UNIT V PROGRAMMING LANGUAGES AND APPLICATIONS

Robot programming - Fixed instruction - sequence control - General programming language - Specific programming languages- Robots for welding, painting and assembly – Remote Controlled robots – Robots for nuclear, thermal and chemical plants.

Robot programming:

The primary objective of robot programming is to make the robot understand its work cycle. The program teaches the robot the following:

- The path it should take
- The points it should reach precisely How to interpret the sensor data
- How and when to actuate the end-effector
- How to move parts from one location to another, and so forth

Programming of conventional robots normally takes one of two forms:

(1) Teach-by-showing, which can be divided into:

  - Powered leadthrough or discrete point programming
  - Manual leadthrough or walk-through or continuous path programming

(2) Textual language programming

In teach-by-showing programming the programmer is required to move the robot arm through the desired motion path and the path is defined in the robot memory by the controller.

Control systems for this method operate in either:

Teach mode: is used to program the robot

Run mode: is used to run or execute the program

Powered lead through programming uses a teach pendant to instruct a robot to move in the working space. A teach pendant is a small handled control box equipped with toggle switches, dials, and buttons used to control the robot's movements to and from the desired points in the space.

These points are recorded in memory for subsequent playback. For playback robots, this is the most common programming method used. However, it has its limitations:

- It is largely limited to point-to-point motions rather than continuous movement, because of the difficulty in using a teach pendant to regulate complex geometric paths in space. In cases such as machine loading and unloading, transfer tasks, and spot welding, the movements of the manipulator are basically of a point-to-point nature and hence this programming method is suitable.

Manual lead through programming is for continuous-path playback robots. In walk-through programming, the programmer simply moves the robot physically through the required motion cycle. The robot controller records the position and speed as the programmer leads the robot through the operation.

If the robot is too big to handle physically, a replica of the robot that has basically the same geometry is substituted for the actual robot. It is easier to manipulate the replica during programming. A teach button connected to the wrist of the robot or replica acts as a special programming apparatus. When the button is pressed, the movements of the manipulator become part of the program. This permits the programmer to make moves of the arm that will not be part of the program. The programmer is able to define movements that are not included in the final program with the help of a special programming apparatus.

Teach-by-showing methods have their limitations:

1. Teach-by-showing methods take time for programming.
2. These methods are not suitable for certain complex functions, whereas with textual methods it is easy to accomplish the complex functions.
3. Teach-by-showing methods are not suitable for ongoing developments such as computer-integrated manufacturing (CIM) systems.

Thus, textual robot languages have found their way into robot technology.

Textual language programming methods use an English-like language to establish the logical sequence of a work cycle. A cathode ray tube (CRT) computer terminal is used to input the program instructions, and to augment this procedure a teach pendant might be used to define on line the location of various points in the workplace. Off-line programming is used when a textual language program is entered without a teach pendant defining locations in the program.

<u>Programming Languages</u>

Different languages can be used for robot programming, and their purpose is to instruct the robot in how to perform these actions. Most robot languages implemented today are a combination of textual and teach-pendant programming.

Some of the languages that have been developed are:

WAVE	VAL
AML	RAIL
MCL	TL- 10
IRL	PLAW
SINGLA	VAL II

VAL II

- It is one of the most commonly used and easily learned languages.
- It is a computer-based control system and language designed for the industrial robots at Unimation, Inc.
- The VAL II instructions are clear, concise, and generally self explanatory.
- The language is easily learned.
- VAL II computes a continuous trajectory that permits complex motions to be executed quickly, with efficient use of system memory and reduction in overall system complexity.
- The VAL if system continuously generates robot commands and can simultaneously interact with a human operator, permitting on-line program generation and modification.
- A convenient feature of VAL If is the ability to use libraries of manipulation routines. Thus, complex operations can be easily and quickly programmed by combining predefined subtasks.

Rules for the location name are as follows:

1. It is any string of letters, numbers, and periods.
2. The first character must be alphabetic.
3. There must be no intervening blank.
4. Every location name must be unique.
5. There may be a limit on the maximum number of characters that can be used.

The following example illustrates the general command format for VAL II:

100 APPRO P1 15

In this example, 100 is the label that refers to this instruction, APPRO is the instruction to the robot to approach the location named P1 by a distance of 15 mm.

In the following, we describe the most commonly used VAL II commands.

MOVE P1	This causes the robot to move in joint interpolation motion from its present location to location P1.
MOVES P1	Here, the suffix S stands for straight-line interpolation motion.
MOVE P1 VIA P2	This command instructs the robot to move from its present location to P1, passing through location P2.
APPRO P1 10	This command instructs the robot to move near to the location P1 but offset from the location along the tool z-axis in the negative direction (above the part) by a distance of 10
DEPART 15	Similar to APPRO, this instructs the robot to depart by a specified distance (15 mm) from its present position. The APPRO and DEPART commands can be modified to use straight-line interpolation by adding the suffix S.

DEFINE PATH 1= PATH(P1,P2,P3,P5) MOVE PATH 1	The first command (DEFTNE) defines a path that consists of series of locations P1, P2, P3, and P5 (all previously defined). The second command (MOVE) instructs the robot to move through these points in joint interpolation. A MOVES command can be used to get straight-line interpolation
ABOVE & BELOW	These commands instruct the elbow of the robot to point up and down, respectively.
SPEED 50 IPS	This indicates that the speed of the end- effector during program execution should be 50 inch per second (in./s).
SPEED 75	This instructs the robot to operate at 75% of normal speed.
OPEN	Instructs end effector to open during the execution of the next motion.
CLOSE	Instructs the end-effector to close during the execution of the next motion.
OPENI	Causes the action to occur immediately.
CLOSEI	Causes the action to occur immediately

If a gripper is controlled using a servo-mechanism, the following commands may also be available.	
CLOSE 40 MM	The width of finger opening should be 40 mm.
CLOSE 3.0 LB	This causes 3 lb of gripping force to be applied against the part.
GRASP 10, 100	This statement causes the gripper to close immediately and checks whether the final opening is less than the specified amount of 10 mm. If it is, the program branches to statement 100 in the program
SIGNAL 4 ON	This allows the signal from output port 4 to be turned on at one point in the program and
SIGNAL 4 OFF	Turned off at another point in the program.
WAIT10 ON	This command makes the robot wait to get the signal on line 10 so that the device is on there.

Logarithmic, exponential, and similar functions:

The following relational and logical operators are also available.

EQ	Equal to
NE	Not equal to
GT	Greater than
GE	Greater than or equal to
LT	Less than
LE	Less than or equal to
AND	Logical AND operator
OR	Logical OR
NOT	Logical complement

IF (Logical expression) THEN
 	
(Group of instructions)
 	
ELSE
 	
(Group of instructions)
 	
END
	If the logical expression is true, the group of statements between THEN and ELSE is executed. If the logical expression is false, the group of statements between ELSE and END is executed. The program continues after the END statement.
	
	The group of instructions after the DO statement makes a logical set whose variable value would affect the logical expression with the UNTIL

DO (Group of instructions) UNTIL(Logical expression)	statement. After every execution of the group of instructions, the logical expression is valuated. If the result is false, the DO loop is executed again; if the result is true, the program continues.

TYPE "text“ This statement displays the message given in the quotation marks. The statement is also used to display output information on the terminal.

PROMPT "text", INDEX This statement displays the message given in the quotation marks on the terminal. Then the system waits for the input value, which is to be assigned to the variable INDEX.

In most real-life problems, program sequence control is required. The following statements are used to control logic flow in the program.

GOTO 10This command causes an unconditional branch to statement 10.

SUBROUTINES can also be written and called in VAL II programs. Monitor mode commands are used for functions such as entering locations and systems supervision, data processing, and communications. Some of the commonly used monitor mode commands are as follows:

EDIT (Program name) This makes it possible to edit the existing program or to create a new program by the specified program name.

EXIT This command stores the program in controller memory and quits the edit mode.

STORE (Program name) This allows the program to be stored on a specified device.

READ (Program name) Reads a file from storage memory to robot controller.

LIST (Program name) Displays program on monitor.

PRINT (Program name) Provides hard copy.

DIRECTORY Provides a listing of the program names that are stored either in the controller memory or on the disk.

ERASE (Program name) Deletes the specified program from memory or storage.

EXECUTE (Program name) Makes the robot execute the specified program. It may be abbreviated as EX or EXEC.

ABORT Stops the robot motion during execution.

STOP The same as abort.

EXAMPLE 1:

Develop a program in VAL II to command a PUMA robot to unload a cylindrical part of 10 mm diameter from machine 1 positioned at point P1 and load the part on machine 2 positioned at P2. The speed of robot motion is 40 in./s. However, because of safety precautions, the speed is reduced to 10 in./s while moving to a machine for an unloading or loading operation.

Solution

1. **SIGNAL 5**
2. **SPEED 40 IPS**
3. **OPEN 100**
4. **APPRO PI, 50**
5. **SPEED 10 IPS**
6. **MOVE PI**
7. **GRASP 10, 100**
8. **DEPART P1, 50**
9. **SPEED 40 IPS**
10. **APPRO P2, 50**
11. **SPEED 10 IPS**
12. **MOVEP2**
13. **BELOW**
14. **OPENI 100**
15. **ABOVE**
16. **DEPART P2, 50**
17. **STOP**

EXAMPLE 2:

Suppose we want to drill 16 holes according to the pattern shown in the Figure. The pendant procedure can be used to teach the 16 locations, but this would be quite time-consuming and using the same program in different robot installations would require all points to be taught at each location. VAL II allows location adjustment under computer control.

