

Chapter 11

Robot Environment



This chapter will illustrate robot environments, exemplified by product assembly processes where robots are a part of a production line or as completely independent units. The example can be easily replicated also to other tasks, such as product inspection and testing, welding, painting, pick and place operations etc.

As a matter of fact, robots represent an ideal solution for many industrial safety and health problems, mainly because they are capable of performing hard and fatiguing tasks in a dangerous environment. Welding and painting robots enable human workers to avoid toxic fumes and vapors. Robots also load power presses, which were frequent causes of injuries to workers in the past. Robots work in foundries and radioactive environments. With the increasing number of robots in industrial processes, there is, however, an increased danger introduced by the robots themselves. Thus, considering safety is of utmost importance when designing a robotic working cell.

11.1 Robot Safety

Industrial robots are strong devices which move quickly in their workspace. An accident in most cases occurs only when a human worker enters the robot workspace. A person steps into the robot vicinity either accidentally or even without knowing or with the aim of robot reprogramming or maintenance. It is often difficult for a human operator to judge what will be the robot's next move. Particularly dangerous are the unexpected robot motions, which are the consequence either of a robot failure or of a programming error. Many governmental organizations and large companies, together with robot producers, have developed safety standards. The approaches assuring safe cooperation of human workers and industrial robots can be divided into three major groups: (1) robot safety features, (2) robot workspace safeguards, and (3) personnel training and supervision.

Today's robots have safety features to a large extent already built-in for all three modes of operation: normal work, programming and maintenance. Fault avoidance features increase robot reliability and safety. Such a feature, for example, prevents the robot from reaching into the press before it is open. The safety features built into the robot control unit usually enable synchronization between the robot and other machines in the robot environment. Checking the signals, indicating when a device is ready to take an active part in the robot cell, must be part of safe robot programming. The use of reliable sensors plays an important role when checking the status of machines in the robot working area. Important safety features of any robot system are also software and electric stops.

When programming or teaching a robot, the human operator must be in the robot working area. In the programming phase the velocity of the robot motions must be considerably lower than during normal work. The speed of the robot must be reduced to such a value that the human operator can avoid unexpected robot motions. The recommended maximal velocity of the robot, when there is a human worker inside the workspace, is 0.25 m/s.

The teach pendant unit can be a critical component in safe robot operation. Programming errors during teaching of a robot often cause unexpected robot motions. The design of a teach pendant unit can have a significant impact on safe operation. The use of joystick control was found safer than the use of control push-buttons. The size of emergency pushbuttons also has an important influence on the human operator's reaction times.

Special safety features facilitate safe robot maintenance. Such a feature is, for example, the possibility of switching on the control system, while the robot arm is not powered. Another feature enables passive manual motion of the robot segments, while the robot actuators are switched off. Some robot features cause the robot to stop as soon as possible, while some allow the control system to execute the current command and stop afterwards.

Most robot accidents occur when persons intentionally or carelessly enter the robot working area. The robot workspace safeguards prevent such entrance into the robot cell. There are three major approaches to the robot workspace protection: (1) barriers and fences, (2) presence sensing, and (3) warning signs, signals and lights.

Most commonly metal barriers or fences are used to prevent unauthorized workers from entering the robot working area. The color of the fence plays an important role, efficiently warning non-informed personnel. The fences are also an adequate protection against various vehicles that are used for transporting materials in the production hall. Safe opening of the gates, which enable entrance into the fenced-off area, must also be provided. A human operator can only enter after switching-off the robot system using a control panel outside the barriers. Well-designed safeguarding barriers may also protect bystanders from objects flying out from the robot's grasp.

Important safeguarding is provided by the devices detecting the presence of a person in the robot working area. These can be pressure-sensitive floor mats, light curtains, end-effector sensors, various ultrasound, capacitive, infrared or microwave sensors inside the robot cell and computer vision. Instrumented floor mats or light curtains can detect the entrance of a person into the robot working area. In such a

case a warning signal is triggered and normal robot working can be stopped. The end-effector sensors detect the unexpected collisions with objects in the robot environment and cause an emergency stop. Contactless sensors and computer vision detect various intrusions into the robot working area.

Warning signs, signals and lights can to a large extent increase the safe operation of robot cells. These warning signs alert the operators to the presence of a hazardous situation. Instruction manuals and proper training are also important for effective use of warning signs. Such signs are more effective with people who unintentionally enter the robot working area, than with operators who are familiar with the operation of the robot cell. Experienced operators often neglect the warnings and intentionally enter the robot workspace without switching off the robot aiming to save some small amount of time. Such moves are often causes of accidents. False alarms may also reduce the effectiveness of warnings.

Selection of qualified workers, safety training and proper supervision are the prerequisites for safe working with robots. Especially critical moments are startup and shutdown of a robot cell. Similarly, maintenance and programming of robots can be dangerous. Some robot applications (e.g. welding) include specific dangerous situations which must be well known to the workers. Those employed in the robot environment must satisfy both physical and mental requirements for their job. The selection of appropriate workers is an important first step. The second step, which is equally important, is extensive safety training. Satisfactory safety is only achieved with constant supervision of the employees. Additional training is an important component of the application of industrial robots. In the training courses the workers must be acquainted with the possible hazards and their severity. They must learn how to identify and avoid hazardous situations. Common mistakes that are causes of accidents should be explained in detail. Such training courses are usually prepared with the help of robot manufacturers.

It is expected that future robots will not work behind safety guards with locked doors or light barriers. Instead they will be working in close cooperation with humans which leads to the fundamental concern of how to ensure a safe human-robot physical interaction. The major progress is expected in the design of lightweight flexible robot segments, compliant joints, novel actuators and advanced control algorithms.

