<u>Lecture notes on Industrial Robotics & Automation</u>

CHAPTER-I (FUNDAMENTAL OF ROBOTICS)

Defination: A reprogrammable multifunctional manipulator designed to move materials, parts, tools or specialized devices through various programmed motions for the performance of a variety of tasks.

Robotics **deals with the design, construction, operation, and use of robots and computer systems for their control, sensory feedback, and information processing**. A robot is a unit that implements this interaction with the physical world based on sensors, actuators, and information processing.

Robot anatomy:

The manipulator of an industrial robot is constructed of a series of joints and links. Robot anatomy is concerned with the types and sizes of these joints and links and other aspects of the manipulator's physical construction.

1 Joints and Links

A joint of an industrial robot is similar to a joint in the human body: It provides relative motion between two parts of the body. Each joint, or *axis* as it is sometimes called, provides the robot with a so called *degree-of-freedom* (d.o.f.) of motion. In nearly all cases, only one degree of freedom is associated with a joint. Robots are often classified according to the total number of degrees-of-freedom they possess. Connected to each joint are two links, an input link and an output link. *Links* are the rigid components of the robot manipulator. The purpose of the joint is to provide controlled relative movement between the input link and the output link.

Most robots are mounted on a stationary base on the floor. Let us refer to that base and its connection to the first joint as link 0.1t is the input link to joint 1, the first in the series of joints used in the construction of the robot. The output link of joint 1 is link 1. Link 1 is the input link to joint 2, whose output link is link 2, and so forth. This joint-link numbering scheme is illustrated in Figure 7.1.

Nearly all industrial robots have mechanical joints that can be classified into one of five types: two types that provide translational motion and three types that provide rotary motion. These joint types are illustrated in Figure 7.2 and are based on a scheme described in [6]. The five joint types are:

Linear joint (type L-joint).The relative movement between the input link and the output link is a translational sliding motion, with the axes of the two links being parallel.

Orthogonal Joint (type U joint). This is also a translational sliding motion, but the input and output links are perpendicular to each other during the move.

Rotational Join (type R joint). This type provides rotational relative motion, with the axis of rotation perpendicular to the axes of the input and output links.

Twisting joint (type T joint) This joint also involves rotary motion, but the axis or rotation is parallel to the axes of the two links.

Revolving joint (type V joint, V from the "v' in revolving). In this joint type, the axis 0' the input link is parallel to the axis of rotation of the joint. and the axis of the output link is perpendicular to the axis of rotation.

Each of these joint types has a range over which it can be moved. The range for a translational joint is usually less than a meter. The three types of rotary joints may have a range as small as a few degrees or as large as several complete turns

2 Common Robot Configurations

A robot manipulator can he divided into two sections: a body-and-arm assembly and a *wrist* assembly. There are usually three degrees-of-freedom associated with the body-and-arm, and either two or three degrees-of-freedom associated with the wrist. At the end of the manipulator's wrist is a device related to the task that must be accomplished by the robot. The device, called an *end effector* (Section 7.3), is usually either (1) a gripper for holding a work-part or (2) a tool for performing some process. The body-and-arm of the rotor is used to position the end effector. and the robot's wrist is used to orient the end effector.

Body-and-Arm Configurations. Given the five types of joints defined above, there are 5 x 5 x 5 = 125 different combinations of joints that can *be* used to design the body-and-arm assembly for a three-degree-of-freedom robot manipulator. In addition, there are design variations within the individual joint types [e.g.. physical size of the joint and range of motion). It is somewhat remarkable, therefore, that there are only five basic configurations commonly available in commercial industrial robots. These five configurations are:

Polar configuration. This configuration (Figure 7.3) consists of a sliding arm (L joint) actuated relative to the body, that can rotate about both a vertical axis (1' joint) and a horizontal axis (R joint).

