1

Manufacturing Automation

1.1. INTRODUCTION

Automation is a word that has many meanings in the industry today. The term was coined after Second World War to describe the automatic handling of materials and parts between process operations.

Automatic machines of all kinds existed long before the term "Automation" was conceived. Some people consider automatic machines of all kinds within the realm of automation. Examples of automatic machines are automatic bar and chucking machines and tracer lathes.

However, the discussion now is devoted to groups of machines in integrated manufacturing systems.

Automation is a technology concerned with combination of mechanical, electronic and computer systems to operate and control production. These include automatic machine tools to process parts, Automatic assembly machines, Industrial robots etc.

1.2. TYPES OF AUTOMATION

(*a*) Fixed Automation
(*b*) Programmable Automation
(*c*) Flexible Automation
(*d*) Integrated Automation

1.2.*a*. Fixed Automation. In this system, the equipment is fixed to perform sequence of processing operations. It may be synchronous system or non-synchronous system.

A Synchronous system also called a dependent unit system. It has a series of machines or operation units in line or around indexing table transfer machines as shown in fig. 1.1 (*a*) and fig. 1.1 (*b*).

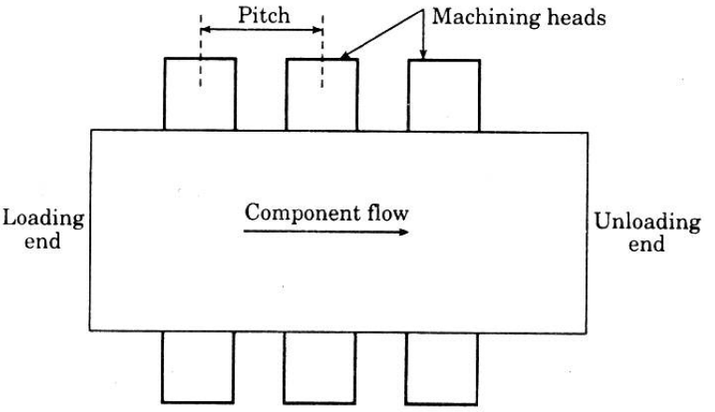

Fig. 1.1 (*a*) In line transfer machine arrangement.

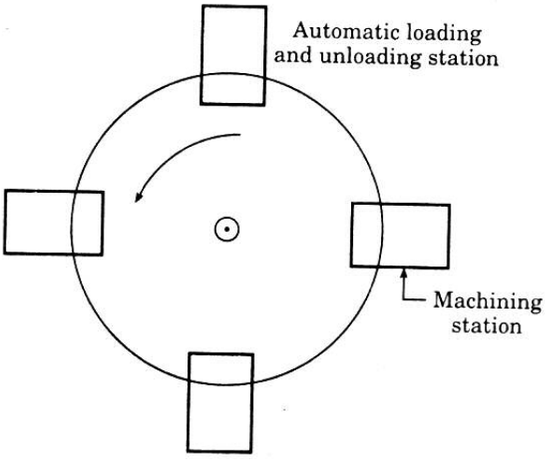

Fig. 1.1 (*b*) Rotary indexing table transfer machine arrangement.

A non-synchronous system also called as independent unit system or power-free system for a lot of parts to supply each machine and permits it to operate at faster rate. Any machine in the system may be shut down temporarily without stopping the others.

Features :

- High initial investment
- Relatively inflexible in accommodating product change.

Fixed automation is used for high volume mass production. Examples of fixed automation are transfer lines and automatic assembly lines, welding, pick and place robots are also comes under this category.

1.2.*b*. Programmable Automation. In this, the production equipment is designed with the capability to change the sequence of operations to accommodate different product configurations. The operation sequence is controlled by a programme. New programmes can be prepared and entered into the equipment to produce new products.

Features :

- High investment
- Flexible to deal with changes in product configuration.

Examples of programmable automation include NC machines and Industrial Robots.

1.2.*c*. Flexible Automation. It is an extension of programmable automation variety of products are made with no time lost for change over from one product to the next. Programmes for new products are made off-line on a computer system. Hence the time required to do the programming for the next job does not interrupt production on the current job. Examples of flexible automation are flexible manufacturing systems (FMS).