The robot installation can be as an individual robot cell or as a part of a larger industrial production line. Industrial robots are position controlled and often without sensors for sensing their surroundings. For this reason the robots must be isolated from human environment in case of improper activity of the robot or its peripheral parts, to prevent human injuries or collisions with other equipment in the robot working cell. The safety risk for each individual robot cell needs to be defined so that appropriate precautions can be taken. Improper robot behavior can be the result of robot system fault or human error, such as:

- unpredictable robot behavior because of a fault in the control system,
- cable connection fault because of robot movement,
- data transfer error producing unpredictable robot movement,
- robot tool fault, e.g. welding gun,

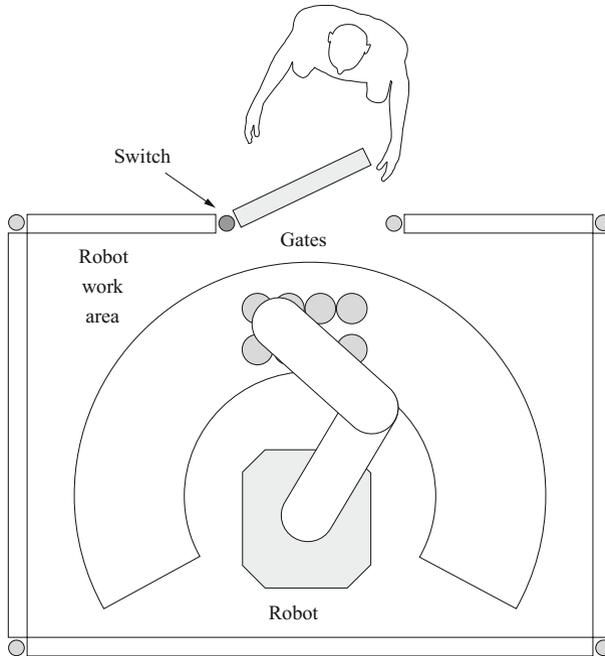


Fig. 11.1 Level 1: mechanical robot cell protection

- software errors,
- worn out robot mechanical components.

The potential dangers of system faults arising from these errors can be divided into three categories:

- **Risk of collision** is the possibility that the moving robot or the tool attached to the robot hits the operator.
- **Danger of pinching** is a situation where the robot, during the movement near the objects in the robot cell (e.g. transport mechanisms), squeezes the operator.
- **Other hazards** that are specific to each robot application, such as the risk of electrical shock, impact of welding arc, burns, toxic substances, radiation, excessive sound levels.

For all these reasons the robot safety demands can be split in three levels.

Level 1 is the level of protection of the entire robot cell. It is usually achieved with physical protection using a combination of mechanical fences, railings and gates (Fig. 11.1). Alongside physical protection also a human presence sensor (e.g. laser curtains) can be installed.

Level 2 includes a level of protection while an operator is in the working area of the robot. Normally, protection is performed by presence sensors. In contrast to the previous level, which is based mainly on mechanical protection, level 2 is based on the perception of the operators presence (Fig. 11.2).

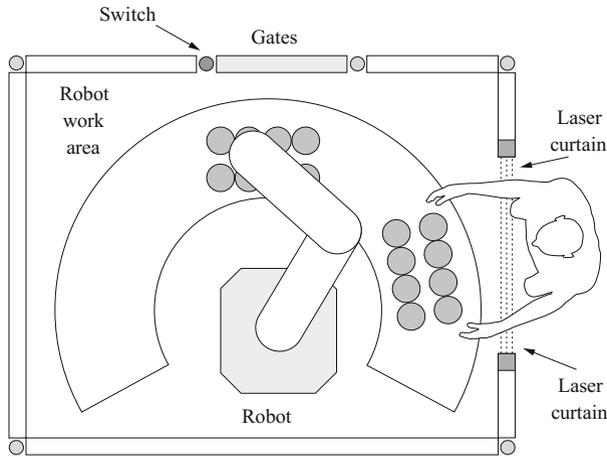


Fig. 11.2 Level 2: opto-electrical robot cell protection

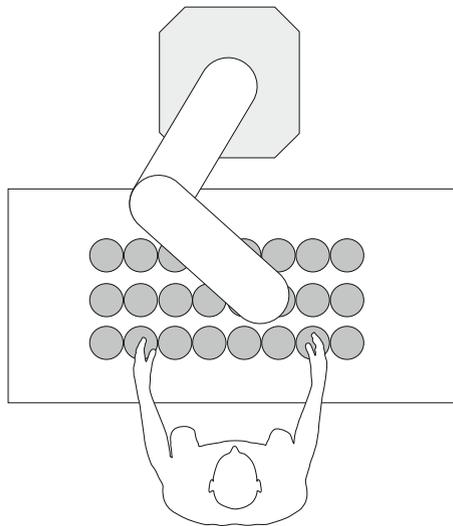


Fig. 11.3 Level 3: collaboration of human and the robot

Level 3 is the level of protection where people are in contact with the robot referred to as collaborative robots. Security at this level is carried out by detecting the presence of a human or obstacles nearby the robot or when the robot and the human are in collaboration (Fig. 11.3). In risk situations the robot system must slow down or stop. These systems incorporate sensors for human tracking, various force and torque sensors and contact or touch sensors. Collaborative robots are described in more details in Chap. 12.

11.2 Robot Peripherals in Assembly Processes

The robot systems installed in industry are usually a part of larger dedicated production lines. The production lines are used for high-volume production of parts where multiple processing operations are necessary. The production line is split in workstations where human workers, dedicated machines or robots perform necessary tasks. Other peripherals can also be incorporated to increase the production line capabilities. The properly selected peripherals also increase system reliability, flexibility and efficiency.