The program allows all holes to be drilled given just one location, called STA at the bottom right-hand corner of the diagram. Actually, two programs are required, since one will be a subroutine.

```
MAIN PROGRAM (MC)
1. K = 0
2. SPEED 20
3. FOR I = 1 TO 4
4. FOR J = 1 TO 4
5. K = K + 1
6. CALL DRILL
7. END
8. END
9. TYPE "DRILLING COMPLETE"
```

```
SUBROUTINE (DRILL)
1. XM = 20 * I
2. YM = 20 * J
3. MOVE SHIFT(STA BY XM,YM,0)
4. DEPART -20
5. SPEED 10
6. DEPART 20
7. TYPE/B,"COMPLETED HOLE",/I2,K
8. SPEED 20
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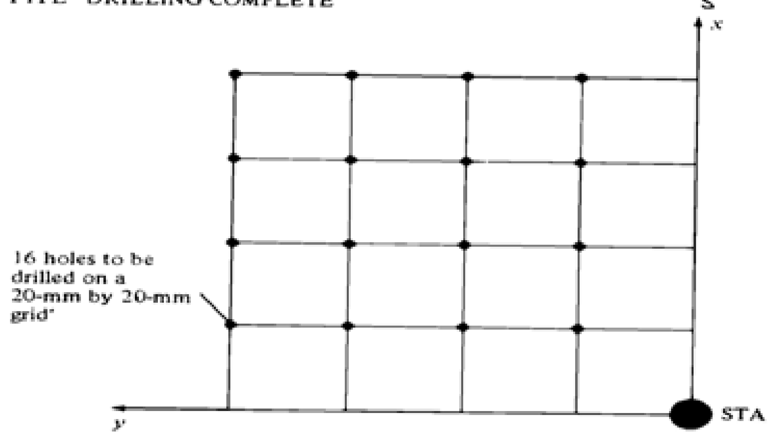


ROBOT SELECTION

This phenomenal growth in the variety of robots has made the robot selection process difficult for applications engineers. Once the application is selected, which is the primary objective, a suitable robot should be chosen from the many commercial robots available in the market.

The technical features are the prime considerations in the selection of a robot. These include features such as:

(1) degrees of freedom,
(2) control system to be adopted,
(3) work volume,
(4) load-carrying capacity, and
(5) Accuracy and repeatability.

The characteristics of robots generally considered in a selection process include:

1. Size of class
2. Degrees of freedom
3. Velocity
4. Actuator type
5. Control mode
6. Repeatability
7. Lift capacity
8. Right-Left-Traverse

9. Up-down-traverse
10. In-Out-Traverse
11. Yaw
12. Pitch
13. Roll
14. Weight of the robot

<u>Robots for nuclear power plants</u>

Once confined to the pages of science fiction, robots have dramatically captured the attention of the public and the industrial business community in recent years. Many observers view robots as a hall mark of neo industrialization, breathing renewed economic vigour and competitiveness into depressed industries through improved productivity and reduced labour costs. At the same time, however, workers often respond with apprehension to the mental image of a robot performing atask that formerly required a human. The social implications of the robotization of American industry will surely become of more concern to workers, managers, and policymakers alike as more robots enter the industrial workplace. According to the Robotics Industries Association, only f>3()() robots had been delivered in the United States by the end of 1983; most of those had been installed since 1976. But the force of technologic change and the pressure on international economic competition promise an accelerated pace of robot deployment in the years ahead. Someexperts predict that as many as 10(1 000 robots may be at work in this country by 1990—one-tenth of the total number projected worldwide. For most industries in which robots have been or are expected to be applied in significant numbers, such as automobile production, metalworking, and machinery manufacture, the incentives to robotize relate directly to preserving or recapturing competitive advantage through lowered unit costs of production and improved product quality. But for some industries, the attraction of robots is their potential to work in hazardous environments, thereby reducing the human risks associated with the work.

The electric utility industry is one such industry. Although utilities are not viewed by most industrial robot manufacturers as a significant potential market, special-application robots are under development for performing inspection and maintenance tasks inside nuclear power plants, where radiation levels, heat, and humidity either rule out the presence of human workers or severely limit their ability to work. For many of these tasks in a nuclear plant, robots would be a welcome additionto the workforce, freeing humans from some of the more onerous and discomforting jobs and, possibly, permitting certain tasks to be performed while a plant remains on-line, thus avoidingcostly plant downtime tor inspection or maintenance. Some of the robots under developmentfor utility applications represent the state of the art of robotics engineering, and the related research efforts could pioneer advances that have broad application to other industries.

Nuclear power and electronics has several current projects aimed at evaluating the technical and economic potential for robot applications in utility operations and at translating the understanding gained from these efforts to the utility professionals who have work aplenty waiting for robots that prove reliable and cost-effective. Such research is necessarily long range. The robotics industry, fewer than 20 years old by the broadest definition, remains in its infancy, awaiting substantial technical advances in vision systems, miniaturization, and computer controls before truly economic, versatile, and powerful robots are commonplace items of commerce. But R&D success with robots in recent years suggests that such machines will emerge from the laboratories and enter the commercial market before this decade is over. EPRl's research in robotic applications, at least in part, is intended to ensure that when that day arrives, utilities will have a clear understanding of the work robots can do for them and whether it makes economic sense to put them to work.

Robots for nuclear plants The use of remotely operated and robot like equipment to protect nuclear workers in high-radiation areas is not new. John Taylor, an EPRI vice president and director of the Nuclear Power Division, divides robotic equipment in nuclear applications into two broad categories: single-purpose devices with limited ability to perform different operations, and reprogrammable, multipurpose robots with some degree of computer-based artificial intelligence.

"I think the first category has reached a reasonable level of maturity," says Taylor At EPRI's Non-destructive Evaluation (NDE) Center and among reactor manufacturers, nuclear service contractors, and some utilities, these types of devices are in use today for such tasks as pipe cutting, welding, steam generator tube inspection and repair, and ultrasonic scanning of pipe sections for crack detection. "These devices have proved to be absolutely essential; we simply could not get some jobs done without them," adds Taylor. Robots in the second category, those with sufficient computer-based intelligence to support a variety of applications, "have a long way to go," in Taylor's words, before they can demonstrate significant practical benefit in nuclear plant operations. But, as Taylor adds, such robots are under development, and their initial trials are expected to provide valuable insight totheir ultimate potential. Soon after remote manipulator arms were developed for use in hot cells and fuel reprocessing activities, an arm mounted on a transporter with cameras and lights made its debut in the 1950s at the government's Hanford nuclear facility in Washington State.

Developedby Westinghouse Hanford Co., the remotely controlled transporter vehicle was dubbed Louie after a technician scrawled the nickname on the robot's arm. Louie has proved to be a versatile and long-lived workhorse and is still in use today. Some fundamental aspects of how this equipment is applied distinguish robotic equipment for nuclear plant applications from the more widely familiar industrial robots—those fixed devices that typically are employed for pick-and-place operations or other highly repetitive tasks. In many industrial applications of robots, the objective is to replace human workers with machines that are more productive, efficient, and accurate. Butfor nuclear applications, the objective is not so much to replace workers as it is to extend their presence—for example, to project their reach into areas of a nuclear plant where the thermal or radiation environment prohibits or limits a human presence.

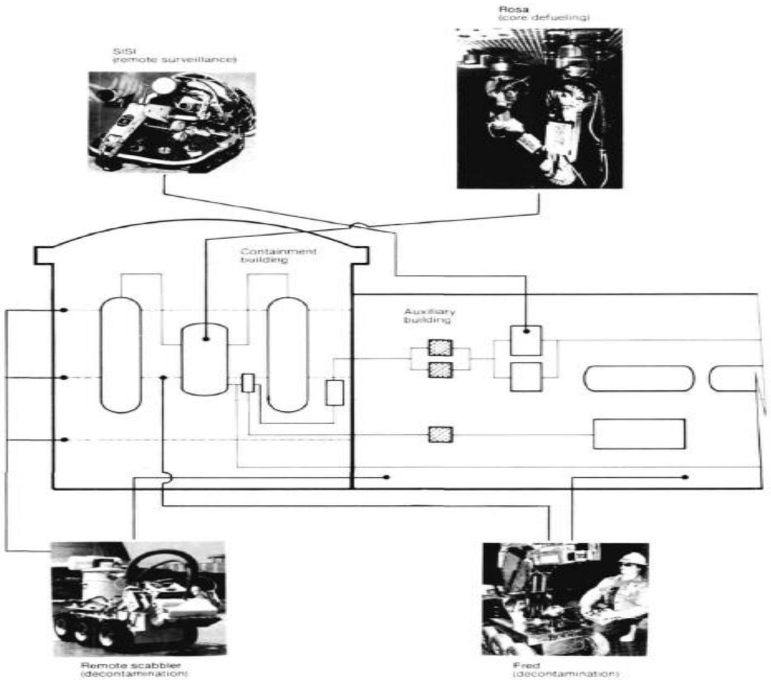
