

UNIT

6

ACTUATORS, FEEDBACK COMPONENTS AND APPLICATIONS



PART-A

SHORT QUESTIONS WITH SOLUTIONS

Q1. Differentiate between pneumatic and hydraulic actuators.

Answer :

Pneumatic Actuators		Hydraulic Actuators	
1.	Operating pressure is low.	1.	Operating pressure is high.
2.	In this system, there is no need of return pipes as air is the working medium.	2.	It requires return pipes, as water is the working medium.
3.	These are fire and explosion proof.	3.	These are not fire and explosion proof.
4.	Accuracy is poor at low velocities.	4.	Accuracy is satisfactory at all velocities.
5.	Output power is less.	5.	Output power is high.

Q2. What are the advantages and disadvantages of electric actuators?

Answer :

Nov.-11, Set-1, Q7(e)

Advantages of Electric Actuators

1. It provides better accuracy and repeatability for electric drives.
2. Electric motors are more compact and requires less floor area.
3. It can be used to operate linear joints.

Disadvantages of Electric Actuators

1. Power or speed of electric system is less, compared to hydraulic system.
2. It requires an actuating system such as D.C stepping motor or D.C servo motor.
3. The cost of electric motor is more compared to hydraulic system.

Q3. What are the advantages of A.C tachometer over D.C tachometer?

Answer :

(Nov.-11, Set-3, Q7(c) | Model Paper-I, Q1(c))

The various advantages of A.C tachometer over D.C tachometer are,

1. It uses a filter, which eliminates the residual ripples caused in the output.
2. It avoids friction, as it has no wiping contacts. Also, it does not require a brush.
3. Less moment of Inertia.
4. Effective measurement of angular velocity, since it utilises a synchronous detector.
5. Cost of A.C tachometer is less as compared to D.C tachometer.
6. Radionoise is reduced.

Q4. What are the drawbacks of incremental encoders?**Answer :**

Incremental encoder consists of a glass disk marked with alternating transparent and opaque stripes aligned radially, which are highly sensitive to light source.

Drawbacks of Incremental Encoders

1. It is not possible to know the orientation of object in absolute terms.
2. It is difficult to know the position of object with respect to starting position.
3. The resolution is independent of the number of tracks.
4. The output is pulse train, whose frequency and speed may vary abruptly.

Q5. What is control system? What are the different types of control systems?**Answer :**

A control system is a systematic arrangement of physical components integrated in such a way, as to command, direct or regulate itself or another system.

Examples are automobile driving system, robot operation, dialogical system of human body, electric heater, speed control system, etc.

The two types of control systems are,

1. Open-loop control system (non-feedback control systems)
2. Closed-loop control systems (feedback control systems).

Q6. Differentiate between tactile and non-tactile sensors.**Answer :**

Tactile Sensors		Non-tactile Sensors	
1.	Tactile sensors are the contact type sensors, used for detecting the position of an object.	1.	Non-tactile sensors are the non-contact type sensors, used for monitoring an object.
2.	It requires object to be directly in contact with sensors for recording a parameter.	2.	It can be operated from a specified distance i.e., away from an object.
3.	Tactile sensors measures force, torque, displacement, etc.	3.	Non-tactile sensors measures or monitors the induction, reflection, image sensing, etc.
4.	Switch sensors, slip sensors, touch sensors are examples of tactile sensors.	4.	Proximity sensors, magnetic sensors, capacitive sensors are examples of non-tactile sensors.

Q7. Distinguish between proximity and tactile sensors used in robotic applications.**Answer :**

[Dec -14, (R09), Q5(a) | Model Paper-III, Q1(c)]

Proximity Sensors		Tactile Sensors	
1.	It may be a non-contact or contact type of sensor.	1.	It is a contact type of sensor.
2.	It gives information about presence of object near the manipulator.	2.	It gives information of the object, which is in contact with the manipulator.
3.	It is used to determine speed, distance, proximity and to detect metal surfaces, etc.	3.	It is used to determine force, displacement and other additional features of object like shape, size, material, etc.
4.	Different types of proximity sensors are optical sensors, inductive sensors, capacitive sensors, eddy current sensors, etc.	4.	Different types of tactile sensors are microswitches, LVDT, pressure sensors, piezoelectric crystals, etc.
5.	These sensor finds its application in safety systems, automobiles, conveyor systems, machine monitoring systems, etc.	5.	These sensors finds its application in security system manufacture of automobiles parts, lamination of batteries, etc.

Q8. Write short notes on range sensors.**Answer :**

Range sensors are non-contact type of sensors and are also called as range finders. It is used in robots, to determine the large distances, surface features of objects and for detection of obstacles. The working of these sensors is based on light, signals from transmitter and ultrasonics. The two different methods of measurement are triangulation and lapsed time.

In triangulation, a light ray is projected on the object, which illustrates the object and forms a spot on it. This spot is then seen by a device called as receiver. The triangles formed between the object, light source and receiver determines the range.

In lapsed time method, a transmitter sends the signal, which gets bounced on contact with the object. This bounced signal is then received by a receiver. Thus, the range is determined by half the distance travelled by a signal.

Q9. What are the basic rules and procedures followed in the use of robots in assembly?**Answer :**

[April/May-13, Set-1, Q5 | Model Paper-II, Q1(e)]

The basic rules and procedures followed in the use of robots in assembling are as follows,

Ease of Assembly

The parts required for assembling the product should be selected such that, they can be easily assembled.

Feeding and Orientation

The design of parts must be simple, so that feeding and orientation for automated assembly are easily achievable.

Design for Grippers

A suitable gripping device should be designed for ease of assembly. In assembly operation, compliance is an important property for the design of grippers. The fingers which are to be designed must be efficient and manageable to overcome any variations in the size and shape of the workpieces to be assembled.

Q10. At time 't', the excitation voltage to a resolver is 24 V and the voltage across the two pairs of stator terminals are 17 V and -17 V. What is the shaft angle?**Answer :**

Model Paper-IV, Q1(f)

$$\begin{aligned} \text{Arc sin } \left(\frac{17 \text{ V}}{24 \text{ V}} \right) \\ = \sin^{-1} \left(\frac{17}{24} \right) \\ = 45^\circ \text{ or } 135^\circ \end{aligned}$$

And,

$$\begin{aligned} \text{Arc cos } \left(\frac{-17 \text{ V}}{24 \text{ V}} \right) \\ = \cos^{-1} \left(\frac{-17}{24} \right) \\ = 135^\circ \text{ or } 225^\circ \end{aligned}$$

∴ The shaft angle must be 135° .**Q11. What is the output value of an absolute encoder if the shaft angle is 1 radian and the encoder has 10 tracks?****Answer :**

$$\text{The resolution} = 2^{10} = 1024 \text{ Parts/Revolution}$$

$$1 \text{ revolution} = 2\pi \text{ radians}$$

$$\therefore \text{Output} = \frac{1024}{2\pi} = 162.97$$

Q12. What is the resolution in degrees of an encoder with 8 tracks?**Answer :**

The number of increments per revolution =

Where,

$$n = \text{Number of tracks on disc}$$

$$\therefore n = 8$$

$$= \frac{\text{Increments}}{\text{Resolution}}$$

$$= 2^n = 2^5$$

$$= 256$$

The angular width of each control increment

$$= \frac{360^\circ}{2^5} = \frac{360^\circ}{256}$$

$$= 1.4062^\circ$$

Q13. At time t the excitation voltage to a resolver is 24 V. The shaft angle is 60° . What is the output signal from the resolver?**Answer :**

Given that,

Excitation voltage to a resolver = 24 V

$$A \sin \alpha = 24$$

$$\text{Shaft angle, } \theta = 60^\circ$$

Output signals from the resolver is the voltage across two pairs of stator terminals given as follows.

$$V_{S_1} = A \sin (\alpha) \sin \theta$$

$$V_{S_2} = A \sin (\alpha) \cos \theta$$

$$V_{S_1} = 24 \sin 60^\circ = 20.78 \text{ V}$$

$$\therefore V_{S_2} = 24 \cos 60^\circ = 12 \text{ V}$$

PART-B

ESSAY QUESTIONS WITH SOLUTIONS

6.1 ACTUATORS - PNEUMATIC AND HYDRAULIC

Q14. Explain the term "Robot actuation" and feedback components.

Answer :

Actuation refers to producing physical changes such as linear and angular displacements, which is obtained with the help of an actuator. Actuator is a device, which provides the actual motive force for the robot joints and it can also modulate the rate and power associated with the displacements change. Actuators are driven by one of the following three sources and it

Model Paper-I, Q5(b)

- (i) Pressurised fluid (hydraulic fluid)
- (ii) Compressed air (pneumatic air)
- (iii) Electricity.

Control of the robot manipulator requires the application of the control theory to a mechanical subsystem. The following are the different types of devices used in a robot control system.

- | | |
|---------------------------------|-----------------------------|
| (i) Position sensors | } Feedback components |
| (ii) Velocity sensors | |
| (iii) Actuators | } Control action components |
| (iv) Power transmission devices | |

Position and velocity sensors are used in robotics as feedback devices, while actuators and power transmission devices are used to accomplish the control actions indicated by controller. Feedback components ensures the robot system for proper speed control of manipulator during the motion in workspace.

Q15. What are the different types of actuators used for robots? Enumerate the advantages and disadvantages of pneumatic actuators.

Answer :

Types of Actuators

Actuator is a device, which provides the actual motive force for the robot joints. Actuators are driven by different power sources i.e., electricity, pressurized hydraulic fluid or compressed air. They produces physical changes such as linear and angular displacements and also modulate the rate and power associated with changes in displacements. There are three types of actuators.

- (i) Hydraulic actuators
- (ii) Pneumatic actuators
- (iii) Electric motor.

(i) Hydraulic Actuator

An actuator, wherein hydraulic energy is used to impart motion is called as hydraulic actuator. This actuator can produce large force or torque to drive the manipulator joints, without the use of reduction gearing and can be easily applied for robotic position control.

(ii) Pneumatic Actuator

Pneumatic actuator is powered by moving fluid (i.e., compressed air). It uses the force of air applied to a piston, which is connected to spool. The working pressure is relatively low as compared to hydraulic actuator.

(iii) Electric Motor

Electric motor is a widely used actuator, as it provides excellent controllability with minimum maintenance required. Most common use of electric motors are D.C. servomotors, stepper motors and A.C. servomotors.

Advantages of Pneumatic Actuators

- (i) It is efficient for small robots, which possess less degrees of freedom.
- (ii) It can be used to operate rotational joints.
- (iii) Power is easily available.

Disadvantages of Pneumatic Actuators

- (i) Pneumatic actuators cannot be used for heavy loads.
- (ii) They are not suitable for heavy duty applications.
- (iii) They are limited to low pressure operations only.
- (iv) These actuators are not much reliable, as compared to other actuators.
- (v) Maintenance of precision parts is very difficult, when they are exposed to polluted environments.

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UNIT-6 Actuators; Feedback Components and Applications

6.5

Q16. Describe the working of hydraulic actuators.

Answer :

Nov-10, Set-1, Q7(a)

An actuator, in which hydraulic energy is used to impart motion is called as hydraulic actuator. These actuators are used, where high speed and large forces are desirable. The fluid in the hydraulic actuator is highly incompressible, as a result of which applied pressure is instantaneously transmitted to the member attached to it. It consists of a servo valve or pilot valve, which is considered as the heart of a hydraulic actuator. This valve is capable of producing an oil flow, proportional to the current supplied by a servo amplifier, which enables the piston to move in the cylinder, producing linear or rotary displacement. Hydraulic actuators are of two types,

- (i) Linear or two stage flow actuator
- (ii) Rotary actuator or hydraulic motor.

Working of a Two Stage Flow Control Servo Valve

It consists of a small D.C permanent-magnet torque motor and a deflector jet hydraulic amplifier, intended to produce the motion in the piston cylinder arrangement by proper control of the fluid. When current flows, the armature rotates in clockwise or counter clockwise direction and alters the position of the deflector accordingly. This causes the pressurized fluid to enter either the right or left hand side of the cylinder and results in pressure difference, that finally moves the mass attached to the piston.

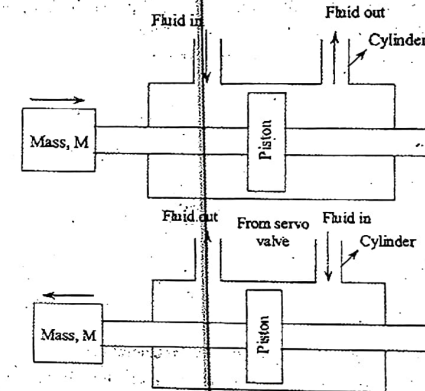


Figure: Cylinder-Piston Arrangement in Hydraulic Actuator

Q17. What are the advantages and disadvantages of hydraulic actuators?

