What is an Industrial Robot?

“An industrial robot is a programmable, multi-functional manipulator designed to move materials, parts, tools, or special devices through variable programmed motions for the performance of a variety of tasks.” Robotics Institute of America.

Since the development of the first articulated arm in the 1950’s and subsequent developments in computer technology, robots have become more widely used and are now available in a variety of types, styles and sizes. Robots are capable of performing a wide variety of tasks and have become an integral part of automated manufacturing systems.

An industrial robot consists of a number of rigid links connected by joints of different types, controlled and monitored by a computer. To a large extent, the physical construction of a robot resembles a human arm. The link assembly mentioned above is connected to the body, which is usually mounted on a base.

This link assembly is generally referred to as a robot arm. A wrist is attached to the arm. To facilitate gripping or handling, a hand is attached at the end of the wrist. In robotics terminology this hand is called an end-effector. The complete motion of the end-effector is accomplished through a series of motions and positions of the links, joints and wrist.
Types of Robots

Robots can be classified in a number of ways and in this section we look at some of the common characteristics by which we can identify robots.

The main characteristics by which a robot can be identified are:

1. Classification based on physical configuration
2. Type of drive
3. Type of end-effectors
4. Reach or work envelope

Classification based on physical configurations.

Four basic configurations are identified with most of the commercially available industrial robots, they are:

- Cartesian configuration
- Cylindrical configuration
- Polar configuration
- Jointed-arm configuration

Cartesian configuration

Robots with Cartesian configurations, as shown in figure 1.1 consists of links connected by linear joints. Because the configuration has three perpendicular slides, they are also called rectilinear robots. Another robot that is similar to this configuration is a gantry robot. The structure of a gantry robot resembles a gantry type crane.

Figure 1.1 Cartesian robot
Cylindrical configuration

In the cylindrical configuration, as shown in the figure below (1.2), robots have one rotary joint at the base and linear joints to connect the links. The space in which this robot operates is cylindrical in shape, hence the name cylindrical configuration.

Figure 1.2 Cylindrical Robot

Polar configuration

Polar robots as shown in (1.3) have a workspace being spherical shape. Generally, the arm is connected to the base with a twisting joint and a combination of rotary and/or linear joints. These robots are called spherical (twisting, rotary and linear joint) or articulated (Twisting, rotary and rotary), the latter more closely resembles the human arm.

Figure 1.3 Polar Robot

Jointed-arm configuration

The jointed arm configuration, as shown in (1.1d), is a combination of cylindrical and articulated configurations. The arm of the robot is connected to the base with a twisting joint. The links in the arm are connected by rotary joints. The rotations generally take place in the vertical plane. Several commercially available robots have this configuration.

Figure 1.4 Jointed-arm Robot
The available axes of movement that a robot has is referred to as the ‘degrees of freedom’. This will vary depending upon the robot's configuration and is an important aspect when considering and selecting robots for particular applications.

A typical Industrial robot with six degrees of freedom is shown in figure 1.2

**Figure 1.2**

![Diagram of a robot with six degrees of freedom](image)

**Figure 1.2.** A typical robot with six-degrees of freedom. The robot’s movement pattern is briefly described as follows: Axis 1 (C), turning of the complete mechanical robot; Axis 2 (B), forward and reverse movement of the lower arm; Axis 3 (A), up and down movement of the upper arm; Axis 4 (D), turning of the complete wrist centre; Axis 5 (E), bending of the wrist around the wrist centre; Axis 6 (P), turning of mounting flange (turn disk).
Types of robot drive.

An important element of a robot is the drive system. The drive system supplies the power, which enables the robot to move. The dynamic performance of the robot is determined by its drive system, which depends on its application and power requirements. The three types of drive systems that are generally used for industrial robots are:

1. Hydraulic drive
2. Electric drive
3. Pneumatic

Hydraulic drive

A hydraulic drive system gives a robot great speed and strength. Because they provide high speed and strength, hydraulic systems are adopted for large industrial robots. Hydraulic robots are preferred in environments in which the use of electric-drive robots may cause fire hazards, for example, in spray painting. The main disadvantages of a hydraulic robot are that they occupy more floor space for ancillary equipment in addition to that required by the robot. Also, there are housekeeping problems such as leaks.

Electric drive

Compared with an hydraulic system, an electric system provides a robot with less speed and strength. Accordingly, electric drive systems are adopted for smaller robots. However, robots supported by electric drive systems are more accurate, exhibit better repeatability, and are cleaner to use. Electrically driven robots are the most commonly available and used industrial robots. Like numerically controlled (NC) machines, electrically driven robots can be classified into two broad categories: stepper motor driven and direct current (DC) servo-motor driven. Most stepper motor-driven robots are of the open loop type, but feedback loops can be incorporated in stepper-driven robots. Servo-driven robots invariably have feedback loops from the driven components back to the driver.