Features :

- High investment
- Flexible to deal with product design variations.

The relative positions of three types of automation for different production volumes and product variety are shown in fig. 1.2

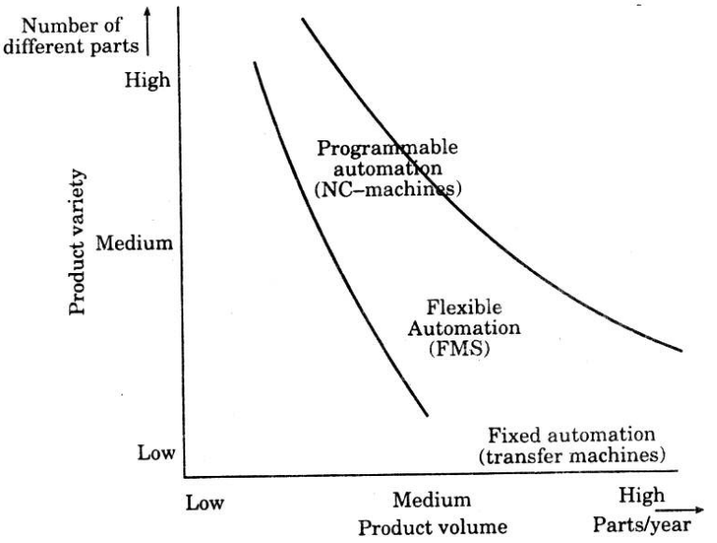

Fig. 1.2 Three types of production automation as a function of production volumes and product variety.

1.2.*d*. Integrated Automation. Integrated automation involves logical organization of design, Engineering, production, testing and distribution functions into a computer integrated system. This concept has led to the development of computer integrated manufacturing (CIM).

1.3. WHY AUTOMATION

(*a*) **High production.** High production rates are achieved with automation than manual operation.

(*b*) **Labour cost.** The high cost of labour is forcing the business management to substitute machines for human labour.

(*c*) **Labour shortage.** In many advanced nations, there has been shortage of labour. US has been forced to import labour from India and other countries. Labour shortages also stimulate (force) the development of automation.

(*d*) **Trend of labour towards the service sector.** There has been a tendency for people to view factory work as tedious, demeaning and dirty. This view forced them to seek employment in the service sectors (Insurance, sales, legal etc.)

(*e*) **Safety.** By automation, work is made safer.

(*f*) **Cost of raw materials.** The high cost of raw material in manufacturing results in the need of greater efficiency in using these materials. The reduction of scrap is one of the benefits of automation.

(*g*) **Manufacturing lead time.** Automation allows the manufacturer to reduce the time between customer order and product delivery.

1.4. TYPES OF MANUFACTURING SYSTEMS

Modern industries can be classified in different ways. These include classification by process, classification by manufacturing and classification based on the production volume. The classification by process includes chemical plants, oil refineries, food process industries. The classification by manufacturing process is exemplified by automotive machine tools, aerospace and electronic groups. The third method is classification based on production volume, identifies three main types of production : (*a*) Job shop production (*b*) Batch production (*c*) Mass Production.

1.4.*a*. Job Shop Production. Job shop production is based on orders for a variety of small lots. Each lot may consist of 20 to 200 parts, depending upon customer's needs. Job shop production is commonly used to meet specific customer needs and there is a great variety in the type of work done in the plant. Therefore the production equipment must be flexible and general purpose to allow for

this variety of work. Also workers should be highly skilled in order to handle a variety of tasks. Examples include space vehicles, machine tools, special tools and prototypes of future products.

1.4.*b*. Batch Production. This category involves the manufacturing of medium size lots of the same item or product. The lot may be produced only once or they may be produced at regular intervals. The purpose of batch production is often to satisfy continuous customer demand for an item. The equipment used in batch production is general purpose but designed for higher rates of production. Batch production plants include machine shops, casting foundries, plastic moulding industries and press working shops. Some types of chemical plants are also in this category.