Answer :

[Nov-11, Set-4, Q7(b) | Model Paper-II, Q5(a)]

Advantages of Hydraulic Actuators

1. Hydraulic actuators produces extremely large forces.
2. They enable precise control of low speeds.
3. Frequent stopping, starting and reversing of motion can be obtained, by a single 4-way, 3-position direction control valve.
4. It is possible to obtain controlled or variable torques.
5. Easy to produce, transmit, store, regulate and control, the power.
6. Possible to produce high power and force amplification i.e., more mechanical advantage.
7. Distribution and division of hydraulic power is easier and simple, as compared to other actuators.
8. Safe, compact and adaptable to other forms of power.
9. Frictional forces are much less as compared to a mechanical system.
10. No mechanical balancing problem involved in these actuators.
11. High efficiency of power transmission.
12. Generates uniform, smooth and stepless motions with high accuracy and precision.

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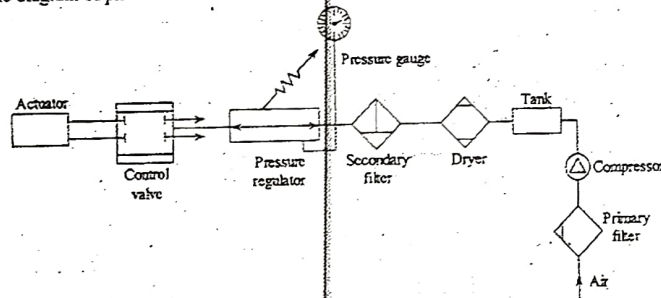
Disadvantages of Hydraulic Actuators

1. Hydraulic actuator needs large infrastructure like high pressure pumps, tank, distribution pipe lines, etc.
2. More chances of hydraulic fluid leakage, which is undesirable in a working environment.
3. Rust, corrosion and dirt problems reduces the long-run operations.
4. Hydraulic oils may pose fire hazards.
5. More maintenance requirements.
6. Vibrations may occur, due to the high pressure operations.
7. Manufacturing cost of hydraulic system is high, since, parts require high degree of precision machining.
8. Hydraulic power is not readily available, as compared to electric power, etc.
9. Hydraulic oil characteristics changes with temperature variations.
10. Hydraulic oil causes corrosion of metal components.

Q18. Describe about the pneumatic actuators.**Answer :****Pneumatic Actuators**

Pneumatic actuator is a power device, used to drive the robot arms, by means of compressed air as working medium. This type of actuator is applied to gripper for opening and closing of jaws. Pneumatic actuator operates in the range of 0.1 – 0.12 kN/m².

The schematic diagram of pneumatic actuator control unit is shown in figure (1),

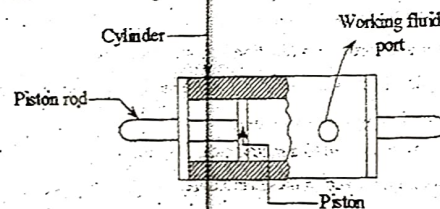
**Figure (1): Pneumatic Actuator Control Unit**

Air is passed through primary filter to remove the dust particles present in air. This filtered air enters into compressor, where the pressure of air increases. The high pressured air is then stored in the tank and it is made to pass through dryer, which reduces the moisture content of air. From the dryer, high pressure air enters into the actuator through secondary filter, pressure regulator and control valve.

Where,

- (i) Secondary filter is used to minimize the impurities of air.
- (ii) Pressure regulator is provided with a gauge to measure and control the pressure of air.
- (iii) Control valve is used to control the direction of fluid flow.

Compressor plays a significant role in the control unit of pneumatic actuator, as the reciprocating motion of the piston, is obtained by the effect of compressed air. Pneumatic actuator utilises the compressed air for actuating the linear joint of robot arms. Cylinder type pneumatic actuator is shown in figure (2).

**Figure (2): Cylinder Type Actuator****UNIT-6 Actuators, Feedback Components and Applications**

The empirical relations which help in deciding the type of actuator are,

1. Actuator velocity in terms of input power,

$$V = \frac{Q}{A}$$

Where,

V – Velocity of fluid

Q – Flow rate of fluid.

2. Force in terms of input power,

$$F = \frac{p}{A}$$

Where,

p – Fluid pressure

A – Area of piston.

Also, the above empirical relations can be used to predict the payload carried by robot at given speed.

Q19. What are the advantages of using pneumatic drives in the robots? Discuss the different types of pneumatic drives used in the robots with the help of neat sketches.**Answer :****Advantages of Pneumatic Drives**

1. Pneumatic drives are reliable, as they possess less moving parts.
2. Components of these drives are readily available and air exists abundantly.
3. Compressed air can be handled easily and stored for long duration.
4. These drives are very quick in operation and allows fast running cycles.
5. Low maintenance cost.
6. It can be employed in explosive areas and in wet conditions.
7. The design is compact and simple. Hence, they are suitable for small robots.
8. Power can be easily available for providing translational movement of sliding joints.
9. Since, the working medium is air, the robots are free from corrosion and dust.
10. These drives are also used to operate rotary actuators for rotational joints.

Types of Pneumatic Drives

The different types of pneumatic drives used in the robots are.

- (i) Pneumatic diaphragm actuator
 - (ii) Electro-pneumatic actuator.
- (i) Pneumatic Diaphragm Actuator

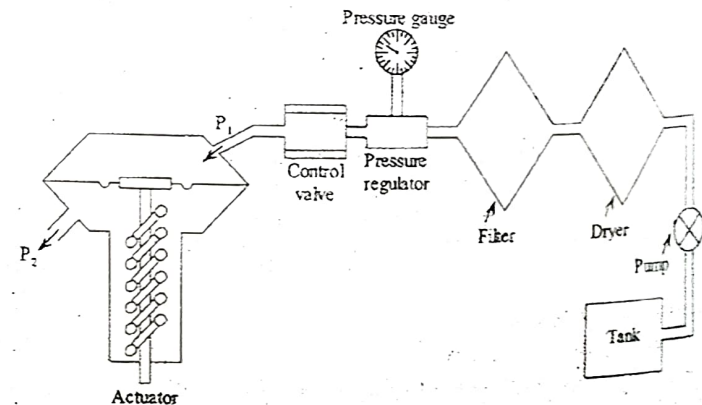
**Figure: Pneumatic Diaphragm Actuator**

Figure illustrates the schematic diagram of pneumatic diaphragm actuator. These are employed in many industries and in automobiles for exhaust gas turbo chargers. These actuators are used due to the following reasons,

- It is very strong and reliable.
- Cheap and simple in construction.
- Reduces the problem of material compatibility with dry air.
- Minimizes fire risk.

Working

The pneumatic diaphragm essentially comprises of a diaphragm with the pressure regulator on one side and an atmospheric pressure valve on the other side. The diaphragm is generally made of rubber and is placed between the centre of the two steel discs. The control part of the diaphragm gives motion to the shaft, which acts on a valve. The diaphragm acts against a return spring which closes or opens, depending upon the working pressure at outlet. The displacement of the actuator occurs, when cylinder and diaphragm changes the external force on the shaft. A position controller is required to control the negative effects that influences the precision of positioning.

(ii) Electro-pneumatic Actuator

Electro-pneumatic actuator is a combination of pneumatic system and electrical system, employed for sequencing and controlling applications. The common components involved in electro-pneumatic systems are,

1. Actuators and Control Elements

This includes pneumatic cylinders, solenoid operated directional control valves, motors, etc.

2. Energy Supplying Elements

This includes compressor to provide compressed air and a power supply, which may be A.C or D.C source.

3. Input Elements

This comprises of proximity sensors, push buttons, limit switches and other switches or contactors.

4. Processing Elements

This includes solenoid actuated DC valves, pneumatic or electric converters, relays and logic elements.

Working

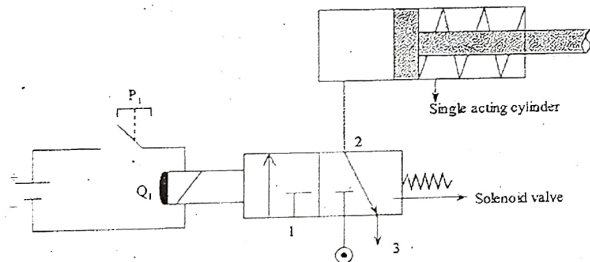


Figure: Electro-pneumatic Actuating System

The above figure shows the direct control of a single acting cylinder, by using an electro-pneumatic system. A single acting cylinder is controlled by a 3/2 solenoid operated valve. Initially, on pressing the push button P_1 , the piston rod moves in the cylinder by the actuation of solenoid valve. As long as the button is pressed, the compressed air is supplied to the cylinder. If the push button is released, the piston returns back to its initial position. The left out air in the cylinder is exhausted from port 3 to the atmosphere.

Advantages of Electro-pneumatic Actuation

This system possess many advantages such as,

- It can transmit signals to a larger distances without any leakage or losses.
- All the valves in the system can be controlled electrically.
- The time taken between transmission and reception of signal is minimised with the aid of electro-pneumatics.

Q20. A double acting hydraulic rotary vane or bucket actuator is used for a twist joint in a robot. The outer and inner radius of the vane is 2.5 mm and 0.75 mm respectively. Thickness of the vane is 0.2 mm. The hydraulic power source can generate up to 1000 kg/mm² of pressure to delivery to the cylinder at the rate of 100 mm³/min, determine the angular velocity and torque generated by the actuator. Also, find the power developed by the hydraulic actuator.

Answer :

April/May-13, Set-1, Q3

Given that,

Inner radius of vane, $r = 0.75$ mm

Outer radius of vane, $R = 2.5$ mm

Thickness of vane, $t = 0.2$ mm

Discharge rate, $Q = 100$ mm³/min = 1.667 mm³/sec

Pressure, $P = 1000$ kg/mm²

Angular velocity,

$$\omega = \frac{2Q}{(R^2 - r^2)t}$$

$$= \frac{(2 \times 1.667)}{((2.5)^2 - (0.75)^2) \times 0.2}$$

$$\therefore \omega = 2.931 \text{ rad/sec}$$

The torque developed is given by,

$$T = \frac{1}{2} P t (R^2 - r^2)$$

$$= \frac{1}{2} (1000 \times 9.81) \times 0.2 ((2.5)^2 - (0.75)^2)$$

$$= 5579.438 \text{ N-mm}$$

$$\therefore T = 5.579 \text{ N-m}$$

Power developed by hydraulic actuator is given by,

$$P_D = \frac{P Q}{1000}$$

$$P_D = \frac{(1000 \times 9.81) \times (1.667)}{1000}$$

$$\therefore P_D = 16.353 \text{ W}$$

6.2 ELECTRIC ACTUATORS AND STEPPER MOTORS

Q21. Explain electric and stepper motor actuators.

Answer :

Electric actuator is a device, which uses electrical energy, to impart motion. Electrical actuator system has the following subsystems,

1. Switching Devices

(a) Mechanical Switches

- Solenoids
- Relays.

(b) Solid State Switches

- Diodes
- Thyristors
- Transistors.

2. Drive Systems

- D.C motors
- Stepper motors and A.C motors.

(a) D.C Motors

D.C motors are straight forward to interface and control. 'A.C motors and stepper motors' are rarely used, because A.C motors are difficult to control and stepper motors have low torque capability. Stepper motor cannot be used for Cartesian space trajectory tracking operations.

(b) Stepper Motors

The stepper motor is a digital device which converts electrical pulses into proportionate mechanical movement. It is a permanent magnet or variable reluctance D.C motor. It moves in accurate equal angular increments, known as "steps" in response to the application of digital pulses to an electric drive circuit. The number and rate of pulses control the position and speed of the motor shaft.

Stepper motors are manufactured with steps per revolution of 12, 24, 72, 144, 180 and 200 resulting in shaft increments of 30° , 15° , 5° , 2.5° , 2° and 1.8° per step. It is used in digitally controlled position control system in open loop mode. The input command is in the form of a train of pulses to turn a shaft through a specified angle. It is either bipolar or unipolar. In bipolar, two power sources required, whereas in unipolar single power source used. Stepper motor produces less than one horse power hence, they are used in low-power position control applications. This motor consists of a slotted stator having multipole multi-phase winding and a rotor structure carrying no winding. The rotors may be of the permanent magnet or variable reluctance type. This motor operate with an external drive logic circuit. When a train of pulse is applied to the input of the drive circuit, the circuit supplies currents to the stator windings of the motor to make the axis of the air-gap field around in coincidence with the input pulses. The rotor follows the axis of the air-gap magnetic field by virtue of the permanent magnet torque or the reluctance torque depending upon the pulse rate and load torque.

