# ROBOT APPLICATIONS IN MANUFACTURING

# INTRODUCTION

- Robots are used in a wide variety of industrial applications. The first commercial application of an industrial robot took place in 1961, when the robot was used to load and unload a die-casting machine.
- The robots were initially applied to the jobs that were hot, heavy, and hazardous, such as die-casting, forging, and spot welding.
- Reasons for implementing robots in engineering applications:
  - Improved productivity
  - Better quality
  - Reduced costs
  - Hazardous work environment for humans
  - Repetitive work cycle
  - Difficult handling for humans
  - Multi-shift operation

- Most of the applications of industrial robots are in manufacturing and these applications are usually classified as follows:

- Material transfer and machine loading/unloading:

- These are applications in which the robot grasps and moves a work part from one location to another. This category includes applications in which the robot transfers parts into and out of a production machine. Examples of these load/unload operations include metal-machining operations, die casting, plastic molding, and certain forging operations.

- Processing operations:

- These are operations in which the robot uses a tool as an end effector to accomplish some processing operation on a work part that is positioned for the robot during the work cycle. Spot welding, arc welding, spray painting, and certain machining operations fall into this application category.

- Assembly and inspection :

- Assembly and inspection are relatively new applications for robots. The robot is used to put components together into an assembly, or the robot is used to perform some form of automated inspection operation. More and more robots in the future will be equipped with vision capability to facilitate the performance of these operations.

# MATERIAL HANDLING APPLICATIONS

- Material handling applications are those in which the robots are used to move materials or parts from one place to another, load or unload a machine, or other similar operations.
- To accomplish the work, the robot is equipped with a gripper type end effector. The gripper must be designed to handle the specific part or parts that are to be moved into the application.
- There are other robot applications which involve parts handling. These include assembly operations and holding parts during inspection.
- When a robot is implemented in material handling applications, the following considerations must be reviewed:

Part positioning and orientation

- In most parts-handling applications the parts must be presented to the robot in a known position and orientation. Robots used in these applications do not generally possess highly sophisticated sensors that would enable them to seek out a part and identify its orientation before picking it up.

# MATERIAL HANDLING APPLICATIONS

Gripper design

- Special end effectors must be designed for the robot to grasp and hold the work part during the handling operation

Minimum distances moved

- The material-handling application should be planned so as to minimize the distances that the parts must be moved. This can be accomplished by proper design of the work cell layout, by proper gripper design, and by careful study of the robot motioncycle.

Robot work volume

- The cell layout must be designed with proper consideration given to the robot's capability to reach the required extreme locations in the cell and still allow room to maneuver the gripper.

Robot weight capacity

- There is an obvious limitation on the material handling operation that the load capacity of the robot must not be exceeded. A robot with sufficient weight carrying capacity must be specified for the application

Accuracy and repeatability

- Some applications require the materials to be handled with very high precision. Other applications are less demanding in this respect.

Robot configuration, degrees of freedom, and control

- Many parts transfer operations are simple enough that they can be accomplished by a robot with two to four joints of motion.
- Machine-loading applications often require more degrees of freedom. Robot control requirements are unsophisticated for most material-handling operations.
- Palletizing operations, and picking parts from a moving conveyor are examples where the control requirements are more demanding.

Machine utilization problems

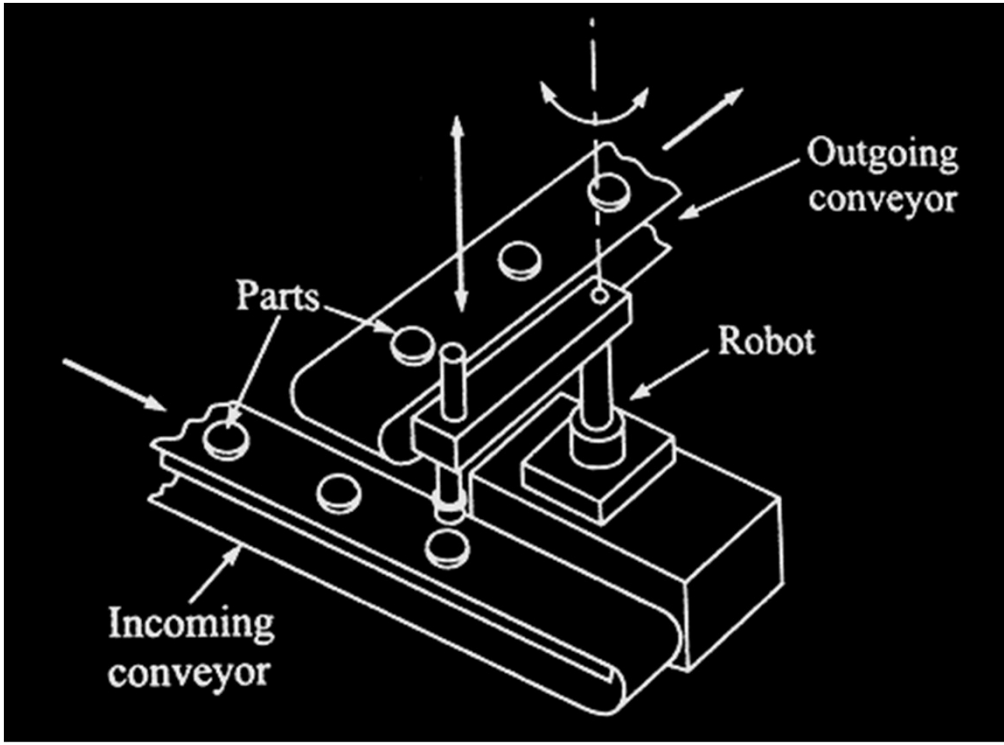
- It is important for the application to effectively utilize all pieces of equipment in the cell. In a machine loading/unloading operation, it is common for the robot to be idle while the machine is working, and the machine to be idle while the robot is working.
- In cases where a long machine cycle is involved, the robot is idle a high proportion of the time.
- To increase the utilization of the robot, consideration should be given to the possibility for the robot to service more than a single machine

