ROBOT SIMULATION

Methods of robot programming

Simulation concept

Off-line programming

Advantages of offline programming.

ROBOT APPLICATIONS

Robot applications in manufacturing-

Material transfer and machine loading/unloading, Processing operations like Welding & painting, Assembly operations, Inspection automation, Limitation of usage of robots in processing operation.

Robot cell design and control

Robot cell layouts-Multiple robots & Machine interference

INTRODUCTION

- Robots are becoming more powerful, with more sensors, more intelligence, and cheaper components. As a result robots are moving out of controlled industrial environments into uncontrolled service environments such as homes, hospitals, and workplaces where they perform tasks ranging from delivery services to entertainment.
- It is this increase in the exposure of robots to unskilled people that requires robots to become easier to program and manage. The flexibility of a robot system comes from its ability to be programmed. How the robot is programmed is a main concern of all robot users.
- A good mechanical arm can be underutilized if it is too difficult to program. Earlier robot programming was easy because it only required guiding the robot through the sequence of desired movements.
- To execute complete tasks of the type found inassembly, robot-programming languages had to be introduced. Although the introduction of robot programming languages has represented an important breakthrough in industrial robotics, currently available languages are not easy to use. The programmer must define all the movements very precisely. Programming the robot is not the same as programming the computer.

ROBOT PROGRAMMING

- A robot program can be defined as a path in space to be followed by the manipulator, combined with peripheral actions that support the work cycle. Robot can perform complex tasks under the control of stored programs, which can be modified at will. Process of robot programming includes teaching it the task to be performed, storing the program, executing the program and debugging it.
- Robotic programming is similar to real-time programming in that the programs must be interrupt driven and take account of limited resources. Robot programs can be simple or complex. Simple programs will have a set of pre-programmed responses to expected events.
- For example, if the robot is hit, it may move in a particular direction. Complex robot programs may include a way to learn from past events and actions and predict what will happen. For example, robot programmed to move left when it reaches a barrier will always move in this direction.
- However, a robot might be programmed to remember which direction has the fewest barriers and will move in that direction. This element of learning is more likely found in robot programs than real-time programs. Examples of the peripheral actions include opening and closing the gripper, performing logical decision making, and communicating with other pieces of equipment in the robot cell.

ROBOT PROGRAMMING TECHNIQUES

- A number of different techniques are used to program robots. Principal task of robot programming is to control the motions and actions of manipulator. A robot is programmed by entering the programming commands into its controller memory. The methods of entering the commands are:

1. On-line programming
2. Lead-through programming
3. Walk-through programming
4. Off-line programming
5. Task programming

ON-LINE PROGRAMMING

- On line programming takes place at the site of programming systems uses a 'teach production itself and involves the workcell. On-line pendant' to direct the robot's movement which allows trained personnel physically to lead the robot through the desired sequence of events by activating the appropriate pendant button or switch.
- Position data and functional information are "taught" to the robot, and a new program is written. Taught data is stored in the pendant's memory then transferred to the robot's controller. The teach pendant can be the sole source by which a program is established, or it may be used in conjunction with an additional programming console and/or the robot's controller.
- When using this technique of teaching or programming, the person performing the teach function can be within the robot's working envelope, with operational safeguarding devices deactivated or inoperative.
- There are a number of teach. On-line Programming pendant types available, depending on the type of application for which they will be used. If the goal is simply to monitor and control a robotics unit, then a simple control box style is suitable. If additional capabilities, such as on the site programming are required, more sophisticated boxes should be used. On line programming is a convenient and easy method of programming when tasks are simple and revisions or adjustments can be made on the spot.
- However, the production line must be stopped during the programming and there are safety issues to consider, as the programmer must work within the robot's work envelope.

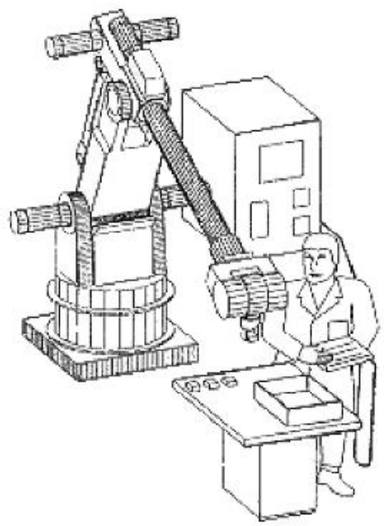


Fig. 16.1. On-line Programming

Advantages

- Easily accessible.
- Robot is programmed in concordance with the actual position of equipment and pieces.

Disadvantages

- Unavailability of robot for production during programming phase.
- Slow movement of the robot while programming.
- Time consuming process.
- Program logic and calculations are hard to program.
- Suspension of production while programming.
- Cost equivalent to production value.
- Inefficient in flexible manufacturing system.

The Teach Pendant (or Manual Control Pendant)

- ➢ The teach pendant has the following primary functions:
  - Serve as the primary point of control for initiating and monitoring operations.
  - Guide the robot or motion device, while teaching locations.
  - Support application programs.
- ➢ The teach pendant is used with a robot or motion device primarily to teach robot locations for use in application programs. The teach pendant is also used with custom applications that employ "teach routines", that pause execution at specified points and allow an operator to teach or re-teach the robot locations used by the program.
- ➢ There are two styles of teach pendants: the programmer's pendant, which is designed for use while an application is being written and debugged, and the operator's pendant, which is designed for use during normal system operation.