11.2.1 Assembly Production Line Configurations

Assembly production lines in industry consist of conveyor belts, pallets traveling with conveyor belts, vision systems, pneumatic cylinders, different sensors and robots or manipulators. The pallets provide the mean to index, locate and track individual manufactured parts traveling through the automation process. The robots provide flexibility and can be integrated into any of the production line configurations. The most usual assembly production line configurations with robot assistance are:

- In-line (direct, L-shaped, U-shaped, circular, rectangular),
- Rotary,
- Hybrid.

In Fig. 11.4 an example of a circular in-line production line is presented. Line workstations are served by humans, dedicated machines and robots.

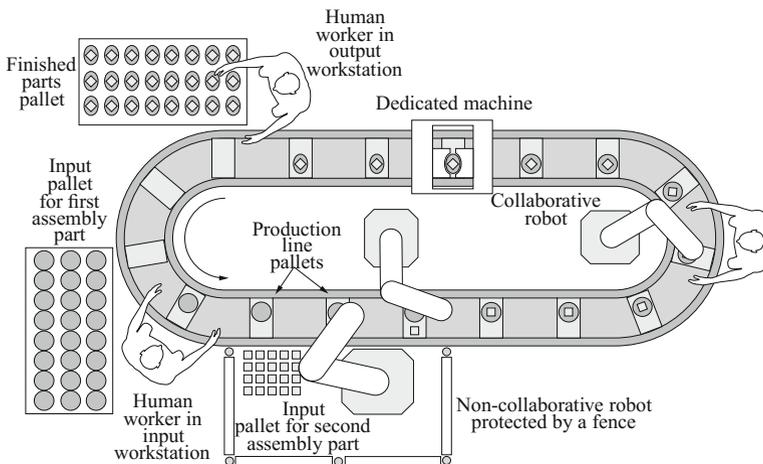


Fig. 11.4 Example of circular in-line assembly production line with human, machine and robot workstations

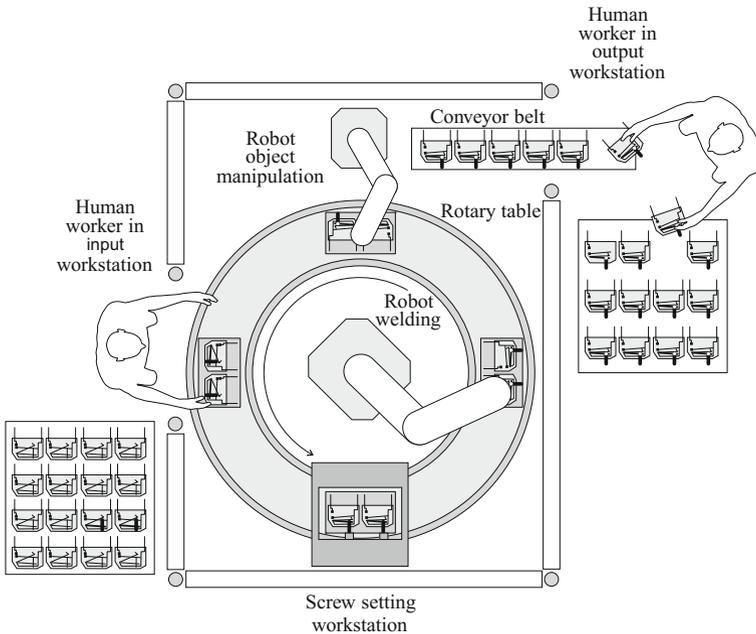


Fig. 11.5 Example of rotary table production line with human, machine and robot workstations

bly are manipulated by hand or by the robot and transferred among workstations by pallets along a conveyor belt. The distance between the pallets is not necessarily constant and their position is monitored by location sensors, usually capacitive or inductive presence sensors. These sensors are necessary to signal the robots or a dedicated machine that the pallet is in the right position and the workstation operation can be performed. The cycle time to transport the part from one workstation to the next is usually constant, making the workstations synchronous. In certain cases the production line developers integrate parts to buffer the pallets, making the production line asynchronous. The need for a buffer arises in cases where some workstations have variable cycle times; with a buffer the overall production line cycle time is not affected.

Another very common assembly line configuration is a rotational or rotary table (Fig. 11.5), usually actuated by electrical motors. The speed and repeatability of positioning are high. The rotary table is often called a dial table or an indexing machine. The advantage of the rotary configuration is that requires less floor space and is often cheaper than other production line configurations. The rotary table is always performing synchronous transfer of parts between workstations with a constant cycle time.

As with the previous example, this configuration can also be served by humans, robots or dedicated machines. The rotary table has a circular shape around which the pallets or part-holders are traveling and transporting parts, in turn, into each manual

or automated workstation where production operations are performed. The rotary table can be split in several workstations (minimum 2), making the rotation angle of 90° . More common are rotary tables with more than 2 workstations, e.g. 4, 5, 6 workstations. The size of the rotary table is defined by the part size, equipment size and number of workstations of the rotary production line. Closed loop controlled turntables are also available.

Usually a combination of the above configurations is installed and is referred to as hybrid production line configuration. Several factors declare the overall configuration of the production line, such as:

- space needed for production line,
- cost of installation of the production line,
- production line cycle time.

11.3 Feeding Devices

The task of the feeding devices is to bring parts or assemblies to the robot or dedicated machine in such a way that the part pose is known. Reliable operation of the feeding devices is of utmost importance in the robot cells without robot vision. The position of a part must be accurate, as the robot end-effector always moves along the same trajectory and the part is expected to be always in the same place.