- The material handling applications into two specific categories:
  - Material transfer applications
  - Machine loading/unloading applications

- Material transfer applications are ones in which the primary purpose of the robot is to move parts from one location to a new location.
- They are usually considered to be among the most straightforward of robot applications to implement.
- The applications usually require a relatively unsophisticated robot, and the interlocking requirements with other equipment are typically uncomplicated.
- These applications are sometimes called pick-and-place operations because the robot simply picks the part from one location and places it in another location.
- Some material transfer applications have motion patterns that change from cycle to cycle, thus requiring a more sophisticated robot. Palletizing and depalletizing operations are examples of this more complicated case. In this type of application, the robot must place each part in a different location on the pallet, thus forcing the robot to remember or compute a separate motion cycle until the pallet is fully loaded.

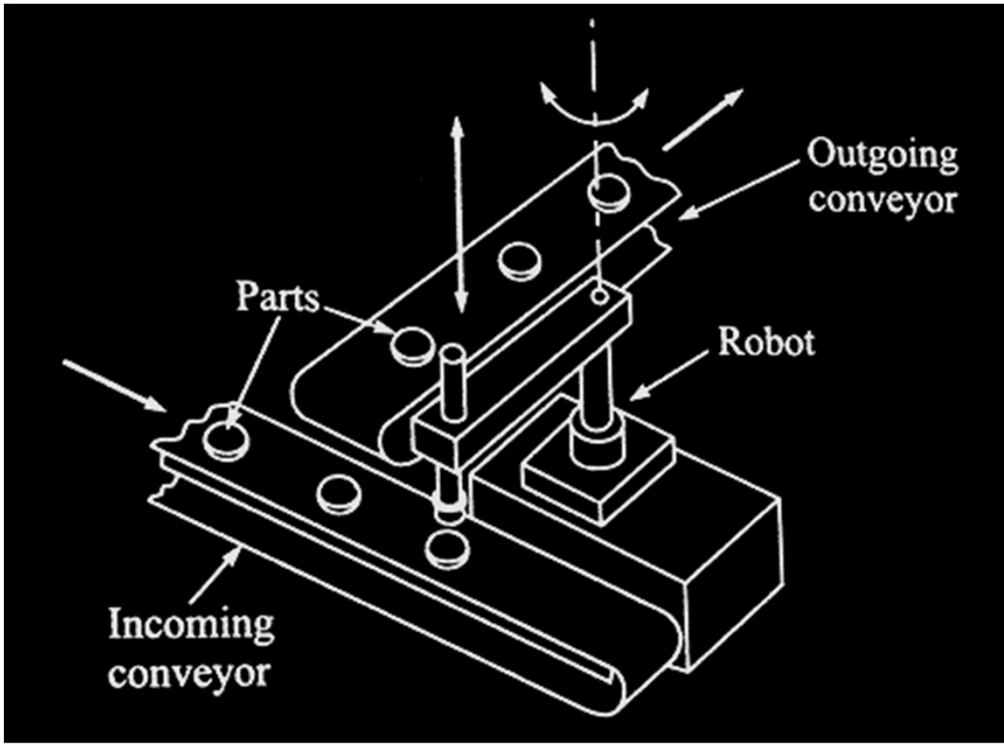
# PICK-AND-PLACE OPERATIONS

- In pick and-place operation, the robot picks up the part at one location and moves it to another location.
- It is a simple application and a low-technology robot is usually sufficient.
- The part is available to the robot by some mechanical feeding device or belt conveyor in a known location and orientation.
- The known location is a stationary location, achieved either by stopping the conveyor at the appropriate position, or by using a mechanical stop to hold the part at the stationary location.



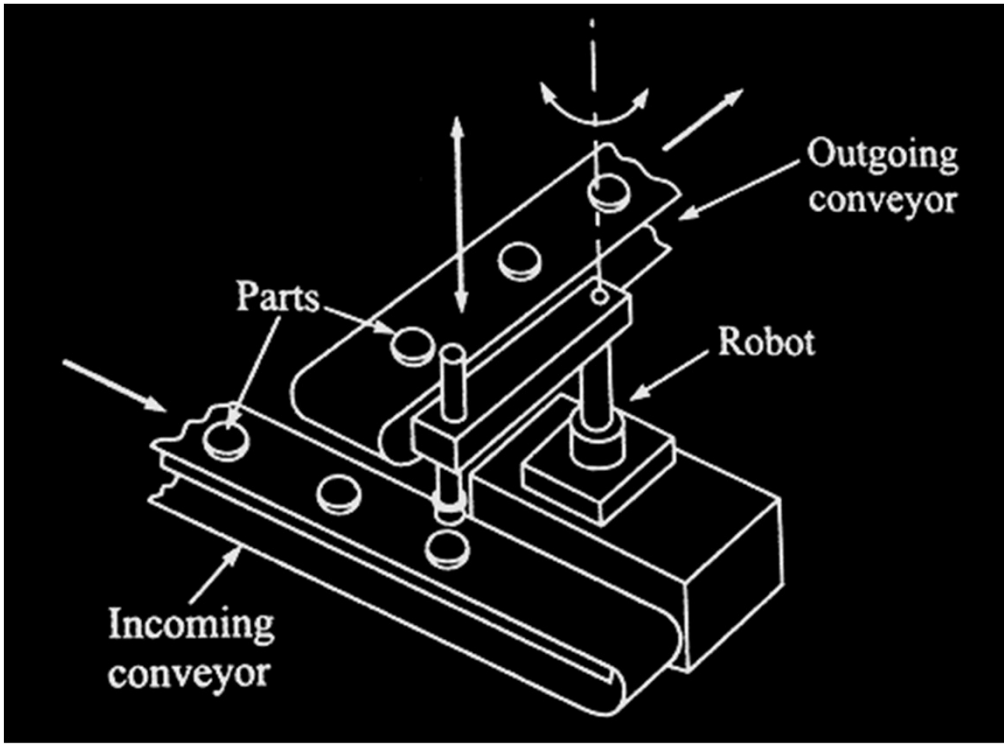
# PICK-AND-PLACE OPERATIONS

- An input interlock (commonly based on using a simple limit switch) would be designed to indicate that the part is in position and ready for pickup.
- Now, the robot grasps the part, picks it up, moves it, and positions it at a desired location. The orientation of the part remains same during the move.
- The desired location is usually at a position where there is the capability to move the part out of the way for the next delivery by the robot.
- The basic operation is shown in figure.