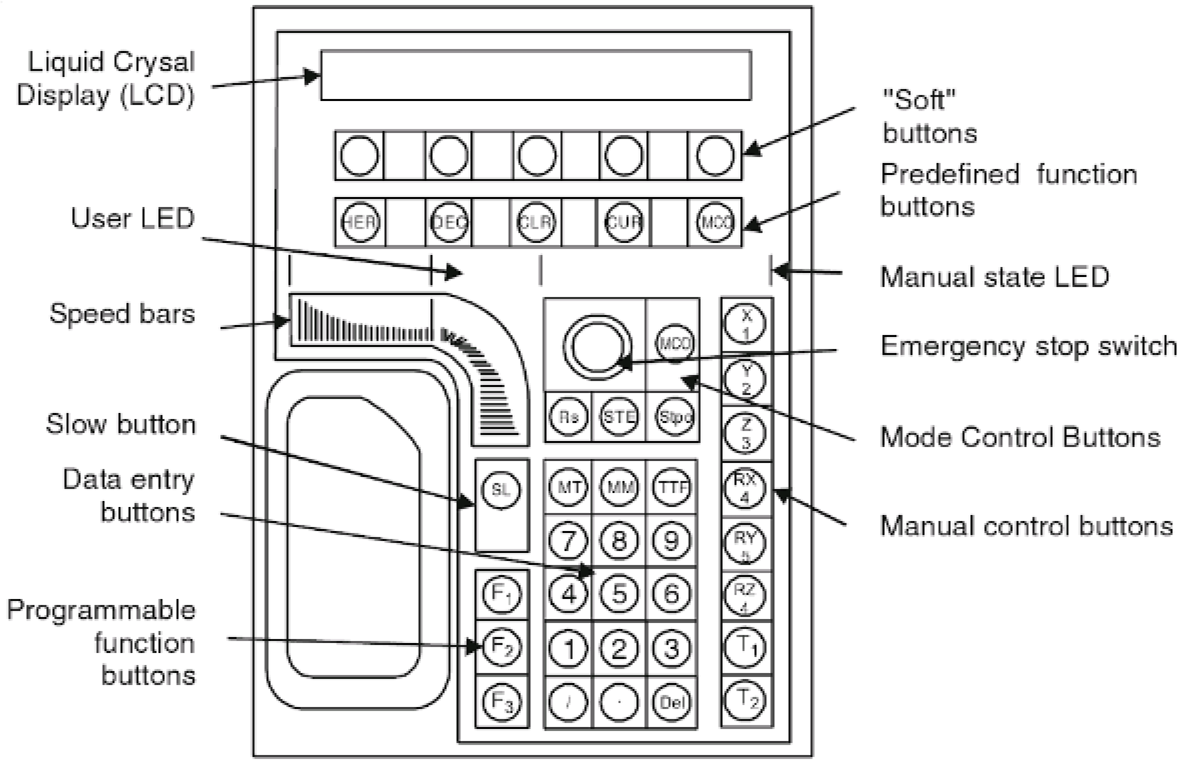


Fig. 16.2. Teach Pendant

LEAD-THROUGH PROGRAMMING

- Lead-through programming requires the operator to move the robot arm through the desired motion path during a teach procedure, thereby entering the program into the controller memory for subsequent playback. There are two methods of performing the lead-through teach procedure:
  - Powered lead-through
  - Manual lead-through
- The difference between the two is the manner in which the manipulator is moved through the motion cycle.

Powered lead-through

- It is commonly used as the programming method for playback robots with point-to-point control. It involves the use of a teach pendant (hand-held control box) which has toggle switches or contact buttons for controlling the movement of the manipulator joints.
- Using the toggle switches or buttons, the programmer drives the robot arm to the desired positions, in sequence, and records the positions into memory. During

subsequent playback, the robot moves through the sequence of positions under its own power.

Manual lead-through

- It is convenient for programming playback robots with continuous path control in which the continuous path isan irregular motion pattern such as in spray painting.This programming method requires the operator to physically grasp the end-of-arm or tools attached to the arm and manually move through the motion sequence, recording the path into memory.
- Because the robot arm itself may have significant mass and would therefore be difficult to move, a special programming device often replaces the actual robot for the teach procedure. The programming device has a similar joint configuration to the robot, and it is equipped with a trigger handle (or other control switch), which is activated when the operator wishes to record motions into memory.
- The motions are recorded as a series of closely spaced points. During playback, the path is recreated by controlling the actual robot arm through the same sequence of points.
- Powered lead-through is the most common programming method in industry at this time.

Advantages

- Easy to program: shop personnel can readily learn it and does not require deeper programming experience.

Disadvantages

- Interruption in production.
- Teach pendant have limitations in the amount of decision making logic that can be incorporated in the program.
- No interface to other computer subsystems in the factory.

WALK-THROUGH PROGRAMMING OR TEACHING

- In walk-through programming, the teacher physically moves ("walks") the robot through the desired positions within the robot's working envelope (Refer Figure 16.3). During this time, the robot's controller may scan and store coordinate values on a fixed-time interval basis. These values and other functional information are replayed in the automatic mode. This may be at a different speed than that used in the walk-through.
- This type of walk-through programming uses triggers on manual handles that move the robot. When the trigger is depressed the controller remembers the position. The controller would then generate the movement between these points when the program is played. The walk-through methods of programming require the teacher to be within the robot's working envelope with the robot's controller energized at least in the position sensors. This may also require that safeguarding devices be deactivated. A person doing the teaching has physical contact with the robot arm and actually gains

control and walks the robot's arm through the desired positions within the working envelope With the walk-through method of programming, the person doing the teaching is in a potentially hazardous position because the operational safeguarding devices are deactivated or inoperative The walk through method is appropriate for spray painting and welding robots.

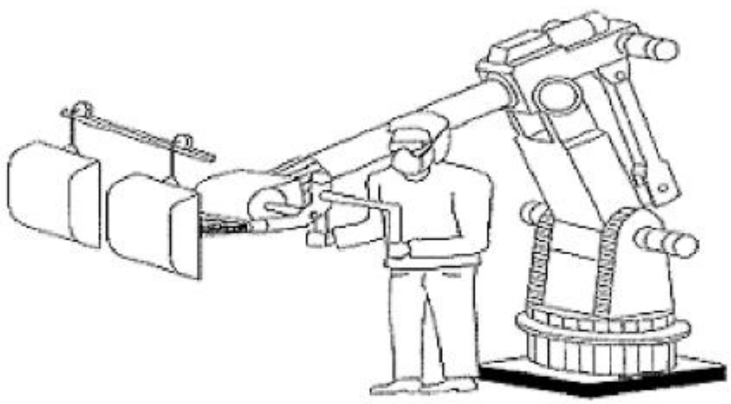


Fig. 16.3. Walk-through Programming Method

OFF-LINE PROGRAMMING

- Off line programming is accomplished on computers located away from the robot station (Refer Figure 164). Using simulation software, data is generated and then sent to the robot's controller where it is translated into instructions. Additionally, the software contains modeling data, which assists selection of the best robot configuration for a particular application. The advantage of this programming method is that programming can be done while the robot is still in production on the preceding job, thus production time of the robot is not lost to delays in teaching the robot a new task. This ensures higher utilization of the robot.

Advantages

- Effective programming of program logics and calculations with state of the art debugging facilities.
- Locations are built according to models and this can mean that programmers will have to fine tune programs on-line or utilize sensors.
- Effective programming of locations.
- Verification of program through simulation and visualization.
- Well documented through simulation model with appropriate programs.
- Reuse of existing CAD data.
- Cost independent of production. Production can continue while programming.
- Process support tools for instance selection of welding parameters.

Disadvantages

- Demands investment in an off-line programming system.
- Needs extensive training.