Utilities may face even tougher ORE limits in the future. In addition to guidelines that call on utilities to reduceOREs to levels "as low as reasonably achievable," NRC for several years has been studying proposals to reduce the ORE standards; such a development could have a multiplicative effect onutility costs for personnel exposure. Feasibility studied EPRI and NRC have both sponsored preliminary assessments of the potential for applying robotics in nuclear power plants. NRC, motivated primarily by the objective of reducing personnel radiation doses, looked mainly at surveillance and inspection tasks in a study performed by Remote Technology * In international usage, the rem has been replaced by the sievert in accordance with recommendations of the International Organization for Standardization. One sievert corresponds to 100 rem. Columbus Laboratories, focused on maintenance activities and attempted to identify potential availability improvements, as well as opportunities to reduce radiation exposure.

Each study attempted to quantify the cost in ORE and man-hours of a variety of jobs that a robot system might be capableof performing; the costs were then compared with those of the robot and its associated support systems and personnel Surveillance and inspection tasks evaluated in the NRC study range fromdetection of steam or water leaks, verification of valve positions, and reading of gages to measurement of radiation levels in components and various methods of sampling to detect contamination. The EPRI study surveyed 22 tasks that are performed routinely or during refuelling, including control rod drive maintenance, steam generator tube repair, and repair or replacement of various pumps and valves. Although the scope of activities analysed were different, both studies concluded there were potentially significant net positive economic benefits of applying robots in nuclear plants The NRC study, based on application of a cost-benefit methodology to two existingplants, concluded that commercially available robotic technology can be retrofitted into existing plants and will reduce both radiation exposure to workers and plant operating costs. The NRC study cautioned, however, that benefits can differ significantly among plants because of dissimilar design factors and operating histories. Some, on the other hand, may be less capable of doing demanding labor, but could be used as intelligent master robots, controlling the work of stronger drones. Several robot prototypes are making their debut in the recovery and cleanup of the damaged Three Mile Island Unit 2 nuclear plant in Pennsylvania, the site of a March 1979 loss-of-coolant accident that destroyed much of the reactor core and left large areas of the reactor containment building inaccessible to humans. Remote inspection has shown radiation fields as high as 3000 rad/h in some areas of the containment.* According to Adrian Roberts, a senior program manager in EPRI's Nuclear Power Division and manager of its TMI-2 information and examination program, the TMI cleanup effort has become a particularly strong spur to robotic equipment development. "At TMI we have a challenge for robotics that is here and now, some of the jobs simply can't be done other than remotely.

The venerable Louie from Westinghouse Hanford has been brought to TMI to perform radiologic characterizationduring decontamination of the water purification system. Officially known as the remotely controlled transporter vehicle, Louie will be used to monitor radiation levels as the demin- * In international usage, the rad has been replaced by the gray. One gray corresponds

Robots atTMI-2

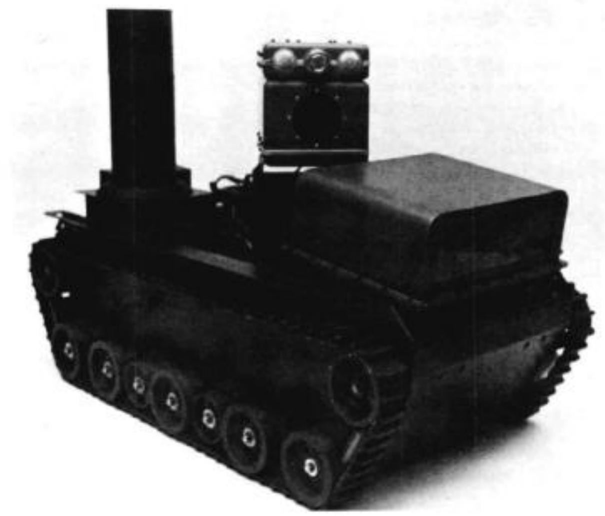
Cleanup and recovery work at the damaged TMI 2 reactor in Pennsylvania presents a unique challenge for the application of robotics technology. Two remotely operated manipulators called Fred and SISI have already seen service in surveillance and decontamination tasks. The RRV, nicknamed Rover, has been assigned the job of inspecting the contaminated basement of the reactor containment building. A remote scabbling machine has been developed to remove contaminated layers from concrete floors. Louie, specially modified for the TMI work, is slated to monitor radiation levels as the plant demineralizer tank is decontaminated. Rosa, a versatile remote manipulator arm, has been proposed to lend a hand in defueling the TMI 2 reactor core.



I hough the robot's nearly KXXl-lb (454-kg) lifting strength will not be needed in this operation, its radiation-hardened television cameras will get a workout near the demineralizer tank, which has a contact reading of 3000 rad/h. Perhaps the most ambitious effort to date to apply robotics in the I'Ml cleanup has been the EPRI-Supported development by Carnegie-Mellon University's (CMU's) Civil Engineering and Construction Robotics Laboratory of the remote reconnaissance vehicle (KRV) to probe the basement of the reactor containment building. The basement level, where no human has entered in over five years, remains highly contaminated with the radioactive sludge left trom some 600,000 gallons (2270 m1) of water, including primary cooling water, most ol which has since been pumped out. The RKV, nicknamed Rover by GI'U Nuclear Corp., the operating utility at I'M I. has been assigned the task of entering the dark and damp basement bv crane hoist, inspecting the scene with its three television cameras, and surveying the area radio logically with several on-board detection instruments. The six-wheel, 1000-lb KRV, developed in a cooperative effort involving EPRI, CMU, C,PU Nuclear, DOE, and the Hen l-'ranklin Partnership in Pennsylvania, was designed by CMU's William Whittaker, an assistant professor of civil engineering and director of the robotics laboratory.

The second RRV base vehicle, modified by 1'entek, Inc., HPKI's site contractor at TMI, is outfitted with a pneumatically powered scabbling machine and vacuum system for removing the contaminated top layer of concrete from floors in parts ot the reactor building. A third RRV remains at CMU's robotics laboratory for future development efforts. Other tasks proposed for future modifications of the prototype RRV include collection of liquid and sludge samples from the containment basement, collection of concrete core samples from the floor and walls, and some minor structural dismantling. "At TMI the interest is in working vehicles with high strength, reliability, and mobility," explains Whittaker, the RRV's designer.

The challenges at TMI are very physical and active, and the equipment that will meet those challengeswill be similarly physical and active. But there is certainly no one machine that will do it all, so we are looking at the evolution of a family of these things. One mode might be a fully configured RRV to supervise the activity of a drone that would earn' tools only. Another possibility is a miniatureversion of the RRV that would operate radio-remote from the mother ship." Clearly, robotic equipment is proving to be a valuable tool in the TMI recovery effort. Other applications of robotsat the site are also planned. A manipulator arm built by Westinghouse Electric Co. and known as Rosa (for remotely operated service arm) has been proposed for use in the defueling of the 1 Ml reactor core, tentatively planned for next year. Rosa, which can also operate underwater, is already known among some utilities operating pressurized water reactors for its ability to automatically inspect and repair steam generator tubes after it is mounted on the steam generator by service personnel. Waiting in the wings In addition to the robots that have been deployed at TMI, EPRI is evaluating two other prototype devices that could prove useful in nuclear plant environments. These machines could become cousins of the TMI machines in the ro



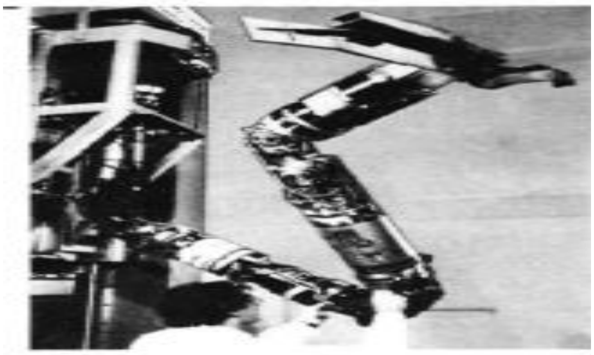
IRIS – for Industrial Remote Inspection system – is a general-purpose robot for hazardous environments. (Credit: EPRI)

One of these, produced by Advanced Resource Development (ARD) Corp., is known as an industrial remote inspectionsystem (IRIS). Designed as ageneral-purpose surveillance and inspectionrobot for hazardous environments,IRIS is a relatively small (compared withthe RRV) battery-powered, trackedtransporter that can be equipped withoptical, audio, and environmental sensors;manipulators; and communicationsand control subsystems.The 200-lb (91-kg) IRIS features aunique high-frequency wireless communicationsystem, specifically designedto operate in an environmentcluttered with physical barriers, as wellas with signal interference, which allowsit greater mobility and range thanmost robots developed to date.

