1.1 INTRODUCTION

Computer Integrated Manufacturing (CIM) encompasses the entire range of product development and manufacturing activities with all the functions being carried out with the help of dedicated software packages. The data required for various functions are passed from one application software to another in a seamless manner. For example, the product data is created during design. This data has to be transferred from the modeling software to manufacturing software without any loss of data. CIM uses a common database wherever feasible and communication technologies to integrate design, manufacturing and associated business functions that combine the automated segments of a factory or a manufacturing facility. CIM reduces the human component of manufacturing and thereby relieves the process of its slow, expensive and error-prone component. CIM stands for a holistic and methodological approach to the activities of the manufacturing enterprise in order to achieve vast improvement in its performance.

This methodological approach is applied to all activities from the design of the product to customer support in an integrated way, using various methods, means and techniques in order to achieve production improvement, cost reduction, fulfillment of scheduled delivery dates, quality improvement and total flexibility in the manufacturing system. CIM requires all those associated with a company to involve totally in the process of product development and manufacture. In such a holistic approach, economic, social and human aspects have the same importance as technical aspects.

CIM also encompasses the whole lot of enabling technologies including total quality management, business process reengineering, concurrent engineering, workflow automation, enterprise resource planning and flexible manufacturing.

A distinct feature of manufacturing today is mass customization. This implies that though the products are manufactured in large quantities, products must incorporate...
customer-specific changes to satisfy the diverse requirements of the customers. This requires extremely high flexibility in the manufacturing system.

The challenge before the manufacturing engineers is illustrated in Fig.1.1.

Manufacturing industries strive to reduce the cost of the product continuously to remain competitive in the face of global competition. In addition, there is the need to improve the quality and performance levels on a continuing basis. Another important requirement is on time delivery. In the context of global outsourcing and long supply chains cutting across several international borders, the task of continuously reducing delivery times is really an arduous task. CIM has several software tools to address the above needs.

Of late, the environmental consciousness has influenced manufacturing considerably. At the design stage itself, one has to plan the disposal of the product after its useful life. Remanufacturing and reuse of components is gaining importance in this context. Green manufacturing will be another focal area in future.

Manufacturing engineers are required to achieve the following objectives to be competitive in a global context:

- Reduction in inventory
- Lower the cost of the product
- Reduce waste
- Improve quality
- Increase flexibility in manufacturing to achieve immediate and rapid response to:
  - Product changes
  - Production changes
Computer Integrated Manufacturing

- Process change
- Equipment change
- Change of personnel

CIM technology is an enabling technology to meet the above challenges to the manufacturing.

The advances in automation have enabled industries to develop islands of automation. Examples are flexible manufacturing cells, robotized work cells, flexible inspection cells etc. One of the objectives of CIM is to achieve the consolidation and integration of these islands of automation. This requires sharing of information among different applications or sections of a factory, accessing incompatible and heterogeneous data and devices. The ultimate objective is to meet the competition by improved customer satisfaction through reduction in cost, improvement in quality and reduction in product development time.

CIM makes full use of the capabilities of the digital computer to improve manufacturing. Two of them are:

i. Variable and Programmable automation
ii. Real time optimization

The computer has the capability to accomplish the above for hardware components of manufacturing (the manufacturing machinery and equipment) and software component of manufacturing (the application software, the information flow, database and so on).

The capabilities of the computer are thus exploited not only for the various bits and pieces of manufacturing activity but also for the entire system of manufacturing. Computers have the tremendous potential needed to integrate the entire manufacturing system and thereby evolve the computer integrated manufacturing system.

1.2 TYPES OF MANUFACTURING

The term “manufacturing” covers a broad spectrum of activities. Metal working industries, process industries like chemical plants, oil refineries, food processing industries, electronic industries making microelectronic components, printed circuit boards, computers and entertainment electronic products etc. are examples of manufacturing industries. Manufacturing involves fabrication, assembly and testing in a majority of situations. However, operations are of a different nature in process industries.

Manufacturing industries can be grouped into four categories:

i. Continuous Process Industries
   In this type of industry, the production process generally follows a specific sequence. These industries can be easily automated and computers are widely used for process monitoring, control and optimization. Oil refineries, chemical plants, food processing industries, etc. are examples of continuous process industries.
ii. **Mass Production Industries**
Industries manufacturing fasteners (nuts, bolts etc.), integrated chips, automobiles, entertainment electronic products, bicycles, bearings etc. which are all mass produced can be classified as mass production industries. Production lines are specially designed and optimized to ensure automatic and cost effective operation. Automation can be either fixed type or flexible. Automobile industries have been using the transfer line concept not only for machining of components but also for assembly.

iii. **Batch Production (Discrete Manufacturing)**
The largest percentage of manufacturing industries can be classified as batch production industries. The distinguishing features of this type of manufacture are the small to medium size of the batch, and varieties of such products to be taken up in a single shop. Due to the variety of components handled, work centres should have broader specifications. Another important fact is that small batch size involves loss of production time associated with product changeover.

