UNIT-I

INTRODUCTION

Introduction

• Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design.

• Computer-aided manufacturing (CAM) is the use of computer systems to plan, manage, and control the operations of a manufacturing plant through direct or indirect computer interface with plant’s resources.

Computer-integrated manufacturing (CIM)

Computer-integrated manufacturing (CIM) is the manufacturing approach of using computers to control the entire production process. This integration allows individual processes to exchange information with each other and initiate actions. Through the integration of computers, manufacturing can be faster and less error-prone, although the main advantage is the ability to create automated manufacturing processes. Typically CIM relies on closed-loop control processes, based on real-time input from sensors. It is also known as flexible design and manufacturing.

Need for CAD/CAM

To increase productivity of the designer

To improve quality of the design

To improve communications

To create a manufacturing database

To create and test tool paths and optimize them

To help in production scheduling and MRP models

To have effective shop floor control
Design Process

Evolution of CIM

1970s - 1980s...Flexible Manufacturing

- Systems/Cells
  - “… a group of CNC machinery/equipment linked by an automated materials handling system, whose operation is integrated by supervisory computer control …”
- Provided efficient mid-volume, mid-variety production
- Increased machine utilization
- Reduced work-in-process inventory, labor and tooling costs, setup costs, lead time, lot size
- Ability to react quickly to engineering changes

1980s...Computer Integrated Manufacturing
•“… computer assisted control and integration at all levels of a manufacturing enterprise …”

•Strict hierarchical information flow

•Totally automated, unmanned, paperless factory

•Integration problems in heterogeneous Environments

1990s…Intelligent Manufacturing

•“… architecture for highly decentralized manufacturing systems, built from a modular mix of autonomous, cooperative, and intelligent elements (agents) …”

•Re-emergence of the human factor seeking to maximize the use of human intellectual skills and flexibility

•Migrating from hierarchy to vertically

•Capability of rapid self-reconfiguration by incorporating human and machine intelligence

Definition of CIM

Computer Integrated Manufacturing is the integration of the total manufacturing enterprise through the use of integrated systems and data communications coupled with new managerial philosophies that improve organizational and personnel efficiency.

CIM Wheel
Production concept

Types of Production

1. Job shop production
2. Batch production
3. Mass production

1. Job shop production.

The distinguishing feature of job shop production is low volume. The manufacturing lot sizes are small, often one of a kind. Job shop production is commonly used to meet specific customer orders, and there is a great variety in the type of work the plant must do. Therefore, the production equipment must be flexible and general-purpose to allow for this variety of work. Also, the skill level of job shop workers must be relatively high so that they can perform a range of different work assignments.

Examples of products manufactured in a job shop include space vehicles, aircraft, machine tools, special tools and equipment, and prototypes of future products.

Construction work and shipbuilding are not normally identified with the job shop category, even though the quantities are in the appropriate range. Although these two activities involve the transformation of raw materials into finished products, the work is not performed in a factory.
2. Batch production:

This category involves the manufacture of medium-sized lots of the same item or product. The lots 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. However, the plant is capable of a production rate that exceeds the demand rate. Therefore, the shop produces to build up an inventory of the item. Then it changes over to other orders. When the stock of the first item becomes depleted, production is repeated to build up the inventory again. The manufacturing equipment used in batch production is general-purpose but designed for higher rates of production.

Examples of items made in batch-type shops include industrial equipment, furniture, textbooks, and component parts for many assembled consumer products (household appliances, lawn mowers, etc.). Batch production plants include machine shops, casting foundries, plastic molding factories, and press working shops. Some types of chemical plants are also in this general category.

3. Mass production:

This is the continuous specialized manufacture of identical products. Mass production is characterized by very high production rates, equipment that is completely dedicated to the manufacture of a particular product, and very high demand rates for the product. Not only is the equipment dedicated to one product, but the entire plant is often designed for the exclusive purpose of producing the particular product. The equipment is special-purpose rather than general-purpose. The investment in machines and specialized tooling is high. In a sense, the production skill has been transferred from the operator to the machine. Consequently, the skill level of labor in a mass production plant tends to be lower than in a batch plant or job shop.