Cylindrical configuration. This robot configuration (Figure 7.4) consists of a vertical column, relative to which an arm assembly is moved up or down. The arm can be moved in and out relative to the axis of the column. Our figure shows one possible way in which this configuration can be constructed, using a T joint to rotate the column about its axis An 1. joint is used to move the arm assembly vertically along the column, while an 0 joint is used to achieve radial movement of the ann,

Cartesian coordinate robot. Other names for this configuration include rectilinear robot and *iyz* robot. As shown in Figure 7 5,it is composed of three sliding joints, two of which are orthogonal.

4, Jointed-arm-robot. This robot manipulator (Figure 7.6) has the general configuration of a human arm. The jointed arm consists of a vertical column that swivels about the

base using a T joint. At the top of the column is a shoulder joint (shown as an R joint in our figure), whose output link connects to an elbow joint (another R joint)

5. SCARA. SCARA is an acronym for Selective Compliance Assembly *Robot Arm.* This configuration (Figure 7.7) is similar to the jointed arm robot except that the shoulder and elbow rotational axes are vertical, which means that the arm is very rigid in the vertical direction. but compliant in the horizontal direction. This permits The robot to perform insertion tasks (for assembly) in a vertical direction, where some side-to-side alignment may be needed to mate the two parts properly.

Wrist Configurations. The robot's wrist is used to establish the orientation of the end effector. Robot wrists usually consist of two or three degrees-of-freedom. Figure 7.8 illustrates one possible configuration for a three-degree-of-freedom wrist assembly. The three joints are defined as: (1) *roll,* using a T joint to accomplish rotation about the robot's arm axis: (2) *pitch,* which involves up-and-down rotation, typically using a R joint; and *(3) yaw,* which involves right-and-left rotation, also accomplished by means of an R-joint, A two-d.o.f wrist typically includes only roll and pitch joints (T and R joints).

To avoid confusion in the pitch and yaw definitions, the wrist roll should be assumed in its center position, as shown in our figure. To demonstrate the possible confusion, consider a two-jointed wrist assembly. With the roll joint in its center position, the second joint (R joint) provides up-and-down rotation (pitch). However, if the roll position were 90 degrees from center (either clockwise or counterclockwise), the second joint would provide a right-left rotation (yaw).

The SCARA robot configuration (Figure 7.7) is unique in that it typically does not have a separate wrist assembly. As indicated in our description, it is used for insertion type assembly operations in that the insertion is made from above. Accordingly. the orientation requirements are minimal, and the wrist is therefore not needed. Orientation of the object to be inserted is sometimes required, and an additional rotary joint can be provided for this purpose. The other four body-and-arm configurations possess wrist assemblies that almost always consist of combinations of rotary joints of types Rand T.

Joint Notation System. The letter symbols for the five joint types (L, 0, R, T, and V) can be used to define a joint notation system for the robot manipulator. In this notation system, the manipulator is described by the joint types that make up the body-and-arm assembly. followed by the joint symbols that make lip the wrist. For example, the notation TLR: TR represents a five degree-of-freedom manipulator whose body-and-arm is made up of a twisting joint (joint 1 = T),a linear joint (joint 2 = L), and a rotational joint (joint 3 = R). The wrist consists of two joints, a twisting joint (joint 4 = T) and a rotational joint (joint 5 '" R). A colon separates the body-and-arm notation from the wrist notation. Typical joint notations for the five common body-and-arm configurations are presented in Table 7.1 . Common wrist joint notations are TRR and TR.