As mentioned earlier, integration of computer in process industries for production automation, process monitoring and control and optimization is relatively easy. In the case of mass production and batch production computer integration faces a number of problems as there are a large number of support activities which are to be tied together. These are discussed in detail later in this chapter.

Automation of manufacture has been implemented using different techniques since the turn of the 20th Century. Fixed automation is the first type to emerge. Single spindle automatic lathe, multi spindle automatic lathe and transfer lines are examples of fixed automation. Fixed automation using mechanical, electrical, pneumatic and hydraulic systems is widely used in automobile manufacturing. This type of automation has a severe limitation - these are designed for a particular product and any product change will require extensive modifications to the automation system.

The concept of programmable automation was introduced later. These were electrically controlled systems and programs were stored in punched cards and punched tapes. Typical examples of programmable automation are:

i. Electrical programme controlled milling machines
ii. Hydraulic copying machines (lathes, milling, etc.)
iii. Automatic lathes with programmable control drum
iv. Sequencing machines with punched card control /plug board control
v. Automatic machines with programmable logic control (PLC)
vi. Transfer lines

Development of digital computers, microelectronics and microprocessors significantly altered the automation scenario during 1950-1990. Machine control systems are now designed around microprocessors and microelectronics is part and parcel of industrial...
drives and control. The significant advances in miniaturization through integration of large number of components into small integrated chips and the consequent improvement in reliability and performance have increased the popularity of microelectronics. This has resulted in the availability of high performance desktop computing machines as well as file servers which can be used for industrial control with the help of application software packages.

1.3 EVOLUTION OF COMPUTER INTEGRATED MANUFACTURING

Computer Integrated Manufacturing (CIM) is considered a natural evolution of the technology of CAD/CAM which by itself evolved by the integration of CAD and CAM. Massachusetts Institute of Technology (MIT, USA) is credited with pioneering the development in both CAD and CAM. The design and manufacturing requirements of aerospace industries after the Second World War necessitated the development these technologies. The manufacturing technology available during late 40’s and early 50’s could not meet the design and manufacturing challenges posed by sophisticated aircraft and satellite launch vehicles. This prompted the US Air Force to approach MIT to develop suitable control systems, drives and programming techniques for machine tools using electronic control.

The first major innovation in machine control is the numerical control (NC), demonstrated at MIT in 1952. Early numerical control systems were all basically hardwired systems, since these were built with discrete systems or with later first generation integrated chips. Early NC machines used paper tape as an input medium. Every NC machine was fitted with a tape reader to read paper tape and transfer the program to the memory of the machine tool block by block. Mainframe computers were used to control a group of NC machines by mid 60’s. This arrangement was then called direct numerical control (DNC) as the computer bypassed the tape reader to transfer the program data to the machine controller. By late 60’s mini computers were being commonly used to control NC machines. At this stage NC became truly soft wired with the facilities of mass program storage, off-line editing and software logic control and processing. This development is called computer numerical control (CNC).

Since 1970’s, numerical controllers are being designed around microprocessors, resulting in compact CNC systems. A further development to this technology is the distributed numerical control (also called DNC) in which processing of NC program is carried out in different computers operating at different hierarchical levels - typically from mainframe host computers to plant computers to the machine controller. Today the CNC systems are built around powerful 32 bit and 64 bit microprocessors. PC based systems are also becoming increasingly popular.

Manufacturing engineers also started using computers for such tasks like inventory control, demand forecasting, production planning and control etc. CNC technology was adapted in the development of co-ordinate measuring machine’s (CMMs) which
automated inspection. Robots were introduced to automate several tasks like machine loading, materials handling, welding, painting and assembly. All these developments led to the evolution of flexible manufacturing cells and flexible manufacturing systems in late 70’s.

Evolution of Computer Aided Design (CAD), on the other hand was to cater to the geometric modeling needs of automobile and aeronautical industries. The developments in computers, design workstations, graphic cards, display devices and graphic input and output devices during the last ten years have been phenomenal. This coupled with the development of operating system with graphic user interfaces and powerful interactive (user friendly) software packages for modeling, drafting, analysis and optimization provides the necessary tools to automate the design process.

CAD in fact owes its development to the APT language project at MIT in early 50’s. APT was so popular that several clones of APT were introduced later, to automatically develop NC codes from the geometric model of the component. With the introduction of the concept of software in 1980’s, several CNC programming languages were developed to automatically generate NC codes from the CAD model of the component. Now, one can model, draft, analyze, simulate, modify, optimize and create the NC code to manufacture a component and simulate the machining operation sitting at a computer workstation.

If we review the manufacturing scenario during 80’s we will find that the manufacturing is characterized by a few islands of automation. In the case of design, the task is well automated. In the case of manufacture, CNC machines, DNC systems, FMC, FMS etc provide tightly controlled automation systems. Similarly computer control has been implemented in several areas like manufacturing resource planning, accounting, sales, marketing and purchase. Yet the full potential of computerization could not be obtained unless all the segments of manufacturing are integrated, permitting the transfer of data across various functional modules. This realization led to the concept of computer integrated manufacturing. Thus the implementation of CIM required the development of whole lot of computer technologies related to hardware and software.