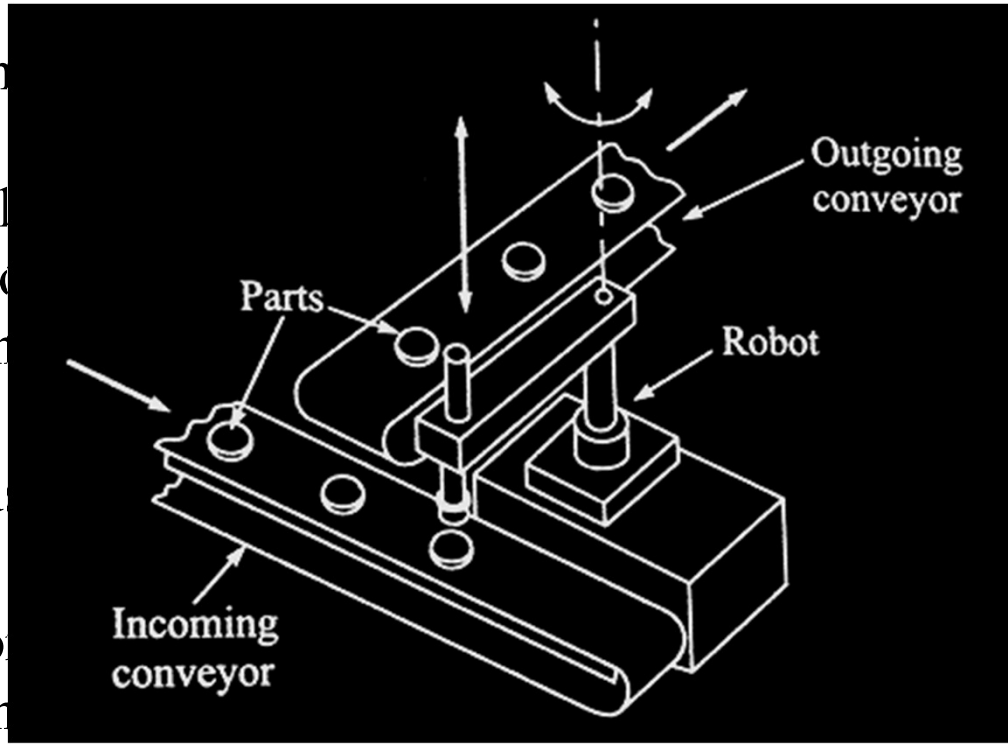
# PICK-AND-PLACE OPERATIONS

- In this simple case, the robot needs only 2 degrees of freedom. As shown in it down at the drop off point. The second degree of freedom is required to move the part between these two positions.
- In some pick-and-place operations, a reorientation of the work-part is accomplished during the move. This part reorientation requires a robot with one or more additional degrees of freedom.
- One complication encountered in material transfer operations is when the robot is required to track a moving pickup point.



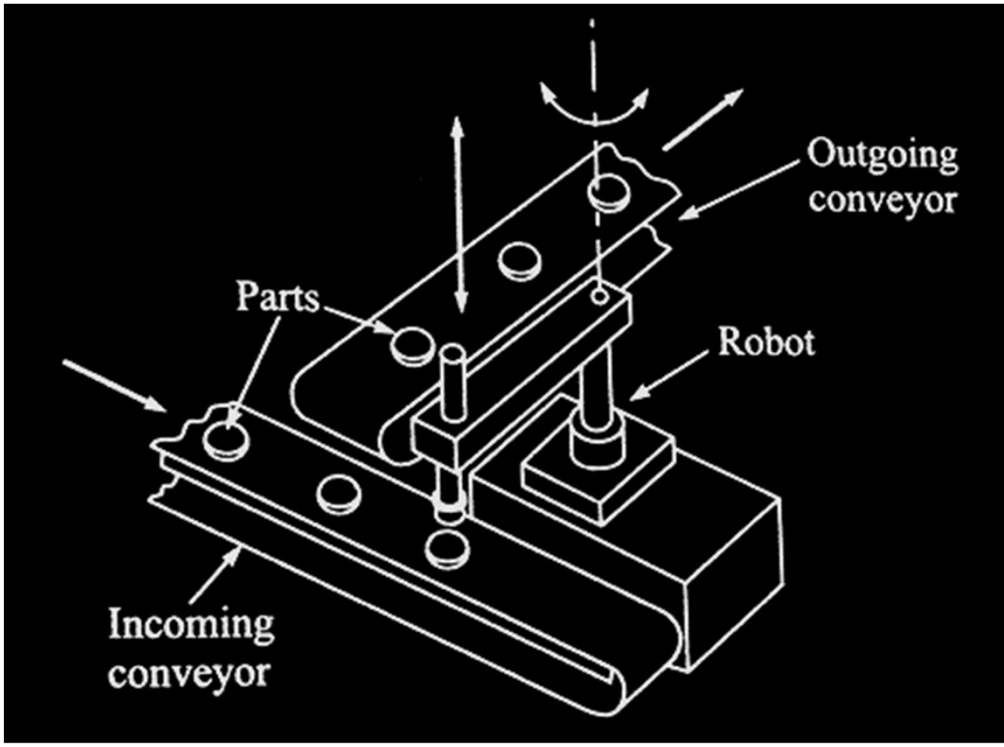
# PICK-AND-PLACE OPERATIONS

- In robotic materials handling, trackin arises when parts are carried along continuously moving conveyor, typicall an overhead hook conveyor, and the robo is required to pick part's from th conveyor.
- The opposite case is when the robot mu put parts onto the moving conveyor.
- In either case a more sophisticated senso interlock system is required to determin the presence and location of the parts in the robot's tracking window.