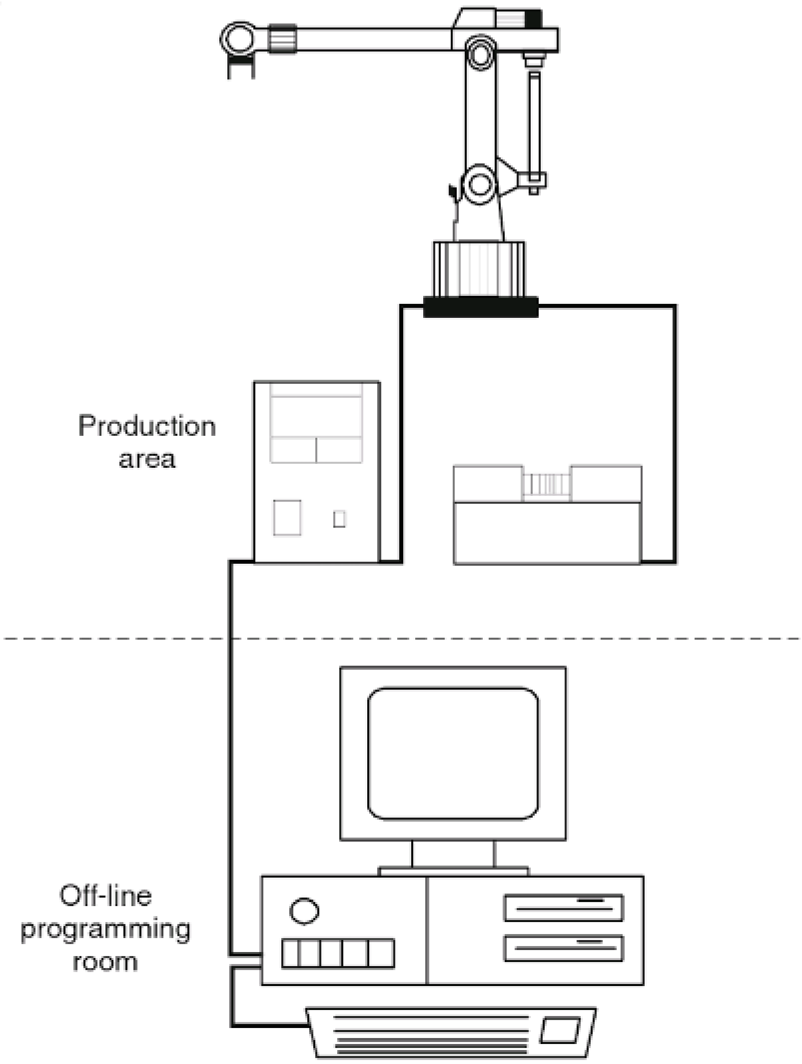


Fig. 16.4. Off-line Programming

TASK LEVEL PROGRAMMING

- Task level programming requires specifying goals for the position of objects, rather than the MORONS of robot needed to achieve those goals. A task level specification is meant to be totally robot independent, no positions or paths that depend on robot geometry are specified by the user.
- Task level programming systems requires complete geometric models of the environment and of the robot as input. In the task level language, robot actions are specified by their effects on objects. For example user would specify that a job should be placed in a pallet rather than specifying the sequence of manipulator motions needed to perform the insertion. A task planner would transfer the task level specifications into robot level specifications.

MOTION PROGRAMMING

- Motion programming with today's robot languages requires a combination of textual statements and lead-through techniques. Accordingly, this method of programming is sometimes referred to by the name on-line/off her programming. The textual statements are used to describe the motion, and the lead-through methods are used to define the position and orientation of the robot during and/or at the end of the motion. The lead-through methods provide a very natural way of programming motion commands into the robot controller.
- In manual lead-through the operator simply moves the arm through the required path to create the program. In powered lead-through the operator uses a teach pendant to drive the manipulator. The teach pendant is equipped with a toggle switch or a pair of contact buttons for each joint, By activating these switches or buttons in a coordinated fashion for the various joints, the programmer moves the manipulator to the required positions in the workspace. Coordinating the individual joints with the teach pendant is sometimes an awkward way to enter motion commands to the robot. For example, it is difficult to co-ordinate the individual joints of a jointed-arm robot to drive the end-of-arm in a straight-line motion.
- Therefore, many of the robots using powered lead-through provide two alternative methods for controlling movement of the manipulator during programming, in addition to individual joint controls. With these methods the programmer can control the robot's wrist end to move in straight-line paths.
- The names given to these alternatives are (1) world co-ordinate system, and (2) tool co-ordinate system.
- Both systems make use of a Cartesian co-ordinate system. ha the world co-ordinate system, the origin and frame of reference are defined with respect to some fixed position and alignment relative to the robot base.
- In the tool co-ordinate system, the alignment of the axis system is defined relative to the orientation of the wrist faceplate (to which the end effector is attached). In this way, the programmer can orient the tool in a desired may and then control the robot to make linear moves in directions parallel or perpendicular to the tool.
- The speed of the robot is controlled by means of a dial or other input device located on the teach pendant and/or the main control panel. Certain portions of the program should be performed et high speeds (e.g., moving parts over substantial distances in the workcell), while other parts of the program require low-speed operation (e.g., moves that require high precision in placing the work part). Speed control also permits a given program to be tried out at a safe slow speed, and then for a higher speed to be used during production.

REQUIREMENTS FORA STANDARD ROBOT LANGUAGE

- Because of the different methods of developing robot languages, many different types of languages are available. Currently there are no standards for robot languages, and each robot manufacturer has developed their own, each with their own syntax and data structures.
- Some factories have robots from multiple robot manufacturers, thus multiple languages are running on these control systems. This requires robot programmers to be proficient in many languages, or for the robot programmers to specialize in certain languages.
- The result of this variety is a demand for a common language that can be used on any type of robot. To develop a new robot programming language, the deficiencies of the existing languages, as well as the requirements of a new language, need to be identified.
- As robot work cells are becoming more complex, the robot has to perform more complicated moves and interact with more sensors and other peripheral devices. Robots often have to decide which part is coming down the line, and determine the proper program to run.
- Existing robot-programming languages, especially the specialized languages, often have limited ability to use subroutines and do logic testing. Some of the early generation controllers just don't have the memory capacity to hold such large programs.
- Most robot languages require the user to compile a program before running it on the robot controller. Compiling a program converts the human-readable source code into a machine-readable form.
- This is usually done to increase the speed of the program execution, since the program is already in the easiest form for the computer to read. Interpreters, on the other hand, convert the human-readable code to computer-readable code on the fly, as the program executes.
- Usually, this results in a significant amount of computer processing time being used to do the conversion. to the early days of robotics, compiling was required because the processors were not fast enough to interpret a program. Many robot controllers still require the programs to be compiled before running, even though there is now plenty of computer power to interpret programs.