Advantages

- High compatibility with digital systems.
- No sensors are needed for position and speed sensing.
- It can be readily interfaced with microprocessor.
- Rotation can be possible in both directions.

Applications

- Positioning of print heads.
- Pens in X-Y plotters.
- Recording heads in computer disc drives.
- Paper feed motors in type writers and printers.
- Positioning of work tables and tools in NC machine tools.
- Employed to perform functions like metering, mixing, cutting, blending, stirring, etc.

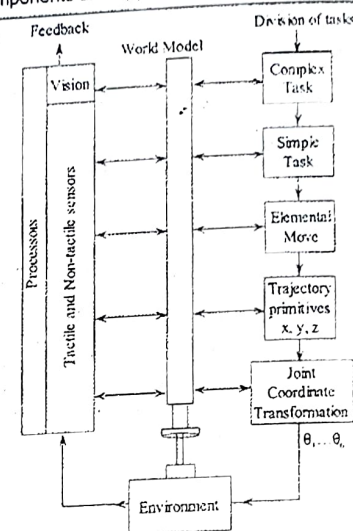
Q22. Distinguish between servo and non-servo robots. What is the hierarchy of control for servo robots? [April/May-13, Set-2, Q1 | Model Paper-III, Q4(a)]

Answer :**Difference between Servo and Non-servo Robots**

Servo Robots	Non-servo Robots
1. It is a closed loop system, as it allows feedback.	1. It is an open loop system, as it does not allow feedback. These robots are also known as limited sequence or fixed-stop robots.
2. It is a motion control system, which can detect and compensate errors.	2. The movement is limited in these type of robots.
3. It responds to complex programs.	3. It responds only to simple programs.
4. It has wide range of capabilities.	4. It is capable of operating at higher speeds.
5. It is relatively expensive.	5. It is relatively inexpensive.
6. It has low precision and reliability	6. It has high precision and reliability.

Hierarchy of Servo Robots

The controller of robot can accommodate the tasks and simplify the task into subtasks in a hierarchical system.

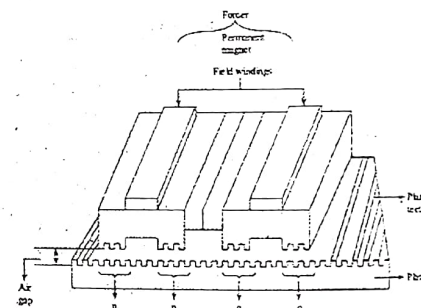
**Figure: Hierarchy of Robot**

The organized hierarchy of robot is examined with the help of a vision robot. As shown in figure, the complex task is divided into simple tasks. A simple task consists of load which is further divided into elemental move and grasp. This elemental move is divided again in x, y, z trajectory primitives as action commands. The commands are then transformed into actuator commands as $\theta_1, \theta_2, \theta_3$ coordinates. Finally, the signals are sent by means of positional and velocity servo of respective joint axes of robot.

Q23. What do you mean by linear stepper motor? Explain.

Answer :

Linear stepper motor is designed with a flat surface, as shown in figure below, which causes its motion along the straight line.

**Figure: Linear Stepper Motor**

The basic components of a linear stepper motor are as follows,

- Fixed stator i.e., platen
- Movable armature i.e., forcer.

The platen is the fixed part of motor, which consists of large number of teeth and its length determines the distance, that a motor can travel. The forcer is on the top of the platen of linear stepper motor and has a movable armature consisting of four pole pieces with 3 teeth on each pole. The pitch of teeth is in accordance with the teeth of the platen. The forcer and the platen do not come in contact with each other, due to the use of mechanical roller bearings. The bearings prevent the contact and raise the forcer above the platen with an air gap.

When the current is passed through the coils of the forcer (i.e., armature), its magnetic field changes and causes the forcer to move in linear path by the movement of set of tooth with respect to next set above the platen. The direction of motion of the forcer is reversed, when the current supply is reversed. If the current flow is stopped, the forcer tends to align with the desired tooth.

Thus, the motor moves smoothly in either forward (or) reversed direction, depending upon the pattern of energizing and de-energizing of the field coils in the linear stepper by the motor controller.

Q24. Explain about A.C servo motor.

Answer :

A.C Servo Motor

A.C servomotor is essentially a two phase induction motor, except with variation in the constructional features of the rotor, which is of drag cup type. It possess low inertia and good accelerating characteristics and hence, mostly preferred for low power applications.

A.C servomotor is shown in figure. It has two windings i.e. control and reference winding. The control voltage V_C is given as input voltage to the control winding through the amplifier. The fixed voltage V_f is given to the reference winding. The phase difference between the fixed voltage and the control voltage is 90° . The torque T_m is developed, due to the control voltage. J_m and B are the moment of inertia of the motor and coefficient of friction respectively. The output θ_m is the angular displacement of the motor and ω_m is the corresponding angular velocity.

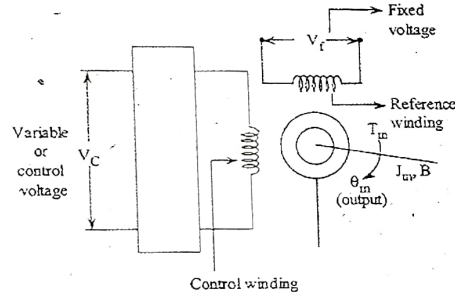


Figure: A.C Servomotor Representation

Q25. Explain the working principle of D.C servo motor.

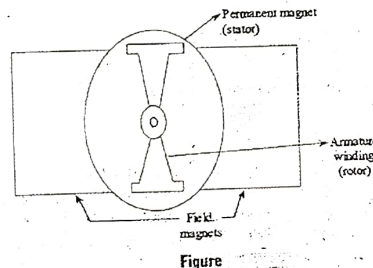
Answer :

D.C Servo Motor

D.C motors which are used in servo systems are called D.C servo motors. It is essentially an ordinary D.C. motor except with few variations in its constructional features.

The D.C servo motors are used when quick response to control signals and high starting torque is required. The figure shows the layout of D.C servo motor.

Working Principle



Figure

UNIT-6 Actuators, Feedback Components and Applications

When an electric current flows through the armature windings, the magnetic field is induced in it. This induced field opposes the field, which is set up by the permanent magnets. The difference in magnetic field produces a torque on the rotor. The torque produced by the rotor will be constant throughout the rotation, since, the field strength depends on the function of current.

The torque of the D.C servo motor is given as,

$$T_m(t) = k_m I_a(t)$$

Where,

T_m - Torque produced.

I_a - Armature current.

k_m - Motor's torque constant.

Q26. Differentiate stepper motor and D.C motor drives of a robot?

Answer :

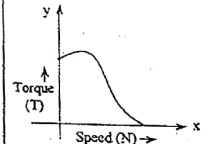
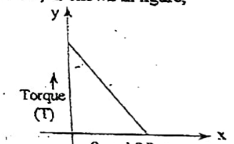
May/June-14, Set-1, Q7(a)

The comparison between stepper motor and D.C motor drives is as follows,

Stepper Motor	D.C Motor Drives
1. A stepper motor is an electromechanical device which actuates a continuous step movements of shafts in response to continuous input pulse.	1. A D.C motor drive is an electromechanical device, which converts electrical energy into mechanical energy.
2. Stepper motor is a form of synchronous machine.	2. D.C motor is a form of D.C machine.
3. These motors are designed with multipole, multiphase stator windings.	3. Electrical D.C motor consists of stator (stationary part) and rotor (rotating part).
4. In this motor, rotor is a type of permanent magnet.	4. In this motor, stator is a type of permanent magnet.
5. Stepper motors rotates with known angle of rotation called as 'step angles'.	5. D.C motors rotates with constant speed at varying load.
6. They require microprocessor circuit for rotation.	6. They require electric current for rotational movement.
7. Power to weight ratio is low.	7. Power to weight ratio is high.
8. It is used in robots, when small amount of power and torques are needed.	8. It is used in robots, when uniform torque is needed.
9. Stepper motors are rarely used in industrial robots.	9. D.C motors are oftenly used in industrial robots.

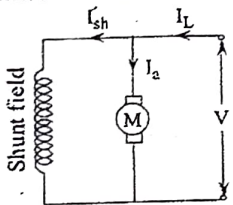
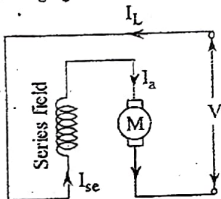
Q27. Compare stepper motor with an A.C servomotor in respect of torque and speed characteristics.

Answer :

Stepper Motor	A.C Servomotor
1. Torque-speed characteristics of a stepper motor is non-linear, as shown in figure, 	1. Torque-speed characteristics of an A.C servomotor is linear, as shown in figure, 
Figure: Torque-speed Characteristics	Figure: Torque-speed Characteristics
2. As the speed of the motor increases, the torque significantly decreases.	2. The torque increases or decreases linearly with respect to speed.
3. Torque to inertia ratio is low.	3. Torque to inertia ratio is high.
4. It is suitable only at low speed torque.	4. It is suitable for both low and high speed torque.
5. It has low output power relative to motor size and weight.	5. It has high output power relative to motor size and weight.
6. Noise is produced, when motor runs at moderate or high speeds.	6. No noise is produced.
7. It cannot accelerate the loads abruptly.	7. It can accelerate the loads abruptly.
8. It does not require any feedback device.	8. It requires feedback devices such as encoders, resolvers, etc.

Q28. Distinguish between D.C shunt motor and D.C series motor.

Answer :

D.C Shunt Motor	D.C Series Motor
1. In a D.C shunt motor, the field winding is connected in parallel with the armature. 2. The circuit representation of a D.C shunt motor is shown in the following figure.  Figure: D.C Shunt Motor. 3. The voltage and current equations are, Armature current, $I_a = I_L - I_{sh}$ Where, I_L - Line current I_{sh} - shunt field current = $\frac{V}{R_{sh}}$ Terminal voltage, $V = E_b + I_a R_a$ 4. Shunt field winding consists of large number of turns of thin wire having high resistance due to which it carries a small current. 5. Shunt motors are also known as constant speed motors, as the torque developed is directly proportional to speed i.e., $T \propto N$ 6. Starting torque is low. 7. Shunt motors can be started on no-load. 8. D.C shunt motors are used in centrifugal pumps, reciprocating pumps, fans, blowers, etc.	1. In a D.C series motor, the field winding is connected in series with the armature. 2. The circuit representation of a D.C series motor is shown in the following figure.  Figure: D.C Series Motor 3. The voltage and current equations are, Armature current = Series field current = Line current, $\therefore I_a = I_{se} = I_L$ Terminal voltage, $V = E_b + I_a(R_a + R_{se})$ 4. Series field winding consists of few turns of thick wire having low resistance, due to which, it carries full armature current. 5. Series motors are also known as variable speed motors as the torque developed varies inversely with the speed i.e., $T \propto \frac{1}{N}$ 6. Starting torque is high. 7. Series motors cannot be started without load. 8. D.C series motors are used in traction work, driving hoist trains, excavators, cranes, etc.

Q29. What is the difference between standard servo and feed forward servo?

May/June-14, Set-1, Q2(b)

Answer :

A servo is a small device that has an output shaft, which can be positioned to specific angular positions by sending the servo a coded signal. As long as the coded signal exists on the input line, the servo will maintain the angular position of the shaft. As the coded signal changes, the angular position of the shaft changes. Generally, servos are used in robots to position the end effector. It draws power proportional to the mechanical load.

1. The feed forward servo is used to reduce response time of control.
2. Standard servo systems are reactive and they suffer lag between the command and actual positions.
3. Feed forward servo provide velocity gain to the position loop of the servo system.
4. PID (Proportional - Integral - Derivative) gain is essential in case of standard servo.
5. The feed forward servo (open loop) is the simplest control servo, if the input-output relation of the system is exactly known.

UNIT-6 Actuators, Feedback Components and Applications

- The standard servo is used to produce a corrective plant input depending on the tracking error.
- The bandwidth of feed forward servo is small, whereas standard servo bandwidth is large.
- Example for feed forward servo is stepper motor and for standard servo is D.C (field controlled) motor.
- Feed forward servo can function at low frequencies also.
- Feed forward servos are used in accelerometers for running disk drives and DVD, camera, recorders respectively.
- Standard servos are not suitable for these applications.
- Standard servo is ideal for robotics and basic movements.
- Standard servo can hold any position over a 180° range.
- Standard servo is a digital servo except for a microprocessor, which analyses the incoming receiver signals and controls the motor.
- Potentiometer is an essential element in standard servo.