Work Volume. **The *work volume* (the term *work envelope* is also used) of the manipulator is defined as the envelope or space within which the robot can manipulate the end of its wrist. Work volume is determined by the number and types of joints in the manipulator (body-and-arm and wrist), the ranges of the various joints, and the physical sizes of the links. The shape of the work volume depends largely on the robot's configuration. A polar configuration robot tends to have a partial sphere as its work volume, a cylindrical robot has a cylindrical work envelope. and a Cartesian coordinate robot has a rectangular work volume.**

3 Joint Drive Systems

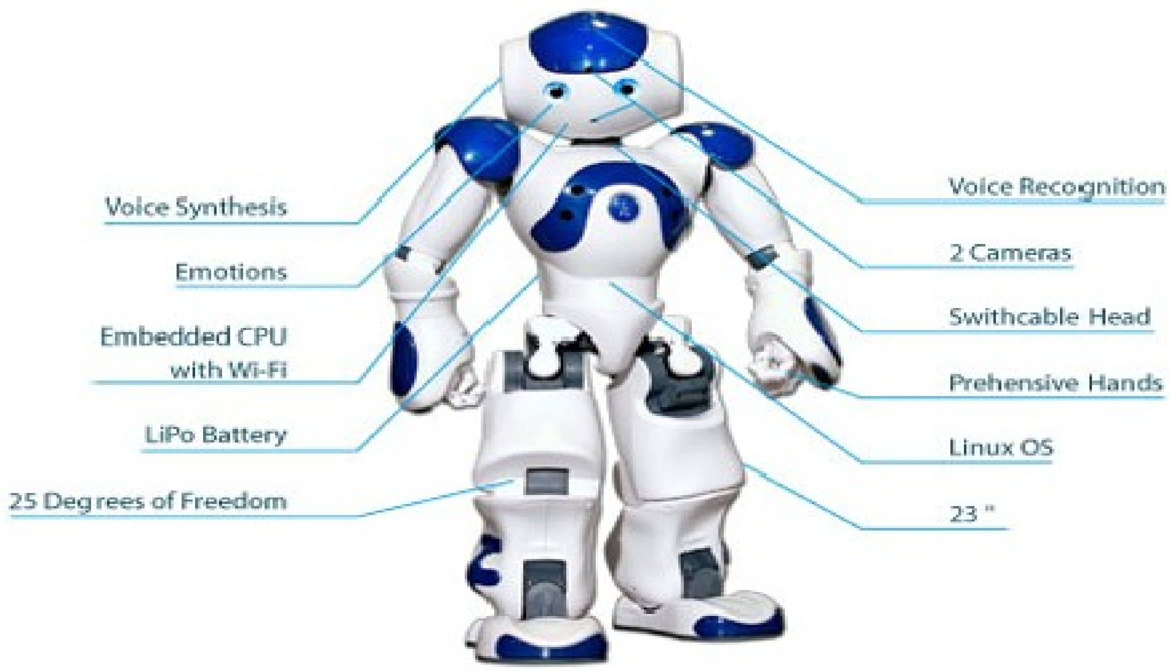
Robot joints are actuated using any of three possible types of drive systems: (1) electric, (2) hydraulic, or (3) pneumatic. Electric drive systems use electric motors as joint actuators (e.g., servomotors or stepping motors, the same types of motors used in NC positioning systems, Chapter 6), Hydraulic and pneumatic drive systems use devices such as linear pistons and rotary vane actuators to accomplish the motion of the joint.