Functions in Manufacturing

1. Processing
2. Assembly
3. Material handling and storage
4. Inspection and test
5. Control

CIM Hardware and Software

CIM Hardware comprises the following:
i. Manufacturing equipment such as CNC machines or computerized work centers, robotic work cells, DNC/FMS systems, work handling and tool handling devices, storage devices, sensors, shop floor data collection devices, inspection machines etc.

ii. Computers, controllers, CAD/CAM systems, workstations / terminals, data entry terminals, bar code readers, RFID tags, printers, plotters and other peripheral devices, modems, cables, connectors etc.

CIM software comprises computer programs to carry out the following functions:

- Management Information System
- Sales
- Marketing
- Finance
- Database Management
- Modeling and Design
- Analysis
- Simulation
- Communications
- Monitoring
- Production Control
- Manufacturing Area Control
- Job Tracking
- Inventory Control
- Shop Floor Data Collection
- Order Entry
- Materials Handling
- Device Drivers
- Process Planning
- Manufacturing Facilities Planning
- Work Flow Automation
- Business Process Engineering
- Network Management
- Quality Management

Elements of CIM
The concept of the automated factory is usually applied in the context of discrete product manufacturing and in connection with products that are made in medium or small batch sizes. The factory of the future will have to perform basic manufacturing functions such as processing, assembly, material handling and storage, inspection, and control.

The objective in the automated factory is to achieve a level of untended integrated operation similar to that which currently exists in a computer-controlled production plant which processes chemicals, petroleum, foods, and certain metals. In such a plant, there exists a relatively small crew of perhaps 5 or 10 persons who observe the production operations. These people perform maintenance and repair functions on the equipment, programming of the computer systems, monitoring the computer controlled processes, activities that involve interactions with the outside world, plant security, and general supervision.

1. The Information System in the Automated Factory

Information system of the future will probably have the capacity to interpret data in more than the conventional data processing sense. Instead of merely performing repetitive calculations on the data, the system will be able to understand the inherent meaning of the data being manipulated. Large computer systems at the third and fourth levels of the computer hierarchy will possess attributes of comprehension and intelligence in their processing of information. They will be able to make decisions and initiate actions in the company for the timely execution of procedures that must occur during the manufacturing cycles. In essence, the information system used to support the automated factory of the future will become a “knowledge base management system” rather than a data base management system.

2. Processing and Assembly
The processing and assembly functions in manufacturing are the fundamental operations that transform raw materials and add value to them. Let us consider some of the changes that are likely to occur in processing and assembly technology.

3. Material Handling

The material handling function looms as a significant obstacle that must be overcome if we are to achieve the future in small- and medium-lot-size manufacturing. Two problem areas regarding material handling will be:

Flexible routing for different parts, and Mechanical interfacing of material handling and production systems.

4. Inspection Systems

The inspection function is to become more automated in the future as quality continues to remain a high-priority issue. Current trends in automated inspection suggest that the future factory will be characterized in the quality control area by following:

Inspection procedures will be integrated into the production process to form a closed loop feedback control system. Processing errors detected in inspection will be corrected on line so that much closer to 100% good product can be achieved.

Automated inspection methods will permit the use of 100% inspection of production output rather than the sampling inspection procedures.

Noncontact sensors, such as machine vision and other optical techniques, will come into widespread use in automated inspection.

Computer-controlled inspection technologies that can be adapted to varying product configurations will grow in importance in the future automated factory.

Impact of CIM

Impact on labours

Retraining and Education

Social and Economic forces
Automated Production Line

Automated production lines are typically used for high production of parts that require multiple processing operations. The production line itself consists of geographically dispersed workstations within the plant, which are connected by a mechanized work transport system that ferries parts from one workstation to another in a pre-defined production sequence. In cases where machining operations, such as drilling, milling, and similar rotating cutter processes, are performed at particular workstations, the more accurate term to use is transfer line, or transfer machine. Other potential automated production line applications include: robotic spot-welding, sheet-metal press-working, and electroplating of metals.