1.4.*c*. Mass Production. Mass production is characterized by the high production volume of the same (or very similar) parts for a prolonged period of time. This is a continuous manufacture of identical parts. The equipment is dedicated to the manufacture of a particular product. Not only the equipment is dedicated to the product, but the entire plant is often designed for the exclusive purpose of producing the particular product. Examples are Automobiles, bulb making, screws, nuts etc.

Automation is concerned with the physical activities in manufacturing. The physical activities includes all the manufacturing processing, assembly, material handling and inspection. These operations come in direct contact with the product during manufacturing. Raw material flow in one end of the factory and finished products flow out at the other end. Manufacturing functions inside a factory is shown in fig. 1.3.

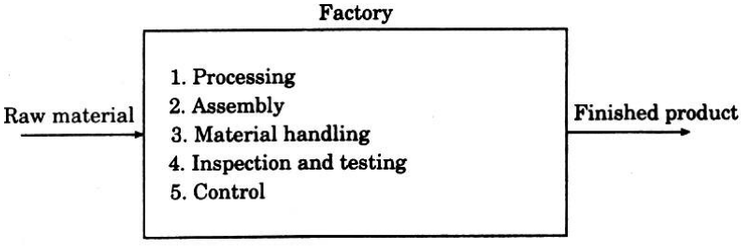

Fig. 1.3 Manufacturing functions.

1.5. MANUFACTURING FUNCTIONS

In a plant there are certain functions required to convert raw materials into finished products. These are :

(*a*) Processing
(*b*) Assembly
(*c*) Material handling and storage
(*d*) Inspection and Testing

(*e*) Control

1.5.*a*. Processing Operations. These transform the product from one state to another state of completion. Processing operations can be classified as (1) Basic process (2) Secondary process (3) Operations to enhance physical properties (4) Finishing operations.

Basic process converts raw material into the required form. Metal casting and plastic moulding are examples.

Secondary processes are performed to give desired geometry on the product.

Examples are turning, milling, drilling etc.

Operations to enhance physical properties are to improve properties. Heat treatment operations are the examples.

Final operations are used to improve the appearance of the product. Painting, polishing and chrome plating are the examples.

1.5.*b*. Assembly Operations. In assembly, two or more components of a product are joined together.

1.5.*c*. Material Handling and Storage. The purpose of material handling in the plant is to move raw materials, work in process, finished parts, tools and supplies from one location to another. It is also concerned with material storage in between the processes and finished parts in wareshouses.

1.5.*d*. Inspection and Testing. Inspection and testing comes under Quality control department Inspection refers to the activity to examining the product whether it satisfies the specified design standards. Whereas testing is used to assess the functional aspect of the product.

1.5.*e*. Control. Control in the plant may be manufacturing or plant level control. Control in manufacturing may be regulation of individual processing and assembly operations *i.e.* process control. Control at plant level includes effective use of labour, maintenance of the labour, maintenance of the equipment, moving material in the plant etc.

Computer integrated manufacturing is concerned with the information processing functions that are required to support the production operation. These include

1. Business functions
2. Product Design
3. Manufacturing plan
4. Manufacturing control

1. **Business Functions.** These links enterprise to the customers and suppliers. Sales and marketing, sales forecasting, order entry, customer billing and others are included in this category.

2. **Product Design.** The product is designed for customers specification or by the manufacturing plant itself. Product design consists of component drawings, assembly drawings, bill of materials etc. A prototype is made for testing and demonstration purpose.

3. **Manufacturing Plan.** This includes process planning, master schedules, capacity planning. Process planning consists of determining the sequence of operations and assembly operations needed to produce the part. The document used for process sequence is route sheet. The master schedule is a list of products to be made. Capacity planning deals with planning the manpower and machine resources of the industry.

4. **Manufacturing Control.** It deals with managing and controlling the physical operations in the industry to implement the manufacturing plan. These include shop floor control, inventory control and quality control.

1.6. PLANT LAYOUT

If refers to the arrangement of various facilities (Equipment, materials, manpower etc.) in a production plant in the most effective manner.

