred for longer travel and heavier workloads.
4. **The Sump:**
   - The used oil is returned to the sump. The oil is feedback to the hydraulic power supply and forms a source of the fluid for power supply.









Robot Drive

Advantages of hydraulic systems:

i. Deliver large power while being relatively small in size that is (i.e. they provide high torque output).
ii. They have small time constants resulting in smooth operation of machine tool slides, and also thus provide rapid system response.
iii. Are used for multi-axis countering applications for vacuum accurate positioning and rapid acceleration where rapid and smooth response is required under conditions of transient or heavy loading.
iv. Good performance in areas of shock or vibration.
v. Develop higher maximum angular accelerations than DC motors of the same power.

College of Engineering Pune (COEP)
Forerunners in Technical Education

Robot Drive

vi. Complete and accurate control over speed position and direction of actuators.

vii. Accuracy maintained under extreme load conditions since hydraulic oil is virtually incompressible (0.5% it at 7000).

viii. Minimises of leakages liquid required.

ix. Self lubricating and non control

Disadvantages of hydraulic systems:

i. Electromechanical actuation systems draw power only when the machine member is in motion. However hydraulic and pneumatic systems must have a high pressure power supply available at all times, hence, pumps run continuously.

Robot Drive

ii. Maintenance and leakage of oil from transmission lines and system components.

iii. Dynamic legs caused by transmission lines being clogged with dirt and viscosity variations with oil temperature.

iv. Hydraulic systems require a closed circuit, and exhaust fluid must be directed back to the pump for circulation

Pneumatic actuation systems:

- They operate on the same principle as hydraulic systems except that pneumatic devices used compressed air as the power transmission medium
- Pneumatic systems are generally comprised of the following components:

Robot Drive

Pneumatic actuation systems

1. A pneumatic power supply (air compressor)
2. A servo valve for each axis of motion
3. A pneumatic actuator (Pneumatic Cylinder / Pneumatic Motor) for each axis of motion.

1. **Pneumatic power supply:**
   a) The air compressor is the power source for pneumatic actuation systems.
   b) They may be either positive displacement: piston compressor or non positive displacement (dynamic) type: centrifugal compressor
      i. In positive displacement compressor, air is confined in a progressively diminishing space, thereby reducing the volume of air and increasing its pressure.

Robot Drive

ii. The centrifugal compressor uses a an impeller to impart considerable kinetic energy to the air as it is turned from an axial to a radial direction that is, at as it draws in air compresses it by mass acceleration, there by converting in kinetic energy to pressure energy as the air moves through the diffuser.
- For extremely high pressure multistage compressor are used to boost pressure in stages.
- Before air is admitted to the circuit it is ONCONDITION

I. Filters are used to protect the server systems from dirt and foreign particles this increases system reliability by,:
   a) lessening wear and damage,
   b) tendency to jam or block up delicate control devices,
   c) Miss operation of circuit components.

Robot Drive

II. Since air absorbs moisture which can condense out within the circuit components it must be dried which is achieved through dehydrator.
III. Air is enriched with fine oil mist to provide lubrication for various system components.

2. Servo Valve:

i. With modifications, the four way proportional valve is used in pneumatic actuation systems.
ii. In this case the flapper control has been replaced by a controller that moves the piston directly.

Robot Drive

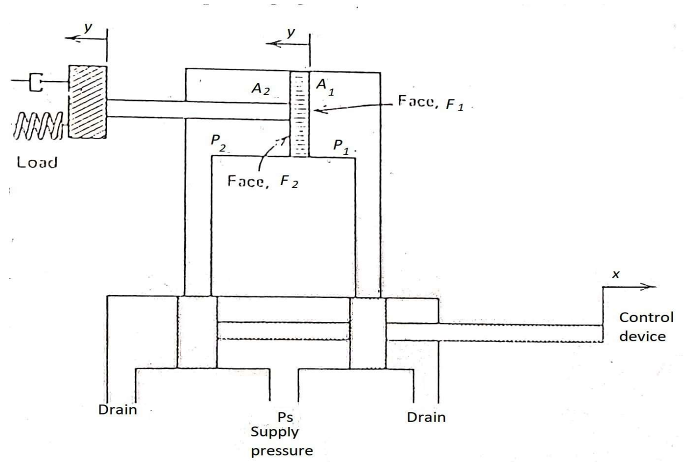
3. Pneumatic actuators:

i. Compressed air can be applied to both linear and rotary actuators.
ii. Linear actuators in the form of double acting pneumatic cylinder are similar in construction and principle of operation, to their hydraulic components except that the cylinder piston arrangement makes possible only a limited traverse motion.
iii. Rotary actuators in the form of pneumatic motors, consists of a rotary vane driver by applied air pressure and unlike its hydraulic counterpart the torque developed by the pneumatic motors is proportional to the supply pressure and independent of motor speed.

Robot Drive

Advantages of pneumatic drives:

i. Air is plentiful.
ii. Compressed air can be stored and conveyed easily over long distances.
iii. Compressed air need be returned to sump tank, it can be vented to atmosphere after it has perform its useful work.
iv. Compressed air is clean, explosion proof and <u>insensible</u> to <u>temperature fluctuations.</u>
v. Operation can be fast and <u>speed and forces</u> can be <u>infinitely adjusted</u> between their operational limits.
vi. Digital and logic switching can be performed by pneumatic fluid logic elements.



Robot Drive

vii. Pneumatic cylinders, comprising proximity sensor to sense the position of the piston allow easily integration of pneumatic systems with computer sensing and control.

viii. Pneumatic elements are simple, reliable in operation and relativity cheap.

Disadvantages of Pneumatic Drives:

i. Since there is compressible, precise control of speed and position is difficult to achieve and power amplification is less than that achievable by hydraulic systems.

ii. System response is slower as compared to hydraulic drives since air will compress significantly before activation begins.