Future development

Technologically, Odex may be close tothe fully autonomous, intelligent robotthat researchers say would representthe ultimate marriage between machineautomation and the developing field ofartificial intelligence Its ability to maneuver around or over obstacles underthe guidance of a remote operator approachesthe level of computer controlintegration that will be needed if a robotis to be capable of autonomously respondingto a programmed set of directionsby referencing a self-containeddata base for its location, destination,route, and tasks.Consummating the union betweenrobots and artificial intelligence is along-range research goal, however, becausethe challenges involve advancingthe frontiers of computer modelling of solid geometry, as well as the structuringof large amounts of computerdata for logical access by the robot.

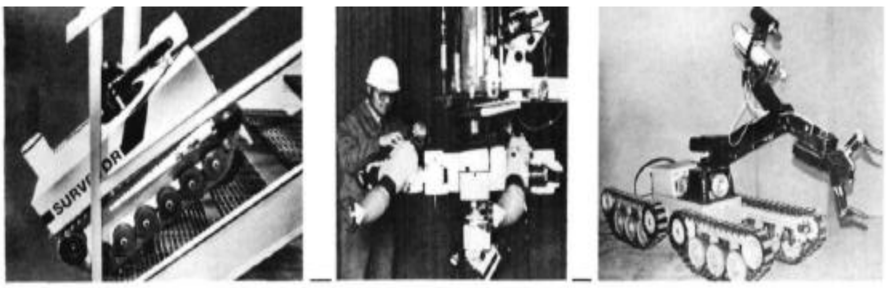
Various military and non-military research programs around the country are now focusing on the mathematicaland computer science aspects that willeventually be brought to bear on thischallenge. The military programs arelargely funded by the Office of Naval Research and the Defence Advanced Research Projects Agency. Others, includingprograms at Stanford University,Purdue University, the Universityof Michigan, the Massachusetts Instituteof Technology, and CMU, involve non-military as well as military-relatedR&D.Irving Oppenheim, an associate professorof civil engineering at CMU, isworking with EPRI on some aspects ofthe problem in a research project to assessthe potential for applying artificialintelligence in robots for constructionand maintenance work. The Japanesealready make significant use of auto made devices for various tasks in construction,but, in general, these devicesare not the smart type. Two elementsthat are needed to make robots autonomous, according to Oppenheim, are theability to logically detect and avoidobstacles and a way of modeling the three-dimensional work environment of the robot so that its "world map" canbe referenced as it proceeds on an assigned task."There" are some attempts at themathematics that will permit a robot tofind a configuration that avoids an obstacle,and we are working with the existingones, testing them out, findingtheir shortcomings, and modifyingthem to accomplish some of the objectivesthat these obstacle avoidancecapabilities are going to have," saysOppenheim.



ISIS, developed by Hispano Suiza, is being used at France's Chinon A3 reactor for repairs. (Credit: Hispano Suiza)

Robotic evolution

ISIS, developed by Hispano Suiza, is being used at France's Chinon A3 reactor for repairs. (Credit: Hispano Suiza) Although the robotics industry itself is less than two decades old, the technology can broadly claim old and distant relatives — from musical statuettes to mechanical manipulators and programmable machines — around the world. Early Greeks, Egyptians, Ethiopians, and Chinese, for example, created a variety of moving figures that were powered by water and steam. Later, in the 18th and early 19th centuries, Swiss craftsmen built life-like "automata" that could write, draw, and play musical instruments; and the French developed mechanical looms controlled by punched cards, introducing the first programmable machine. The term "robot" itself, however, was not widely used until 1921, when the play *Rossum's Universal Robots* opened in London. Written by Czechoslovakian dramatist Karel Capek, the play popularized the derivative of the Czech *robota,* which means forced labourer. Today the definition of the word "robot" illustrates both rapid technological advances and modern expectations. In the USA, the Robotics Industries Association defines a robot as a "reprogrammable multifunctional manipulator designed to move material, parts, tools, orspecialized devices through variable programmed motions for the performance of a variety of tasks". In Japan, classifications are used: M1 are simple tele-operated manipulators; M2A are devices that can be programmed to do fixed repetitions; M2B are those that can perform variable repetitions; M3A are more sophisticated devices that can be taught a sequence of steps by an operator leading them through the motions;



Nuclear power and electronics

Under an EPRI contract, Westinghouse's Advanced Energy Systems Division studied the feasibility of using robots in a large-scale prototype breeder reactor. The analysis considered various routine and non-routine maintenance and inspection tasks and outlined design factors that could enhance the applicability of robots These include provision of adequate work and access areas, lighting and power outlets, and location of equipment and other potential obstructions. As more special-purpose robots are developed for-nuclear applications, the job of technically evaluating these devices with utility requirements in mind will also grow. EPRI's NDE Center may take on expanded responsibilities in this regard, having already participated in the technical evaluation of IRIS. **Breaking new ground** Directed R&D efforts and the immediate needs in nuclear power plants for reduced maintenance costs and lower occupational radiation exposure are breaking new ground in the application of robots to tasks with which most people would rather not be burdened. Despite the significant achievements to date, however, researchers caution that much more progress must be made before robots are seriously considered as reliable, economic tools. The entry of robots into the nation's nuclear plants will not occur rapidly, but a trend in industry thinking toward applying robotic equipment when and where it is feasible is already clear. Michael Kolar, until recently an EPRI senior program manager who was involved in the Institute's study of robotic applications since the effort began in 1981, reflects the mixed viewpoints among many researchers in the field. "There is some robotic technology that will let you do certain jobs, but it's not at all clear that you'll see many of these machines in wide use in the near future," says Kolar.

There are significant unresolved uncertainties, relating not only to the technology's hardware and software but also to other issues. Will the time required to train crews and execute a job with robots be short enough to be practical? That's not yet clear. NRC may decide to regulate some aspects of plant maintenance, and the role of robots in licensing issues has not yet been defined. "Ultimately it will all come down to economics—are robots truly cost beneficial?" asks Kolar. "Unless the costs of robot systems come down, or someone offers to provide them as part of a service package, I don't think we'll see widespread use of sophisticated robots soon. For EPRI, the issue is to ensure that good technology gets into the plants. But first, we have to find out what these machines can do. If we succeed, robots just might make it." Utilities are expressing increasing interest in robots for nuclear plant applications, and as a result, the R&D community and the robot industry are responding with a range of devices and machine capabilities The current activity represents a model of cooperative research, with both large and small companies, universities, government, and industry research groups working together to advance the technology. If recent success is any indication of the future, the outlook for robots to make a significant contribution to improved plant economics is encouraging.

OC Robotics: Nuclear remote handling

Remote handling in radioactive environments often requires dextrous manipulators that can access a radioactive space through a small opening and avoid obstacles between the entry point and work site. OC Robotics is the world leader in snake-arm robots: remote tele-operated manipulators that can 'follow-their-nose' into confined spaces.

OC Robotics snake-arm robots

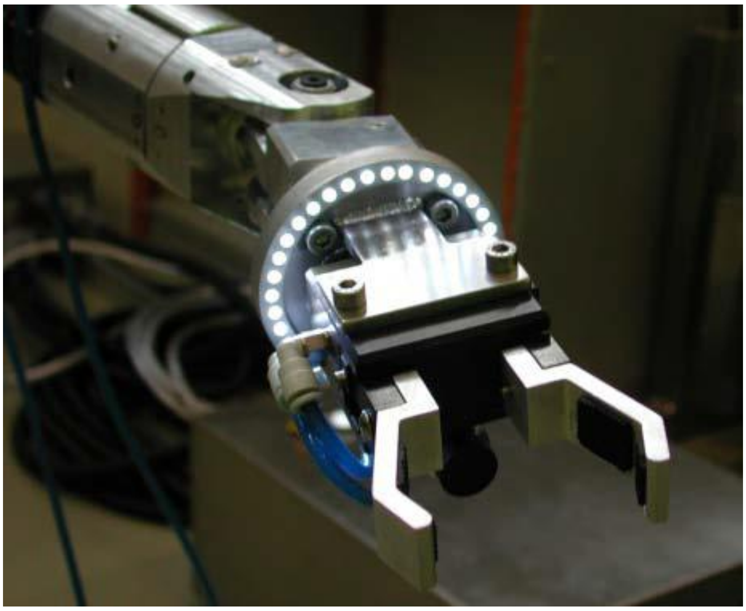