The requirements for the robot feeding devices are much more strict than in manual assembly, unless the robot cell is equipped with a robot vision system. The robot feeding devices must not deform the parts, must operate reliably, position the parts accurately, work at sufficient speed, require minimal time of loading and contain sufficient number of parts.

The feeding device should not cause any damage to the parts handled, as damaged parts would afterwards be inserted by the robot into assemblies which cannot function properly. The cost of such damaged assemblies is higher than the cost of a more reliable feeding device. The feeding device must reliably handle all the parts whose dimensions are within tolerance limits. It must also be fast enough to meet the requirements of the whole production line cycle time and should never slow down its operation. Further, the feeding device should require as little time as possible for loading of the parts. It is more desirable to fill a large amount of parts into the feeding device at once than inserting them manually one by one. The feeding devices should contain as large number of parts as possible. This way the number of loadings required per day is reduced.

The simplest feeding devices are pallets and fixtures; an every-day example is the carton or plastic pallets used for eggs. The pallets store the parts, while determining their position and sometimes also orientation. In an ideal situation the same pallet is used for shipping the parts from the vendor and for later use in the consumer's robot cell. The pallets are either loaded automatically by a machine or manually. Fragile parts, flexible objects or parts with odd shapes must be loaded manually. Loading of

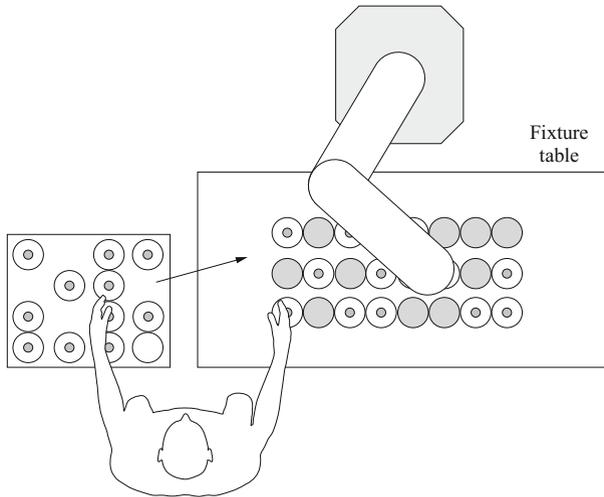


Fig. 11.6 Simultaneous loading of a fixture table

the pallets represents the weakest point of palletizing. Another disadvantage of pallets is their rather large surface, taking up considerable area in the robot workspace.

The simplest way to bring parts into the robot cell is represented by a fixture table. The human operator takes a part from a container, where the parts are unsorted, and places it onto the fixture table inside the robot workspace (Fig. 11.6). The fixture table must contain special grooves which assure reliable positioning of a part into the robot workspace. Such a fixture table is often used in welding where the component parts must be also clamped onto the table before the robot welding takes place. The time required for robot welding is considerably longer than loading and unloading which can justify the use of a fixture table.

The pallets can be loaded in advance in some other place and afterwards brought into the robot cell (Fig. 11.7). This avoids a long waiting period for the robot while the human operator is loading the pallets. The human worker must only bring the pallet into the robot workspace and position it properly using special pins in the working table. It is important that the pallet contains a sufficient number of the parts to allow continuous robot operation. Exchanging the pallets in the robot workspace represents a safety problem as the operator must switch off the robot or the robot cell must be equipped with other safety solutions (e.g. rotary table or collaborative robot).

A larger number of pallets can be placed on a rotary table (Fig. 11.8). The rotary table enables loading of the pallets on one side, while the robot activities take place on the other side of the turntable. This way robot cell inactivity is considerably reduced and the human operator is protected against the movements of the robot.

There are generally three types of pallets used: vacuum formed or, injection molded plastic and metal pallets. Since the cost of vacuum formed pallets is low,