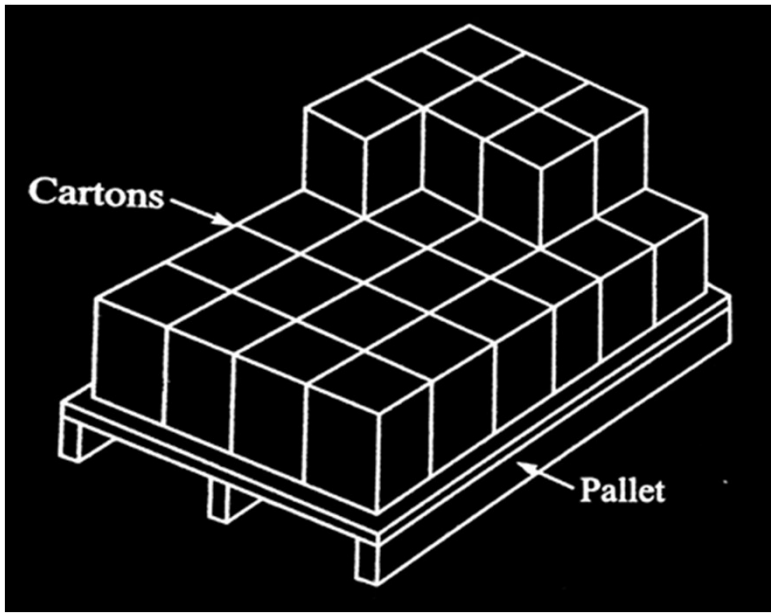
# PICK-AND-PLACE OPERATIONS

- Another complication arises in material transfer operations when different objects are being handled by the same robot.
- In material transfer, a single conveyor might be used to move more than one type of part.
- The robot must be interfaced to some type of sensor system capable of distinguishing between the different parts so that the robot can execute the right program subroutine for the particular part



# Palletizing and Related Operations

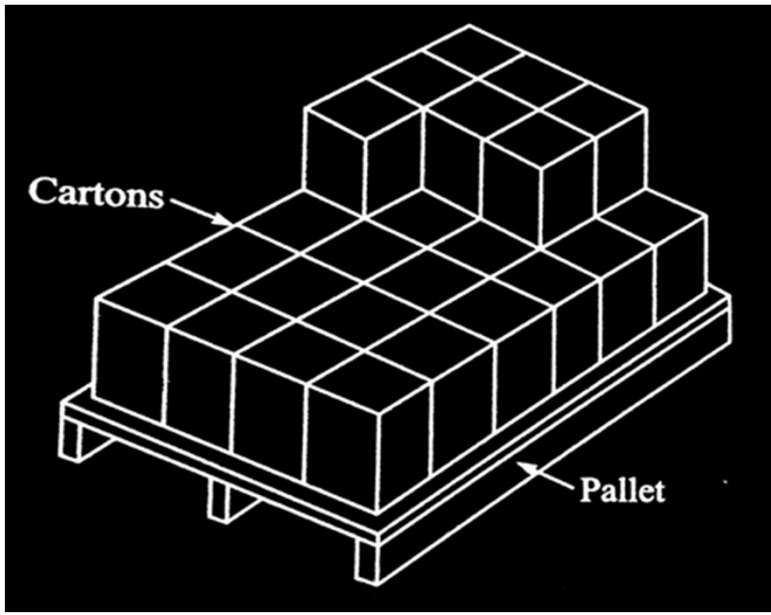
- The use of pallets for materials handling and storage in industry is widespread.
- Instead of handling individual cartons or other containers, a large number of these containers are placed on a pallet, and the pallet is then handled.
- The pallets can be moved mechanically within the plant or warehouse by fork lift trucks or conveyors.




- Shipments of palletized product to the customer are very common because of the convenience in handling, both at the manufacturer's warehouse and the customer's receiving department.

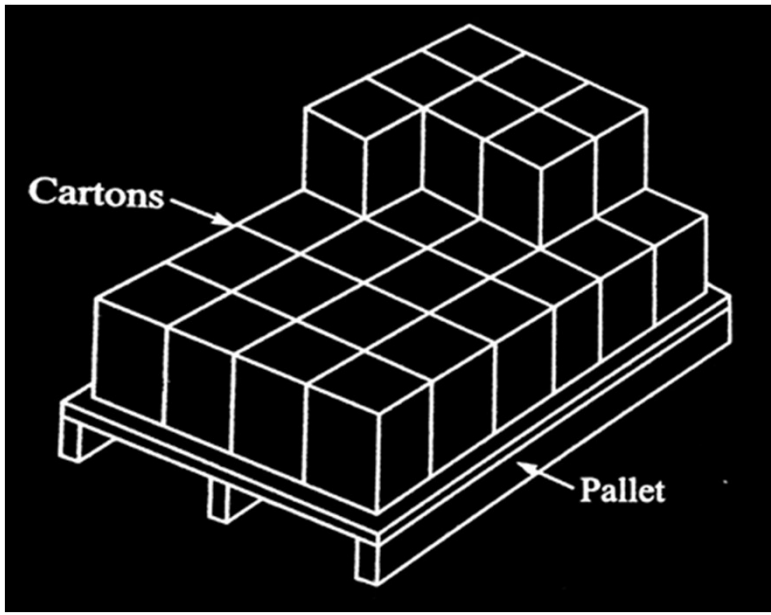
# Palletizing and Related Operations

- The only handling of the individual cartons arises when the product is placed onto the pallet (palletizing) or when it is removed from the pallet (depalletizing).
- The loading of cartons onto pallets is typically heavy work, performed manually by unskilled labor. It is also repetitive work (picking cartons up at one location and putting them down at another location)
- A typical pallet configuration is illustrated in the fig. showing how each container must be placed at a different location on the pallet.