Q30. Distinguish between hydraulic actuators and stepper motors used joint actuation in robots.

Answer :

Hydraulic Drives	Electrical Drives
1. Hydraulic drives obtain their power from pressurized fluid. 2. These are used for large robots that are employed to move heavy loads. 3. These possess high positional stiffness and have highest power to weight ratio. They also provide greater speed and strength. 4. No need of any reduction gears. 5. High maintenance. 6. There is a chance of fluid leakage, thus not fit for clean room application. 7. Occupies considerable amount of floor space. 8. These drives can be used to actuate either rotational joints or linear joints.	1. Electrical drives obtain their power from electricity. 2. These are used for robots of all sizes. 3. These possess excellent controllability and precision. 4. Reduction gears are used. 5. Low or negligible maintenance. 6. No leakage, thus, better for clean room application. 7. Occupies less floor space. 8. These drives can be used to actuate both rotational and linear joints.

Q31. State some advantages of hydraulic power compared with D.C electrical servos with respect to usage in robotic systems.

Answer :

The advantages of hydraulic power when compared with D.C electrical servos are as follows.

- Hydraulic power possess high positional stiffness.
- Power to weight ratio is high and provides greater speed and strength.
- Hydraulic system can be used to actuate either rotational joints or linear joints.
- Accuracy of the hydraulic power is more.
- It produces high pressures, torque and inertia.
- There is no generation of spark in hydraulic system.
- It provides a wide range of operational speeds.
- Heavy loads are moved rapidly and in a precisely controlled manner.

Q32. What are the different types of electric actuators used in robots? Explain their relative advantages.

Answer :

Types of Electric Actuators

Electric actuators are classified into three types. They are,

- D.C servo motor
- A.C servo motor
- Stepper motor.

Relative Advantages of Different Types of Actuators

ROBOTICS (JNTU-KAKINADA)

Relative advantages of different types of actuators are as follows,

1. It is easy to interface and control a D.C motor.
2. Uniform torque rating for a D.C motor.
3. D.C motors are simple and highly reliable.
4. D.C motors provide higher power to weight ratio and have high acceleration.
5. A.C motors uses neither a commutator nor a brush.
6. In A.C motors, rotational movement is possible in reverse direction also.
7. Better heat dissipation capacity in case of A.C motors.
8. Nominal speed is kept constant in A.C motors.
9. Stepper motors are extensively employed in robotic devices.
10. Stepper motors are highly compatible with sensing systems.
11. Stepper motors provide a rotational movement in accurate equal angular increments.
12. No sensor is required for position and speed sensing in stepper motors.

Q33. For each of the following applications, what is a good choice for the type of electric motor used? Justify your choice.

- | | | |
|-------------------------------|------------------------|----------------------------|
| (a) Robot arm joint | (b) Ceiling fan | (c) Electric trolley |
| (d) Circular saw | (e) NC milling machine | (f) Electric crane |
| (g) Disk drive head actuator | (h) Disk drive motor | (i) Windshield wiper motor |
| (j) Industrial conveyor motor | (k) Washing machine | (l) Clothes dryer. |

Answer :

April/May-13, Set-3, Q3

Sl. No.	Application	Type of Motor Selected	Characteristics
(a)	Robot arm joint	Servo motor	This type of motors are called control motors, as it controls the variables such as mechanical position, velocity and acceleration.
(b)	Ceiling fan	AC induction motor	This type of motor starts up easily from rest and there is no need of any auxiliary motor.
(c)	Electric trolley	DC series motor	It has high starting torque. Also, can sustain high loads at low speeds.
(d)	Circular saw	AC induction motor	It does not require brushes during normal running condition. Thus, frictional losses are reduced.
(e)	NC milling machine	Servo motor	It can control the variables such as mechanical position, time derivatives, etc.
(f)	Electric crane	DC series motor	It is used in low-power position control applications.
(g)	Disk drive head actuator	Stepper motor	It is preferable, as it maintains constant speed.
(h)	Disk drive motor	Synchronous motor	It is desired, as it maintains constant speeds with varying load.
(i)	Windshield Wiper motor	DC motor	
(j)	Industrial conveyor motor	AC induction motor	
(k)	Washing machine	AC motor	It is desired due to its reliability, low cost, rugged construction and negligible maintenance.
(l)	Clothes dryer	AC motor	

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UNIT-6 Actuators, Feedback Components and Applications

Q34. A permanent magnet DC motor is coupled to a load through a gearbox. If the polar moments of inertia of the rotor and load are J_r and J_l , the gearbox has a $N:M$ reduction from the motor to the load, the motor has a starting torque T_s and a no-load speed ω_{max} , and the load torque is proportional to its speed ($T_l = k\omega$):

- What is the maximum acceleration that the motor can produce in the load?
- What is the steady state speed of the motor and the load?
- How long will it take for the system to reach a steady state speed?

Answer :

April/May-13, Set-2, Q3

Given that,

Polar moment of inertia of rotor = J_r

Polar moment of inertia of load = J_l

Speed reduction = $N : M$

Starting torque = T_s

Speed at no-load = ω_{max}

Load torque, $T_l = k\omega$

- The maximum acceleration occurring at the starting torque is given by,

$$\alpha_{max} = \frac{T_s}{J}$$

Where,

$$J = J_r + J_l \left(\frac{N}{M} \right)^2$$

- The torque at the motor is given by,

$$T_m = \left(\frac{N}{M} \right) \cdot T_l \quad (\text{or}) \quad \omega_l = \frac{N}{M} \cdot \omega_m$$

$$T_m = \left[\frac{N}{M} \right] \cdot (k\omega_l) \quad [\because T_l = k\omega_l]$$

The torque on motor is also given by,

$$T_m = T_s - T_l \cdot \frac{\omega_m}{\omega_{max}}$$

- Equating (1) and (2),

$$\left(\frac{N}{M} \right) (k\omega_l) = T_s - T_l \cdot \frac{\omega_m}{\omega_{max}}$$

$$k \left(\frac{N}{M} \right)^2 \cdot \omega_m = T_s - T_l \cdot \frac{\omega_m}{\omega_{max}}$$

$$k \left(\frac{N}{M} \right)^2 \cdot \omega_m + T_l \cdot \frac{\omega_m}{\omega_{max}} = T_s$$

$$\omega_m \left(k \left(\frac{N}{M} \right)^2 + \frac{T_l}{\omega_{max}} \right) = T_s$$

$$\omega_m = \frac{T_s}{\left(k \left(\frac{N}{M} \right)^2 + \frac{T_l}{\omega_{max}} \right)}$$

Q35. If a linear stepper has a pitch of 0.040 mm and micro stepping is used to divide this distance into 400 micro steps (i.e., one micro step moves the motor 0.0001 mm), what pulse frequency must be applied to the motor to achieve velocities from 0 to 60 mm/s?

Answer :

April/May-13, Set-3, Q5

Given that,

Pitch, $P = 0.04$ mm

Steps, $N = 400$

Resolution, $R_c = 0.0001$ mm

Velocity, $V = 60$ mm/s

The degree of step angle is given as,

$$A_s = \frac{360 \times R_c}{P}$$

$$A_s = \frac{360 \times 0.0001}{0.04}$$

$$A_s = 0.9^\circ$$

Number of step angles, $N = \frac{360}{0.9} = 400$ steps

The pulse count is given by,

$$n = \frac{N_R \times 360}{A_s}$$

Where, N_R = Number of revolutions = 1

$$\therefore n = \frac{1 \times 360}{0.9}$$

$$= 400 \text{ pulses}$$

The pitch, $P = 0.04$ mm movement rotates the shaft by one revolution. The movement for 60 mm/s velocity is given by,

$$N_R = \frac{60}{0.04}$$

$$= 1500 \text{ rps}$$

The pulse frequency is given as,

$$n_r = \frac{N_R}{R_s}$$

$$= \frac{1500}{0.0025} \quad (\because R_s = \frac{0.9}{360} = 0.0025)$$

$$= 600 \times 10^3 \text{ pulses/sec}$$

6.18

ROBOTICS [JNTU-KAKINADA]

Q36. A D.C servo motor is used to actuate speed of a robot joint. It has torque constant of 10 mm-kg/A and voltage constant of 12 V/Kr/min (1 Kr/min = 1000 r/min). The armature resistance is 2.5 Ω . At a particular moment during the robot cycle, the joint is not moving and a voltage of 25 V is applied to the motor,

- Determine torque of the motor immediately after the voltage is applied.
- As the motor accelerates, the effect of back-emf is to reduce the torque. Determine the back emf and corresponding torque at 250 r.p.m and 500 r.p.m.
- Sketch a graph between the torque and the speed.

Answer :

April/May-13, Set-4, Q3

Give that,

$$\begin{aligned}\text{Torque constant, } K_m &= 10 \text{ mm-kg/A} \\ &= 10 \times 9.81 \times 10^{-3} \text{ A-mm} \\ &= 0.0981 \text{ N-m/A}\end{aligned}$$

$$\begin{aligned}\text{Voltage constant, } K_b &= 12 \text{ V/Kr/min} \\ &= 12 \times 10^{-3} \text{ K/r.p.m}\end{aligned}$$

$$\text{Armature resistance, } R_a = 2.5 \Omega$$

$$\text{Initial voltage, } V_m = 25 \text{ V}$$

- Torque after Voltage is Applied

The torque applied is given by equation as,

$$\begin{aligned}T_m &= K_m I_a \\ &= K_m \left(\frac{V_m - e_b}{R_a} \right) \\ &= \frac{K_m (V_m - K_b \omega)}{R_a}\end{aligned}$$

Initially speed of rotation, $\omega = 0$

$$\begin{aligned}\therefore T_m &= \frac{K_m (V_m)}{R_a} \\ &= \frac{0.0981 \times 25}{2.5}\end{aligned}$$

$$T_m = 0.981 \text{ N-m}$$

- Back emf and Torques at 250 r.p.m and 500 r.p.m

When speed of rotation, $\omega = 250 \text{ r.p.m}$

$$\begin{aligned}\text{Back emf, } e_b &= K_b \omega \\ &= 12 \times 10^{-3} \times 250 \\ &= 3 \text{ V}\end{aligned}$$

$$\begin{aligned}\text{Torque, } T_m &= \frac{K_m (V_m - e_b)}{R_a} \\ &= \frac{0.0981 \times (25 - 3)}{2.5} \\ &= 0.863\end{aligned}$$

$$\therefore T_m = 0.863 \text{ N-m}$$

UNIT-6 Actuators, Feedback Components and Applications

When speed of rotation, $\omega = 500 \text{ r.p.m}$

$$\begin{aligned}\text{Back emf, } e_b &= K_b \omega \\ &= 12 \times 10^{-3} \times 500 \\ &= 6 \text{ V}\end{aligned}$$

$$\begin{aligned}\text{Torque, } T_m &= \frac{K_m (V_m - e_b)}{R_a} \\ &= \frac{0.0981 \times (25 - 6)}{2.5} \\ &= 0.746 \text{ N-m}\end{aligned}$$

- Graph between Torque and Speed

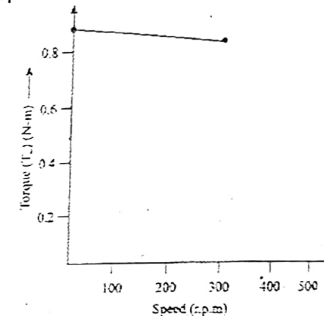


Figure: Torque Vs Speed

6.3 FEEDBACK COMPONENTS - POSITION SENSORS - POTENTIOMETERS, RESOLVERS, ENCODERS - VELOCITY SENSORS

Q37. Classify the various feedback devices used in robotics.

Answer :

Sensors acts as feedback devices to control the actions of the manipulator arm and an end effector.

Various feedback devices are classified into two types. They are,

- Tactile sensors or contact type robotic sensors. It includes,
 - Force sensors
 - Position sensors
 - Torque sensors
 - Touch sensors.
- Non-tactile sensors or non-contact type robotic sensors. It includes,
 - Proximity sensors
 - Contact proximity sensor
 - Non-contact proximity sensor
 - Optical proximity sensor
 - Ultrasonic proximity sensor
 - Capacitive sensor
 - Fibre optic scanning sensors
 - Hall-effect sensors
 - Inductive sensors
 - Pneumatic sensors
 - Scanning laser sensors
 - Electro-optical sensors.
 - Range imaging sensors.