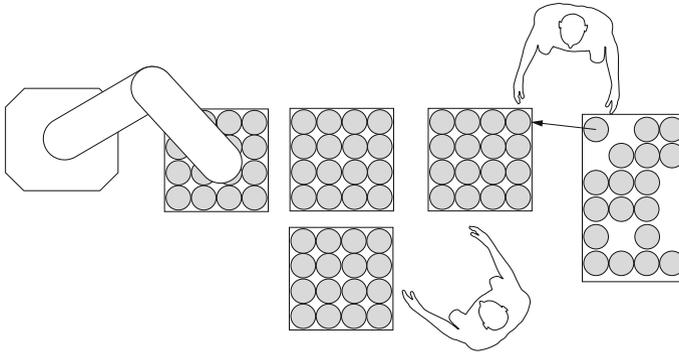


Fig. 11.7 Loading of the pallets in advance

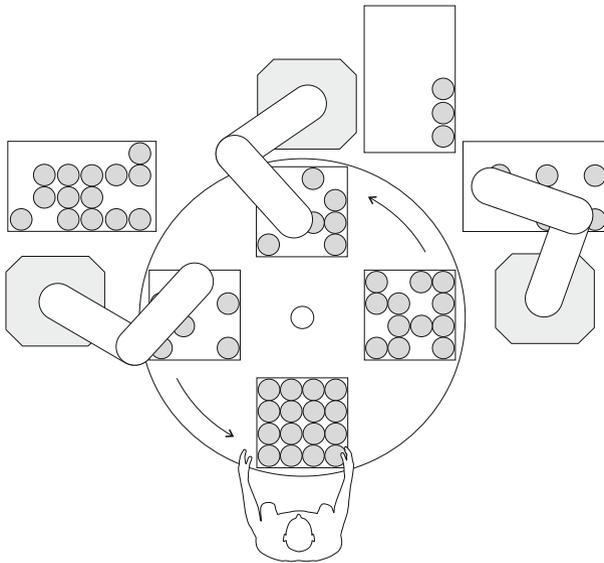


Fig. 11.8 Rotary table with pallet stages

they are used both for packaging and shipping of the parts and for use in the robot cell. Reference holes must be built into the all pallets to match pins in the worktable to enable simple and fast positioning. As the vacuum formed pallets are inexpensive, it is not difficult to understand that they are not the most accurate, reliable, or durable. They are made of a thin sheet of plastic material which is heated and vacuum formed over a mold. The inaccuracy of the pallet is the consequence of its low rigidity. Injection molded plastic pallets are used when more accurate and more durable pallets are required. The production of the mold is rather expensive, while the cost of production of a single pallet is not high. We must keep in mind that most vacuum and molded plastic pallets are flammable. Metal pallets are the only ones

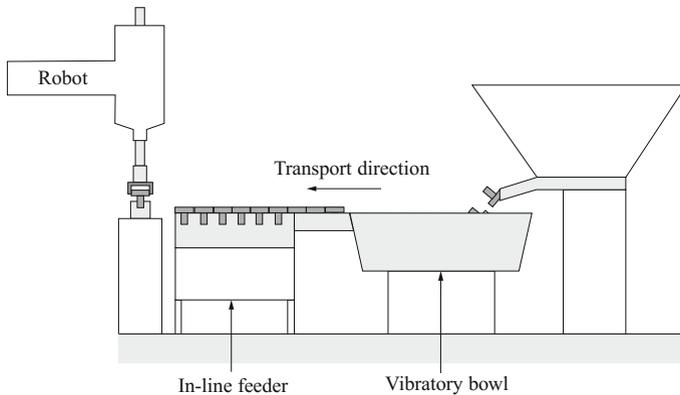


Fig. 11.9 Vibratory bowl feeder

which are non-flammable. They are produced by various machining approaches. The metal pallets are the most reliable and durable, while their cost is higher than that of plastic type. They are therefore only used inside the robot assembly process.

Part feeders represent another interesting family of feeding devices which are used not only for storing parts, but also for positioning and even orienting them into the pose appropriate for robot grasping. The most common are vibratory bowl feeders (Fig. 11.9). Here, the parts are disorderly loaded into the bowl. The vibration of the bowl and the in-line feeder is produced by an electromagnet, and the proper vibration is obtained by attaching the vibratory feeders to a large mass, usually a thick steel table. The vibrations cause the parts to travel out of the bowl. Specially formed spiral shaped fences force them into the required orientation. The same bowl feeder can be used for different parts, however not at the same time. Another benefit is that the bowl can hold a large number of parts while occupying only a small area in the robot workspace. Bowl feeders are not appropriate for parts such as soft rubber objects or springs. Another disadvantage is possible damage caused by the parts becoming jammed in the bowl. The noise of vibratory feeders can also be disturbing.

A simple magazine feeder consists of a tube storing the parts and the sliding plate, pneumatically or electrically actuated, which takes the parts one by one out of the magazine (Fig. 11.10). The magazine is loaded manually, so that the orientation of the parts is known. Gravity pushes the parts into the sliding plate. The mechanism of the sliding plate must be designed in such a way that it prevents jamming of the parts, while only a single part is fed out from the feeder at a time. The sliding plate must block all the parts except the bottom one.

Magazine feeders are excellent solutions for handling integrated circuits (Fig. 11.11). Integrated circuits are already shipped in tubes which can be used for feeding purposes. The magazine feeder for integrated circuits usually consists of

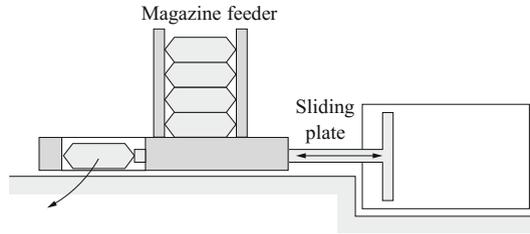


Fig. 11.10 Magazine feeder

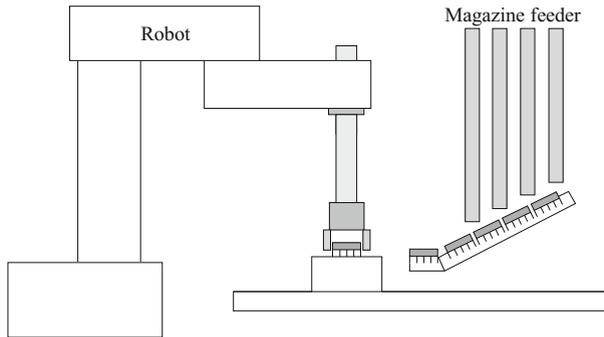


Fig. 11.11 Integrated circuit magazine feeder

several tubes. The tubes are aligned along a vibratory in-line feeder. The main disadvantage of magazine feeders is manual loading. They are also inappropriate for handling large objects.

11.4 Conveyors

Conveyors are used for transport of parts, assemblies or pallets between the robot cells. The simplest conveyor makes use of a plastic or metal chain which pushes the pallets along a metal guide (Fig. 11.12). An electrical motor drives the chain with constant velocity. The driving force is represented by the friction between the chain and the pallet. The pallet is stopped by special pins actuated by pneumatic cylinders. The chain continues to slide against the bottom of the pallet. When another pallet arrives, it is stopped by the first one. This way a queue of pallets is obtained in front of the robot cell.