1.6.1. Principle of plant layout.

Many principles of plant layout are developed during past years to guide the plant layout engineers. Besides these ready-made principles, considerable art and skills are required in designing a good plant layout. But certain principles are used, they are

(*a*) **Overall integration.** It means the integration of production center facilities like workers, machinery, raw material etc. in a logical and balanced way.

(*b*) **Minimum movements.** The number of movements of workers and materials should be minimized. It is better to transport materials in optimum bulk rather than in small amounts.

(*c*) **Effective use of available space.** Besides using the floor space of a room, if the ceiling height is also utilized, more material can be accommodated in the same room. Boxes or bags containing raw materials can be stacked one above the other to store more items in the same room.

(*d*) **Maximum visibility.** Men, machines and materials of the plant should be visible at all times.

(*e*) **Safe and improved environments.** Working place safe, well ventilated and free from dust noise fumes and other hazardous conditions increase the operating efficiency of the workers.

(*f*) **Flexibility.** In automative and other industries where models of products change after sometime, it is better to permit all possible flexibility in the layout. The machinery is arranged in such a way that the changes of the production process can be achieved at the least cost or disturbance.

1.6.2. Types of Layouts.

Layouts are basically of the three types
(*a*) Process or functional layout
(*b*) Product or Line Layout
(*c*) Fixed position layout.

1.6.2.*a* Process Layout.

It is also known as functional layout and is characterized by keeping similar machines or similar operations at one location (place). In other words, all lathes will be at one place, all milling machines placed at another place, drilling machines are kept at another place and so on. This type of layout is used for industries engaged in job shop and batch production. A simple sketch of a Process layout is shown in fig. 1.4.

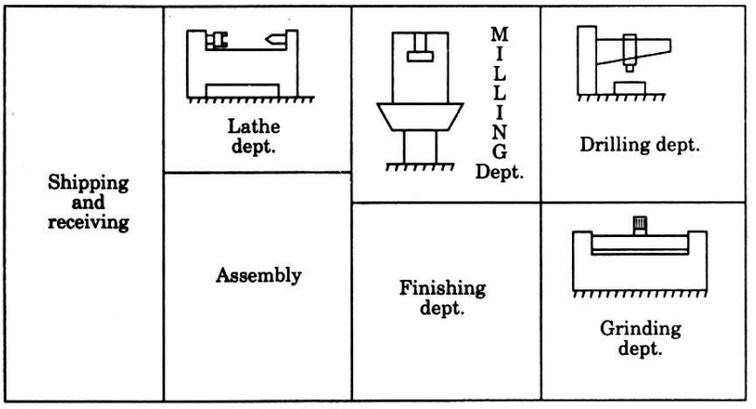

Fig. 1.4 Process layout.

Advantages of process layout :
(*i*) Lower capital investment on account of comparatively less number of machines and lower cost of general purpose machines.
(*ii*) Better utilization of the available equipment.
(*iii*) Greater flexibility in regards to allocation of work to equipment and workers.
(*iv*) Better product quality because the workers attend one type of machines and operations.

(*v*) Workers attain greater skills.

(*vi*) Imbalance of work in one section does not affect the working of the other section.

(*vii*) Variety of jobs coming as different job orders make the work more interesting for the workers.

Disadvantages :

(*i*) For the same volume of production, space requirements are higher.

(*ii*) Automatic material handling is extremely difficult.

(*iii*) Work-in-process inventory is higher since jobs have to queue up for each operation.

(*iv*) Routing and scheduling is difficult since different jobs have different operation sequences.

(*v*) Set up costs are high because of frequent changes of jobs.

1.6.2.*b* Product or Line Layout.

Product layout is also called "layout by sequence". In this type, various operations on raw material are performed in a sequence and the machines are placed along the product flow line. This type of layout is preferred for continuous production. Fig. 1.5 shows a product type of layout.