ROBOT LANGUAGES

- A language is a system of communication, which usually is connected to human spoken language and which is based on an arbitrary system of symbols. The most important feature of a language is its ability to produce messages.
- In a computer the executable control program is formed of a sequence of machine language commands. A machine-language command consists of a numerical code,

which contains the type of the command and the source and destination addresses of the information.

- To make programming easier several high-level programming languages have been developed. Instead of numbers and addresses the developer can now use words and names. Before the use of such a high-level control program it must be compiled to machine-language code. This is done by compilers, which have been developed for each language.
- Different languages have different aims and are suitable for different purposes. For example MATLAB is a mathematical language, which has been developed to solve mathematical problems.
- It has built-in functions for powerful mathematical analysis, but it is not suitable for real-time control of a mobile robot. HTML is a markup language to describe how information appears in web browsers, but it is not suitable to solve mathematical problems. Some of the basic types of commands in programming languages are:
    1. Motion and sensing functions (e.g. MOVE, MONITOR)
    2. Computation functions (e.g. ADD, SORT)
    3. Program flow control functions (e.g. RETURN, BRANCH)

TYPES OF ROBOT LANGUAGES

- The earliest methods for training a robot like mechanical setup, point-to-point path recording, and task lead through did not use word-based languages. Some of the high-level computer languages now used to program robots are: Wave, AL, ACL, AML, APT, ARCL, ZDRL, HELP, Karel, CAP 1, MML, RIPL, MCL, RAIL, RPL, ARMBASIC, Androtext, VAL, IBL and Ladder Logic.

Robot applications in manufacturing

- Robotics technology has found wide acceptability in a large variety of manufacturing applications.

Major areas of robot applications are as follows:

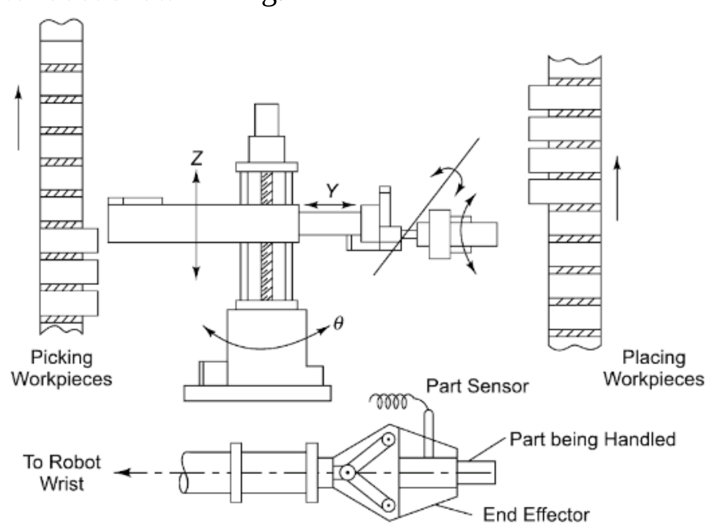
- In Material transfer or handling
- Machine loading/unloading
- Processing operations like Welding & painting
- Assembly operations
- In Inspection automation

Materials Handling

- Materials handling applications are varied in nature. It may be simple parts transfer—a robot may pith up a part from a conveyor or take a part from a machine and place it on a conveyor. Robots used for this purpose are usually stationary. They may be mounted on rats or slides to add to horizontal mobility. They may even be placed on automated guided vehicle (AGV) moving on the shop floor.
- Whenever the robots are mounted overhead, they are called gantry robots. Robots are very useful for palletizing parts. Fragile objects are conveniently transferred with the help of materials handling robots in conjunction with the sensors. Robots of different geometries may be employed in a number of typical materials handling operations such as:
    - Picking and placing
    - Machine loading and unloading
    - Parts feeding, storage and retrieval
    - Sorting of the parts from conveyors

Picking and placing

A typical pick and place operation by a suitable end-effector can be performed by a cylindrical coordinate robot shown in Fig.