Q38. Using block diagrams differentiate between a closed-loop and an open-loop robot control operation with details of the actuator, encoders and type of actuator, motion control signals.

Answer :

A control system is an arrangement of physical components connected or related in such a manner as to command, direct or regulate itself or another system. A control system consists of following elements,

- (i) Controlled variable
- (ii) Command
- (iii) Reference input
- (iv) Actuating signal
- (v) Disturbance
- (vi) System error
- (vii) Feedback element, etc.

Control system are two types. They are,

1. Open-loop control system
2. Closed-loop control system.

Differences between Open-loop and Closed-loop Control Systems

The differences between an open-loop robot control system and closed-loop robot control system are,

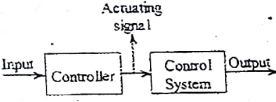
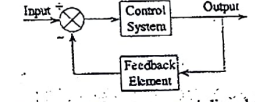
Open-loop Robot Control System	Closed-loop Robot Control System
1.  2. The changes in output due to external disturbances are not corrected automatically. 3. Inaccurate and unreliable. 4. Simple and economical. 5. They are generally stable. 6. Absence of feedback devices. 7. Error detector is absent. 8. Highly effected by non-linearities.	1.  2. The changes in output due to external disturbances are corrected automatically. 3. Accurate and reliable. 4. Complex and costlier. 5. Greater efforts are required to design a stable system. 6. Feedback devices are essential. 7. Error detector is necessary. 8. Reduced effect of non-linearities.

Figure (1) shows a block diagram of a control system for one-joint robot manipulator.

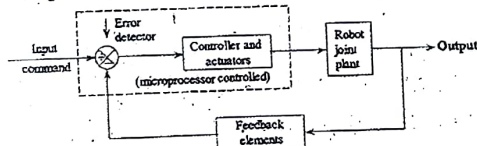


Figure (1)

The input command is the defined position, to which the joint is directed to move. The output variable is the actual position of the joint. The computational functions of the joint controller is carried out by a microprocessor (shown by dotted line). The figure (2) shows actuators, encoders, motion control signal, etc. The load due to gravity acting on the arm by W and is opposing the torque generated by the motor. The term J_r is the total inertia of the system (kg-m^2) which includes inertia of gears, armature, the torque developed is carried out by using the sensor. The amount of pressure increased depends on the distance between the sensor and object.

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Let,

k_p = Proportional gain

k_i = Integral gain

k_t = Tachometer gain.

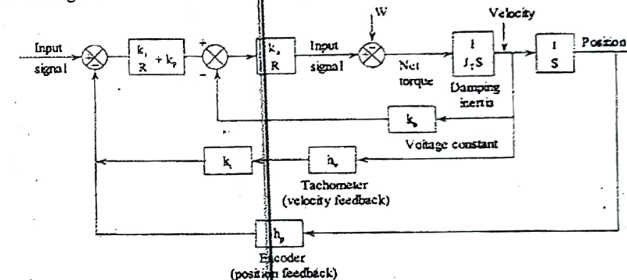


Figure (2): Block Diagram of a Robot Joint

The implementation of the controller is done by microprocessor. It reads the value of velocity and position from feedback devices and compare it with desired parameter. The error signal is multiplied with integrator and proportional gains to generate a command signal for power amplifier which drives the electric motor. The quantity of load may change during working cycle. The microprocessor performs computations in support of control function, to determine the appropriate value of damping constant for change in-load mass.

Q39. Explain the principle used in the following sensors,

- (a) Acoustic sensors
- (b) Pneumatic sensors
- (c) Force or torque sensors.

Answer :

(a) Acoustic Sensors

Acoustic sensors utilizes the principle of detecting the distance of the target by using speed of sound in a medium. These sensors emits acoustic waves, which reaches the target and reflects back to the sensors. The system then measures the time for the echo to return to the sensor and calculates the distance of the target by using the speed of echo in the medium. The figure shows a typical echomode acoustic sensor.

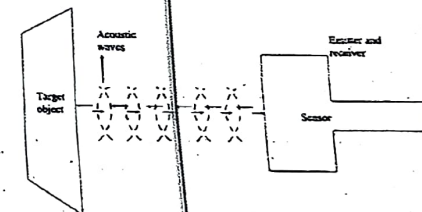


Figure: Typical Echomode Acoustic Sensor

(b) Pneumatic Sensors

Pneumatic sensors utilizes the compressed air for sensing the object. Low pressure air is allowed to pass through a port, which is in front of the sensor. The air escapes freely from the output port, if there is no object. If an object is placed near the sensor, the air from output port cannot escape freely thus more pressure is developed in the port. The measurement of pressure developed is carried out by using the sensor. The amount of pressure increased depends on the distance between the sensor and object.

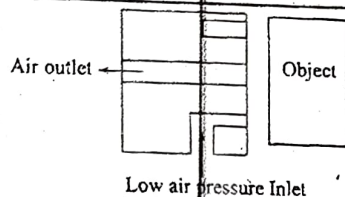


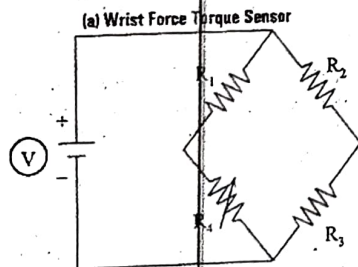
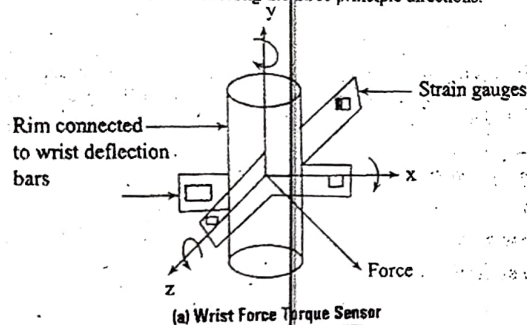
Figure: Pneumatic Sensors

(c) Force or Torque Sensors

Force or torque sensors are based on the principle of strain gauge. When a force is applied on a strain gauge, it results in changing the resistance of it. The amount of change depends on the force applied.

The figure shows a wrist force sensor utilising strain gauges. The sensor consists of two annular rings i.e., inner and outer rings, which are connected to the wrist and end-effector end. The gauges are mounted as eight pairs on the cross of the rings. The strain gauges are connected in the form of wheat stone bridge. There is a galvanometer connected, which shows the potential of the sensor. As the force is applied on wrist, it changes the resistance at one end of ring. This change results in current flow and leads to the movement of the needle of galvanometer.

Thus, the sensor detects the forces and moments along the three principle directions.



(b) Wheat Stone Bridge

Figure: Force or Torque Sensor

Q40. Explain about position sensors.

Answer :

In most cases of robotics, a primary interest is to control the position of the arm. There is a large variety of devices available for sensing position such as potentiometers, resolvers and encoders. Sensor is a transducer used to make a measurement of physical variable. The position sensor is used to know the position of each joint and end effector. The movement of joint can be either linear or angular, depending on the type of robot.

There are two types of position sensors. They are,

- (i) Absolute position sensor
- (ii) Incremental position sensor

The common type of position sensor is potentiometer.

Potentiometer

It is a simplest device that can be used to measure position. "Potentiometer" is an analog device, whose output voltage is proportional to the position (angular or linear) of a wiper. They may be either linear or angular type

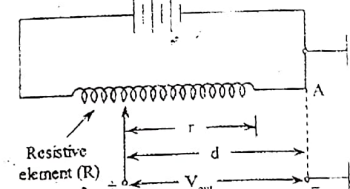


Figure (1): Linear Wire Wound Potentiometer

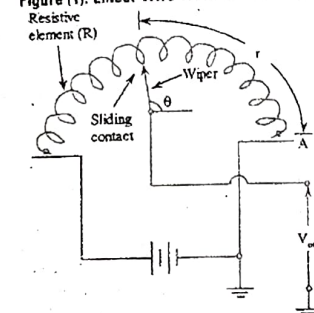


Figure (2): Rotary Wire Wound Potentiometer

Potentiometer is used in robots to monitor either angular position of a revolute joint or linear position of a prismatic joint.

Above figures show linear and rotary wire wound potentiometers. By applying a D.C voltage (V_{in}) across the entire resistance R , the voltage V_{out} is proportional to the linear or rotary distance of sliding contact or "wiper" from reference point 'A'.

$$\text{Mathematically, } V_{out} = V_{in} \times \frac{r}{R}$$

Where, r - Resistance of coil between the wiper and the reference.

Q41. Write short notes on resolvers.

Answer :

[Nov-10, Set-4, Q7(a)] Model Paper-4, Q41(a)

'Resolver' is a robotic sensory device, which is analogical in nature. It is an internal state sensor, whose output is proportional to the angle of a rotating element with respect to a fixed element point. It is a form of 'synchro' in which, the stator and rotor windings of the resolver are displaced mechanically at 90° to each other. It consists a single rotor and two stator windings, as shown in figure below.

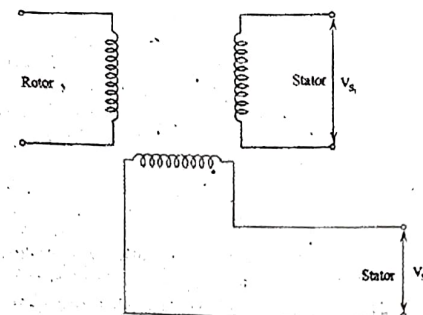


Figure: Electrical Circuit of a Resolver

Characteristics

1. It consists of devices used to measure position, velocity and acceleration of robot joints or end-effector.
2. The resolver converts available A.C signal into a digital form.
3. Tracking Synchro-to-Digital (SD), converts available signal into a velocity output.
4. It can be used as a servo system.
5. It eliminates the separate input and output transformers.
6. It can be used as an incremental encoder.
7. A resolver produces torque output.
8. It performs all the synchronous functions.

Q42. What are the different types of optical encoders? Explain them briefly.

Answer :

Optical Encoders

Nov.-11, Set-4, Q7(a)

Optical encoders are the devices commonly used as sensors, which converts the linear or angular displacements into digital signals.

They are grouped into two categories,

1. Absolute encoders.
2. Incremental encoders.

1. Absolute Encoders

These are used to sense actual position with respect to fixed frame of reference. For each increased value of resolution, different output digital signal is obtained.

The constructional details of absolute encoders are,

- (i) They comprises of multiple track light source, a multi-track receiver and multi-track rotary disc. The tracks on the disc are in the form of circular slots and radial sectors to produce the digital signals.
- (ii) The LED-photodiode pairs, depending on the number of tracks, are provided around the tracks, to avoid the signal interference.
- (iii) The slots of tracks are of transparent and opaque, represented with codes 1 and 0 respectively. Thus, the output digital signal obtained is a binary code signal.
- (iv) Number of bits in the binary code = Number of tracks on disc.

Example : An absolute encoder has 9 tracks on disc.

Therefore, it has 9 bits in its binary code.

Number of positions that can be detected = $2^9 = 512$

$$\text{Resolution of encoder} = \frac{360^\circ}{512} = 0.7^\circ$$

- (v) They are also called absolute transducers, which enables the position to be sensed directly.
- (vi) The main problem with the absolute encoders is that, the output values rapidly changes, during power-off conditions.

Incremental Encoders

These are used to sense the actual position with respect to the previous position. For each increased value of resolution, same output signal is obtained.

The construction details of incremental encoders are,

- (i) These encoders comprises of a disc, encoder shaft and motor. The disc and motor are connected by means of shaft.
- (ii) The disc is coated such that, it has alternate transparent and opaque slots. When the disc is rotated, the light is transmitted to the sensor through transparent slots and thus, output signals are produced.
- (iii) These signals are then transmitted to the counter, to know the number of pulses or signals obtained, which results in the determination of total angle of rotation of the shaft.
- (iv) The resolution of incremental encoder is,

$$\text{Basic resolution} = \frac{360^\circ}{m}$$

Where,

m - Number of sectors on disc (each sector is half transparent and half opaque)

- (v) Generally, an incremental encoder consists of 2500 sectors on its disc and with basic resolution of 0.144° . The resolution and accuracy can be improved by using multiplier circuits and many other techniques.

Example: If the incremented signal factor is '4', then the resolution of encoder is 0.036° .