To date OC Robotics has focused on life extension projects for power generating plant. Customers around the world, including Ontario Power Generation, Areva and Ringhals AB (Sweden) have used OC Robotics' systems to conduct 'minimally invasive' maintenance and repair operations through small (typically pre-existing) access holes. Focusing on profit-generating plant has enabled OC Robotics to grow and develop nuclear capabilities. This experience can also be applied to decommissioning tasks. This document provides an overview of OC Robotics' snake-arm robot technology and previous nuclear experience.

Whilst OC Robotics' core technology is snake-arm robots, a turn-key solution would be tailored to the demands of the specific application. OC Robotics products include a mobile vehicle, vision systems, sensors and tooling, user interface, software and electronics infrastructure that allow remote control.

- **Tooling:** Confined spaces often require specialist tools which are small enough to be manoeuvred in the space available. OC Robotics has designed tools for visual and UT inspection, manipulation (gripper), cutting/cropping, welding and fastening (below).

- **Tool services:** Snake-arm robots all have a hollow bore, which means that services are routed inside the arm to the base avoiding the risk of snagging and maintaining a smooth external surface. Snake-arm robots can also be used a guide for delivering active or passive tools, e.g. another snake-arm robot or a video probe.

• Contamination: Snake-arm manipulators can be designed without prominent ‘elbows’ making them straightforward to seal against contamination or water. OC Robotics has also delivered systems that are fully sealed and air-tight to prevent air-borne contamination being taken up into the mechanisms.



Example tooling

• **Tool services**: Snake-arm robots all have a hollow bore, which means that services are routed inside the arm to the base avoiding the risk of snagging and maintaining a smooth external surface. Snake-arm robots can also be used a guide for delivering active or passive tools, e.g. another snake-arm robot or a videoprobe.

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• **Materials**: OC Robotics has delivered systems with specific material requirements. Systems can be designed without any prohibited materials so that they are suitable for use in the nuclear industry.

• **Electronics**: A design principle of snake-arm robots is that the motors and related electronics are located in the base of the arm. There are three reasons for this: first, a lighter arm can be a longer arm; second, motors are bulky so an arm can be either smaller in diameter or have more space internally for services; third, main systems, including electronics, can be kept in an accessible area. This final point is critical for high radiation dose and wet environments.

• **Control**: The OC Robotics user interface is intuitive and easy tounderstand. It can be tailored to each application to ensure that theuser has all the information required without being overloaded.

• **Data collection and management**: OC Robotics' user interface is ableto record video and images alongside text or audio.

• **Technology integration**: The customer's own capabilities can beintegrated with a solution. For example a solution may combine asnake-arm manipulator with in-house UT inspection developments.

• **Quality Assurance**: OC Robotics has worked as prime contractor to the nuclear sector and operates to a Quality Management System certified to ISO 9001

<u>Explorer range of Snake-Arm Robots</u>

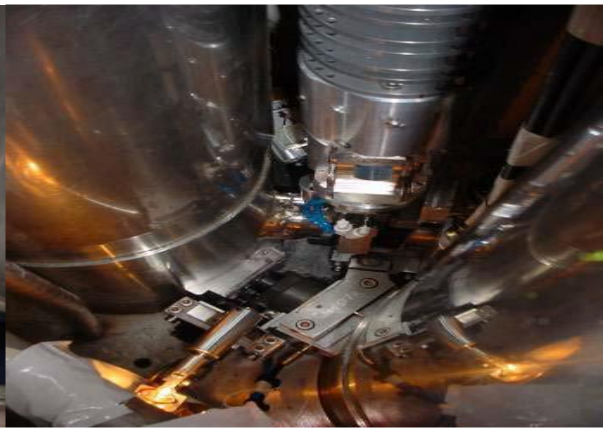
Explorer range snake-arm robots vary in size from 40mm to 150mm in diameter and from 1m to 3.25m in length. These dimensions represent the mid-range of our capabilities. The strength of the Explorer design is that is scalable, so both smaller diameters and longer reach versions are possible.

Options include “quick release” mechanisms between the arm and the actuators, 1 or 2 degree of freedom wrists, and a variety of different tools. Snake-arms can be integrated with an introduction axis – a linear rail, industrial robot or vehicle – to enable controlled ‘nose-following’ motion.

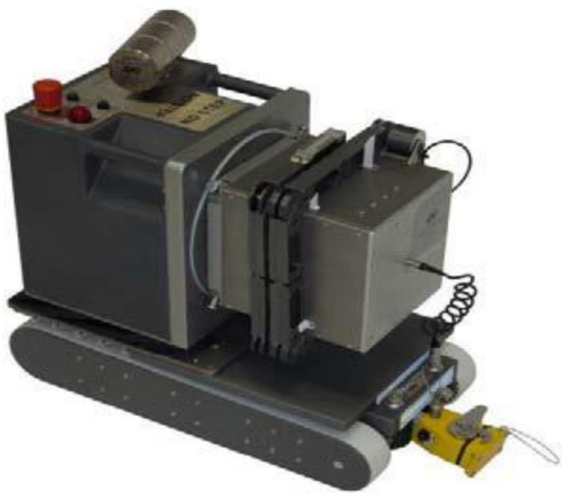
The Explorer range of snake-arm robots is designed to operate as a standalone unit or with an OC Robotics introduction axis. Alternatively it can be integrated with a standard industrial robot, a crane or a mobile vehicle. Using industrial robots as an example, the Explorer range can be considered as a tool on the end of the industrial robot or as a flexible fore-arm for the robot. Our proprietary software controls both the industrial robot and the snake-arm to coordinate their motion.

OC Robotics completed its first commercial nuclear contract in the summer of 2004. Working with Areva, two types of snake-arm robot were supplied to Ringhals AB to complete an urgent pipe replacement in an extremely awkward area below Ringhals 1. The Inspection Arm, the more flexible of the two snake-arms, was 1000mm long and 35mm in diameter and was used to get the ideal camera location to monitor the process. The Manipulation Arm, which was 800mm long and 60mm in diameter, was used to deliver the processing tools and fixtures, remove the old pipe, introduce the new pipe and conduct tasks such as welding and inspection. Replacing the leaking section of pipe involved more than 30 distinct procedures with the majority being conducted by the robots working cooperatively

Ringhals Inspection Arm



Ontario Power Generation, Pickering, Canada

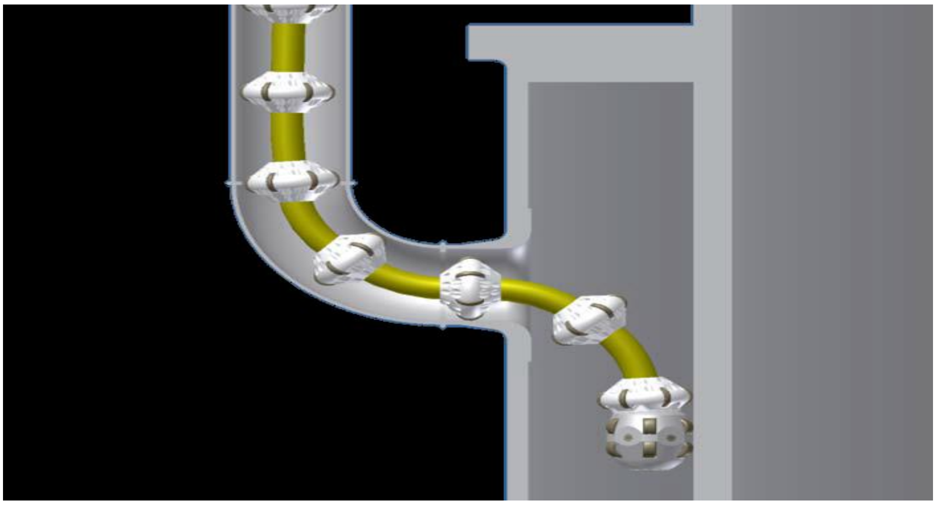


OC Robotics' SAFIRE (Snake-Arm Feeder Inspection Robotic Equipment) was designed to conduct inspections within the Upper Feeder Cabinet (UFC) of CANDU nuclear reactors in Ontario, Canada. The 2.2m long, 25mm wide snake-arm is mounted on a tracked mobile vehicle which is driven along walkways in the UFC. The snake-arm is stowed coiled for compactness and is deployed by unwinding and 'nose-following' between pipes. The snake-arm can be deployed at any angle to reach below or above the walkway, and can reach 100% of the UFC. Side and forward facing tool-mounted cameras are used for navigation and image capture. Pan-tilt-zoom cameras on the mobile and base units provide scene views and additional inspection capability.

OC Robotics investigated the design of a snake-arm to reach in excess of 10m down a multi-curved pipe in order to measure vessel wall thickness from within a vessel cooling jacket, see image below. Working within pipework requires a device which is compliant and will adapt to the bends in the pipe. However, to reach deep into a pipework system an endoscope will not suffice – friction will simply stop it going round more than a few bends. A snake-arm robot, on the other hand, is controllable along its length which means that the body of the device can be biased around each of the bends, not just at the tip.

The OC Robotics Pipe Snake™ needs some structure to support its weight, such as a pipe, yet it is steerable and can be guided around bends. The biggest benefit of a snake-arm robot over an endoscope is that a snake-arm robot can be designed to include shape measurement which means that the user can know the shape of the arm and therefore the location of the tip. Users can record where defects are found and then return to the same spot during subsequent inspections to check defects over time.

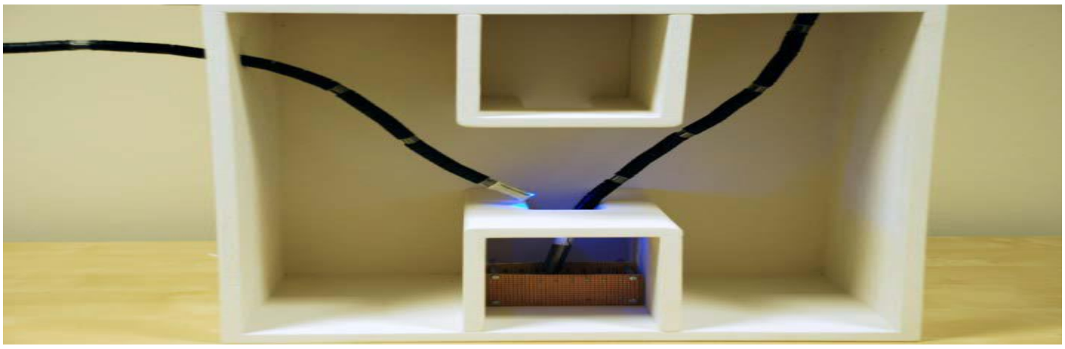
The OC Robotics Pipe SnakeTM Sellafield



OC Robotics portable snake-arm tools

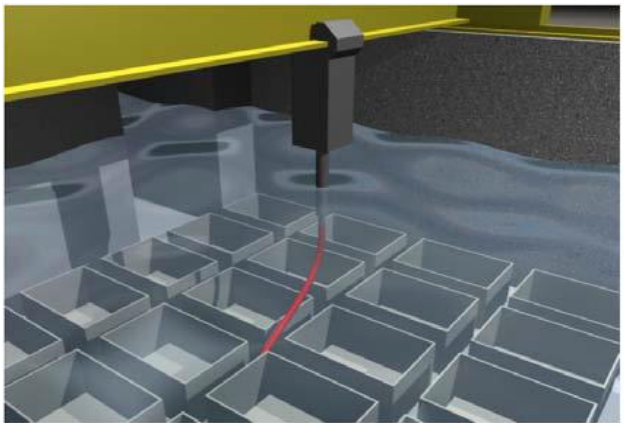
Standard flexible endoscopes - also known as borescopes or video scopes - have a long flexible body with a steerable tip. They are useful for inspection in confined spaces but they suffer from a lack of control and a reliance on the environment to support the body of the device. This means that flexible scopes cannot bridge large horizontal gaps and cannot advance around multiple corners. Snake-arm robots do not need support from the environment, they are self-supporting, and are steerable along their entire length.

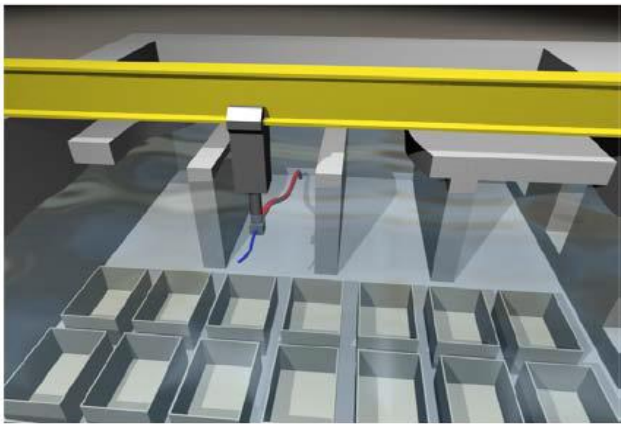
The smallest fully self-supporting arm to date is 12.5mm in diameter and 400mm in length (below). It is stored in a self-contained portable unit and can be battery or mains powered.



When the environment can be used for support then snake-arms can be much more slender. This is also true when gravity is no longer an issue, for example if the arm is hanging vertically or operating underwater. We have designed a neutrally buoyant arm for underwater operations.