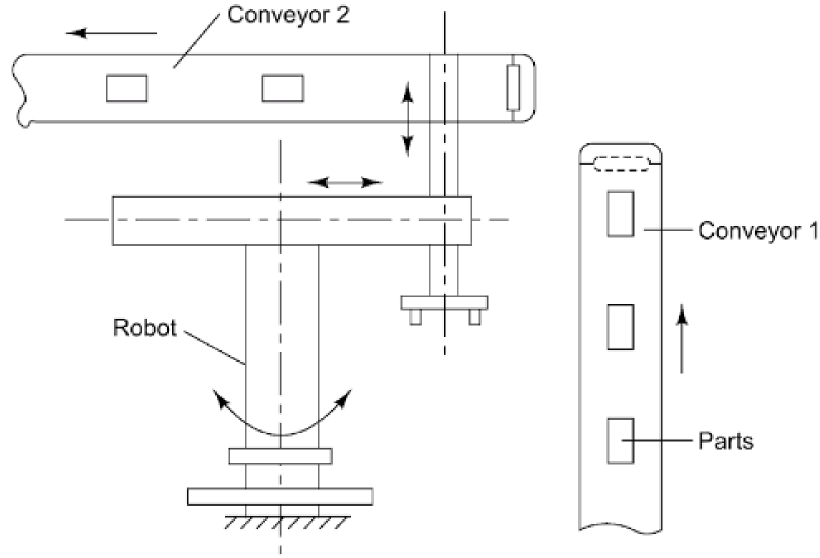


FIG. 10.2(b) *Pick and place operation on conveyors*

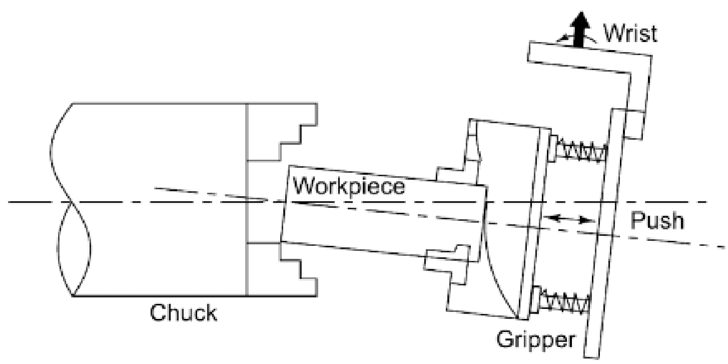


FIG. 10.3 *Inserting a part into a lathe chuck*

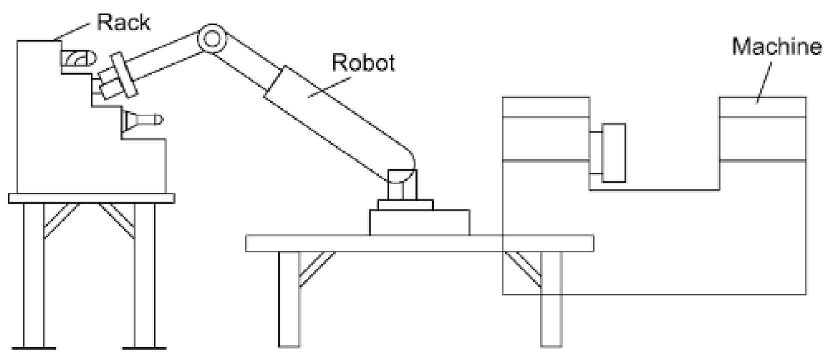


FIG. 10.4 *A robot picking a tool from a rack and loading on a machine*

Machine Loading and Unloading

- In machine loading and unloading problems, a robot should be able to orient the workpiece correctly so as to locate it accurately to a particular machine after picking up from the bins or from the conveyor.

- In a similar way, the robot gripper should be able to take the part back after processing. Loading and unloading machine tools, forging, cold working presses and injection moulding machines are examples of robotic applications.
- Several kinds of mechanical, vacuum and magnetic grippers may be employed to handle and manipulate objects of varying shapes, weights and materials. For example, specially designed water cooled tong-type grippers can be fitted to the wrist of the robot for handling hot billets.
- Figure 103 indicates how a single robot is employed to perform a number of operations and service several machines organized in a flexible manufacturing cell (FMC). A spherical robot may pick up a part and transfer it to the cutting off machine tool and feed the parts to CNC lathe and CNC drilling machine.
- The robot can also present the mechanical part to the inspection workstation. Thus a single robot interacts with many machines in the cell. Figure 10.8 indicates a robot mounted on rags to add mobility for serving two workstations and thus a single robot's able to cope with an enhanced cycle time of operation.

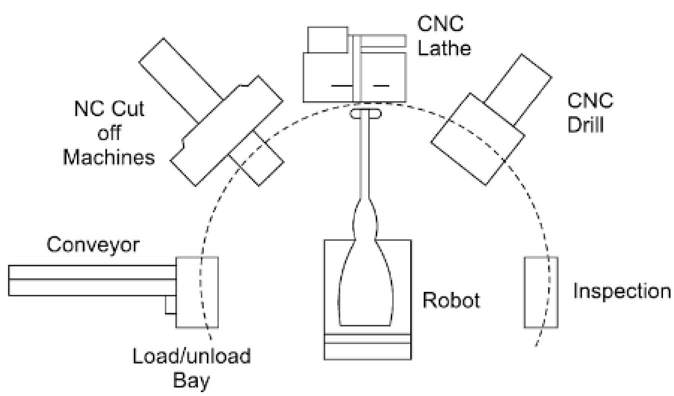
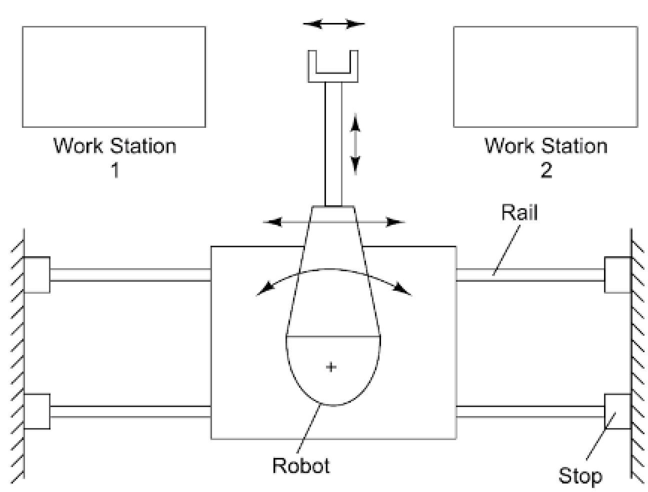


FIG. 10.7 *A robot serving a number of machines in FMC (flexible measuring cell)*



Robot Assembly

- In recent decades the development of production techniques has been considerably quicker in the realm of component manufacture than in that of assembly. As a rule, assembly 6 carried out manually and accounts for between 20 and 60% of the total production time.
- The increase in productivity is often achieved by the application of the assembly line principle, division of work and methods related to time and motion studies. Significant improvement in productivity has been achieved by bringing in flexibility in the machine and striving for an optimal utilization of the human labour force.
- The major problem in manual assembly is that in many cases the operator's work becomes monotonous with frequent, repetitive movements resulting in both physical and psychological problems.
- It can be expected therefore that significant changes will take place in the field of assembly in the coming years, on account of both competitiveness and working environment.

Types of Assembly system

- Manual Assembly
- Semi-Automatic Assembly
- Automatic Assembly
- Flexible Assembly

Manual System Assembly is carried out by the assembler who has simple and mostly passive auxiliary equipment at his disposal, such as tables, fixtures, component boxes, conveyors belt and hand tools. It is the most flexible system but it lacks consistency due to the fatigue of the assemblers.

Semi Automatic Assembly The assembly is carried out with automatic machines in which some manual operations are also adopted.

Automatic Assembly It is a mechanical assembly comprising machine systems which follow a program. The system accomplishes the tasks based on the pre-planned program.

Flexible Assembly Flexibility refers to the system's ability to accept variations in different modes of the assembly tasks accommodating the design characteristics of the components and product variations without any considerable change in the toolings. Flexible assembly includes versatility and adaptability to cope with the new demands. It takes decisions depending on the system conditions. It is suitable for multistation assembly tasks.

Robots for Assembly Work

There are three main types of robots suitable for assembly operations. They are:

- Cartesian robots
- Revolute robots
- SCARA robots

Cartesian robots or gantry robots with the gripping device having 2-3 degrees of freedom are suitable for some simple assembly operations as they have high accuracy and repeatability. Figure 10.20 indicates a cartesian robot manipulator with 3 degrees of freedom. Revolute robots are also used for the assembly tasks. PUMA (Programmable Universal Machine for Assembly) type robots as shown In Fig. 10.21 that operate on high level languages, VAL and VAL 0 or V' have six degrees of freedom. There are two coordinate systems. They are: World and Tool coordinate systems. World coordinate system is one in which software can be used to drive the robot manipulator through three mutually perpendicular axes (cartesian) from the base of the robotic manipulator. The tool coordinate system can be set up around the tool centre point by using tool transformation software. The tool centre point can be set up with respect to the end-effector attached to the wrist of the robot and the robot end-effector can be given motion in three mutually perpendicular axes through the tool centre point. Usually by defaults, the tool centre point up at the centre of the end-effector flange.