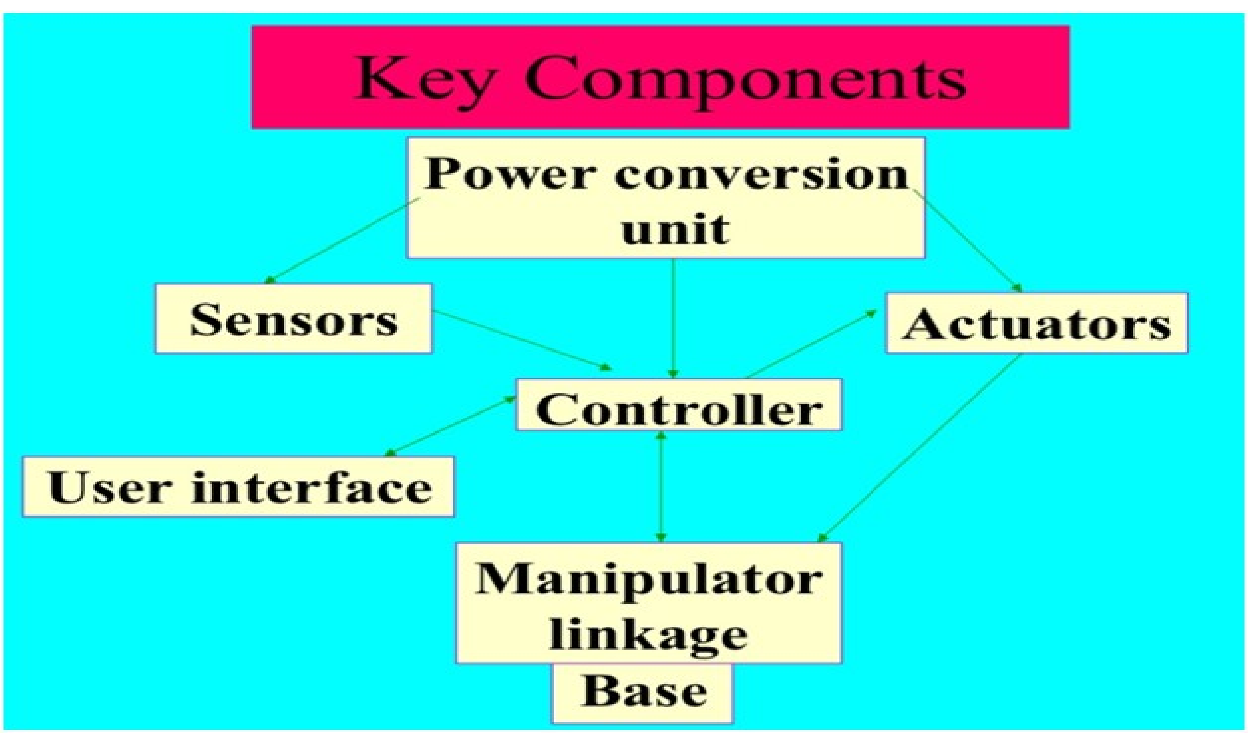
Pneumatic drive is typically limited to smaller robots used in simple material transfer applications. Electric drive and hydraulic drive are used on more-sophisticated industrial robots. Electric drive has become the preferred drive system in commercially available robots, as electric motor technology has advanced in recent years. It is more readily adaptable to computer control, which is the dominant technology used today for robot controllers. Electric drive robots are relatively accurate compared with hydraulically powered robots. By contrast, the advantages of hydraulic drive include greater speed and strength.

The drive system, position sensors (and speed sensors if used), and feedback control systems for the joints determine the dynamic response characteristics of the manipulator. The speed with which the robot can achieve a programmed position and the stability of its motion are important characteristics of dynamic response in robotics. *Speed* refers to the absolute velocity of the manipulator at its end-of-arm. The maximum speed of a large robot is around 2 rn/sec (6 ft/sec). Speed call be programmed into the work cycle so that different portions of the cycle are carried out at different velocities. What is sometimes more important than speed is the robot's capability to accelerate and decelerate in a controlled manner. In many work cycles. much of the robot's movement is performed in a confined region of the work volume; hence, the robot never achieves its top-rated velocity. In these cases, nearly all of the motion cycle is engaged in acceleration and deceleration rather than in constant speed. Other factors that influence speed of motion are the weight (mass) of the object that is being manipulated and the precision with which the object must be located at the end of a given move. A term that takes au of these factors into consideration is *speed of response,* that refers to the time required *for* the manipulator to move from one point in space to the next. Speed of response is important because it influences the robot's cycle time, that in turn affects the production rate in the application. *Stability* refers to the amount of overshoot and oscillation that occurs in the robot motion at the end-of-arm as it attempts to move to the next programmed location. More oscillation in the motion is an indication of less stability. The problem is that robots with greater stability are inherently slower in their response, whereas faster robots are generally less stable.