Pneumatic drive

Pneumatic drive systems are generally used for smaller robots. These robots generally have fewer axes of movement, carry out simple pick-and-place material-handling operations, such as picking up an object at one location and placing it at another location. These operations are generally simple and have short cycle times. The pneumatic power can be used for sliding or rotational joints. Pneumatic robots are less expensive than electric or hydraulic robots.
The end-effector (commonly known as robot hand) mounted on the wrist enables the robot to perform specified tasks. Various types of end-effectors are designed for the same robot to make it more flexible and versatile. End-effectors are categorised into two major types:

1. Grippers
2. Tools

Grippers are generally used to grasp and hold an object and place it at a desired location. Grippers can be further classified as mechanical grippers, vacuum or suction cups, Fig. (a), magnetic grippers, adhesive grippers, hooks, scoops and so forth. A double gripper can handle two objects at the same time, and the two gripping devices can be actuated separately. More than two grippers can also be classified as external or internal, depending on whether the part is grasped on its external or internal surface.

At times, a robot is required to manipulate a tool to perform an operation on a work part. In such applications the end-effector is used as a gripper that can grasp and handle a variety of tools and the robot has multitool handling function. However, in most robot applications in which only one tool is to be manipulated, the tool is directly mounted on the wrist, here the tool itself acts as the end-effector. Spot welding tools, arc-welding tools, Fig. (b), spray painting nozzles and rotating spindles for drilling and grinding are typical examples of tools used as end-effectors.
Robot reach or more commonly referred to as the ‘work envelope’, describes the operational range of an Industrial Robot. All Robots have a work envelope or reach capability dependant upon their particular design. For example Cartesian robots work within a ‘cube’ as shown in Figure 1.3 (a) Cylindrical robots have a work envelope of a ‘cylinder’ as shown in (b). Polar and Jointed-arm robots extend the flexibility to incorporate parts of ‘spheres’, as shown in (c) and (d).
Typical robot applications

The application of robots to specific tasks is determined by a number of factors, which, together identify the total performance capability of the robot. The capability of a robot refers to all the factors previously mentioned, i.e. axes of movement, type of drive, end effectors and the range or envelope of movement. Other factors that can also be included are:

- Speed of operation
- Load capability
- Working environment sensitivity
- Structural rigidity

Consequently, each application demands a performance capability peculiar to that task. Some typical applications for robots can include:

- Welding operations
- Pick and place activities
- Clamping for machining
- Transfer and manipulation of parts.
- Multiple activities
The operational capability of a robot and its associated equipment is subject to the ongoing maintenance and service function within the area it operates. Principles and procedures of Ford Total Productive Maintenance (FTPM) should be applied to robots and robot installations on an ongoing basis to ensure early fault identification and consequent remedy action is undertaken.

The first three steps of FTPM are appropriate in this case for initial inspections i.e.

- Cleaning is inspection
- Cleaning, lubricating and safety procedures
- Eliminating the sources of contamination

Follow up procedures can include checks for:

- Robot structural integrity
- Signs of physical damage
- Contamination
- Integrity of services including:
  1. The supply of power
  2. The condition of cables and hoses
  3. The condition of end-effectors i.e. weld guns, grippers & clamps.
**Glossary**

Words and terms to know about robots:

Add words to the list as you learn more about robots.

<table>
<thead>
<tr>
<th><strong>Cartesian Configuration</strong></th>
<th>Linear movement on all axes</th>
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</thead>
<tbody>
<tr>
<td><strong>Cylindrical Configuration</strong></td>
<td>Rotary movement on main axis.</td>
</tr>
<tr>
<td><strong>Polar Configuration</strong></td>
<td>A combination of rotary and linear movement</td>
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<tr>
<td><strong>Jointed Arm configuration</strong></td>
<td>A combination of rotary and rotary movement.</td>
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<tr>
<td><strong>Envelope of movement</strong></td>
<td>The operational range of the robot.</td>
</tr>
<tr>
<td><strong>End-effectors</strong></td>
<td>Commonly known as the robot hand, ie, grippers &amp; tools</td>
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<tr>
<td><strong>Robot Reach</strong></td>
<td>More commonly refered to as ‘work envelope’.</td>
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<td><strong>FTPM</strong></td>
<td>Ford Total Productive Maintenance.</td>
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Bibliography


Pictures
Figure 1.1 - Courtesy of ABB Robotics, Inc.
Figure 1.2 - Courtesy of ABB Robotics, Inc.
Figure 1.2 - Courtesy of Robotics in Practice, J.F. Engelberger, 1980. AMACOM, New York

Other references
T.A.C.S 5520G Ford Motor Company of Australia
T.A.C.S 5520N Ford Motor Company of Australia