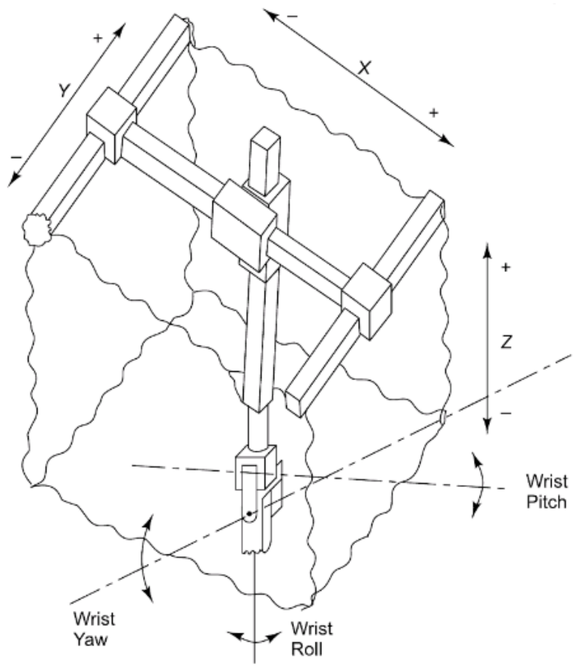


FIG. 10.20 *Cartesian (Gantry configuration) robot*

SCARA (Selective Compliance Arms for Robotic Assembly or Selective Compliance Assembly Robot Arm) robots are the robots suitable for assembly. These robots are provided with direct drive motors that allow high speeds with accelerations and backlash-free, fast and accurate motions. The accuracy is around t0.076 mm and repeatability is x0.025. Figure 10.22 illustrates a robot having three perpendicular straight line axes with a servoed Z-axis. The controller can execute instructions with the aid of (say) VAL U programming language. The input and output data can be handled during the execution of robot moves. A variety of instrumented grippers can be accommodated on the joint-3. A fourth axis with an independent degree of freedom may also be added in the robot hand.

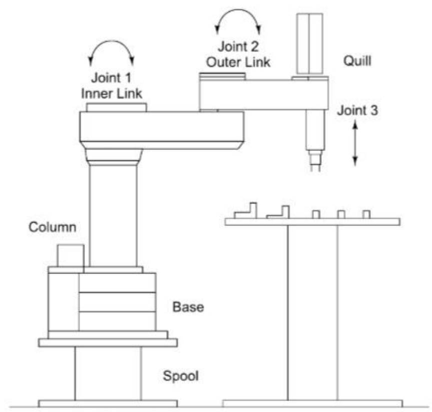


FIG. 10.22 *A Scara robot*

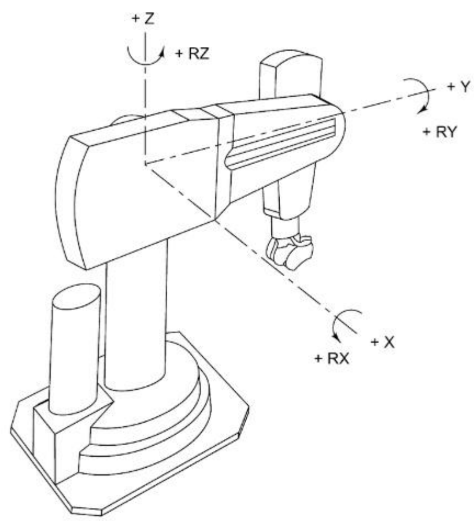


FIG. 10.21 (a) *A robot in world coordinate system*

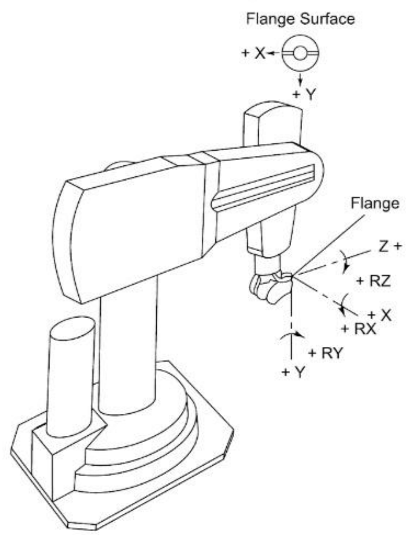


FIG. 10.21 (b) *A robot in tool coordinate system*

Inspection:-

- The product quality can be assured by inspection and testing. A product or a component can satisfy a given function for which it has been designed only if inspection and test results are good. Inspection involves the measurement or checking of certain specified features of parts or assemblies or products.
- The features like geometric dimensions, surface quality, positional accuracy, assembly integrity as desired by the design department am checked. Inspection function is carried out from raw material stage to the stage of producing the finished product depending on the requirements of the production process.
- Testing, on the other hand, is involved with examination of some functional aspects of the products for quality control. For example, if the product should withstand fatigue, fatigue testing should be carried out.
- The part may be physically inspected with respect to Its diameter, length and other dimensions. Robotics provides an important aid for inspection as well as testing. This section deals with inspection accomplished by the robots.
- Robots usually work with some peripheral equipment and auxiliary systems to provide automated inspection. Automated inspection a performed by the robots using various sensors or probes. Part presence or absence in many cases can be determined by using some mechanical probes or part sensors in the robot grippers.

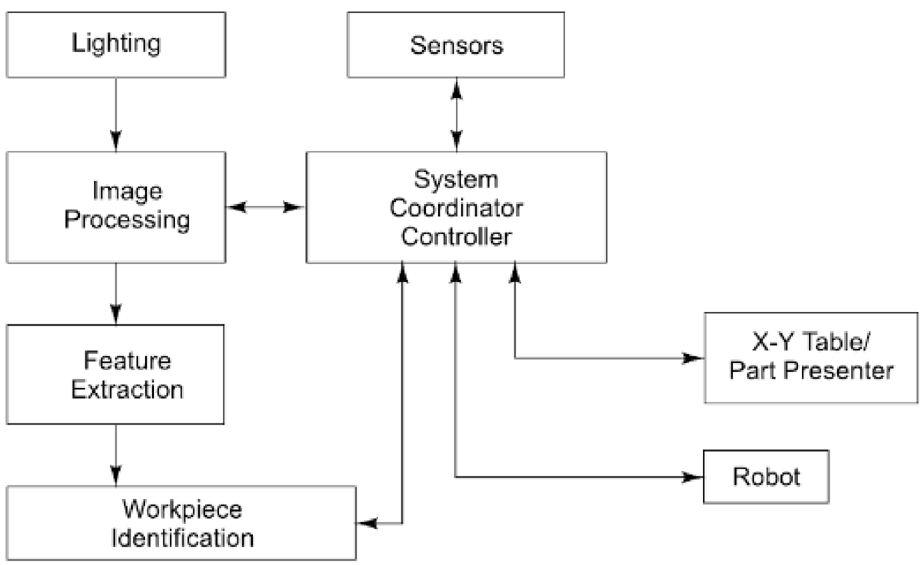


FIG. 10.26 *Vision-based inspection system*

- Human vision can be emulated by using machine vision in robotics. Even 3-dimensional inspection is possible by stereo vision. Two dimensional scenes can be analyzed by robotic vision systems by (i) frame grabbing (ii) detecting edges and (iii) windowing on the selected area of the image. Solid state cameras or TV cameras are employed to digitize the images and store them in memory.