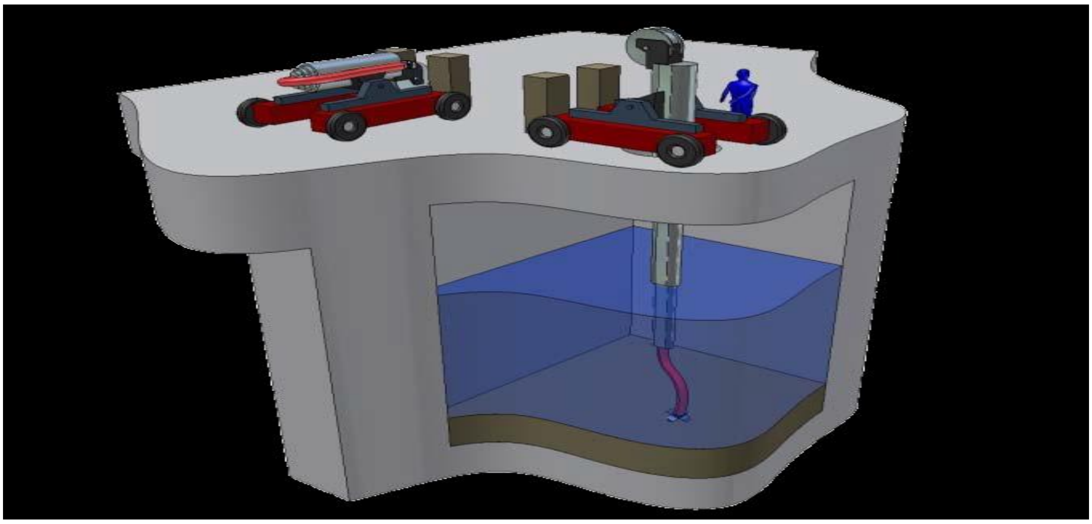
Snake-arm robots can have smooth, continuous external surfaces with all services running internally, which greatly reduces the likelihood of snagging and makes sealing and resealing easier. The combination of an easy-to-seal smooth arm and an actuator pack within an air tight container means that snake-arms are the ideal platform for washable, wet or fully submerged applications.





Long reach and high payload manipulators

The general snake-arm robot design is very scalable and OC Robotics has talked to customers about manipulators up to 15m in length to carry significant payloads. While very slender snake-arm robots will inevitably be unable to move large tools, a shorter, thicker arm can carry significant payloads. These arms will likely have fewer segments and are ideally suited to glove box work as an alternative to master-slave manipulators.



Introduction - Industrial Applications of Robots

Robots are widely used in Industries for automation purposes.

• Automation –

(a) Fixed

(b) Flexible

(c) Programmable.

They remove human labors and can be used for continuous or Batch processing purposes. By use of these robots Productivity, quality both increases. Time for production reduces.

Major applications of robots in industries can be classified as follows.

(a) Material Handling Applications

(b) Processing Operations

(c) Assembly and Inspection Applications

GENERAL CONSIDERATIONS FOR ROBOT'S IN MATERIAL HANDLING APPLICATIONS

- Part Positioning and Orientation.
- Gripper Design.
- Minimum Distances Moved. Robot Work Volume.
- Robot Weight Capacity.
- Accuracy and Repeatability. Robot Configuration.
- Machine Utilization Problems.
- Material Handling Applications

This is the major application area of Robots inIndustry & most widely used. This application can be classified into

- Material Transfer Applications.
- Material Loading/Unloading Applications.

MATERIAL TRANSFER APPLICATIONS

Divided into: Pick and place robots, Palletizing, Depalletizing and Related Robots.

PICK AND PLACE ROBOTS

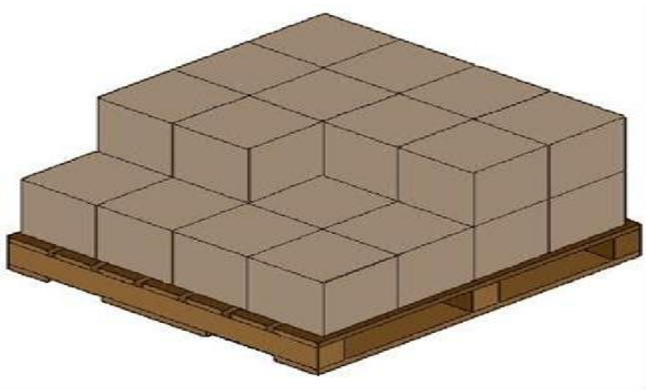
- Picks a part Job piece from one location and moves it to another location.
- Part may be presented by mechanical feeding device or conveyor.
- For simple case, robot needs only 2 degree of freedom. One to lift and drop, other is to move between the pickup point and drop point.
- Has to track a moving pickup point or drop onto a moving conveyor. Either case requires sophisticated system inter-locks system.
- When different objects are handled, the robot must distinguish between them.
- To handle this issue, sensor system which executes the respective module must be used.

PALLETIZING AND RELATED OPERATIONS

Large amount of containers (cartons) are placed on a pallet (wooden platform) and then it is handled by fork-lift trucks or conveyors.

- These are very convenient method for shipping large quantity of products.
- Computer controlled robot, using high-level programming language is suitable for this operation.

Other Operations are:



Depalletizing Operations [Reversal of palletizing operations].

- Inserting parts into cartons / conveyor.
- Stacking and un-stacking operations.

The robot maybe called to load/unload different pallets differently like (which may): vary in size. Different products loaded onto pallets. Differences in numbers and combinations of cartons to different customers.Bar codes are used to solve the identification problem for depalletizing the optical reader system can be used. Differences in loading and unloading can be accomplished by loading the respective subordinate in to controller. Usually the palletizing operation is much complex then Depalletizing because of customer's orders (different boxes of different sizes has to be delivered to different customers.

MACHINE LOADING / UNLOADING

It is used to service a production machine by transferring parts to/from the machine.

There are 2 cases: **Machine load/Unload** : Loads raw material and unloads finished part.

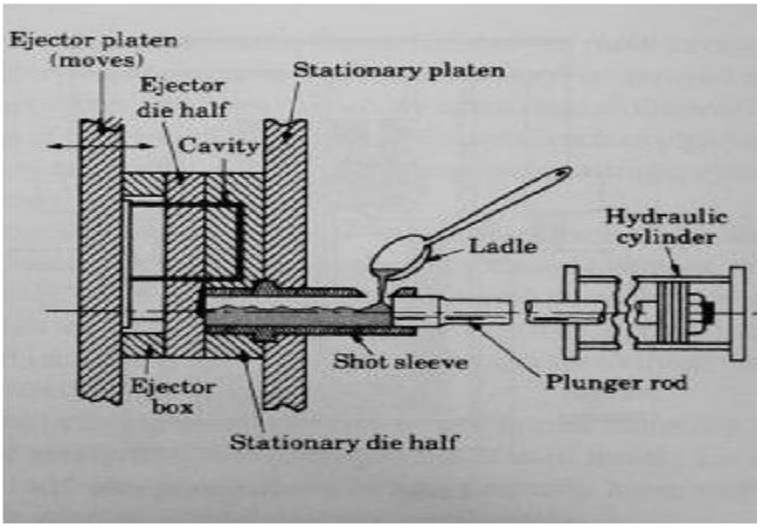
Machine Loading: Load the raw material but the finished part is ejected by other mechanism. Example: Presswork

Machine Unloading: Raw materials automatically loaded and the machine produces finished product. The robot unloads the finished product.

Successful Operations in which robots are used:

- Die Casting
- Plastic Molding
- Forging and related operations
- Machining operations
- Stamping press operations

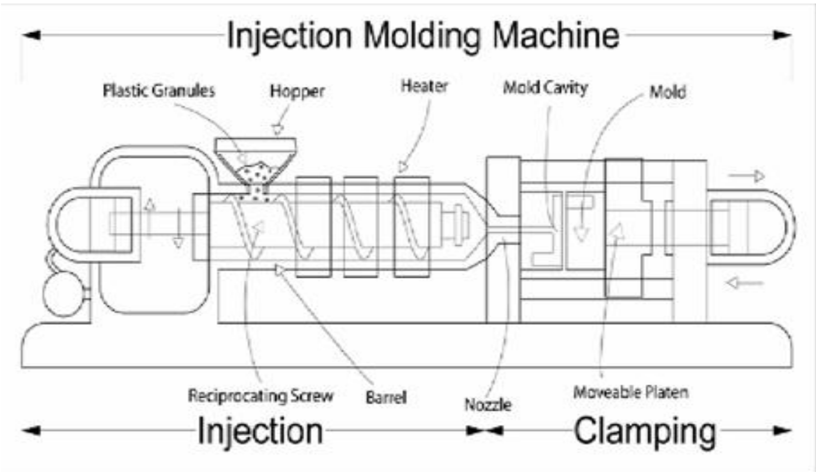
DIE CASTING



Molten metal forced into cavity of a mold under high pressure. Mold is called die hence named die casting. Common metals include alloys of zinc, tin, lead, aluminium, magnesium and copper. The die is closed and molten metal is force in using pump. To ensure cavity is filled enough metal is forced in that causes overflow and flash in the space between die halves. When metal has solidified it is ejected by using pins (usually) and quenched in water bath. The flash is removed using trimming operation. It's a straight forward approach & limit switches are used for providing Interlocks. Thus die casting involves the following Casting Removing the part from the machine Quenching, Trimming

Range: 100 to 700 openings of the die per hour depending upon the machine. Problems encountered here are in Programming side , Design of Grippers, Transporting the molten metal to the injection Chamber etc.

PLASTIC MOLDING



Batch-volume or high volume process used to make plastic parts to finite shape and size.

Covers Number of process:

- Compression molding
- Injection Molding (Most common)
- Thermoforming
- Blow Molding
- Extrusion etc.,

A thermoplastic material is introduced in form of small pellets from storage hopper. Heated in heating chamber to 200-300 C and injected in to mold cavity under pressure. If much is injected flash is created, if little is inserted sink holes are created rendering unacceptable. Highly sophisticated production machine capable of maintaining temperature, pressure, amount of material injected called "INJECTION MOLDING MACHINE" is used. If the part struck in the mold then we can use Gravity to cause the product to drop, directing an air stream to force the part out etc. Based on the molding job the method of part removal is done.

Disadvantage:

Production time is larger than the Die castingmethod. Robot is idle for most time till the processing finishes. Part inspection & Flash removal is difficult.

FORGING AND RELATED OPERATIONS

Metalworking process where metal is pressed or hammered into desired shape. It is of two types:

(1) Hot forging here the metal is heated to high temperature before forging.

(2) Cold forging it adds strength to the metal and used for high quality products.

The operations include: Die Forging and Upset Forging. Die Forging: Accomplished on a machine tool called drop hammer where raw billet is hit 1 or more times between upper and lower portions of forging die. Upset Forging: Also known as upsetting, where size of a portion of work path is increased by squeezing the material into the shape of die.

Some technical and economic problems include:

- Production runs are typically older machines.
- Short production runs.
- Parts occasionally stick in the dies. Can be readily detected by humans but posses problem for robots.
- Design of gripper is significant engg. problem because it must withstand shock from hammer blows.

Some of technical & Economical Problems are: Machines are older ones (designed for manual operations) which can't be easily interfaced with Robots.

- Due to short forging cycles its not economical for robots to be installed.

- Parts occasionally stick in dies. Humans can easily bring it out but it's a difficult job for Robots.

- Design of Grippers is another problem.

MACHINING OPERATIONS

Machining is metalworking in which the shape of the part is changed by removing excess material with a cutting tool. Principal types : Turning , Milling, Shaping, Planning, Grinding. Robots utilized to perform the loading and unloading functions in machining operations. The following robot features contribute to success:

•Dual Gripper.

•Up to six joint motions.

•Good Repeatability.

•Palletizing and Depalletizing capabilities.

•Programming Features.

STAMPING PRESS OPERATIONS

Used to cut and form sheet metal parts. Performed by means of a die set held in a machine tool called a PRESS. Raw material in the form of coils, sheets and individual flat blanks. One limiting factor is the cycle time of the press. These are too fast for currently available commercial robots.

SPOT WELDING

Process in which 2 sheet metal parts are fused together by passing a large electric current through the part where the weld is to be made.

ROBOTS FOR SPOT WELDING

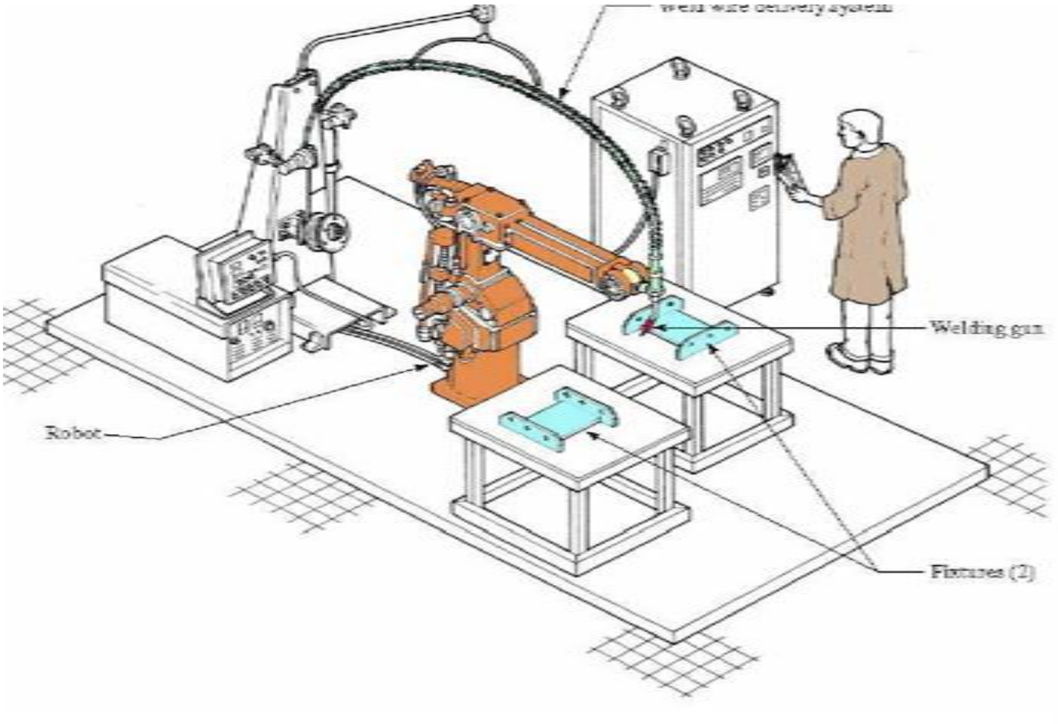
A welding gun is attached as the end effector to the robot's wrist.

Advantages of robots use in spot welding: Improved quality, Operator safety, Better control over production operation.Features of robots for spot welding: Relatively large. Sufficient payload to manipulate the welding gun. Work volume must be adequate for the size of product. Position and orient the weld gun in places difficult to access. Controller memory should have enough capacity.

Operation - Spot Welding

Two Electrodes are in the shape of Pincer. When this pincer opens the electrodes are positioned at the point where the metal part has to be fused. Prior clamping or fixing of the part is must. Electrodes are squeezed together and current is applied so a large heat is produced at that point. This heat fuses the metal parts together.

ARC (Continuous) WELDING



• It's a continuous welding process.

• Used to make long welded joints in which airtight seal is required between the two metal pieces which are to be joined together.

• Electrode in the form of rod or metal wire is used.

• 100 to 300 Ampere current with 10 to 30 voltage is used.

• High temperature is used to create pool of molten metal to fuse the two pieces together.

Problems faced by Human operatorUnpleasant and Hazardous Environment. • The Arc creates ultraviolet radiation which is harmful to human eyes.

• For this they use Dark window/Glass. It effectively filters these radiations but the welder is virtually blind while wearing it except when there is arc.

• High temperatures, sparks, Smoke are also potential threat.

ARC (Continuous) WELDINGProblems in Robot arc welding: Variations in the components to be welded. To compensate these variations and irregularities correct the upstream production operation so that the variations are reduced to a point where they do not create problem in arc welding.

Provide the robot with sensors to monitor the variations and control logics to compensate for part variations.There are a variety of arc welding process. For robot arc welding Gas Metal Arc Welding (GMAW) and Gas Tungsten Arc Welding (GTAW) are used. GMAW also known as MIG welding (Metal Inert Gas Welding) involves the use of a welding wire made of same or similar metals as the parts being joined. The weld wire acts as a welding electrode. In GTA welding (also known as Tungsten Inert Gas Welding) a tungsten rod is used as electrode to establish the arc. Tungsten had high melting point so the electrode doesn't melt during the fusion process.

The filler materials have to be added separately. GTA is used for welding aluminium, copper, stainless steel, etc.. In both these types inert gases such as helium and argon are used to surround the welding arc to protect the fused surfaces from oxidation. In GMA the electrode is continuously supplied from a coil and contributes to the molten metal pool, used in the fusion process.

Features of welding robots:

Work volume and degree of freedom.

Motion control system

Precision of motion

Interface with other system Programming

SENSORS IN ROBOT ARC WELDING: Contacting type and Non Contacting type Vision Based Systems.

ADVANTAGES OF Robot ARC WELDING:

Higher productivity,

Improves safety & quality of work cycle

Greater quality of product,

Process rationalization

SPRAY PAINTING AND ASSEMBLY :

Immersion and floor coating methods [bath type]. low technology methods. Here the part is dipped into the paint tank of liquid paint. when object removed the excess paint drains back to the tank. in flow type, part is positioned above the tank & stream of paint flow over the object. Spray Coating method.A new technique used is electro deposition Method: The part to be painted is given Negative charge and dipped into water containing suspended particles of paint. Paint particles are given Positive charge, and consequently they are attracted towards negative charged part.The next major industrial painting is Spray Coating.

- It comes with air spray, airless spray & electrostatic Spray.
- This involves use of spray guns to apply paint on the part or object.
- Air spray uses compressed air mixed with paint to atomize it into high velocity stream, which is directed out towards the object through the nozzle.
- Air less spray uses liquid paint to flow through the nozzle under high pressure instead of pressurized air.

This makes the liquid to break up into fine droplets. Electrostatic spray method uses either air spray or airless spray guns.

- Here the object is electrically grounded and the paint droplets are given Negative charge.
- This makes the paint to get fixed on the object evenly.
- Problems faced by human operators:
  - (a) Fumes & Mist in air
  - (b) Noise in the nozzle
  - (c) Fire Hazards
  - (d) potential cancer Hazards

FEATURES OF SPRAY COATING ROBOTS:

Continuous path control.Manual lead through programming.Multiple program storage.Benefits / Advantages: It saves human operators from hazardous environments. Low energy consumption, Consistency of finish. Reduced usage of coating material. Greater productivity. Other processing operations where robots can be used:- Drilling, Routing, Grinding, Polishing, Reverting, Water jet cutting, Laser drilling and cutting etc.Robots in Assembly operationsAssembly -fitting together of two or more parts to form new thing.

• Traditionally automation is done in high volume productions.

• By using robots low & medium volume productions can also be automated effectively.

• Main areas in which we can use robots are: Parts presentation methods, Assembly Tasks

Parts Presentation methods: When the robot has to perform assembly task operation, the parts has to be presented to it.

For this several ways can be used as given below:

(1) Parts located in a specific area. [Parts not positioned or oriented]

(2) Parts located at a known position [parts not oriented]

(3) Parts located at a known position & orientation.

There are lot of methods used to present part which is in a known position & orientation such as

(1) Bowl Feeders

(2) Magazine Feeders

(3) Trays & Pallets etc.,

Bowl feeders

Used to feed & orient small parts in automated assembly operations.

(a) Bowl

(b)Vibrating base

A track rising in a spiral up the side of bowls is used to feed the parts as shown in the diagram.Base contains leaf spring & oscillatingelectromagnet which causes the Track & Bowl to vibrate. To orient the parts in right way we use two methods.

(1) Selection- taking parts that are not properly oriented & rejecting them. (sent back to bowl to reorient themselves)

(2) Orientation - Physically reorienting the parts. Both methods use series of obstacles through which the parts are allowed to travel.

• Obstacles physically change the orientation of the parts when they move over it.

• Exiting parts travel down to some holding fixture (located @ outlet point of bowl feeder ,so gravity is used to deliver the part.)

Disadvantages:

BACK PRESSURE Due to parts lying along the track leading to holding fixture.

• Result of two forces (a) force due to vibration in track and (2) force due to weight of all parts present in the track.

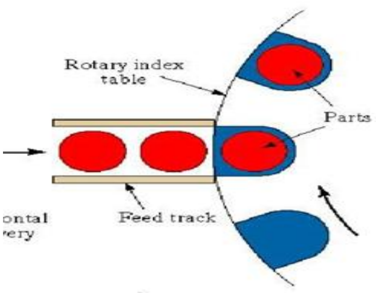
- It doesn't allow the robot to move the part successfully.
- Mainly used to reduce the back pressure.
- Other ways are to reduce the back pressure by(1) making the angle to holding fixture relatively small and (2) to turn off the vibrator when enough no of parts present in the track.

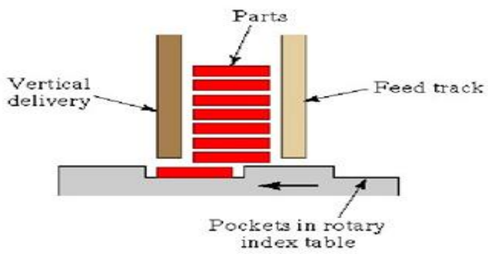
VARIOUS ESCAPEMENT &PLACEMENT DEVICES

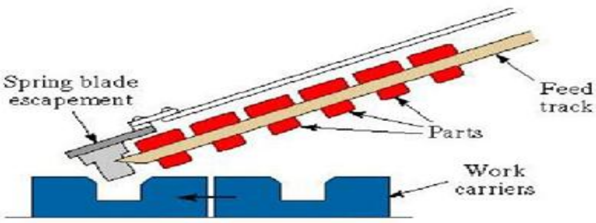
Magazine Feeders