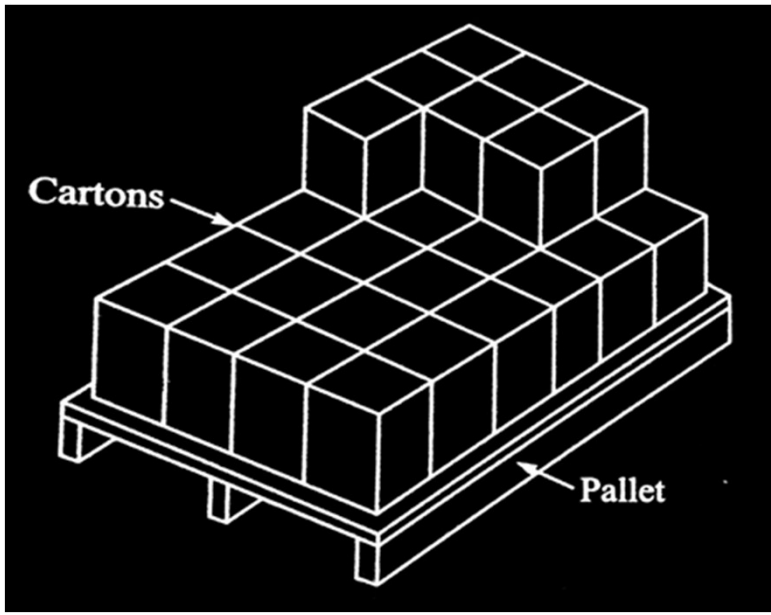

- The variation in carton location is in three dimensions, not simply two dimensions, since the pallets are usually stacked on top of each other in layers.

# Palletizing and Related Operations




- Robots can be programmed to perform this type of work. Because the motion pattern varies in the palletizing operation, a computer-controlled robot using a high-level programming language is convenient.
- This feature facilitates the mathematical computation of the different pallet locations required during the loading of a given pallet.
- A less sophisticated robot limited to lead-through programming can also be used, but the programming becomes laborious because each individual carton location on the pallet must be individually taught.
- Another technical problem that must be addressed is that when humans perform palettizing, the cartoons are often randomly located prior to loading.

# Palletizing and Related Operations




- Unless some sensor scheme is used to identify these carton locations, they must be delivered to a known pick up point for the robot.
- There are a number of variations on the palletizing operation, all of which use a similar work cycle and a robot with the same general features needed for the generic case. These other operations include:
- Depalletizing operations, the reverse of palletizing, in which the robot removes cartons from a pallet and places them onto a conveyor or other location.
- Inserting parts into cartons from a conveyor. This is similar to palletizing.
- Removing parts from cartons. This is the reverse of the preceding situation.
- Stacking and unstacking operations, in which objects are stacked on top of other

# Palletizing and Related Operations

- In palletizing and related operations, the robot may be called on to load different pallets differently. Reasons for these differences may include the following:
  - pallets may vary in size;
  - different products may be loaded onto the pallets;
  - and there may be differences in the numbers and combinations of cartons going to different customers.
- To deal with these variations, methods of identifying the cartons and/or pallets and the way in which they are to be loaded or unloaded must be devised.
- Bar codes and other optical schemes are sometimes are used to solve the identification problem.
- Differences in the loading or unloading of the pallets must be accomplished by means of program subroutines which can be called by the work cell controller.

# Palletizing and Related Operations

- For depalletizing operations, the optical reader system would identify the pallet and the appropriate unloading subroutine would then be applied for that pallet.
- For palletizing operations, the systems problems can become more complicated because there may be an infinite number of different situations can arise.
- As an example if the robot were used to palletize cartons for different customer orders, it is conceivable that each customer order would be different.
- A method would have to be devised were used to palletize cartons for different customer orders, it is conceivable that each customer order would be different.
- A method would have to be devised for delivering the correct combination of cartons to the palletizing workstation, and integrating that process with the robot loading procedure.

MATERIAL TRANSFER APPLICATION

# PICK & PLACE ROBOT ARMS

## AT METALEX 2011

BANGKOK, THAILAND
DECEMBER 24, 2011

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# MACHINE LOADING AND UNLOADING

- In machine loading and/or unloading applications, the robot transfers parts into and/or from a production machine. The three possible cases are:
  - Machine loading: This is the case in which the robot loads parts into the production machine, but the parts are unloaded from the machine by some other means. In a press working operation, the robot may be programmed to load sheet metal blanks in to the press , but the finished parts are allowed to drop out of the press by gravity.
  - Machine unloading: In this case, the raw materials are fed into the machine without using the robot, and the robot unloads the finished parts. machine. Examples in this category include die casting and plastic modeling applications.
  - Machine loading and unloading: This case involves both loading of the raw work-part into the process and unloading of the finished part by the robot. A machning operation is an example of this case

## MACHINE LOADING AND UNLOADING APPLICATIONS

- Industrial robot applications of machine loading and/or unloading include the following processes:

- **Die casting:**

- A typical die-casting production cycle consists of casting, removing the part from the machine, quenching, and trimming.
- The robot unloads parts from the die casting machine. Peripheral operations sometimes performed by the robot include dipping the parts into a water bath for cooling.
- The production rates in the die casting processes range from 100 to 700 openings of the die per hour, depending on type of machine, the metal being cast, and the design of the part.
- For small parts, the die can be designed with more than one cavity, thus multiplying the number of parts made for each casting cycle.
- The die-casting machines have traditionally been tended by human operators. The work tends to be hot, repetitive, dirty, and generally unpleasant for humans.