- The Images are analyzed and features like the object's area, centroid, perimeter and orWreation are extracted. These features are compared and the products are inspected or gauged. Edge detection is done by the connectivity analysis.
- Windowing is done round a specific area of interest of the product. in the field of view. For example, a hole size on the product can be determined by windowing. A typical machine vision inspection system may check workpiece dimensions, transport and position the workpiece.
- The system components viz., sensor or machine vision systems, lighting techniques, vision guided robot manipulator for part handling and robotic X-Y table or part presenter for part presentation may be organized to have full automated inspection. Figure 10.26 illustrates the block diagram of a vision-based inspection system. The part presenter may be loaded with multiple parts. The X-Y table brings the parts within the field of view of cameras mounted over the table. The vision system identifies the desired part. If the system cannot recognize the part, it sends a signal for rejection and fresh parts are loaded. If a part is recognized, the controller directs the part presenter to position and orient the part, such that the robot manipulator can pick up the part for further processing or assembly.

- Defects of the parts can be detected by vision-based robot inspection system. It can also check whether a hole is missing or an edge is defective. Binary Images of the top views sketches of the components as shown in Fig. 10.27 may be taken by Prof., Hresholding (vide Fig. 5.33) for inspection.

Welding

- Robots find wide applications in welding and the robots used for the purpose of welding are tool handling robots. Two important classes of welding are performed by the robots.
- They are **spot welding** shown in Fig. and **arc welding**

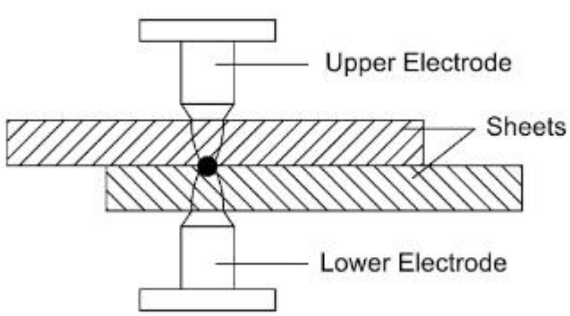


FIG. 10.29 (a) *Spot welding*

- Spot welding is widely used in fastening sheet metals and in automobile body assembly, frames, panels, fabrication of metal furniture, domestic appliances, etc. Arc welding is done by the fusion of two surfaces by the heat generated from a continuous electric am. The common arc welding methods are tungsten inert gas mc), metal inert gas (MIG), gas metal arc welding (GMAW) and submerged arc welding (SAW). They are used for multi-pass-multilayered welding of metal parts and replace many rivetting operations.
- **Spot Welding** Spot welding is done by fusing two metals at the spots where heat is generated by allowing an electric current to pass through the electrodes for a specific duration of time and pressing the joining surfaces with the electrodes. The basic process of spot welding is indicated in Fig. 10.29(a).

A Robotic Spot Welder A spot welding robot has

1. a robotic manipulator with several degrees of freedom
2. a welding gun held on a robot wrist
3. controller and power sources 4. VO interfaces

The operations involved in spot welding are

1. squeezing the two metal surfaces between the electrodes
2. welding by passing current for specific duration of time depending on the type of the material and its thickness
3. releasing the grip

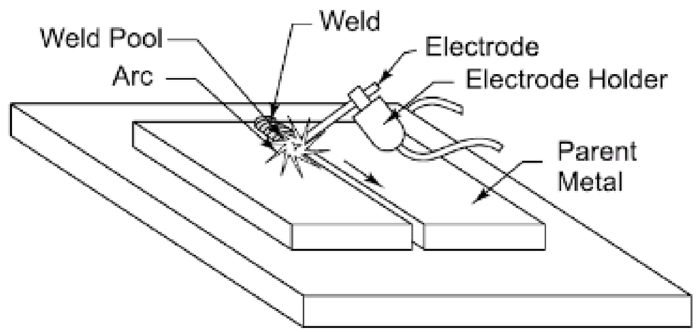


FIG. 10.29 (b) *Basic arc welding*

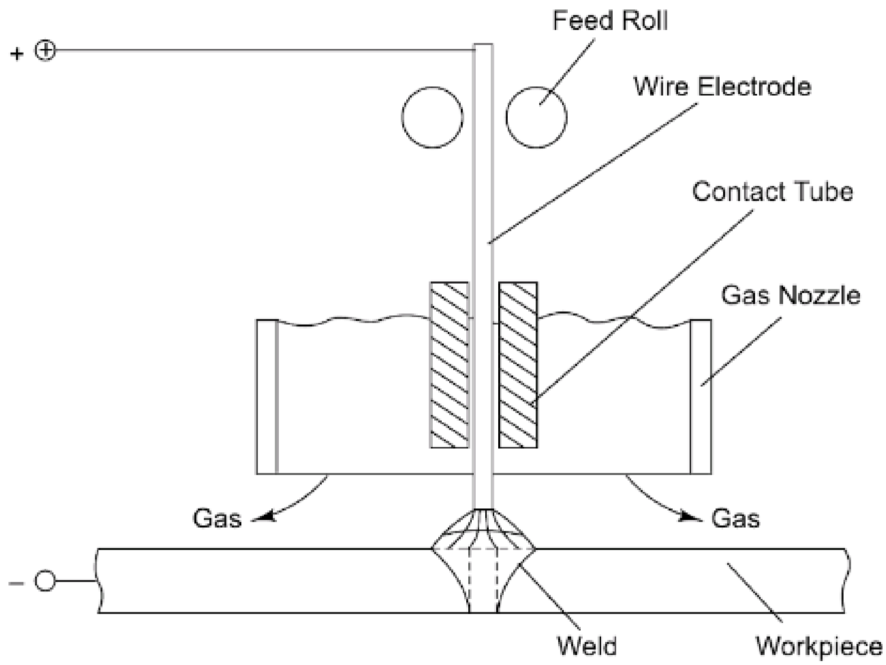


FIG. 10.29 (c) *Basic MIG welding*

Arc Welding

- Arc welding Is a continuous welding process in which the work pieces are joined by an airtight seal between the pieces to be joined. An electric arc struck between the welding electrode and the workpiece produces necessary heat that causes fusion of two metal surfaces.
- Basic Components of a Robotic Arc Welding System A complete robotic welding system includes the robot, its controls, suitable fasteners for the work and the welding equipment. If necessary, it may require one or more welding positioners with controls. While installing a system, cam should be taken to provide correct safety barriers and screens around the workstation. The component units of a robotic welding system are described below.