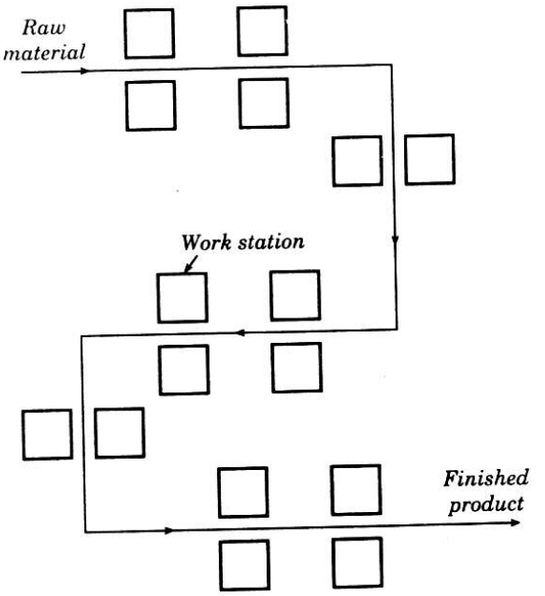

Fig. 1.5 Product or line layout

Advantages :

(*i*) Less space requirements for the same volume of production.

(*ii*) Automatic material handling.

(*iii*) Less in-process inventory.

(*iv*) Smooth and continuous work flow.

(*v*) Less skilled workers may serve the purpose.

Disadvantages :

(*i*) A change in product involves major changes in Layout .

(*ii*) Breakdown of any of machines in the line renders other machines idle till it is repaired.

1.6.2.*c*. Fixed Position Layout

In this type of layout, the term "fixed position" refers to the product. Because of size and weight, the product remain in one location and men and the equipment are moved near the product for fabrication (Assembly). Large aircraft assembly and shipbuilding are the examples of fixed position layout. Fixed position layout is shown in Fig. 1.6.

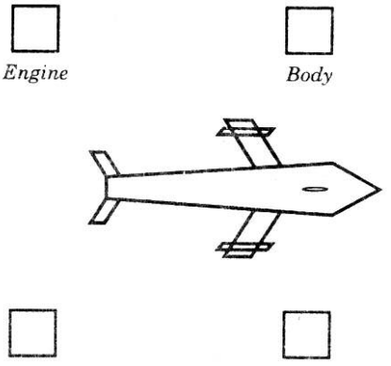

Fig. 1.6 Fixed position layout.

Project layout is similar to fixed-position layout. This is used for construction of building, bridges and dams. In this, when the job is completed, the equipment is removed from the construction site. In fixed-position layout, the product is moved out of the plant and the plant remains for the next job.

1.7. AUTOMATED FLOW LINES

An automated flow line consists of several machines or workstations which are linked together by work handling devices that transfer parts between stations. The transfer of work parts occurs automatically and the work stations carry out their functions auto-

matically. A raw material enters at one end of the line and the processing steps are performed sequentially as the part moves from one station to the next. Buffer storage zones can be introduced either at a single location or between every work station.

The objectives of the use of flow line automation are :

(*i*) To reduce labor costs
(*ii*) To increase production rates
(*iii*) To reduce work-in process
(*iv*) To minimize distances moved between operations.

Work flow can be either in line type or rotary type. The choice between the two types depends on the application. Rotary type is limited to small work pieces and requires less floor space. The number of workstations in rotary type is limited due to the size of the dial table. The inline design is best suited for larger workpieces and can accommodate a large number of workstations.

1.7.1. Methods of work part transport.

The transfer mechanism of the automated flow line is not only move the parts between the adjacent work stations, it also orient and locate the parts in position for processing at each station. The general methods are

(*a*) Continuous transfer
(*b*) Intermittent or synchronous transfer
(*c*) Asynchronous or power and free transfer

The type of transport system for a given application depends on such factors as (*i*) the type of operations to be performed (*ii*) the number of stations on the line (*iii*) the weight and size of the workpart (*iv*) production rate requirements.

1.7.1 (*a*) **Continuous Transfer.** In this system the work parts are moved continuously at constant speed. Examples are beverage bottling operations, packing etc.

(*b*) **Intermittent Transfer.** In this method the work pieces are transported with an intermittent or discontinuous motion. The work stations are fixed in position and the parts are moved between stations and then registered at the proper locations for processing. Examples are machining operations, press working etc.