System Configuration

In-line Lay-out

Consists of a sequence of workstations in a straight-line arrangement. Common for machining big work pieces, such as automotive engine blocks, engine heads, and transmission cases. Can accommodate a large number of workstations, and buffer storage can also be planned for the configuration.

L shaped Lay-out
U shaped Lay-out

Consists of two or more straight-line transfer sections, where the segments are usually perpendicular to each other. Layout designs include the L-shaped layout, the U-shaped layout, and the Rectangular layout. Reasons for favouring segmented in-line over in-line configurations include: floor space considerations; reorientation of workparts to present different surfaces for machining in different line segments; the swift return of workholding fixtures (in the rectangular arrangement).

Rectangular Lay-out

Rotary Layout
Consists of a circular worktable around which work parts are fixed to work holders. The worktable rotates to move each work part, in turn, into each automated workstation which is located around the circumference of the worktable. The worktable is often called a dial, and the equipment is referred to as a dial indexing machine, or simply, indexing machine. Commonly limited to smaller work parts and relatively few workstations, and they cannot readily accommodate buffer storage capacity. However they require less floor space, and are generally less expensive than other configurations.

Work part transfer Mechanism

The function of the work part transfer system is to move parts between stations on the production line, a function performed by means of transfer mechanisms that are either synchronous or asynchronous. Synchronous transfer is the traditional method of moving parts within a production system, but asynchronous transfer has the following advantages:

- Greater Flexibility
- Fewer pallet fixtures needed

Types of Work part transfer mechanism

1. Linear Transfer System

2. Rotary Indexing Mechanism

   1. Linear Transfer System
Types of linear transfer systems used for work part transfer include powered roller conveyors, belt conveyors, chain driven conveyors, and cart-on-track conveyors. The typical installation of a conveyor system for work part transfer is depicted in Figure 1. Work carriers attached to the conveyor ensure that work parts are transferred in a synchronous fashion from one workstation to the next, while the ‘over-and-under’ design of the conveyor belt ensures a continuous supply of empty carriers for reloading. The belt conveyor can also be used for asynchronous transfer of parts by using friction between the belt and the part to move parts between stations. Parts are stopped in their forward motion by means of pop-up pins, or other stopping mechanisms.

Cart-on-track conveyors provide asynchronous movement of parts, and are designed to position their carts within about ±0.12mm, which is adequate for many processing operations. Other mechanisms for locating carts may also be used, such as pin-in-hole devices and detente devices.

Rotary Indexing Mechanism

Several mechanisms can be used to generate the type of rotary power required by rotary indexing machines. Two of these are the Geneva mechanism, and the cam drive.
The Geneva mechanism uses a continuously rotating driver to index the table through a partial rotation.

Cam drive mechanisms may also be favoured as an alternative to the Geneva mechanism (see Figure). They provide an accurate and reliable method of indexing a rotary dial table. Additionally it can be designed to provide a variety of velocity and dwell characteristics that are more complex than those that can be created by means of the Geneva mechanism. Its major disadvantage is its expense: cam drives have to be custom-designed for each operation that they are required for.

Storage Buffers

Automated production lines may also contain storage buffers, which act as temporary storage for parts that are traversing the line, before being released from the buffer so that they may proceed to downstream workstations. Storage buffers are either manually operated or automated. In automated versions, a mechanism is used to accept parts from upstream workstations, a place is designated as storage for the incoming parts, and a mechanism subsequently releases the parts, as required, to supply downstream workstations. Storage capacity—the number of parts a particular storage buffer may hold—is an important metric for determining storage effectiveness; as well as the location and arrangement of storage buffers—which may be located between every pair of adjacent workstations, or between lines stages containing multiple workstations. The latter arrangement is illustrated in Figure
Applications of Automated Production line

Automated production lines are found in both processing and assembly environments, but here we focus upon processing applications, in particular operations of machining. Other processes that can be performed include sheet metal forming and cutting, rolling mill operations, spot welding, painting, and plating operations.