Load carrying capacity depends on the robot's physical size and construction as well as the force and power that can be transmitted to the end of the wrist. The weight carrying capacity of commercial robots ranges from less than 1 kg up to approximately 900 kg (2000 lb). Medium sized robots designed for typical industrial applications have capacities in the range 10 to 45 kg (25 to 100 Ib). One factor that should be kept in mind when considering load carrying capacity is that a robot usually works with a tool or gripper attached to its wrist Grippers are designed to grasp and move objects about the work cell. The net load carrying capacity of the robot is obviously reduced by the weight of the gripper. If the robot is rated at a 10 kg (22 lb} capacity and the weight of the gripper is 4 kg (9 lbs}, then the net weight carrying capacity is reduced to 6 kg (13Ib)

Components of Robot





- **Power Supply -** The working power to the robot is provided by batteries, hydraulic, solar power, or pneumatic power sources.

- **Actuators -** Actuators are the energy conversion device used inside a robot. The major function of actuators is to convert energy into movement.
- **Electric motors (DC/AC)-** Motors are electromechanical component used for converting electrical energy into its equivalent mechanical energy. In robots motors are used for providing rotational movement.
- **Sensors -** Sensors provide real time information on the task environment. Robots are equipped with tactile sensor it imitates the mechanical properties of touch receptors of human fingerprints and a vision sensor is used for computing the depth in the environment.
- **Controller -** Controller is a part of robot that coordinates all motion of the mechanical system. It also receives an input from immediate environment through various sensors. The heart of robot's controller is a microprocessor linked with the input/output and monitoring device. The command issued by the controller activates the motion control mechanism, consisting of various controller, actuators and amplifier.

UNIT-I
INTRODUCTION

- The field of robotics has its origins in science fiction. The term robot was derived from the English translation of a fantasy play written in Czechoslovakia around 1920. It took another 40 years before the modern technology of industrial robotics began. Today Robots are highly automated mechanical manipulators controlled by computers. We survey some of the science fiction stories about robots, and we trace the historical development of robotics technology. Let us begin our chapter by defining the term robotics and establishing its place in relation to other types of industrial automation.

Robotics: -

- Robotics is an applied engineering science that has been referred to as a combination of machine tool technology and computer science. It includes machine design, production theory, micro electronics, computer programming & artificial intelligence.
- OR
- "Robotics" is defined as the science of designing and building Robots which are suitable for real life application in automated manufacturing and other non-manufacturing environments.

Industrial robot: -

- The official definition of an industrial robot is provided by the robotics industries association (RIA). Industrial robot is defined as an automatic, freely programmed, servo-controlled, multi-purpose manipulator to handle various operations of an industry with variable programmed motions.

Automation and robotics:-

- Automation and robotics are two closely related technologies. In an industrial context, we can dean automation as a technology that is concerned with the use of mechanical, electronic, and computer-based systems in the operation and control of production Examples of this technology include transfer lines. Mechanized assembly machines, feedback control systems (applied to industrial processes), numerically controlled machine tools, and robots. Accordingly, robotics is a form of industrial automation.
- Ex:- Robotics, CAD/CAM, FMS, CIMS

Types of Automation:-

- Automation is categorized into three types. They are,
- 1)Fixed Automation
- 2) Programmable Automation
- 3) Flexible Automation.

(1) Fixed Automation:-

- It is the automation in which the sequence of processing or assembly operations to be carried out is fixed by the equipment configuration. In fixed automation, the sequence of operations (which are simple) are integrated in a piece of equipment. Therefore, it is difficult to automate changes in the design of the product. It is used where high volume of production is required Production rate of fixed automation is high. In this automation, no new products are processed for a given sequence of assembly operations.
- Features:-
- i) High volume of production rates,
- ii) Relatively inflexible in product variety (no new products are produced). Ex:- Automobile industries … etc.