(*c*) **Asynchronous Transfer.** In this method each workpart move to the next station when processing at the current station has been completed. Each part moves independently of other parts.

It offers flexibility. In-process storage of work parts can be incorporated. Parallel stations or several series stations can be used for the longer operations and single station can be used for shorter operations.

1.7.2. Transfer Mechanisms. There are various types of transfer mechanisms used to move parts between stations. These mechanisms can be grouped into two types. These are

(*a*) Linear Transfer Mechanisms
(*b*) Rotary Transfer Mechanisms

1.7.2 (*a*) Linear Transfer Mechanisms. These are used to provide linear travel for in-line machines. These are

(*i*) Pawl type system
(*ii*) Walking beam systems
(*iii*) Roller conveyor system
(*iv*) Belt conveyor system
(*v*) Chain conveyor system
(*vi*) Slat conveyor system

1.7.2. (*a*) (*i*) Pawl Type System.

This is a simple and inexpensive type of transfer mechanism in which the parts are slid from one machining station to the next. A single transfer bar either round or rectangular in section has a series of pivoted fingers mounted upon it. These fingers are either spring loaded or weighed so as to latch against the rear surface of the parts. The mechanism is illustrated in fig 1.7.

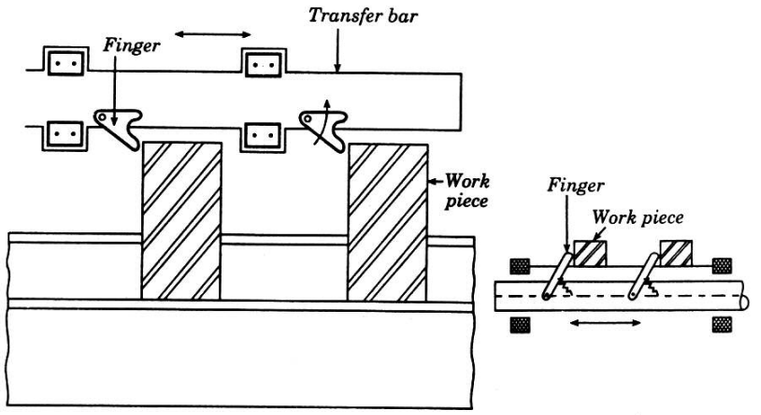

Fig. 1.7 Pawl type system.

1.7.2 (*a*) (*ii*) Walking Beam System.

The work parts are lifted up from their work station locations by transfer bar by actuating the cylinder B and moved to the next station by advancement of cylinder A as shown in Fig. 1.8.

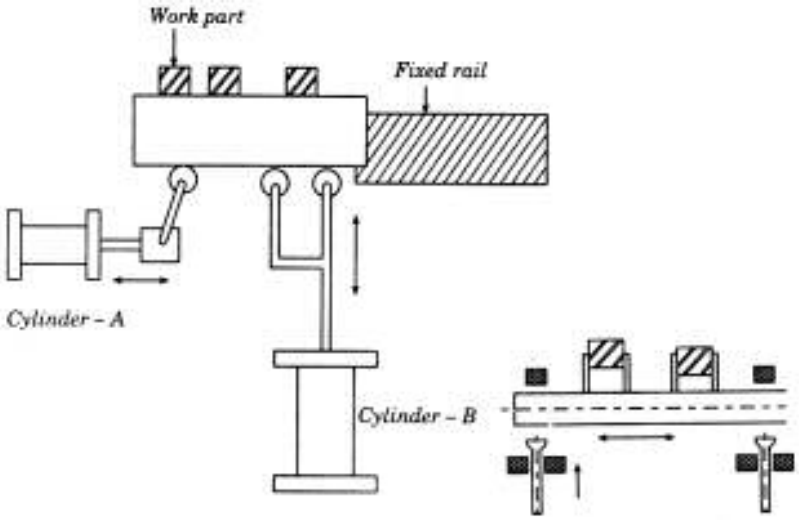

Fig. 1.8 Walking beam system.

1.7.2 (*a*) (*iii*) Roller Conveyor System.

