EXPERIMENTS IN COMPUTER INTEGRATED MANUFACTURING

# SMT. S. R. PATEL ENGINEERING COLLEGE
# DABHI-UNJHA - 384 170

## DEPARTMENT OF MECHANICAL ENGINEERING

SUBJECT : COMPUTER INTEGRATED MANUFACTURING

SUBJECT CODE: 171903



# INDEX

# Practical: - 01

**AIM:-Introduction of CIM and its importance in manufacturing environment.**

## CIM (Definition):-

CIM means exactly what it says: computer-integrated manufacturing. It describes integrated applications of computers in manufacturing. A number of observers have attempted to refine its meaning:

- "CIM 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." (By CASA/SME)
- "CIM is nothing but a data management and networking problem."
- "computer-integrated manufacturing is contagious."
- "CIM is an amorphous beast. It will be different in every companies."
- "CIM is a management philosophy, not a turnkey computer product. It is a philosophy crucial to the survival of most manufacturers because it provides the levels of product design & production control & shop flexibility to compete in future domestic and international markets."
- "CIM is an opportunity for realigning your two most fundamental resources people and technology. CIM is a lot more than the integration of mechanical, electrical , and even informational systems. It's an understanding of the new way to manage."

## CIM Hardware & CIM Software:-

CIM Hardware comprises the following:

- Manufacturing equipment such as CNC machines or computerised work centres, robotic work cells, DNC/FMS systems, VNC systems, work handling & tool handling devices, inspection machines etc…
- Computers, controllers, CAD/CAM systems, workstations/terminals, data entry terminals, bar code readers, 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
- Modelling 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
- Work flow automation
- Business process engineering
- Network management
- Quality management

## Nature and Role of the CIM System:

Nine major elements of a CIM system are

- Marketing
- Product Design
- Planning
- Purchase
- Manufacturing Engineering
- Factory Automation hardware
- Warehousing
- Finance
- Information management

**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.

**Product Design:** The design department of the company establishes the initial database for production of a proposed product. In CIM system this is accomplished through activities such as geometric modelling and computer aided design while considering the product requirements and concepts generated by the creativity of the design engineer.

**Planning:** The planning department takes the database established by the product design and enriches it with production data and information to produce a plan for the production of the product.

**Purchase:** The purchase department is responsible for placing the purchase orders and follows up, receive the items, arrange for inspection and supply the items to stores for eventual supply to manufacture and assembly.

**Manufacturing Engineering:** 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.

**Factory Automation hardware:** 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.

**Warehousing:** Warehousing is the function involving storage and retrieval of raw materials, components, finished goods as well as shipment of items.

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

**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.

CIM technology ties together all the manufacturing and related functions in a company. (**Various Activities in CIM**)

- CAD, Shop data, FEM, MEM, Analysis, Drafting, Process Planning, Tool design, Product Planning, Scheduling, Simulation, CNC, Robots, FMS, AS/RS, QC.
- Marketing, Finance, Purchase, Human Resource, ERP, Shipping, Data Base, Internet an
- Machine tool, Material handling system, Computer system, Human labour FME-Finite Element Modelling , MEM- Mechanism Modelling , ERP-Enterprise Resource Planning, QC-Quality Control

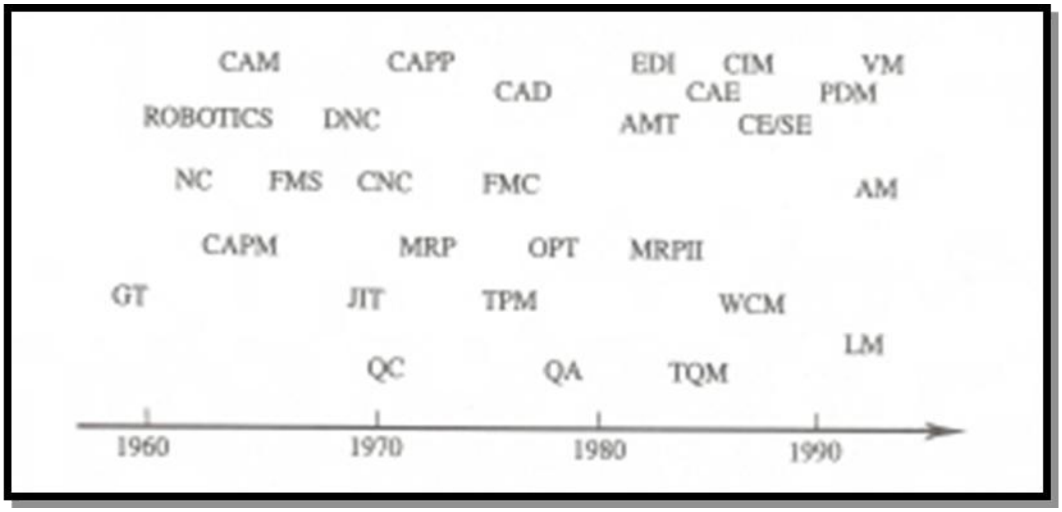



**Fig.1: Activities in CIM**

## Key Challenges:

### External Challenges

- Niche market entrants
- traditional competition
- suppliers
- global economy
- cost of money
- customers