## MACHINE LOADING AND UNLOADING APPLICATIONS

- The die-casting process represents a relatively straightforward application for industrial robots.
- The alterations required of the die-casting machine are minimal, and the interlocking of the robot cycle with the machine cycle can be accomplished by simple limit switches.
- Few problems are encountered in either the programming of the robot or the design of the gripper to remove the part from the machine when the die is opened. The process requires only that the robot unload the die-casting machine, since the metal is in the molten state before the part is formed.
- On some die-casting machines (called cold-chamber die-casting machines), the molten metal must be ladled from the melting container into the injection system. This part of the process is more difficult for robots to accomplish.

## MACHINE LOADING AND UNLOADING APPLICATIONS

- **Plastic moulding:**

- Plastic moulding is a batch-volume or high-volume manufacturing process used to make plastic parts to final shape and size.
- The term plastic moulding covers a number of processes, including compression moulding, injection moulding, thermoforming, blow moulding, and extrusion.
- Injection moulding is the most important commercially, and is the process in this group for which robots are most often used.
- Traditionally, injection-moulding machines have been operated on a semi-automatic cycle, with human operators used to remove the parts from the mould.
- Industrial robots are sometimes employed to unload injection-moulding machines
- It is a robot application similar to die casting. The robot is used to unload moulded parts from the injection moulding machine.

## MACHINE LOADING AND UNLOADING APPLICATIONS

- **Forging:**
  - Forging is a metal shaping process that uses force to compress and align the metal's internal structure.
  - It is one of the oldest processes and derived from the kinds of metalworking operations performed by blacksmiths in ancient times.
  - The robot is typically used to load the raw hot billet into the die, hold it during the forging blows, and remove it from the forge hammer.
- **Machining operations:**
  - Machining is a metal removal process in which the shape of the part is changed by removing excess material with a cutting tool.
  - Machining operations include turning, drilling, milling, shaping, planeing, and grinding.
  - The robot is used to load raw work-parts into the machine tool and unload finished parts from the machine.

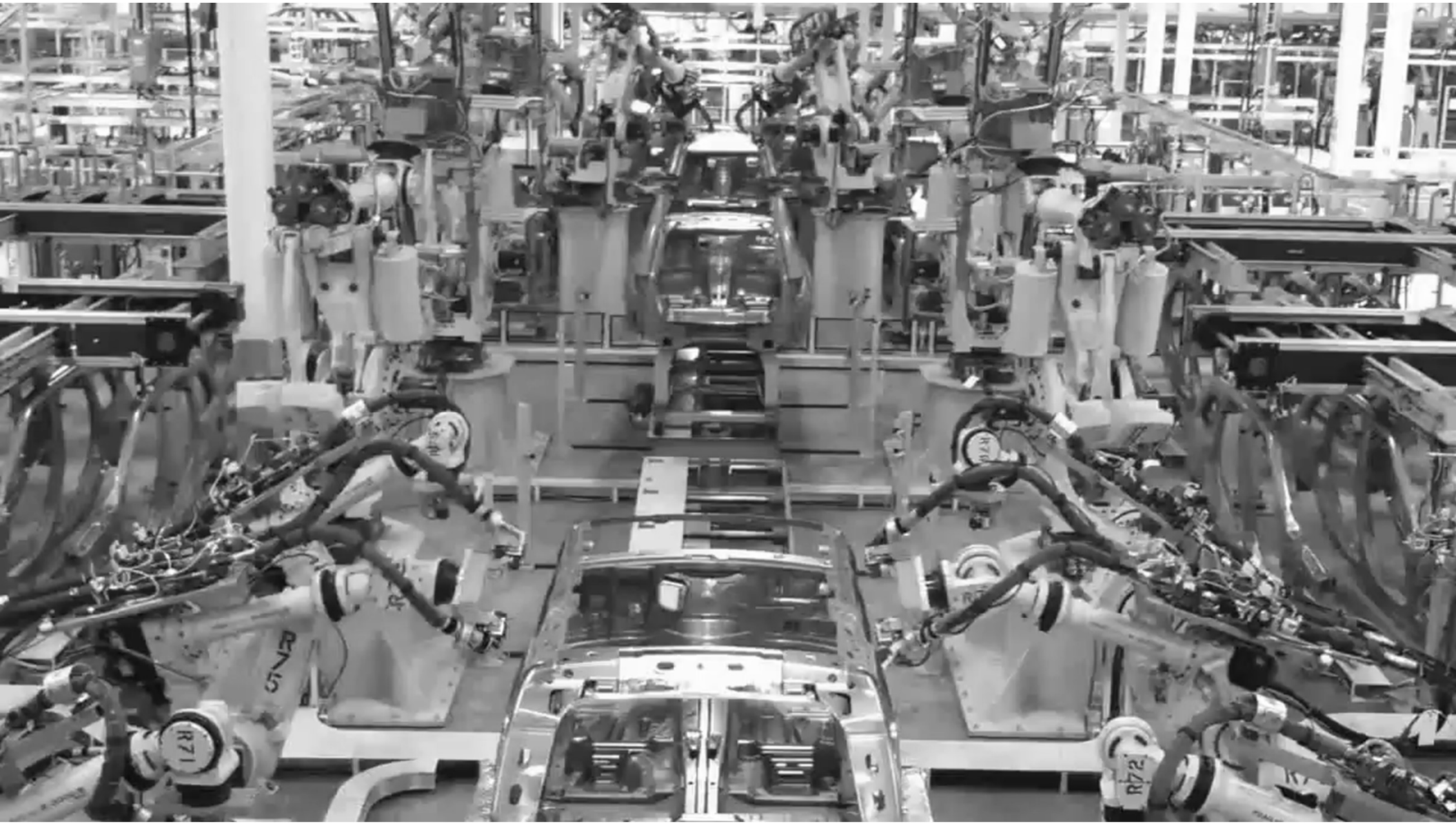
MACHINE LOADING AND UNLOADING APPLICATIONS

- **Stamping press operations:**
  - Stamping press operations are used to cut and form sheet metal parts.
  - The process is performed by means of a die set held in a machine tool called a press (or stamping press).
  - Human operators work at considerable risk in sheet metal press working operations because of the action of the press.
  - Robots are used as substitutes for the human workers to reduce the danger.
  - In these applications, the robot loads the blank into the press, the stamping operation is performed, and the part falls out the back of the machine into a container.