Roller conveyors are either gravity aided or powered and are employed for transporting parts or pallets possessing flat riding surfaces. Gravity conveyors are easy to setup as it does not involve any power drive. The gravity types are arranged so that the path way is along a downward slope sufficient to overcome downward friction. The roller conveyors can be powered by either belt drive or chain drive. In belt drive the flat belt runs beneath the rollers to provide rotation of the rollers by friction. Roller conveyors are shown in fig. 1.9.

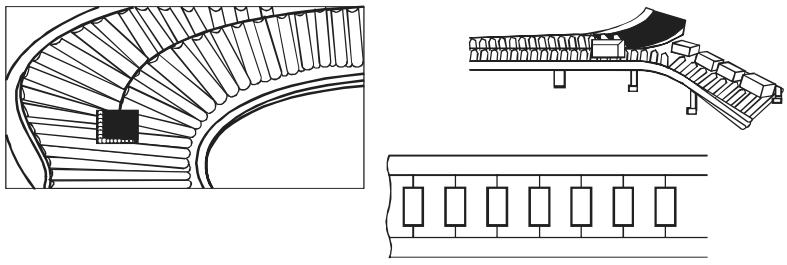

Fig. 1.9 Roller conveyor.

1.7.2 (*a*) (*iv*) Belt Conveyor System.

Belt conveyors (Fig. 1.10) are flexible and can be designed to handle almost anything. These are used to carry objects over short

as well as long distances and to convey goods to upper floors. These are in two forms : Flat belt for pallets parts and troughed belts for bulk materials. Materials are placed on the upper surface of the belt. The belt is made into a continuous loop so that half of its length can be used for delivering the goods and the other half is idle return run. The belt is supported by a frame that has rollers or other supports spaced every few metres.

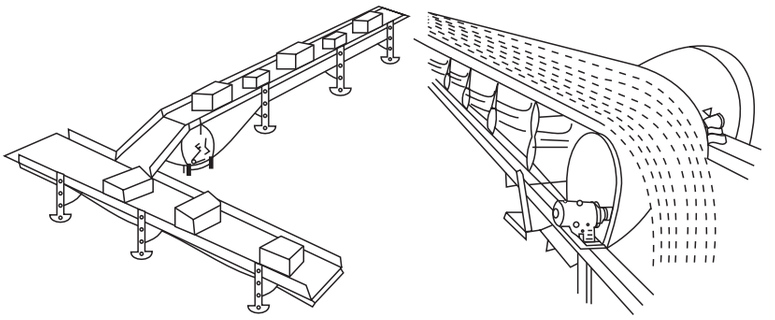

Fig. 1.10 Belt conveyor.

1.7.2 (*a*) (*v*) Chain Conveyor System.

A chain conveyor (Fig. 1.11) consists of overhead mounted endless chain. It is supported from the ceiling and has a fixed path of travel. It saves valuable floor space. Chain conveyors are used in refrigeration industries for painting and plating of the refrigerator shells.

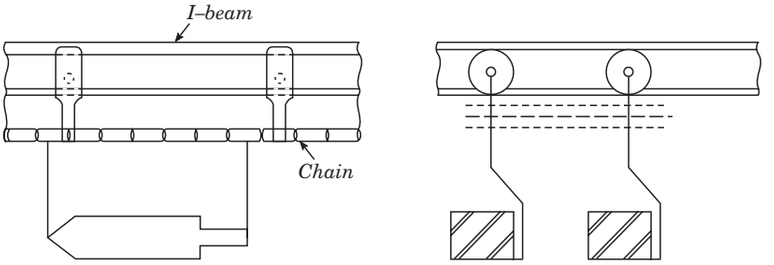

Fig. 1.11 Chain conveyor.

1.7.2 (*a*) (*vi*) Slat Conveyor System.

The slat conveyor used individual platforms, called slats that are connected to a continuously moving chain. Although its drive mechanism is the powered chain, it operates like a belt conveyor. Parts are placed on the flat surface of the slats. Straight line flows are common in slat conveyor system (See Fig. 1.12).