Automated Assembly System

The use of mechanized and automated devices to perform the various assembly tasks in an assembly line or cell

Fixed automation usually

- Most automated assembly systems are designed to perform a fixed sequence of assembly steps on a specific product that is produced in very large quantities

Need/Application of AAS

Where is automated assembly appropriate:

- High product demand
- Stable product design
- The assembly consists of no more than a limited number of components
- The product is designed for automated assembly

Products in AAS

- Alarm clocks
- Ball bearings
- Ball point pens
- Cigarette lighters
- Door mechanisms
- Gear boxes
- Light bulbs
- Locks
- Mechanical pencils
- PCB assemblies
- Small electric motors
- Wrist watches
System Configuration

In-line assembly machine

Dial indexing machine

Carousel assembly system

Single-station assembly cell

In-line Assembly Machine

A series of automatic workstations located along and in-line transfer system

- Either synchronous or asynchronous work transfer used

Dial Indexing Machine

Base parts are loaded onto fixtures or nests attached to a circular dial table, and components are added at workstations located around the periphery of the dial as it indexes from station to station.
Carousel assembly system

A hybrid between circular work flow of dial indexing machine and straight work flow of in-line system

![Carousel Assembly System Diagram](image)

Single Station Assembly System

Assembly operations are performed on a base part at a single location

- A robot is sometimes used as the assembly machine

![Single Station Assembly System Diagram](image)

Multi station vs Single Station

- Multi-station assembly machine or line
  
  Faster cycle rate
High production quantities
More operations possible
More components per assembly

- Single-station assembly cell
  Suited to robotic assembly
  Intended for lower production quantities

Part Delivery at Work Stations

Typical parts delivery system at a workstation consists of the following hardware components:

Hopper - container for parts
Parts feeder - removes parts from hopper
Selector and/or orientor - to assure part is in proper orientation for assembly at workhead
Feed track - moves parts to assembly workhead
Escapement and placement device - removes parts from feed track and places them at station

Parts Delivery System at Station
Vibratory Bowl Feeder

Automated Guided Vehicle System

A Computer-Controlled, Non-manned, Electric Powered Vehicle Capable of Handling Material

Use of AGV

- Repetitive motion
- Distances over 150 feet
- Multi-shift operation
- Desire to save costs and improve efficiency

Need of AGV

Not a permanent obstacle

- Paths can be changed easily
- System can be expanded easily
- Does not represent a single point of failure - system has built-in redundancy
- Favorable cost/benefit compared to other automated material handling solutions
Types of AGV

Driverless trains

AGV’s pallet trucks

Unit load carriers

Driverless Trains

It consists of a towing vehicle that pulls one or more trailers to form a train.

This type is applicable in moving heavy pay loads over large distance in warehouses or factories with or without intermediate pickup and drop off points along the route.

It consists of 5-10 trailers and is an efficient transport system.

AGV Pallet Trucks

Pallet trucks are used to move palletized loads along predetermined routes.

The capacity of an AGV pallet truck ranges up to several thousand kilograms and some are capable of handling two pallets.

It is achieved for vertical movement to reach loads on racks and shelves.
Unit Load Carriers

These are used to move unit loads from one station to another.

It is also used for automatic loading and unloading of pallets by means of rollers.

Load capacity ranges up to 250 kg or less.

Especially these vehicles are designed to move small loads.

Types of navigation in AGV’S

  Wired navigation

  Guide tape navigation

  Laser target navigation

Wired Navigation
The wired sensor is placed on bottom of the AGV’S and is placed facing the ground. A slot is cut in the ground and a wire is placed approximately 1 inch below the ground. The sensors detect the radio frequency being transmitted from the wire and follows it.

Guide Tap Navigation

The AGV’S( some known as automated guided carts or AGC’S) use magnetic tape for the guide path. The AGC’S is fitted with the appropriate guide sensors to follow the path of the tape. It is considered a “passive” system since it does not require the guide medium to be energized as wire does.