The turn of a conveyor is made by bending the metal guide. The advantages of the sliding chain conveyor are low cost and simplicity in handling the pallets and performing the turns. The disadvantage is that perpendicular intersections cannot be made. Also, the turns must be made in wide arcs, which takes considerable floor

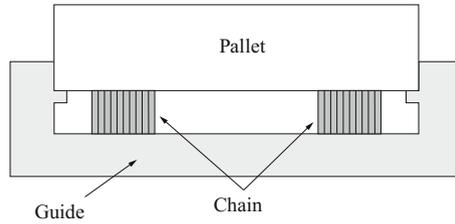


Fig. 11.12 Sliding chain conveyor (end view)

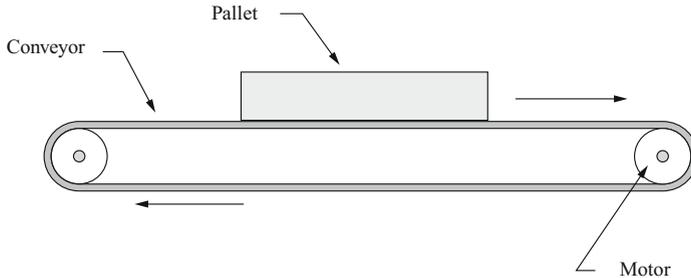


Fig. 11.13 Belt conveyor

space in the production facility. The sliding chain conveyor is best suited when used as a single loop feeding system.

With the belt-driven conveyor, the upper part of the belt is driving pallets or other objects or material (Fig. 11.13). A turn or intersection is made with the help of a special device enabling lifting, transfer and rotation of pallets.

A conveyor can also consist of rollers which are actuated by a common driving shaft (Fig. 11.14). The driving shaft transmits torque through a drive belt to the roller shaft. The advantage of the conveyor with rollers is in low collision forces occurring between the pallets or objects handled by the conveyor. They are the consequence of low friction between the rollers and the pallets. The turns are made by the use of lift and transfer devices. The disadvantages of the conveyors with rollers are high cost and low accelerations.

11.5 Robot Grippers and Tools

In the same way as robot manipulators are copies of the human arm, robot grippers imitate the human hand. In most cases robot grippers are considerably simpler than the human hand, encompassing wrist and fingers, altogether 22 degrees of freedom. Industrial robot grippers differ to a large extent, so it is not difficult to understand that their cost range from almost negligible to higher than the cost of a robot manip-

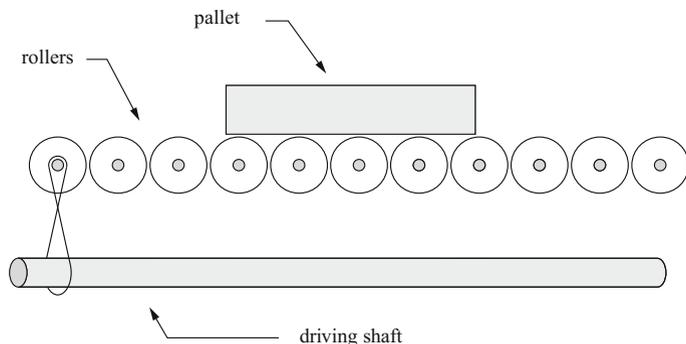


Fig. 11.14 Conveyor with rollers

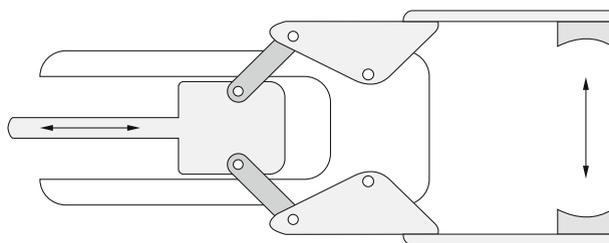


Fig. 11.15 Robot gripper with two fingers

ulator. Although many various robot grippers are commercially available, it is often necessary to develop a special gripper to meet the requirements of a specific robotic task.

The most characteristic robot grippers are those with fingers. They can be divided into grippers with two fingers (Fig. 11.15) and multi-fingered grippers. Most multi-fingered grippers have three fingers (Fig. 11.16), to achieve a better grasping. In industrial applications we usually encounter grippers with two fingers. The simplest two-finger grippers are only controlled between the two states, open and closed. Two-finger grippers, where the distance or force between the fingers can be controlled, are also available. Multi-fingered grippers usually have three fingers, each having three segments. Such a gripper has 9 degrees of freedom which is more than robot manipulator. The cost of such grippers is high. In multi-fingered grippers the motors are often not placed into the finger joints, as the fingers can become heavy or not strong enough. Instead, the motors are all placed into the gripper palm, while tendons connect them with pulleys in the finger joints. Apart from grippers with fingers, in industrial robotics there are also vacuum, magnetic, perforation and adhesive grippers. Different end-effector tools, used in spray painting, finishing or welding, are not considered robot grippers.

Two-fingered grippers are used for grasping the parts in a robotic assembly process. An example of such a gripper is shown in Fig. 11.15. Different end-points can

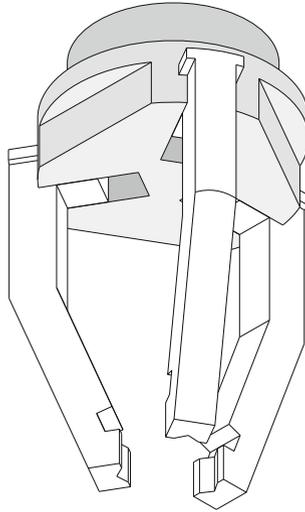


Fig. 11.16 Robot gripper with three fingers

be attached to the fingers to adapt the robot grasp to the shape and surface of the part or assembly to be grasped. With two-fingered robotic grippers pneumatic, hydraulic or electrical motors are used. Hydraulic actuation enables higher grasping forces and thus handling of heavier objects. Different structures of two-fingered grippers are presented in Fig. 11.17. Simple kinematic presentations enable the choice of an appropriate gripper for the selected task. The gripper on the right side of Fig. 11.17 enables parallel finger grasping.