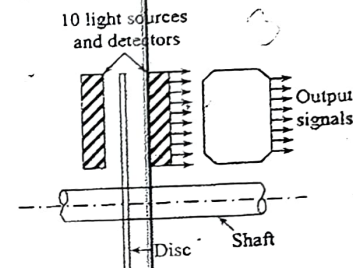


Figure (a): Absolute Optical Encoder

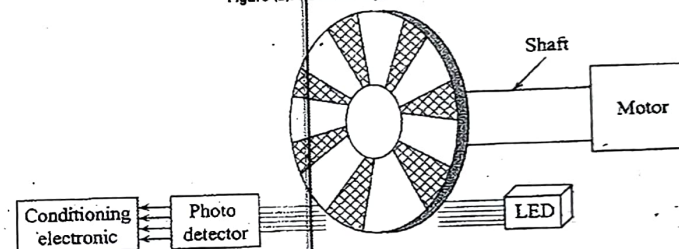


Figure (b): Incremental Encoder

Q43. Explain about construction and working of absolute encoders.

Nov.-11, Set-2, Q7(c)

Answer :

Absolute encoders consists of a photo transmitter, photo receiver and a rotating disc connected to the motor shaft. The disc is divided with opaque and transparent slots, which are known as tracks. Both these slots are arranged alternately, such that the output generated by the encoder results in a binary code. Tracks are surrounded with LED pairs to avoid the turbulence in the signals.

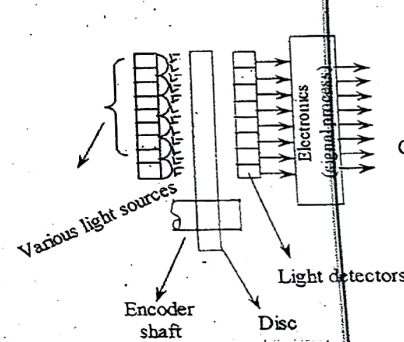


Figure (1): Absolute Encoder

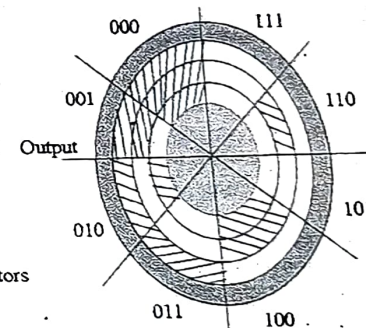


Figure (2): Absolute Encoders with 3-bits

The above figure (2) shows a 3 bit disc in which, transparency is taken as '1' and opaqueness as '0'. The number of tracks or channels on the disc are same as the number of bits on the code, which is proportional to the angle made by the shaft. As the tracks are equal to bits, resolution of this encoder depends on the number of tracks marked on the disc.

Example, number of tracks = 8, then number of bits will also be equal to '8'.

∴ Number of increments/positions that can be detected per revolution = 2^n
 $= 2^8$
 $= 256$

And resolution or angular width of each increment = $\frac{360^\circ}{256}$
 $= 1.40^\circ$

Hence, angular displacement is measured directly from the encoder.

Q44. Explain the velocity sensors.

Answer :

Velocity sensor is a device used in control system of a robot as feedback of velocity information. Example of velocity sensor is a D.C tachometer.

A tachometer is essentially an A.C generator providing an output voltage proportional to the angular velocity of the armature. It is described by the relation,

$$V_o(t) = k_t(t) \cdot \omega$$

Where,

$V_o(t)$ – Output voltage of the tachometer (Volts)

$k_t(t)$ – Tachometer constant (Volt rad/sec)

ω – Angular velocity (rad/sec).

$$= \frac{d\theta}{dt} = \theta^\circ$$

Tachometer is used to provide velocity information to the controller. This can be used for performing velocity control of a device or in many cases, to increase the value of k_d (gain constant) in the system, thereby improving the stability of the system and its response to disturbances.

D.C tachometer provides a voltage output proportional to the armature rotational velocity (analog device function, whereas digital D.C tachometer provides a pulse train output of a frequency proportional to the angular velocity.

Q45. Describe briefly about tachometers.

Answer :

[Nov.-10, Set-1, Q7(c) | Model Paper-IV, Q7(a)]

Tachometer is a speed measuring device. It is broadly classified into two types. They are,

1. Electrical Tachometers

- (i) Tachogenerators
- (ii) Contactless tachometer
- (iii) Drag cup tachometer
- (iv) Commutated capacitor tachometer.

2. Mechanical Tachometers

- (i) Vibrating reed tachometer
- (ii) Centrifugal force tachometer
- (iii) Slipping clutch tachometer
- (iv) Hand speed indicator

Among the above listed tachometers, most widely used tachometer is described below.

Tachogenerators

Tachogenerators are classified into two types,

- (i) D.C tachometer generator
- (ii) A.C tachometer generator.

(i) D.C Tachometer Generator

It consists of a permanent magnet and a small armature. The armature is placed between the poles of the magnet. The object whose angular speed or velocity to be measured, is coupled to the armature.

When the object rotates, the armature also revolves in the magnetic field of the permanent magnet. As the armature is made up of a conducting material, its rotation results in the generation of e.m.f. The current flowing in the armature is collected through commutator and brushes and thus, voltage is generated, which can be measured using a moving coil voltmeter. In case of a short circuit, the current from the generator is limited by a series resistance.

The voltage generated is proportional to the speed of the object and the direction of rotation is determined from the polarity of the output voltage.

The figure below shows a D.C tachogenerator,

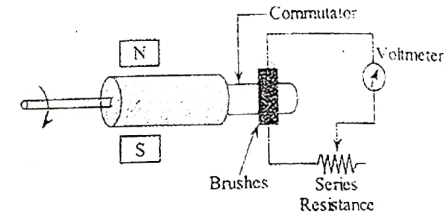


Figure: D.C Tachometer Generator

(ii) A.C Tachometer Generator

The problems associated with commutator, as in D.C tachometers, are not present in A.C tachometers, because the coil is wound on the stator and the magnet is allowed to rotate. The rotating magnet can be either an electromagnet or permanent magnet.

The machine whose angular speed is to be measured is connected to the rotating magnet. When the magnet rotates, the flux lines are cut by the stationary coil and thus, according to the electromagnetic induction law an e.m.f is induced in the stator coil. The amplitude or frequency of the induced voltage gives the measure of speed as both the parameters are proportional to speed of rotation.

The circuit shown below is used, when it is required to measure speed in terms of amplitude of induced voltage. The voltage generated by A.C tachometer generator is rectified and smoothened, before it is measured by moving coil voltmeter.

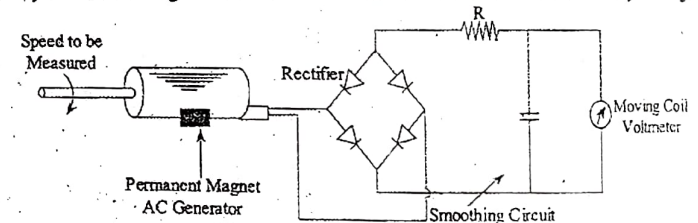


Figure: A.C Tachometer Generator

Q46. What are the characteristics of a D.C tachometer?

Answer :

The following are the characteristics of a D.C tachometer,

- (i) It enables feedback information in a robotic control system.
- (ii) Its output voltage is proportional to the rate of change of angular displacement of motor armature shaft.

$$\text{i.e., } V_o \propto \frac{d\theta}{dt}$$

$$V_o = k_t \cdot \frac{d\theta}{dt}$$

$$V_o = k_t \cdot \theta^\circ$$

$$\therefore V_o = k_t \cdot \omega$$

- (iii) It is capable of performing velocity control function.
- (iv) it helps in improving the stability of the system.
- (v) It has characteristic of analog device function.
- (vi) It has a digital equivalent measuring characteristic.

Q47. Explain the working of any two proximity sensors.

Answer :

Proximity Sensors

Proximity sensors or external state sensors usually have a binary output and is used to determine the presence of an object within a specified distance of interval. Proximity sensors can be classified as follows,

1. Contact proximity sensors
 - (a) Contact rod proximity sensor
2. Non-contact proximity sensors
 - (a) Optical proximity sensors
 - (b) Capacitive sensors
 - (c) Fibre optic scanning sensors
 - (d) Hall-effect sensors
 - (e) Inductive sensors
 - (f) Eddy current sensors
 - (g) Pneumatic sensors
 - (h) Scanning laser sensors.

1. Contact Proximity Sensors

(a) Contact Rod Proximity Sensor

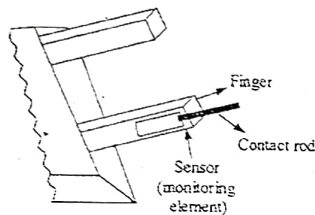


Figure (1): Contact Rod Proximity Sensor

A simple type of contact proximity sensor is shown in figure (1). It essentially comprises of a rod, which protrudes from one end and a monitoring component (i.e., switch to change the position of an object), located inside the body of sensor. The monitoring component can also be placed anywhere on robot's arm or wrist. Initially, due to movement of a robotic manipulator, the rod comes in contact with an object or obstacle, by which the sensor becomes active. This results in change of state of switch (i.e., ON/OFF) and is monitored by robot's input or output interface, to perform required operation or task.

This type of sensors, enables the sensing of obstacle and object simultaneously. However, contact proximity sensor cannot give any information about the nature or shape of either object or obstacle. But, the use of arrays with this type of devices furnish some degree of object recognition.

2. Non-Contact Proximity Sensors

(a) Optical Proximity Sensor

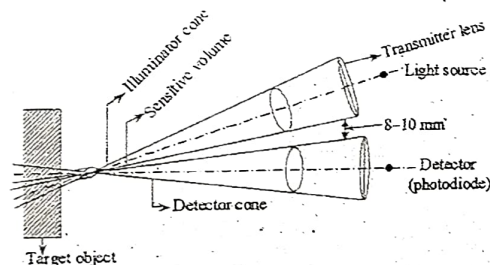


Figure (2): Optical Proximity Sensor

A simple type of non-contact proximity sensor is shown in figure (2). Its operation is based on the principle of reflection light from an object. An optical proximity sensor comprises a source of light i.e., LED and a detector (usually photodiode). These are fitted symmetrical towards one another and are separated at a distance of about 8 to 10 mm. The light rays coming from the source and detector, intersect on the same plane in the form of long cone like volume, which defines the sensor field operation. The cones of light is reflected and intersected by a reflective surface. Thus, the reflective surface is illuminated by the source and seen by the receiver simultaneously. Proximity can also be monitored in several directions such as beneath and ahead of robot's hand, if many sensors are used and are placed on a robotic gripper.

A graph is plotted to show the variation between the object distance from the receiver and a photo detector voltage.

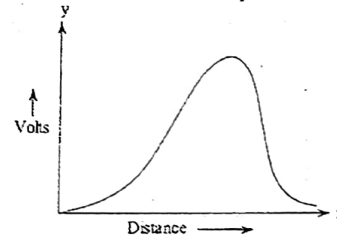


Figure (3)

Q48. A new experimental strain gauge is mounted on a 0.25 mm diameter steel bar in the axial direction. The gauge has a measured resistance of 120 Ω and when the bar is loaded with 500 kg in tension, the gauge resistance increases by 0.01 Ω . What is the gauge factor of the gauge?

Answer :

April/May-13, Set 2, Q6

Given that,

Diameter of steel bar, $d = 0.25$ mm

Resistance, $R = 120 \Omega$

Load, $P = 500$ kg

Change in resistance, $\Delta R = 0.01 \Omega$

The gauge factor is given by,

$$G.F = \frac{\Delta R}{\frac{R}{E}}$$

But,

$$\text{Strain, } \epsilon = \alpha/E$$

$$\therefore G.F = \frac{\Delta R}{\frac{R}{\frac{\alpha}{E}}} = \frac{\Delta R}{\frac{R}{E}}$$

$$= \frac{\Delta R}{\left(\frac{P}{AE}\right)}$$

$$\text{Area, } A = \frac{\pi}{4}(d)^2$$

$$= \frac{\pi}{4}(0.25)^2$$

$$= 0.049 \text{ mm}^2$$

Assume, Young's modulus, $E = 30 \times 10^6 \text{ N/mm}^2$

$$\therefore G.F = \frac{0.01 \times 0.049 \times 30 \times 10^6}{500 \times 120} = 0.245$$

Q49. A certain potentiometer is to be used as the feedback device to indicate position of the output link of a rotational robot joint. The excitation voltage of the potentiometer equals 15 V and the total wiper travel of the potentiometer is 320°. The wiper arm is directly connected to the rotational joint so that the given rotation of the joint corresponds to an equal rotation of the wiper arm.