Laser target navigation

The AGV’S carry’s a laser transmitter and receiver on a rotating turret. The laser is sent off then received again the angle and distances are automatically calculated and stored into AGV’S memory. The AGV’S has reflector map stored in memory and can correct its position based on errors between the expected and received measurements. It can then navigate to a destination target using the constantly updating position.
Applications of AGV

Aerospace 	 Apparel
Automotive 	 Beauty Products
Books and Library Systems 	 Dairy
Food and Beverage 	 Mail Order Fulfillment
Office and Computer Equipment 	 Pharmaceuticals and Health Care
Refrigerator and Freezer Applications 	 Retail
Sporting Goods 	 Textiles

Safety

Mechanical Protection Group

1. Side Optical Bumper
2. Front & Rear Bumpers
3. Most industrial-use AGVs travel at a speed between 100 and 300 feet per minute
Electromagnetic Protection Group

1. Optical Front Warning Zone Front Stop Zone
2. Rear Warning & Stop Zones
3. Optional Tower Protection
4. Side Protection

Storage System

Function – to store materials (e.g., parts, work-in-process, finished goods) for a period of time and permit retrieval when required

- Used in factories, warehouses, distribution centers, wholesale dealerships, and retail stores
- Important supply chain component
- Automation available to improve efficiency
Material Handling

Material handling is the function of moving the right material to the right place in the right time, in the right amount, in sequence, and in the right condition to minimize production cost. The cost of MH estimates 20-25% of total manufacturing labor cost in the United States [The Material Handling Industry of America (MHIA)]

Goals of Material Handling

- The primary goal is to reduce unit costs of production
- Maintain or improve product quality, reduce damage of materials
- Promote safety and improve working conditions
- Promote productivity
  - Material should flow in a straight line
  - Use gravity! It is free power
  - Move more material at one time
  - Mechanize material handling
  - Automate material handling
- Promote increased use of facilities
- Reduce tare weight (dead weight)
- Control inventory

Overview of Material Handling Equipment

**Material handling equipment includes:**

**Transport Equipment:** industrial trucks, Automated Guided vehicles (AGVs), monorails, conveyors, cranes and hoists.

**Storage Systems:** bulk storage, rack systems, shelving and bins, drawer storage, automated storage systems.

**Unitizing Equipment:** palletizers
Identification and Tracking systems

Considerations in Material Handling System Design

1. Material Characteristics

<table>
<thead>
<tr>
<th>Category</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical state</td>
<td>Solid, liquid, or gas</td>
</tr>
<tr>
<td>Size</td>
<td>Volume; length, width, height</td>
</tr>
<tr>
<td>Weight</td>
<td>Weight per piece, weight per unit volume</td>
</tr>
<tr>
<td>Shape</td>
<td>Long and flat, round, square, etc.</td>
</tr>
<tr>
<td>Condition</td>
<td>Hot, cold, wet, etc.</td>
</tr>
<tr>
<td>Safety risk and risk of damage</td>
<td>Explosive, flammable, toxic; fragile, etc.</td>
</tr>
</tbody>
</table>

Considerations …cont.

2. Flow rate

Considerations …cont.

3. Plant Layout

<table>
<thead>
<tr>
<th>Layout Type</th>
<th>Characteristics</th>
<th>Typical MH Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>Fixed – position Process Product</td>
<td>Large product size, low production rate Variation in product and processing, low and medium production rates Limited product variety, high production rate</td>
<td>Cranes, hoists, industrial trucks Hand trucks, forklift trucks, AGVs Conveyors for product flow, trucks to deliver components to stations.</td>
</tr>
</tbody>
</table>

* Storage System Performance

Performance measures for storage systems:

Storage capacity - two measures:

- Total volumetric space
- Total number of storage compartments (e.g., unit loads)

Storage density - volumetric space available for storage relative to total volumetric space in facility

Accessibility - capability to access any item in storage

System throughput - hourly rate of storage/retrieval transactions

Utilization and availability (reliability)

* Storage Location Strategies

Two strategies: 1. Randomized, and 2. Dedicated

Randomized storage –

- Incoming items are stored in any available location
- Usually means nearest available open location

Dedicated storage –

Incoming items are assigned to specific locations in the storage facility
Typical bases for deciding locations:

- Items stored in item number sequence
- Items stored according to activity level
- Items stored according to activity-to-space ratios

* Conventional Storage Methods

Bulk storage - storage in an open floor area

- Problem: achieving proper balance between storage density and accessibility

Rack systems - structure with racks for pallet loads

- Permits vertical stacking of materials

Shelving and bins - horizontal platforms in structural frame

- Steel shelving comes in standard sizes
- Finding items can be a problem

Drawer storage - entire contents of each drawer can be viewed

* Bulk Storage

Bulk storage arrangements:

a) high-density bulk storage provides low accessibility,
b) bulk storage with loads forming rows and blocks for improved accessibility
c) Low cost per sq meter
* Pallet Rack System

Pallet loads placed on racks in multi-rack structure

- Low cost
- Good storage density
- Good accessibility

* Drawer Storage

Contents easily visible

- Good accessibility
- Relatively high cost
Small items (tools, repair parts, etc.)

*Automated Storage Systems

Mechanized and automated storage equipment to reduce the human resources required to operate a storage facility

Significant investment

Level of automation varies

In mechanized systems, an operator participates in each storage/retrieval transaction

In highly automated systems, loads are entered or retrieved under computer control

Objectives and Reasons for Automating Storage Operations

To increase storage capacity
To increase storage density
To recover factory floor space currently used for WIP
To improve security and reduce pilferage
To reduce labor cost and/or increase productivity
To improve safety
To improve inventory control
To improve stock rotation
To improve customer service
To increase throughput

Types of Automated Storage System

Automated Storage/Retrieval System (AS/RS)
Rack system with mechanized or automated crane to store/retrieve loads
Carousel Storage System
Oval conveyor system with bins to contain individual items
AS/RS Types

Unit load AS/RS - large automated system for pallet loads

Deep-lane AS/RS - uses flow-through racks and fewer access aisles

Miniload AS/RS - handles small loads contained in bins or drawers to perform order picking

Man-on-board AS/RS - human operator rides on the carriage to pick individual items from storage

Automated item retrieval system - picks individual items

Vertical lift storage modules (VLSM) - uses a vertical aisle rather than a horizontal aisle as in other AS/RS types

AS/RS Applications

1. Unit load storage and retrieval
   Warehousing and distribution operations
   AS/RS types: unit load, deep lane (food industry)

2. Order picking
   AS/RS types: miniload, man-on-board, item retrieval

3. Work-in-process storage
   Helps to manage WIP in factory operations
   Buffer storage between operations with different production rates
   Supports JIT manufacturing strategy
   Kitting of parts for assembly

Carousel Storage Systems

Horizontal

Operation is similar to overhead conveyor system used in dry cleaning establishments
Items are stored in bins suspended from the conveyor.
Lengths range between 3 m and 30 m.
Horizontal is most common type.

Vertical

Operates around a vertical conveyor loop.
Less floor space required, but overhead room must be provided.

Application

Storage and retrieval operations
Order picking
Kitting of parts for assembly
Transport and accumulation
Progressive assembly with assembly stations located around carousel
Work-in-process
WIP applications in electronics industry are common

Unique applications
Example: time testing of electrical products

Deadlocks in in Automated Manufacturing System
A deadlock is a situation in which two or more competing actions are each waiting for the other to finish, and thus neither ever does.

A PETRI NET is a bipartite graph which consists of two types of nodes: places and transitions connected by directed arcs.

Two types P1 and P2 of products are produced.

The production of each product requires two operations.

The first operation is performed by a shared machine.

The second operation is performed by a dedicated machine.

There is at most one product of each type loaded in the system at any time.

When a product finishes, a new product of the same type is dispatched.
PN models of key characteristics

Precedence relation:

Alternative processes:

Parallel processes:

Synchronization:
PN models of key characteristics

Buffer of finite capacity (4):

FIFO system:

PN models of key characteristics

Shared resources:

PN models of key characteristics

Dedicated machine:
Shared machine:

PN models of key characteristics

Assembly operation:

Unreliable machines:

A robotic cell