Spray Painting or Spray Coating Systems

- For Spraying A spray gun is employed to paint the object. There are various systems of applying spray paint to the component. The systems are:
  1. air spray
  2. airless spray.
  3. electrostatic spray
- In an spray system, air is mixed with the paint and passes through a nozzle at high velocity and air atomizes the paints. In airless spray, liquid paint under high pressure flows past the nozzle and the liquid is transformed into minute droplets. In electrostatic spray, Faraday cage effect occurs.
- Negatively charged paint particles are attracted to the object that is electrically grounded. In electrostatic spray, the nozzle employs either air spray or airless spray

Spray Painting Robots and Programming Method

- Spray pointing robots have usually 6 degrees of freedom. Additional degrees of freedom are provided by mounting them on horizontal, vertical, transverse and longitudinal tracks for better accessibility. The part may be stationary or may be carried by some conveyor. Proper interfacing and interlocks are used to control the movement of the conveyor or tracking system.
- The most difficult part is the art of spraying that human operator accomplishes with a proper coordination of eye and brain. For a robot, it must have CP control, hydraulic drives, program storage capability and good memory for keeping many subroutine programs and teaching arrangement for the program. For teaching a robot, Manual lead through programming or Teach arm approach may be employed.
- In the Manual lead through programming, an operator guides the robot as shown in Fig. 10.42 by the aid of a handle attached to the spray gun. The operator who knows the technique of spray painting leads the arm through different spraying motions. During this manipulation, the trajectory or path is recorded as the information for joint positions is stored on a time base.
- The triggering of the spray gun is also recorded in the controller. The sequential steps as taught by the operator may be seen, changed and repeated. Once the teaching is complete, the path of spray gun with a definite velocity may be played back and the process may be repeated during automated spraying. Editing the path is difficult in lead through programming.

- Another way to teach the spray painting programme is to use a light teach arm (like master-slave) which is geometrically and kinematically similar to the actual spray painting robot manipulator as schematically shown in Fig. 10.43. The joints have sensors that can record the movement during spraying manipulation. The spray gun may be mounted on the robot and the robot may act as a slave manipulator and wi0 repeat the motion according to the movement taught by the teach arm.

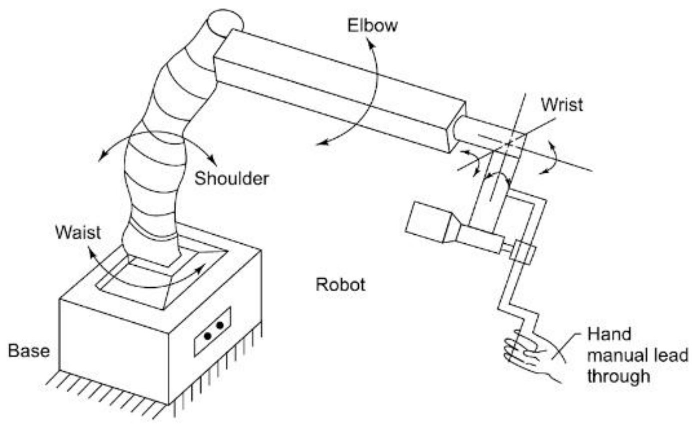


FIG. 10.42 *Spray painting robot with manual lead through programming*

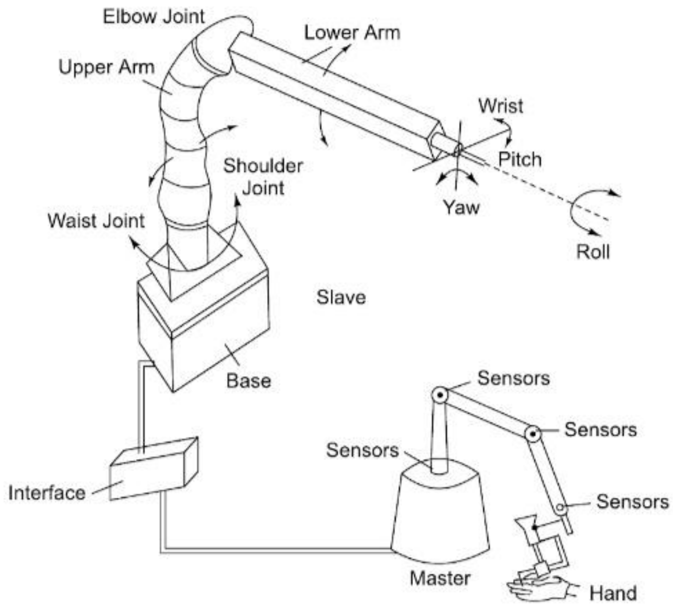


FIG. 10.43 *Master–slave technique of spray painting*

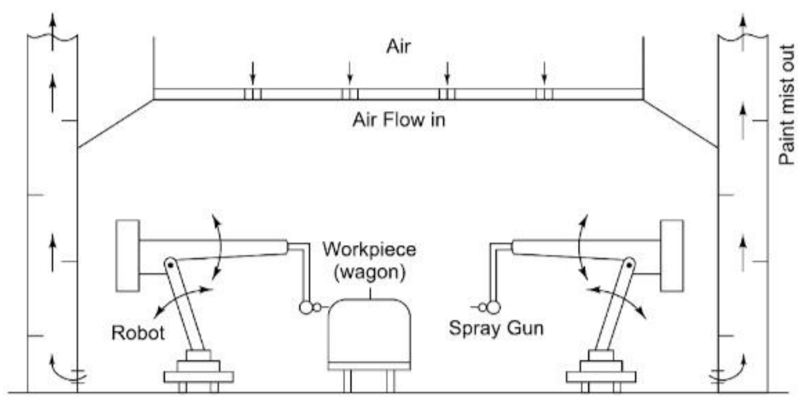


FIG. 10.44 *Typical painting booth*