- (a) Determine the voltage constant of the potentiometer.
- (b) The robot joint is actuated to a certain angle, causing the wiper position to be 38°. Determine the resulting output voltage of the potentiometer.
- (c) In another actuation of the joint, the resulting output voltage of the potentiometer is 3.75 V. Determine the corresponding angular position of the wiper and the output link.

Answer :

Given that,

Excitation voltage, $V_e = 15$ V

Total angle = 320°

- (a) Voltage constant of the potentiometer
 $= 15/320 = 46.87 \text{ mV/deg.}$
- (b) For the wiper position of 38° output voltage
 $= (38 \times 46.87)/1000 = 1.7810 \text{ V}$
- (c) For the output voltage of potentiometer i.e., 3.75 V angular position of output link,
 $= (320/15) 3.75 = 80^\circ$

Since, the output link and wiper are directly connected, the angular position will be same for the both.

Q50. Find the output voltage of a potentiometer with the following characteristics,

Also determine the voltage constant (K_p) of the PA.

The excitation voltage = 12 V, total wiper travel = 330°, wiper position = 56°.

Answer :

Given that,

Excitation voltage = 12 V

Total wiper travel = 330°

Wiper position = 56°

Voltage constant of the potentiometer.

$$K_p = \frac{\text{Excitation voltage}}{\text{Total wiper travel}}$$

$$K_p = \frac{12}{330^\circ}$$

$$\therefore K_p = 0.0363 \text{ V/deg}$$

Output voltage of the potentiometer,

$$V_{\text{output}} = (\text{wiper position}) \times K_p$$

$$= 56^\circ \times 0.0363$$

$$\therefore V_{\text{output}} = 2.036 \text{ V}$$

Q51. An incremental optical encoder gives 360 pulses per revolution. Clock pulses at a repetition rate of five pulses per second are available for starting and stopping a counter. What is the maximum angular velocity that can be measured, if the capacity of the counter is 1024 (decimal)?

Answer :

Given that,

Output of incremental optical encoder,
= 360 pulses/revolution

Clock pulse rate = 5 pulses/second

Capacity of counter = 1024 decimal (resolution lines)

i.e., the disc of 10 tracks and number of positions detected is,

$$2^{10} = 1024$$

The encoder resolution,

$$\frac{2\pi}{1024} = \frac{360}{1024} = 0.352^\circ$$

The maximum angular velocity that can be measured,

$$= \frac{5}{360^\circ} \times 1024$$

$$= 14.22 \text{ rev/sec}$$

$$= \frac{14.22}{0.352^\circ} \times \frac{\pi}{180^\circ}$$

$$= 0.71 \text{ rad/sec}$$

6.4 MATERIAL HANDLING, LOADING AND UNLOADING - PROCESSING

Q52. What are the general considerations in selecting a robot for material handling?

Answer :

The general considerations to be followed in selecting a robot for material transfer operation are as follows,

(i) **Part Positioning and Orientation**

In application of parts handling, the parts should be introduced to the robots in a specified position and orientation.

(ii) **Gripper Design**

For the pick and place operation, distinguished end-effectors should be designed.

(ii) **Minimum Distance Travel**

The distance travelled by the parts in the material handling operation should be minimum.

(iv) **Robot Work-Volume**

The amount of work carried out by the robot should not exceed the specified limit.

(v) **Robot Weight Capacity**

Robots should be specified with sufficient load carrying capacity, to ensure that capacity limit does not exceed.

(vi) **Accuracy and Repeatability**

High accuracy is required in the pick and place operations of materials. Therefore, robots must be built with high accuracy.

(vii) **Machine Optimum Utilisation**

For an application to be effective, it is necessary that all the equipments in the cell should be used at optimum level. In order to ensure the optimum utilisation of machine, the robots should work effectively.

(viii) **Robot Configuration, DOF's, Control, etc**

Maximum degree of freedom's are required in the applications of machine loading. In the operation of palletizing and picking parts from conveyors, the requirements for control are more complicated.

Q53. Describe the material handling operations.

Answer :

Material handling operations involve usage of robots to move the parts from and to the machine and to load or unload the parts from the machine. The three main operations are,

1. **Machine Load or Unload**

While doing operation on a production machine, the loading of raw materials and unloading of finished products is done by robots. This reduces the human effort and ensures minimum wastage of time. For example, in case of machining operation, the job to be machined is fixed in the machine and the final part is collected by the robot after completion of finishing operations.

2. **Machine Loading**

In this operation, the robot only loads the raw materials for machining, while the finished parts are collected by separate arrangements.

Example: Presswork operation, in which the parts to be pressed are loaded by the programmed robot and the pressed parts are collected separately.

3. **Machine Unloading**

In this operation, the raw materials are loaded by some external sources and finished parts are unloaded by a robot.

Example: Die casting and plastic moulding.

In order to improve the production rates, the robot assisted workhouse is developed, in which, a production machine, robot, etc., are located. These workhouses are designed separately for different operations. Some are designed such that, same identical parts are produced, while in some workhouses, different types of models on different machines at different times are produced. In both cases, robot plays a key role in loading or unloading the parts.

UNIT-6 Actuators, Feedback Components and Applications

Q54. Discuss the material transfer applications of robot.

Answer :

In pick-and-place operation, the robot picks up the part at one location and moves it to another location. The part is available to the robot by mechanical feeding device or belt conveyor in a known location and orientation. A simple limit switch is used to stop the component to allow the part to be gripped by robot. The robot then moves and position the part at a desired location. The stop the component to allow the part to be gripped by robot. The basic operation is shown in figure. In this case, 2 DOF is involved, one degree of freedom is required to lift component from pickup point and put it down at the drop-off point and second DOF is needed to move the part between these two positions. In some cases, a reorientation of the component is accomplished during the move period.

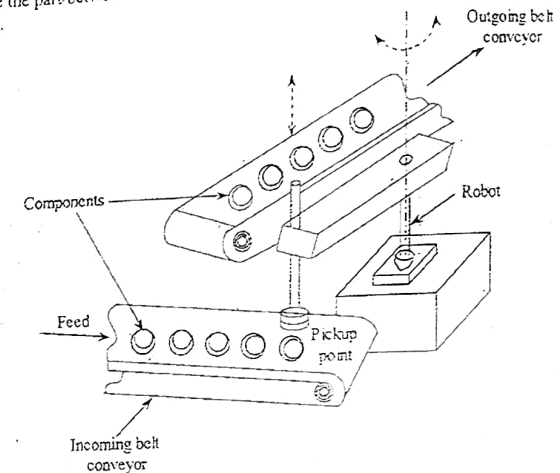


Figure: Pick-and-place Operation

In material transfer application of robot, pallets are used for material handling and storage. Large number of containers are placed on a pallet, instead of handling individual cartons. The pallets are moved mechanically within the manufacturing plant or warehouse, by fork lift trucks or conveyors. The only handling of the individual cartons arises, when the component is placed onto the pallet or when it is removed from the pallet. The loading of cartons onto pallets is typically a heavy work performed manually by unskilled labour. A typical pallet configuration is shown in figure below. Each carton is placed at a different location on the pallet, the variation in carton location is in three dimensions. The pallets are usually stacked on top of each other in layers as shown in figure.

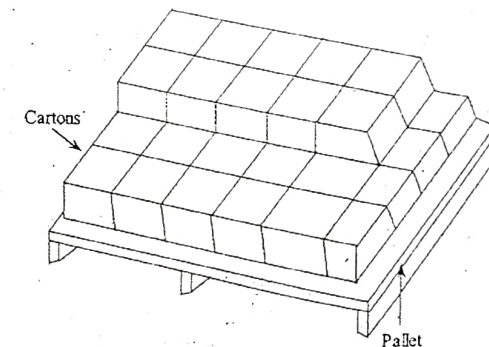


Figure: A Typical Pallet Configuration

The robot is to be programmed to perform desired motion pattern in palletizing operations. Also, sensors are incorporated to identify carton locations and their delivery point. Depalletizing operation is the reverse of palletizing, in which, the robot removes cartons from a pallet and places them onto a conveyor or other location.

Q55. What are the desirable features of a robot for successful machine tool load or unload application?

Answer : Nov.-10, Set-1, Q8(b)

The desirable features of a robot for successful machine tool load or unload applications are as follows,

(i) Dual Gripper

It allows the robot to handle the raw material and finished work parts simultaneously, due to which the production cycle time reduces.

(ii) Degrees of freedom

To manipulate and position the part in the machine tool, robot requires more number of degrees of freedom of the arm and wrist.

(iii) Good Repeatability

To position the part into chuck or other work holding devices, robot requires comparatively high level of precision.

(iv) Palletizing and Depalletizing Capabilities

The use of robot is to place the raw work parts on pallets (palletizing) and move it to the work cell and then remove the work parts from pallet (depalletizing). The robots controller and programming capabilities must be sufficient to accomplish the specified task.

(v) Programming Features

The use of robots allows several programming features in machining applications. In batch production of different parts, the change over of set up is required from batch to batch. This change over causes the change in robot program among different batches. Thus, the robot must have high storage medium like disks, tapes, etc., for storing and changing large number of programs in between batches. Robot requires another programming feature for machining i.e., it must be able to accept programs for tool or pallet changes.

Q56. What is the role of robots in loading and unloading?

Answer :

1. Robots are used for loading raw materials and unloading finished products in manufacturing process.
2. Increases the rate of production and minimizes the idle time.
3. Robots are highly efficient, while working in hazardous environments.
4. The parts are loaded with high accuracy, thereby eliminating human errors.
5. Robots are also used for loading of tools, special fixtures or attachments, etc. on a machine.
6. Handling of parts in a work cell, containing multiple machine tools.
7. The robot is used to load the finished product into an inspection gauge for quality inspection.
8. The parts are loaded on functional testers, which measures the responses of system to certain controlled inputs.

9. Use of robots increases the flexibility of the system and reduces the material handling costs.

10. They are effectively used for palletizing, loading and unloading of irregular or complex parts.

Q57. Discuss the application of robots in plastic moulding operation.

Answer :

Robots are used in plastic injection moulding machines for mass production. The figure below shows the plastic moulding operation with incorporation of robot.

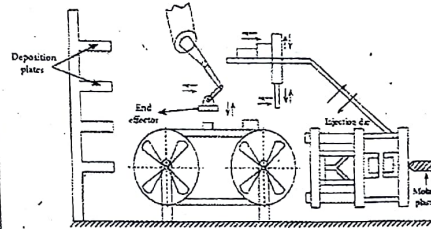


Figure: Plastic Moulding Operation

Plastic moulding robot is of large servo transverse type, whose applied capacity is in tonnes. They remove the runners, sprues and eject the products from the mould of plastic injection machine, which are in line automatically. The benefits are reduced labour requirement and increased output leading to lower unit costs.

The robot may be linear (cartesian) or articulated arm type. Linear robots are mounted on either the fixed or moving plate and with the main axis of the robot at 90° to the moulding machine axis (transverse) or in line with the moulding machine axis. Transverse mounted robots allow part removal at the front or rear of the machine, while longitudinal robots allow parts to be deposited at the end of the machine.

6.5 SPOT AND CONTINUOUS ARC WELDING, SPRAY PAINTING, ASSEMBLY AND INSPECTION

Q58. What are the features of robots in arc welding? Explain.

Answer :

Following are the features of robots in arc welding,

(i) Work Envelope and Degrees of Freedom

Work envelope of robot must take into consideration, the size of the parts being welded and space required for the manipulation of welding torch. Generally, an arc welding robot requires five to six degrees of freedom. Lesser degrees of freedom affects the motion capability of the manipulator.

(ii) Motion Control System

Robots should be able to produce smooth continuous motion required in arc welding to maintain uniformity of the welding seam.

(iii) Precision Motion Requirements

Quality of the job depends to a larger extent on the accuracy and repeatability. Therefore, these requirements which vary according to size and industrial practice should be clearly defined, that helps in the selection of most appropriate robot.

(iv) Interface Capabilities

Robot must possess sufficient control capabilities to work with different equipments in the cell. The controller must coordinate speed and path with parameters of welding such as wire feed rate and power level.

(v) Programming

The robot should be programmed carefully for continuous arc welding along paths with irregular shapes, weave pattern, etc.

Q59. What is spot welding? Describe briefly the operations involved in robotic spot welding. What are the advantages of robotic welding over manual welding.

Answer :

The welding, which involves fusion of two metals through electrodes or welding guns is known as spot welding. In spot welding, fusion is obtained by generating heat at the desired point, through electrodes. The electrodes are supplied with current for specific duration of time, depending on the metal thickness.