In industrial processes, robot manipulators are often used for machine loading. In such cases the robot is more efficient when using a twofold gripper. The robot can simultaneously bring an unfinished part into the machine while taking a finished part out of it. A twofold gripper is shown in Fig. 11.18.

Specific grippers are used for grasping hot objects. Here, the actuators are placed far from the fingers. When handling hot objects air cooling is applied, while often the gripper is immersed into water as part of the manipulation cycle. Of utmost importance is also the choice of appropriate material for the fingers.

When grasping lightweight and fragile objects, grippers with spring fingers can be used. This way the maximal grasping force is constrained, while at the same time it enables a simple way of opening and closing of the fingers. An example of a simple gripper with two spring fingers is shown in Fig. 11.19.

The shape of the object requires careful design of a two-fingered robot gripper. A reliable grasp can be achieved either by form or force closure of the two fingers. Also possible is the combination of the two grasp modes (Fig. 11.20).

When executing a two-fingered robot grasp, the position of the fingers with respect to the object is also important. The grasping force can be applied only on the external

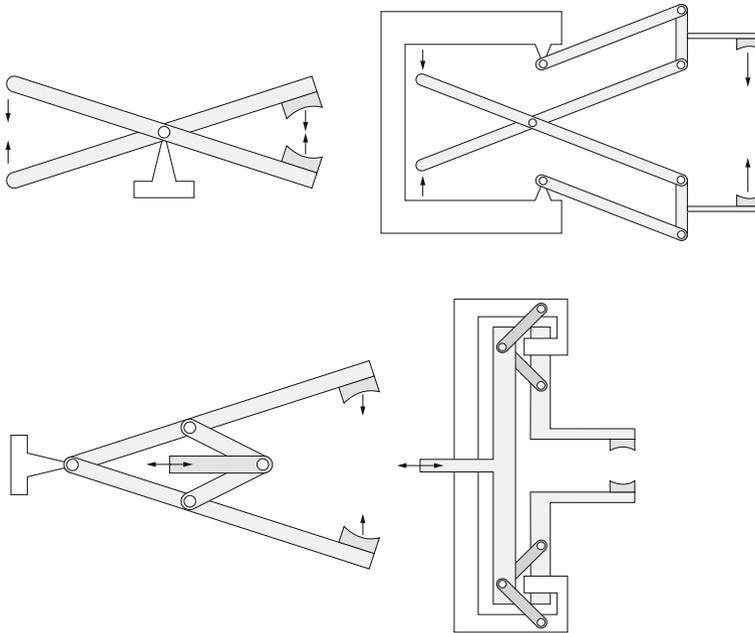


Fig. 11.17 Kinematic presentations of two-fingered grippers

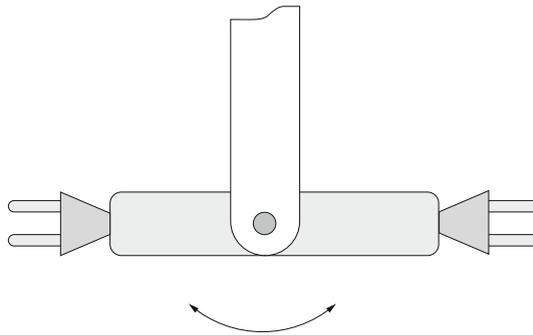


Fig. 11.18 Twofold robot gripper

surfaces or only on the internal surfaces of a work-piece. An intermediate grip is also possible where the object is grasped on internal and external surfaces (Fig. 11.21).

Among the robot grippers without fingers, vacuum grippers are by far the most frequently used. Vacuum grippers or grippers with negative pressure are successfully applied in cases, where the surface of the grasped object is flat or evenly curved, smooth, dry and relatively clean. The advantages of these grippers are reliability, low cost and small weight. Suction heads of various shapes are commercially available. Often several suction heads are used together, being put into a pattern that suits the