Bowl feeders - used for bulk parts received at work station, but when doing this orientation gets changed. This is a major disadv of bowl feeders. Alternative method is using Magazine Feeders. This method transfers the pblm of orientation from the work station. Parts are feed in an orderly pre oriented way. Parts are loaded in a tube like arrangement or container, in a oriented way. (Usually any o/p from production process will have a orientation.)

- This container is known as Magazine.
- An Escapement device is used to remove the parts from the magazine.







• If the parts can't be loaded directly to the magazine then it has to be done manually.but then there is no use for magazine feeder in this case. Trays & Pallets Main Advantage is they can be used for variety of different part geometries.

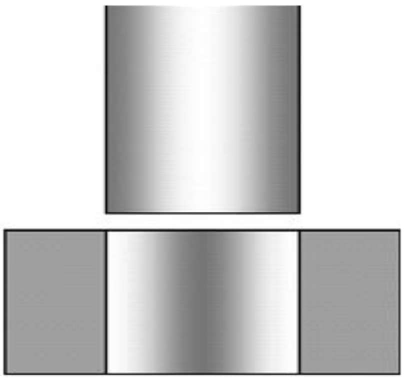
• Conditions to be satisfied to use pallet & tray are part should be in known location & orientation. If cycle time is large & tray size is also large then manual presentation is required. If cycle time is very fast then an automated operation of part presenting is needed.

Bin picking is an alternative procedure. Robots in Assembly Operations (tasks)Divided into two categories:

(1) Part mating - Two or more parts are brought into contact.

(2) Part joining - Parts mated & then additional steps used to make the parts to be together with each other. Part mating: Peg-in-hole. Hole-on-peg. Multiple peg-in-hole. Stacking.

Peg-in-hole



It involves the insertion of onepart into another. It's a common assembly task. Can be of two ways

(1) **Square peg in hole** - where base object is rectangle or square in shape and inserting object is square type. [Hole is square in shape]

(2) **Round peg in hole** - base part is rectangle & the part to be mated is circular [Hole is circular/round in shape].

Hole-on-peg: inverse of peg -in-hole method.

- Need better DOF for putting the peg into the hole.
- Needs better compliance.
- Example: Placing of a gear onto the shaftMultiple peg-in-holeAnother version of peg-in-hole.
- One part has multiple pegs & the other corresponding part has multiple holes.
- Example: mounting of microelectronic chip into a circuit. multiple pin chip is joined on circuit board with appropriate holes.

Stacking

Several components are placed one on top of the other with no pins or devices for locating the parts relative to each other Example: motor armature or transformer in which individual laminations are stacked over the other.Parts joining tasksIncludes Mating & fastening (holding) procedures.

(1) Fastening screws: common method, self tapping screws are used. uses rotation & simultaneous advancing (drilling). Power screw drivers are used.

(2) Retainers: Pins inserted through several parts in order to retain the mated parts together.

(3) Press fits: here peg is slightly larger than the hole. Extra force is needed to accomplish the task.

(4) Snap fit: Has both benefits of retainers & Press fitting techniques. Involves joining of parts where one part elastically deforms to accommodate the other part.

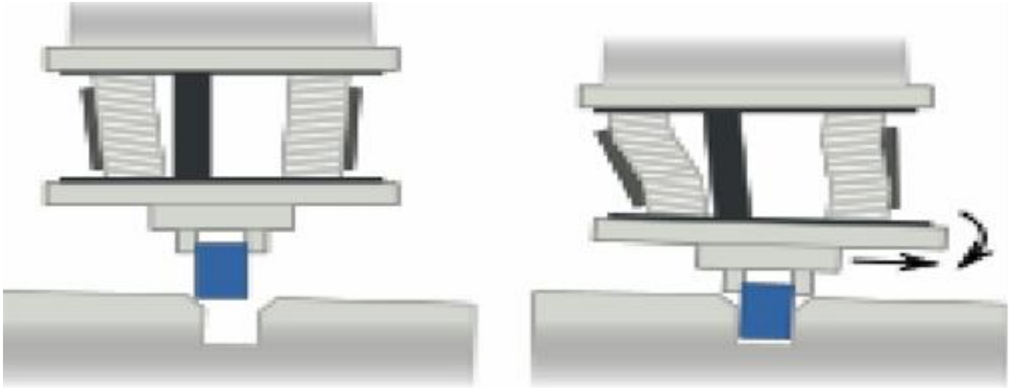
(5) Welding & related joining methods: Continuous & Spot welding are used.

(6) Adhesives: Glue or other adhesives can be applied to join parts by making adhesive bed on a part, along a path where second part is to be placed or applying glue at selected points & joining the parts together.

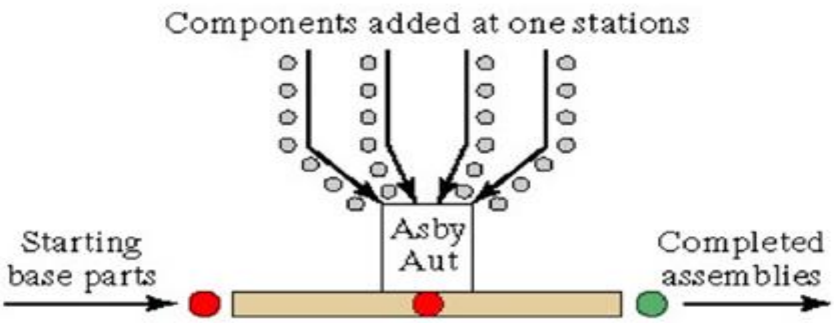
(7) Crimping: Deforming a portion of one part to fasten it with other part.

(8) Sewing: used only in soft, & flexible parts.

REMOTE CANTERED COMPLIANCE(RCC)



Compliance - is a measure of the amount in angle or distance that a robot axis or end effectors will move when a force is applied to it. Remote centred compliance(RCC) is a mechanical device that facilitates automated assembly by preventing peg-like objects from jamming when they are inserted into a holeAssembly system configurationsDefinition The use of mechanized and automated devices to perform various assembly tasks in an assembly line or cell .When to use Automated Assembly System High product demand Stable product design A limited number of components in the assembly Product designed for automated assembly Types Single workstation Series workstation parallel workstation etc., Assembly configuration - Single work station All the parts are presented to the robot @ a single work station. • All the tasks are accomplished at the single workstation. Generally used for low volume products with limited no of assembly tasks. Needs only less capital expense **Disadvantage**: not very fast, less reliable if more parts to be assembled, gripper or tool design is complex.



Most common configuration

- Used in medium & high production situations.
- Assembly line consists of series of workstations, with each station performing few operations on the product.
- Product gradually builds up as they move down the line.
- Continuous, synchronous or asynchronous transfer systems can be used with the in-line configuration Series or in line assembly

Dial type assembly machine –

- Series Operations
- Parallel operations

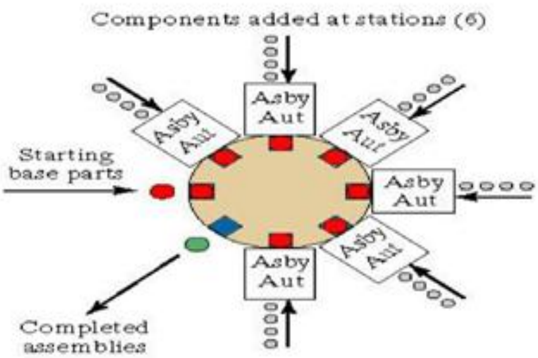
Same operations are performed in two or more routes.

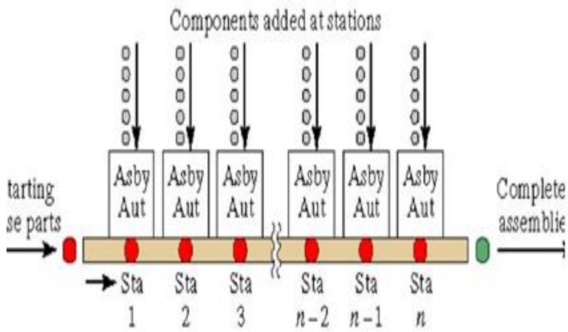
- Based on Two conditions parallel operations can be considered.

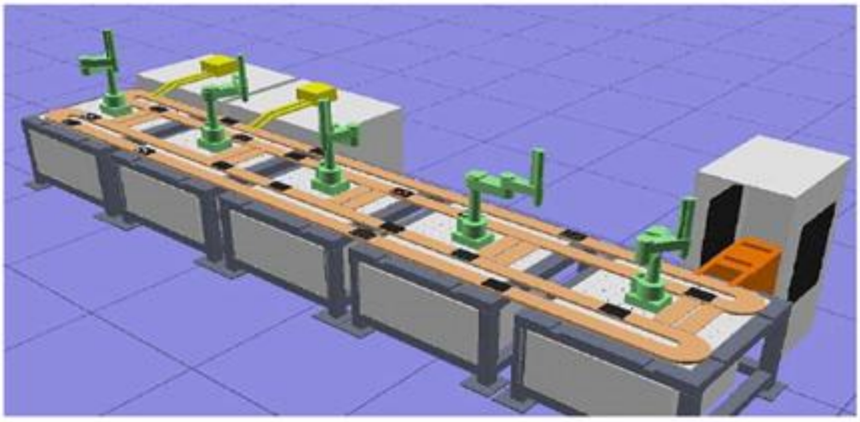
(1) When production cycle time is too long in one line when compared with other sections.

(2) Reliability - when break down occurs in one line then other parallel line can be used to perform the task without actually shutting the process Inspection Systems Why?

- Used for quality inspections of products.
- Used to Identify the part position & Orientation of parts.
- Testing of Equipments or parts
- Performance Analysis
- Interfacing with other hardware's etc.







VISION INSPECTION SYSTEM

Acts as a sensor, which is used for inspection purpose. Capable of 2D scene analysis applications

- Part location
- Part identification
- Bin picking etc.,

Vision Inspection System Robot Role

(1) To present the part to the vision system in proper position & orientation

(2) To manipulate (movement) the vision system

Factors/Requirements of machine vision system

- Resolution.
- Field of view (focusing)
- Special Lightning.
- Throughput etc.,

There are two types/methods. They are

(1) Robot Manipulated Inspection or Test Equipment. The robot moves the inspection or testing device around the part. Example: car body dimension measurement by moving electronic or LASER probe over the edges/corners of car.

(2) Robot Loaded Test Equipment used mainly in machine loading / unloading process. Mechanical, electrical, pneumatic gauges, functional testing devices can be connected to the robot end effecter for testing purposes.

Robot unloads a finished part & gives it to testing equipment where the product is tested. If the part is within tolerable limit its accepted and sent to next step for further processing otherwise part is rejected.This testing process acts as a feedback control system such that the tools can be adjusted based on test result. Functional test is widely used in electronics Industry. Quality & performance cannot be determined by the visual inspection process alone. So functional or performance test are used.

QUESTIONS

PART-A

1. What is an industrial robot?

2. What are the salient features of industrial robot?

3. List out the applications of robotics in various fields.

4. Give some examples of robot programming languages.

5. How to select the robot according to application?

6. Give some examples of production operations where the robots are used for loading and unloading.

7. What is branching instructions?

8. What are Interlocks?

9. What is RCC?

PART-B

1.What are the possible robot applications in manufacturing industries?

2. What special feature of robot operations affect safety criteria for a robot cell?

3. Explain the robots used for welding, painting and assembling.

4. Explain any one of the robot based automated industry.

5. What is meant by tooling of robot? Illustrate with the help of sketches the functions of a few type of tooling commonly used in industrial robots.

6. Discuss about continuous arc welding robot.