A robotic spot welding consists of a robotic manipulator, welding gun, controller and power sources. The manipulator with several number of degrees of freedom is utilized. The welding gun is situated on the robot wrist in connection with controllers and power sources.

The two metal pieces are placed on the work table. Then, squeezing of metal surfaces between the electrodes is carried by generating heat for specific time. Thus, welding is done by application of load and heat on the metal surfaces. The robot then releases the metal surfaces after welding operation.

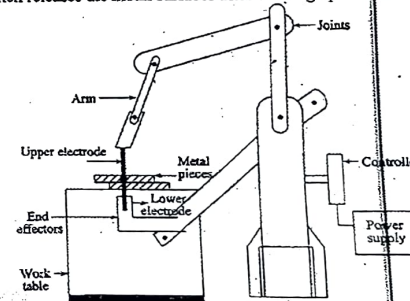


Figure: Robotic Spot Welding

Advantages of Robotic Welding Over Manual Welding

1. Robotic welding consumes less time than manual welding. Hence, the work can be performed quickly.
2. Efficient and accurate welding can be achieved by using robotic welding.

3. Accurate welding results in conservation of materials.
4. Welding is reliable and repeatable with high precision.
5. Welding can be carried out in harmful environment.
6. Robotic welding reduces the cost of labour and increases the safety.

Q60. What are the desired capabilities and features of robots in spot welding? Explain.

Answer :

Following are the capabilities and features of robots to perform spot welding.

1. It should have enough payload capacity to manipulate the welding gun for the application.
2. It should be able to position and orient the welding gun over surfaces of the product that are difficult to reach.
3. It should have increased number of degrees of freedom that help in carrying out the process with great ease.
4. Capacity of controller memory must be large enough to store many positioning steps required in the welding process.
5. With change of models, robots must be able to switch from one welding sequence to other.
6. Spot welding by robots leads to improved product quality in the form of more consistent and better repeatable locations of the welds.
7. It leads to improved safety due to the absence of human in the work environment, thus preventing hazards like electrical shocks and burns.
8. It gives better control over the production process, leading to improvement in areas like production scheduling and in-process inventory control.

Q61. Explain the advantages of using robots in arc welding operations.

Answer :

[Nov.-10, Set-1, Q8(a)] Model Paper-III, Q8(a)

Arc welding is a continuous welding process, in which long weld joints with air tight seal is maintained in between the two pieces of metal being joined. The process uses an electrode in the form of rod or wire of metal to supply the high electric current needed for establishing the arc.

A continuous path servo controlled robot that is often specifically designed for single application is used. The parts to be welded are positioned and held in place, the 3-dimensional path can be pre-taught and no external sensors may be used. The position sensor is placed in front of the welding tool, which provides information concerning irregularities in the weld path. For wide joints, the robot is programmed to produce a weave type of motion, which ensures that weld covers the entire gap. The workspace of the welding robot should be large enough to accommodate size of the parts to be welded. A 5-DOF manipulator can weld plane parts, while 6-DOFs are required for welding complex contours. The robotic welder controls the arc time effectively, which defines the weld strength. The following are the advantages of robotic welding.

- (i) Good quality of weld product
- (ii) Improved safety aspects in working environment
- (iii) Better control over welding process
- (iv) Higher productivity
- (v) Optimum utilisation of electrodes
- (vi) Elimination of human errors etc.

Q62. Explain the robotic non-contact arc welding sensor system.

Answer :

These sensor systems are classified as,

- (i) Arc sensing systems
- (ii) Machine vision systems.

Arc sensing systems, also called as through-the-arc systems is based on feedback measurements. These feedback measurements can be of current (constant voltage welding) or the voltage (constant current welding).

Robot is programmed to perform a wave pattern. This waving motion can be interpreted as vertical and cross seam position of the welding torch. Adaptive positioning of the torch is done by the controller, by regulating the arc length (constant current systems), when it encounters the irregular edges or gaps.

Machine vision system consists of a vision camera in order to view the weld path. This camera is mounted near the welding torch. Robot must be programmed for the desired welding path. Two approaches i.e., single pass system and double pass systems are followed. Generally, single pass system detects and corrects the variations in the welding seam in just one welding pass. Double pass system initially do a high speed scan of the seam to record any deviations from the programmed path. In the second pass, welding is performed after analysis of the deviations by the controller.

Q63. Discuss the problems for robots in arc welding.

Answer :

Problems of robots in arc welding:

1. It becomes more difficult to weld components involving large amount of variations.
2. If the variation is in the dimensions of the parts, the path to be followed changes slightly from one part to the other.
3. Variation in the edges and surfaces of the parts to be welded i.e., irregular edges lead to errors in gaps between the parts.
4. Robots in arc welding do not have the sensing capability, skill and judgement when compared to a human welder in compensating the above variations.
5. Problems occur in positioning the robot while performing arc welding in confined areas like areas inside pressure vessels, ship hulls, etc.
6. Demand for skill and judgement from the robot is difficult to fulfill.

Q64. What are the requirements of the robot for spray-coating applications?

Answer :

The following are the requirements of a robot for spray-coating applications,

(i) **Continuous Path Control**

Robot requires large number of degrees of freedom for its manipulator and it should possess the capability for following a continuous path to perform smooth movement of spray painting, better than a human operator.

(ii) **Hydraulic Drive**

In spray-coating applications, hydraulic drive is mostly employed, when compared to electric drive and pneumatic drive, due to the following reasons,

Nov.-11, Set-2, Q8(b)

May/June-14, Set-1, Q8(a)

UNIT-6 Actuators, Feedback Components and Applications

- (a) In electric drive, generally spark is produced, which may ignite the paint fumes.
- (b) In pneumatic drive, the motions generated are too erratic or uncontrollable, which is unacceptable for spray-coating applications.

(iii) **Manual Lead through Programming**

Manual lead through programming is considered as the most suitable method for teaching the robot, in which the robot arm is moved manually in the desired motion patterns, with the help of skilled human operator. While programming the robot, a teach arm may be used instead of actual robot, as actual robot is heavier and possess difficulties in manipulating smoothly.

(iv) **Multiple Program Storage**

The use of robot in spray-coating applications, requires multiple programs storage for different styles of spraying and it also requires the capability to quickly access the program for current part. Robot requires large memory to setup programs for different styles of spraying.

Q65. Explain how the robot is used for spray painting applications.

Answer :

Nov.-10, Set-2, Q8(b)

Industrial robots are used to perform spray painting to avoid hazards to humans like fumes, mist in air, noise from nozzle, fire hazards and cancer hazards, etc. In robot spray painting operations, the spray gun is the robot's end-effector. Robots employed for this purpose are capable of performing both straight line and continuous path motions. Programming a spray painting robot is performed by a highly skilled operator. The spray painting application does not require the use of external sensors.

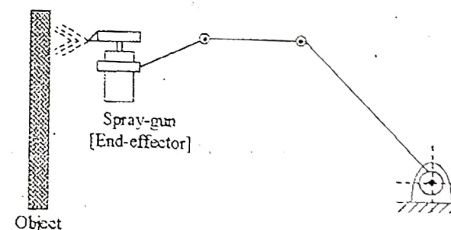


Figure: Spray Painting

Advantages of using Robots in Spray Painting

1. Consistency in operation
2. Less energy consumption
3. Optimum use of paint material
4. Higher product quality

5. Higher productivity
6. Improved safety and quality of work life
7. Process rationalization
8. Reduced direct labour costs etc.

Q66. Discuss the applications of robots in automated assembly operations.

Answer :

[Nov.-11, Set-1, Q8(a) / Nov.-10, Set-4, Q8(a)]

Assembly is defined as fitting two or more discrete parts together, to form a new subassembly. Assembly operation consists of the sequential addition of components to a new part to create a more complex subassembly or a complete product.

Fastening operation using screws, nuts, bolts, springs, rivets, etc. and insertions of shafts in holes are examples of assembly operations. Assembly operations are divided into two basic types,

- (i) Parts mating
- (ii) Parts joining.

In parts mating, two or more parts are brought into contact with each other, while in parts joining, two or more parts are mated and then additional steps are adopted to ensure that the parts will remain in contact with each other.

Example: Peg-in-hole assembly tasks.

There are two basic assembly system configurations i.e. a single workstation and a series of workstations (an assembly line). Combinations of these two basic types are also possible.

The design for robotic assembly depends on the design of the product. The design considerations are,

- (i) Ease of assembly
- (ii) Feeding and orientation.

The compliance of the gripper is the most important property in the assembly operation. There are three types of robots for assembly operations,

- (a) Cartesian robots (Gantry robots)
- (b) Revolute robots ("PUMA" robots)
- (c) "SCARA" robots.

(a) **Cartesian Robots (Gantry Robots)**

They are suitable for simple assembly operations as they have high accuracy and repeatability. These robots have grippers with 2 to 3 degrees of freedom.

(b) Revolute Robots

They are suitable for moderate assembly tasks. PUMA (Programmable Universal Machine for Assembly) type robots (high level language robots) VAL and VAL II or V⁺ have 6-DOF's. They have two coordinate systems,

- (i) Tool coordinate system
- (ii) World coordinate system.

(c) "SCARA" Robots

SCARA robots are highly accurate and precise machines, which has direct drive motors for allowing high speed, backlash-free, fast and accurate assembling of parts.

Q67. Discuss the single station robotic assembly system.

Answer :

In single station robotic assembly system, all the parts that are required to complete the desired assembly are presented to the robot at a single work station. All the parts mating and joining tasks for the assembly are accomplished at the single workstation. A single-station robotic assembly system would be used for low and medium volume work, in which, limited number of assembly tasks and parts are to be handled.

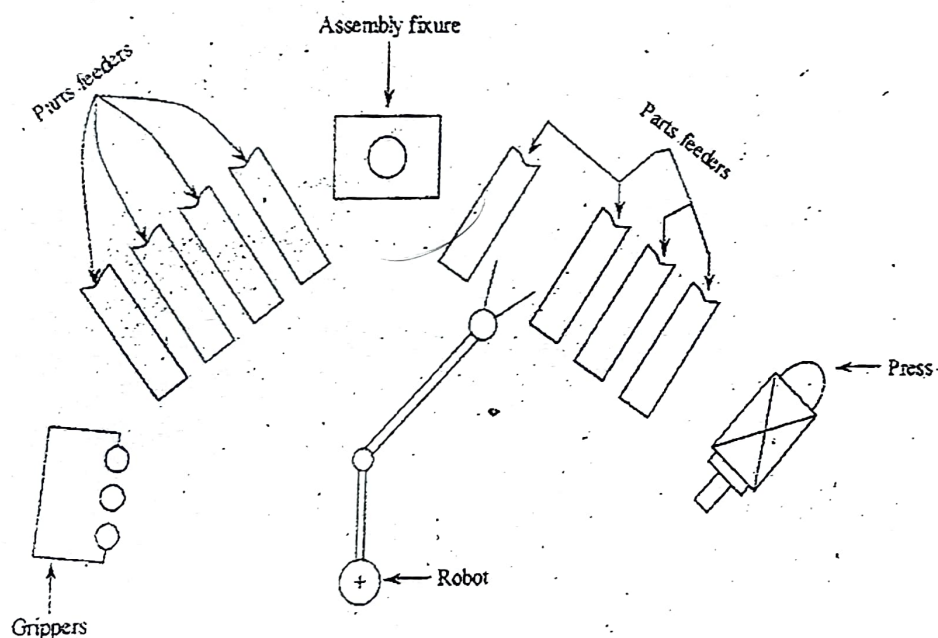


Figure: Single Station Robotic Assembly System

The single work station configuration is not very fast, even for assemblies of relatively low complexity. The production rate of the work station is inversely proportional to the number of parts in the assembly. Larger number of parts assembly by one gripper is difficult to design. This system is economical, for low-volume automated production. Some disadvantages like changing grippers during the work cycle and reorienting the parts, results in loss of time.

Q68. Discuss the robotic series assembly system.

Answer :

Assembly robots are used in expanded production capabilities in the manufacturing systems. Robots save the workers from tedious and dull assembly line jobs and increase production and savings in the process.

Assembly line constitutes the series assembly system, which is used in many medium and high production assembly areas, such as automobiles, household appliances, small power tools, etc. It consists of a series of work stations at which, only a few operations are performed on the product at each station. Each station works on different products, and the products are gradually built up, as they move down the line. The production rate for this type of system is higher than the single station system. The work stations are handled by robots instead of humans in in-line configuration.

Following figure shows a series of assembly systems employed for motor assembly job. An assembly of an electric motor consisting components like rear end bell, front end bell, rotor, stator, two brushes, two bearings, two screws.