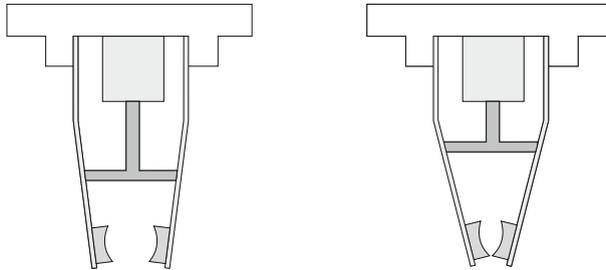


Fig. 11.19 Gripper with spring fingers

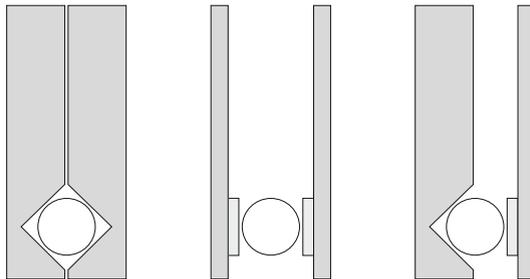


Fig. 11.20 Form closure, force closure and combined grasp

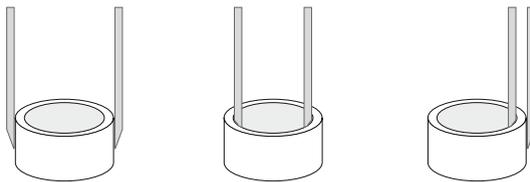


Fig. 11.21 External, internal, and intermediate grip

shape of the object to be grasped. Figure 11.22 shows the shape of two frequently used suction heads. The head on the left is appropriate in cases when the surface is not completely smooth. The soft material of the head adapts to the shape of the object. The small nipples on the head presented on the right side of Fig. 11.22 prevent damage to surface of the object. Vacuum is produced either with Venturi or vacuum pumps. The Venturi pump needs more power and produces only 70% vacuum. However, it is often used in industrial processes because of its simplicity and low cost. Vacuum pumps provide 90% vacuum and produce considerably less noise. In all grippers, fast grasping and releasing of the objects is required. Releasing very lightweight and sticky objects can be critical with vacuum grippers. In this case we release the objects with the help of positive pressure as demonstrated in Fig. 11.23.

Magnetic grippers are another example of grippers without fingers: these use either permanent magnets or electromagnets. The electromagnets are used to a larger extent.

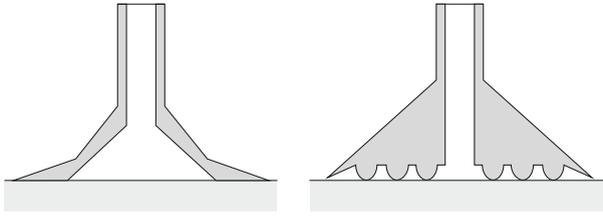


Fig. 11.22 Suction heads of vacuum grippers

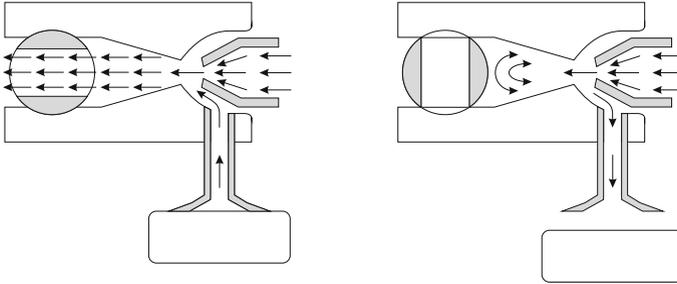


Fig. 11.23 Grasping and releasing of an object with the help of negative and positive pressure

With permanent magnets the releasing of the object presents a difficulty. The problem is solved by using a specially planned trajectory of the end-effector where the object is retained by a fence in the robot workspace. In magnetic grippers several magnets are used together, placed into various patterns corresponding to the shape of the object. Already small air fissures between the magnet and the object considerably decrease the magnetic force. The surfaces of the objects being grasped must be therefore even and clean.

Perforation grippers are considered as special robot grippers. Here the objects are simply pierced by the gripper. Usually these are used for handling material such as textile or foam rubber. Such grippers can be used only in cases when perforation does not cause damage to the object. Sheets of textile can be grasped by large brushes made of stiff nylon hairs or simply of Velcro straps.

Adhesive grippers can be used when grasping very lightweight parts. Release of the parts must be solved by special robot end-point trajectories where the part collides with the fence in the robot workspace and is thus removed from the adhesive gripper. Sufficient adhesive force is provided using adhesive tape which must move during the operation.

Besides grippers the robot can have other tools attached to its end. The shape and the function of the tool depends on the task of the robot cell. The most frequent operation that robots perform is welding. For welding purposes several different approaches can be used. Among them the most frequent tool attached to the robot

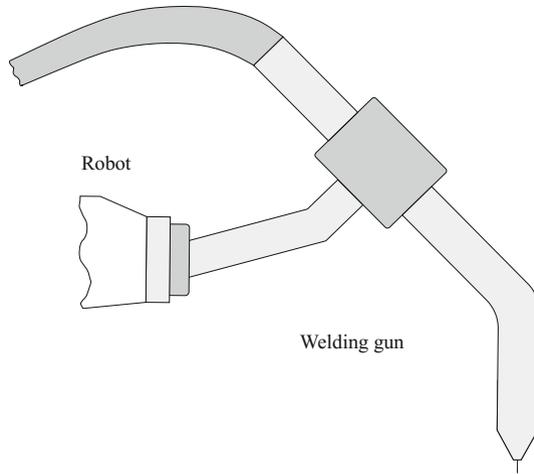


Fig. 11.24 Robot with welding gun attached to its end

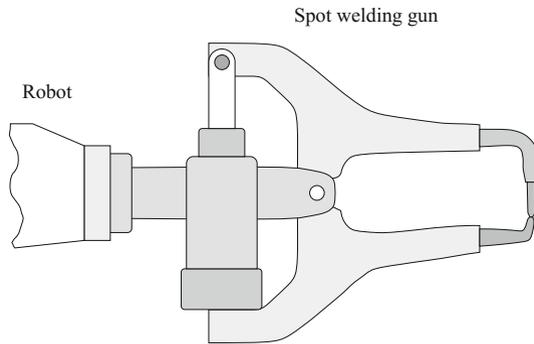


Fig. 11.25 Robot with spot welding gun attached to its end

end is an arc welding gun or torch (Fig. 11.24) to transmit welding current from a cable to the electrode. The task is performed in many different areas of manufacturing. Besides arc welding also spot welding guns (Fig. 11.25) can frequently be found in manufacturing processes, mainly in the automotive industry.