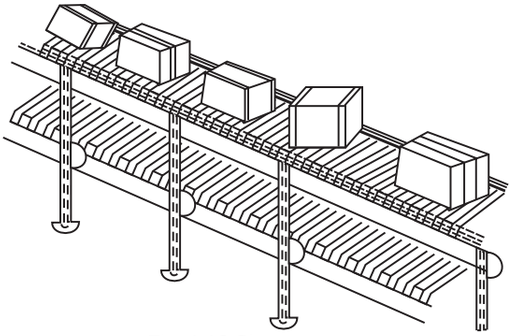

Fig. 1.12 Slat conveyor.

1.7.2 (*b*) Rotary Transfer Mechanisms. There are several methods to index a circular table or dial at various angular positions corresponding to workstation locations. These are

(*i*) Rack and pinion
(*ii*) Ratchet and pawl
(*iii*) Geneva mechanism
(*iv*) Cam mechanism

1. **Rack and Pinion.**

This is very simple mechanism. A hydraulic piston is used to drive the rack. This rack causes the pinion gear to rotate which inturn rotates the indexing table which is attached to it (see Fig. 1.13).

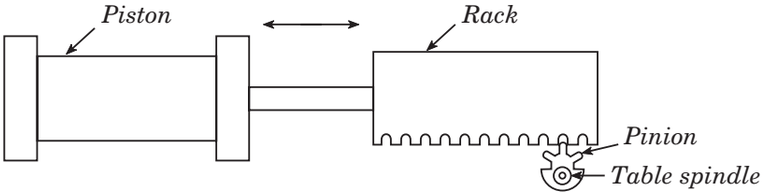

Fig. 1.13 Rack and pinion for table indexing.

1.8. Buffer Storage

There are two advantages for the use of buffer storage zones in automated flow lines.

The first one is, to reduce the effect of individual station break downs on the flow line. When a break down occurs on the flow line, the purpose of the buffer storage is to allow a portion of the line to continue operating, while the remaining portion is stopped and under repair. As shown in fig. 1.14 an automated flow line is divided into two sections and connected by buffer storage (Parts) which

collects parts from the first section and feed them to the second section. If a station jam is the cause the first section of the line to stop, the second section will continue to operate till the parts exhausted in the buffer zone. Similarly if the second section is shut down, the first section will continue to operate as long as there is a room in the buffer zone to store parts.

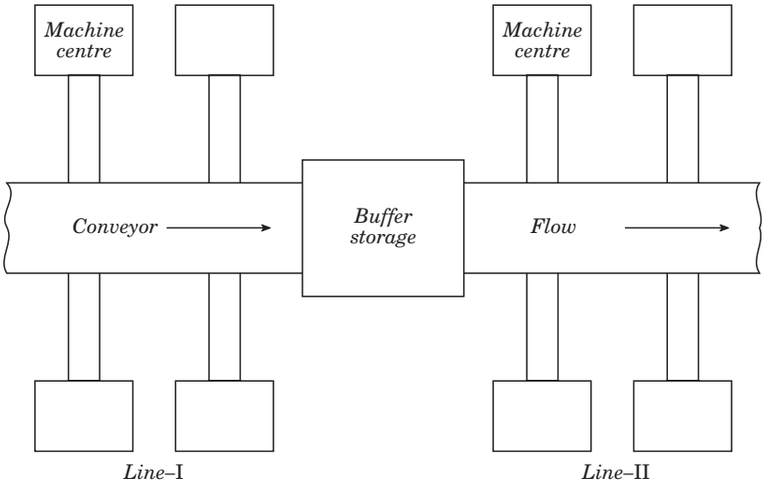

Fig. 1.14 Two flow lines separated by storage buffer.

The second reason for using buffer storage in the flow line is to smooth out the effects of variations in cycle times.

QUESTIONS

1. Define Automation. Explain various types of automation.
2. Why Automation ?
3. Describe various types of production.
4. Explain various functions in manufacturing.
5. Describe various types of plant layouts used in the industry.
6. Differentiate between Automation and computer integrated manufacturing (CIM).
7. What are the objectives of automated flow lines ?
8. Explain different transfer mechanisms used in automated flow lines.
9. What is Buffer Storage and state its advantages.