### 1.4 CIM HARDWARE AND CIM SOFTWARE

CIM Hardware comprises the following:

i. Manufacturing equipment such as CNC machines or computerized work centres, 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 programmes 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

1.5 NATURE AND ROLE OF THE ELEMENTS OF CIM SYSTEM

Nine major elements of a CIM system are in Fig 1.2. They are:

- Marketing
- Product design
- Planning
- Purchase
- Factory automation hardware, work centres
Logistics and supply chain management, warehousing finance
Information and data management,

![Fig.1.2 Major Elements of a CIM System](image)

i. **Marketing**: The need for a product is identified by the marketing division. The specifications of the product, the projection of manufacturing quantities and the strategy for marketing the product are also decided by the marketing department. Marketing also works out the manufacturing costs to assess the economic viability of the product.

ii. **Product Design**: The design department of the company establishes the initial database for production of a proposed product. In a CIM system this is accomplished through activities such as geometric modeling and computer aided design while considering the product requirements and concepts generated by the creativity of the design engineer. Configuration management is an important activity in many designs. Complex designs are usually carried out by several teams working simultaneously, located often in different parts of the world. The design process is constrained by the costs that will be incurred in actual production and by the capabilities of the available production equipment and processes. The design process creates the database required to manufacture the part.

iii. **Planning and Manufacturing Engineering**: The planning department takes the database established by the design department and enriches it with production data and information to produce a plan for the production of the product. Planning involves several subsystems dealing with materials, facility, process, tools, manpower, capacity, scheduling, outsourcing, assembly, inspection, logistics etc. In a CIM system, this planning process should be constrained by the production costs and by the production equipment and process capability, in order to generate an optimized plan.
Manufacturing Engineering is the activity of carrying out the production of the product, involving further enrichment of the database with performance data and information about the production equipment and processes. In CIM, this requires activities like CNC programming, simulation and computer aided scheduling of the production activity. This should include on-line dynamic scheduling and control based on the real time performance of the equipment and processes to assure continuous production activity. Often, the need to meet fluctuating market demand requires the manufacturing system flexible and agile.

iv. **Purchase:** The purchase departments is responsible for placing the purchase orders and follow up, ensure quality in the production process of the vendor, receive the items, arrange for inspection and supply the items to the stores or arrange timely delivery depending on the production schedule for eventual supply to manufacture and assembly.

v. **Factory Automation Hardware:** Information about factory automation equipment further enriches the database with equipment and process data, resident either in the operator or the equipment to carry out the production process. In CIM system this consists of computer controlled process machinery such as CNC machine tools, flexible manufacturing systems (FMS), Computer controlled robots, material handling systems, computer controlled assembly systems, flexibly automated inspection systems and so on.

vi. **Supply Chain Management:** Supply chain management (SCM) is a critical function involving storage and retrieval of raw materials, components, finished goods as well as shipment and logistics of items. In today’s complex cross border outsourcing scenario and the need for just-in-time supply of components and subsystems, logistics and supply chain management assume great significant.

vii. **Finance:** Finance deals with the resources pertaining to money. Planning of investment, working capital, and cash flow control, realization of receipts, accounting and allocation of funds are the major tasks of the finance departments.

viii. **Information Management:** Information Management is perhaps one of the crucial tasks in CIM. This involves master production scheduling, database management, communication, manufacturing systems integration and management information systems.

It can be seen from Fig 1.3 that CIM technology ties together all the manufacturing and related functions in a company. Implementation of CIM technology thus involves basically integration of all the activities of the enterprise. Product development starts with a CAD model meeting the specifications laid down by the design team. Design is verified by several analysis packages like FEA, Mechanism analysis, CFD etc. After the design is optimized, component drawings and assembly drawings are created.
Engineering activities like process planning, tool design, production planning, scheduling etc. are taken up next. Digital manufacturing packages are used to simulate and optimize manufacturing. Sourcing department arranges the procurement of raw materials, components, sub-assemblies etc. as and when required. The hardware includes CNC and other automated manufacturing equipment, robots, flexible manufacturing cells, automatic storage and retrieval systems, flexible inspection systems etc. The hardware elements communicate with each other using different types of networking systems and protocols. Enterprise resource planning software links several manufacturing, marketing, sourcing, servicing and accounting functions based on the central database. Thus the CIM system automates the entire product development and manufacturing. Product life cycle management consolidates coherently the various systems associated with manufacturing and has been adopted by several industries.

CIM ties together the data required for the entire manufacturing activity. Networked systems and hardware ensure that correct data is available to all involved in manufacturing regardless of the physical location. This eliminates delays and errors in manufacturing, accelerating product development process, thereby reducing time to market. Optimization during design and manufacturing reduces the time and cost of manufacturing. Thus CIM helps the manufacturing engineers to meet the continuous challenges of cost reduction, quality improvement and reduction in time to market.

![Fig.1.3 Various Engineering Activities in CIM](image)