(2) Programmable Automation:-

- It is the automation in which the equipment is designed to accommodate various product configurations in order to change the sequence of operations or assembly operations by means of control program. Different types of programs can be loaded into the equipment to produce products with new configurations (i.e., new products). It is employed for batch production of low and medium volumes. For each new batch of different configured product, a new control program corresponding to the new product is loaded into the equipment. This automation is relatively economic for small batches of the product.
- Features:-
- i) High investment in general purpose,
- ii) Lower production rates than fixed automation,
- iii) Flexibility & Changes in products configuration,
- iv) More suitable for batch production.
- Ex:- Industrial robot, NC machines tools… etc.

(3) Flexible Automation:-

A computer integrated manufacturing system which is an extension of programmable automation is referred as flexible automation. It is developed to minimize the time loss between the changeover of the batch production from one product to another while reloading. The program to produce new products and changing the physical setup i.e., it 4

- produces different products with no loss of time. This automation is more flexible in interconnecting work stations with material handling and storage system.
- Features:-
- i) High investment for a custom engineering system.
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- ii) Medium Production rates
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- iii) Flexibility to deal with product design variation,
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- iv) Continuous production of variable mixtures of products. Ex:- Flexible manufacturing systems (FMS)
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Advantages:-

- 1.High Production rates
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- 2. Lead time decreases
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- 3. Storing capacity decreases
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- 4. Human errors are eliminated.
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- 5. Labour cost is decreases.
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Disadvantages:-

- 1.Initial cost of raw material is very high,
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- 2. Maintenance cost is high,
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- 3. Required high skilled Labour.
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- 4. Indirect cost for research development & programming increases.
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Reasons for implementation of automated systems in manufacture industries:-

- The reasons for the implementation of automated systems in manufacturing industries are as follows,
- (i) To Increase the Productivity Rate of Labour
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- (ii) To Decrease the Cost of Labour
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- (iii) To Minimize the Effect of Shortage of Labour
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- (iv) To Obtain High Quality of Products
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- (v) A Non-automation nigh Cost is Avoided
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- (vi) To Decrease the Manufacturing Lead Time
-
- (vii) To upgrade the Safety of Workers.
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Need for using robotics in industries:-

- Industrial robot plays a significant role in automated manufacturing to perform different kinds of applications.
- 1. Robots can be built a performance capability superior to those of human beings. In terms of strength, size, speed, accuracy…etc.

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- 2. Robots are better than humans to perform simple and repetitive tasks with better quality and consistence’s.
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- 3. Robots do not have the limitations and negative attributes of human works .such as fatigue, need for rest, and diversion of attention…..etc.
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- 4. Robots are used in industries to save the time compared to human beings.
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- 5. Robots are in value poor working conditions
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- 6. Improved working conditions and reduced risks.
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CAD/CAM & Robotics:-

- CAD/CAM is a term which means computer aided design and computer aided manufacturing. It is the technology concerned with the use of digital computers to perform certain functions in design & production.
- CAD:- CAD can be defined as the use of computer systems to assist in the creation modification, analysis OR optimization of design.
- Cam:- CAM can be defined as the use of computer system to plan, manage & control the operation of a manufacturing plant, through either direct or in direct computer interface with the plant’s production resources.

Specifications of robotics:-

- 1.Axil of motion
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- 2. Work stations
-
- 3. Speed
-
- 4. Acceleration
-
- 5. Pay load capacity
-
- 6. Accuracy
-
- 7. Repeatability etc…
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Overview of Robotics:-

- "Robotics" is defined as the science of designing and building Robots which are suitable for real life application in automated manufacturing and other non-manufacturing environments. It has the following objectives,
- 1.To increase productivity
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- 2. Reduce production life
-
- 3. Minimize labour requirement
-
- 4. Enhanced quality of the products
-
- 5. Minimize loss of man hours, on account of accidents.
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- 6. Make reliable and high speed production.