Die Cast
Loading/unloading
www.motoman.com


Injection Moulding Application


YouTube/CGTN


R75
R71
R72


RAS

## Processing Operations

- In addition to parts-handling applications, there is a large class of applications, in which the robot actually performs work on the part.
- This work almost always requires that the robot's end effector is a tool rather than a gripper. Accordingly, the use of a tool to perform work is a distinguishing characteristic of this group of applications.
- The type of tool depends on the processing operation that is performed.
- The processing operations that are performed by a robot are divided into the following categories :
  - 1. Spot welding
  - 2. Arc-welding
  - 3. Spray coating
  - 4. Other processing operations

## Processing Operations

- Spot welding
  - As the term suggests, spot welding is a process in which two sheet metal parts are fused together at localized points by passing a large electric current through the parts where the weld is to be made.
  - The fusion is accomplished at relatively low voltage levels by using two copper (or copper alloy) electrodes to squeeze the parts together at the contact points and apply the current to the weld area. The electric current results in sufficient heat in the contact area to fuse the two metal parts and hence producing the weld.
  - The two electrodes have the general shape of a pincer. With the two halves of the pincer open, the electrodes are positioned at the point where the parts are to be fused.
  - The two electrodes are squeezed together against the mating parts, and the current is applied to cause heating and welding of the contacting surfaces.
  - Then the electrodes are opened and allowed to cool for the next weld.
  - A water circulation system is often used to accelerate the cooling of the electrodes.

## Processing Operations

- Spot welding

- The actual welding portion of the sequence typically requires less than a second. Therefore, the rates of production in spot welding are largely dependent on the time required for positioning of the welding electrodes and the parts relative to each other.
- Another factor that affects production rate is the wear of the electrodes. Because of the heat involved in the process, the tips of the electrodes gradually lose their shape and build up a carbon deposit which affects their electric resistance.
- Both of these effects reduce the quality of the welds made. Therefore, the electrode tips must periodically be dressed to remove the deposits and restore the desired shape.
- The process involves manipulating a portable spot-welding gun into Position relative to the parts. This would be used for larger work such as automobile bodies.
- The welding gun consists of the pair of electrodes and a frame to open and close the electrodes. In addition, large electrical cables are used to deliver the current to the electrodes from a control panel located near the workstation.

## Processing Operations

- Spot welding

- The welding gun with cables attached is quite heavy and can easily exceed 100 lb in weight. To assist the operator in manipulating the gun, the apparatus is suspended from an overhead hoist system. Even with this assistance, the gun represents a heavy mass and is difficult to manipulate by a human worker at the high rates of production desired on a car body assembly line.
- There are often problems with the consistency of the welded products made on such a manual lines as a consequence of this difficulty.
- As a result of these difficulties, robots have been employed with great success on this type of production line to perform some or all of the spot-welding operations.
- A welding gun is attached as the end effector to each robot's wrist, and the robot is programmed to perform a sequence of welds on the product as it arrives at the workstation.
- Some robot spot-welding lines operate with several dozen robots all programmed to perform different welding cycles on the product.

## Processing Operations

- Spot welding

- The robots used in spot welding must possess certain capabilities and features to perform the process.
- First the robot must be relatively large. It must have sufficient payload capacity to readily manipulate the welding gun for the application.
- The work volume must be adequate for the size of the product.
- The robot must be able to position and orient the welding gun in places on the product that might be difficult to access. This might result in the need for an increased number of degrees of freedom.
- The controller memory must have enough capacity to accomplish the many positioning steps required for the spot-welding cycle.
- In some applications, the welding line is designed to produce several different models of the product. Accordingly, the robot must be able to switch from one programmed welding sequence to another as the models change.

## Processing Operations

- Spot welding

➢ For welding lines in which there are multiple robots, programmable controllers are used to keep track of the different models at the various welding stations and to download the programs to the robots at individual workstations as needed.

➢ The benefits that results from automation of the spot welding process by means of robots are improved product quality, operator safety, and better control over the production operation.

## Processing Operations

- ARC WELDING

- Arc welding is a continuous welding process as opposed to spot welding which might be called a discontinuous process.
- Continuous arc welding is used to make long welded joints in which an airtight seal is often required between the two pieces of metal which are being joined.
- The process uses an electrode in the form of a rod or wire of metal to supply the high electric current needed for establishing the arc. Currents are typically 100 to 300 A at voltages of 10 to 30 V.
- The arc between the welding rod and the metal parts to be joined produces temperatures that are sufficiently high to form a fool of molten metal to fuse the two pieces together.
- The electrode can also be used to contribute to the molten pool, depending on the type of welding process.
- Arc welding is usually performed by a skilled human worker who is often assisted by a fitter who organize the work and to fixture the parts for the welder.

## Processing Operations

- ARC WELDING

- The working conditions of the welder are typically unpleasant and hazardous. The arc from the welding process emits ultraviolet radiation which is injurious to human vision. As a result, welders are required to wear eye protection in the form of a welding helmet with a dark window. This dark window filters out the dangerous radiation, but it is so dark that the welder is virtually blind while wearing the helmet except when the arc is struck.
- Other aspects of the process are also hazardous. The high temperatures created in arc welding and the resulting molten metals are inherently dangerous. The high electrical current used to create the arc is also unsafe. Sparks and smoke are generated during the process and these are a potential threat to the operator.
- Because of the hazards for human workers in continuous arc welding, it is logical to consider industrial robots for the process. However, there are significant technical and and economic problems encountered in applying robots to arc welding.
- Continuous arc welding is commonly used in the fabrication industries where products consisting many components are made in low quantities.

- ARC WELDING

- It is difficult to justify automation of any form in these circumstances. A related problem is that arc welding is often performed in confined areas that are difficult to access, such as the insides of tanks, pressure vessels, and ship hulls. Humans can position themselves into these areas more readily than robots.
- Because of the technical and economic problems discussed above, the typical arc-welding application for a robot is one in which the quantities of production are medium or high.
- In these cases, a robot cell can be justified which consists of a welding robot and a part holder or part manipulator. The part holder is used to fixture the components and position them for welding welding. A part manipulator provides an additional capability in the form of 1 or 2 degrees of freedom to position and orient the components relative to the robot.
- The robot is equipped with a welding rod or wire-feed system, and the required power source to provide the electric current for the operation.
- The workcell controller is used to coordinate the robot motion, the welding current, the wire feed, the part manipulator, and any other activities in the cell.

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- ARC WELDING

➢ A human operator is typically used to load and unload the part fixtures. Two part fixtures are often used in the cell. In this way, the robot can perform its welding cycle while the operator is unloading the previously welded assembly and loading the components into the holder for the next cycle. This arrangement permits higher utilization of the robot and greater productivity of the cell.



- Robots in Spray Coating

➢The spray-coating methods, when accomplished manually, result in many health hazards to the human operators. These hazards include:

➢Fumes and mist in the air: These result naturally from the spraying operation. Not all of the paint droplets become attached to the surface of the object. Some remain suspended in the atmosphere of the spray painting booth. To protect the human operators, ventilation systems must be installed in the booth and protective clothing and breathing masks must be worn. Even with this protection, the environment is uncomfortable and sometimes toxic for humans.

➢Noise from the nozzle: The spray gun nozzle produces a loud shrill noise. Prolonged exposure by humans can result in hearing impairments.

➢Fire hazards: Flammable paint, atomised into fine mist and mixed with air can result in flash fires in the spray painting booths

➢Potential cancer hazards: Certain of the ingredients used in modern paints are believed to be carcinogenic, with potentially unsafe health consequences to humans.

## Robots in Spray Coating

- Because of hazards nature of spray coating processes, the use of industrial robots has developed as an alternative means of performing spray-coating operations.
- Spray-coating operations to which robots have been applied include painting of car bodies, engines, and other components in the automotive industry, spraying of paint and sound absorbing coating on appliances, application of porcelain coating in bathroom fittings and spray staining of wood products.
- Some of the applications have consisted of a stand-alone robot spraying a stationary work-part that has been positioned in a paint booth by a human worker.
- However, these applications are generally less successful because they rely heavily on the human worker and the utilization of the robot is relatively low.
- In most robot spray-coating applications, the robots are usually part of a system that includes a conveyor for presenting the parts to the robot, and a spray booth for shielding the spraying operation from the factory environment.
- When a conveyor-robot system is used, the operation of the robot and the conveyor must be closely synchronized.

- Robots in Spray Coating
- In the case of an intermittent conveyor system, interlocks are used to coordinate the start and finish of the robot program with the movement of the conveyor . With a continuously moving conveyor, some form of baseline tracking system is required in order to synchronize the robot's motions with the movement of the conveyor.
- Another feature of many robot spray-coating applications is that the system must be designed to process a variety of part styles, each with its own unique configuration. This is usually accomplished by providing the workcell with parts identification system. Once the part has been properly identified, the robot can then apply the correct spray cycle for that part.
- Use of robots to perform spray-finishing operations provide the following advantages:
  - Removal of operators from hazardous environment
  - Lower energy consumption
  - Consistency of finish
  - Reduced coating material usage
  - Greater productivity

- OTHER PROCESSING OPERATIONS USING ROBOTS
- In addition to spot welding, arc welding, and spray coating, there are a number of other robot applications which utilize some form of specialized tool as the end effector.
- Operations which are in this category include:
  - Drilling, routing, and other machining operations
  - Grinding, polishing, deburring, wire brushing, and similar operations
  - Riveting
  - Waterjet cutting
  - Laser drilling and cutting
- This category excludes the applications in assembly, inspection, and non-manufacturing operations which might employ a tool as end effector.
- From the preceding list, it can be seen that a typical end effector in this category is a powered spindle attached to the robot's wrist.

- OTHER PROCESSING OPERATIONS USING ROBOTS
- The spindle is used to rotate a tool such as a drill or grinding wheel. The purpose of the robot is to position the rotating tool against a stationary work part in order to accomplish the desired processing operation.
- In the other examples given in the above list (riveting, waterjet cutting, and laser operations), the end effector is not a powered spindle, but the job of the robot is still to position the tool relative to the part.
- Requirements of these applications vary, but one of the inherent disadvantages of robots in some of these operations is their relative lack of accuracy as compared to a regular machine tool.
- Small robots tend to be more accurate than large robots, but large robots are more likely to possess the strength and rigidity necessary to withstand the forces involved to hold the powered spindle against the part during the process.

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# ASSEMBLY AND INSPECTION

## Assembly

- The assembly system is a combination of a robot, a transfer device and part feeders.
- One approach in designing assembly systems is that the assembled object is moving on a straight line indexing or rotary indexing table and in each station a robot is adding one part to the assembled object.
- This configuration requires many simple robots along the assembly line, each performing a particular operation.
- The advantage of this system is the small cycle time per product.

## Inspection

- The robots perform loading and unloading tasks to support an inspection or testing machine.
- This case is really machine loading and unloading, where the machine is an inspection machine. The robot picks parts that enter the cell, loads and unloads them to carry out the inspection process.
- In some cases, the inspection may result in parts sortation that must be accomplished by the robot.
- The robot manipulates an inspection device, such as a mechanical probe, to test the product. This case is similar to a processing operation in which the end effector attached to the robot wrist is the inspection probe.