### Internal Challenges

- Analyse every product and agree on the order- qualifying and order winning criteria for the current market conditions for every product.
- For every product, project the order winning criteria in the market in the future.
- Determine the fit between the criteria necessary to succeed in the market place and the current capability in manufacturing.
- Change or modify either the marketing goals or the manufacturing process choices and infrastructure to force internal consistency

- Set-up time, Quality, Manufacturing space ratio, Inventory, Flexibility, Distance, Uptime

## Development of CIM:

CIM is an integration process leading to the integration of the manufacturing enterprise. Dictated by the need of the individual enterprise this process usually starts with the need to interchange information between the some of the so called ISLANDS OF AUTOMATION. Flexible manufacturing cells, Automatic Storage & Retrieval Systems, CAD/CAM based design are the examples of islands of automation.

## CIM Wheel:

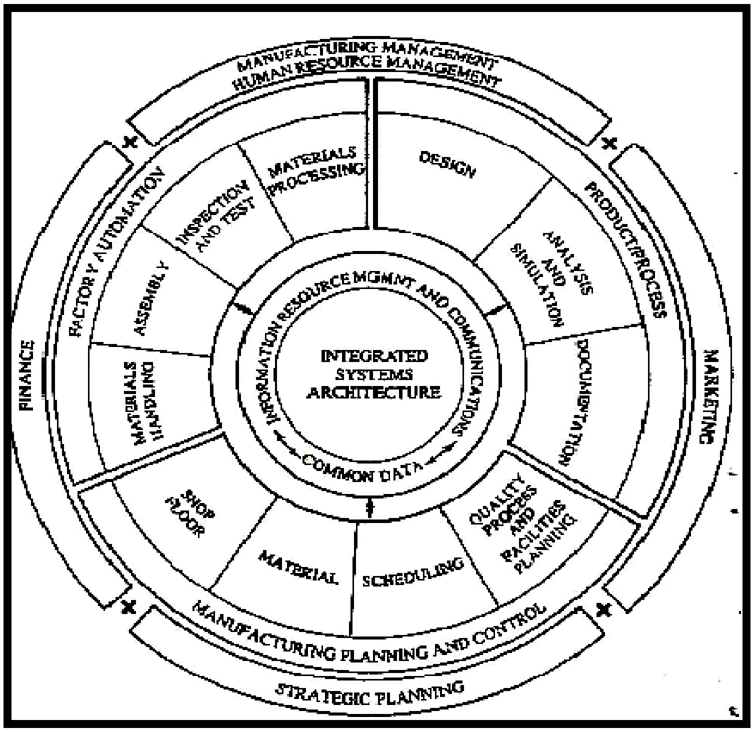



**Fig.2: CASA/CME'S CIM Wheel-An embodiment of the concept of computer integrated manufacturing**

CASA/SME has suggested a framework, the CIM WHEEL. to elucidate the meaning of CIM.

CIM is closed loop system whose prime inputs are product requiring concept prime output are finished product.

CASA/SME: Computer and Automated system Association of the Society of Manufacturing Engineers.

The CIM Wheel:  It depict a central core [ Integrated System architecture] that handles the common manufacturing data and is concern with information resources management & communications.

The radial sectors surrounding the core (wheel hub) represents the various act ivies of manufacturing processing design, material, processing & inspection.

These Activities has been grouped under three categories.

- Manufacturing planning & control
- Product process ,&
- Factory automation.

As depicted in the wheel's inner Rim.

The outer Rim represents the upper management functions, grouped into four categories:

- Strategic planning
- Marketing
- Manufacturing & HR management
- Finance

- Fig.2 shows the CIM Wheel. (CASA/SMA)
- The CIM Wheel depicted in fig. is the expanded version of an earlier model.
- The outer Rim was added in1985, to compile the need of including both management and technology function with in the scope of CIM.
- CIM is broad enough to en-compass all aspect of the manufacturing enterprise & its management, including those of personnel & finance.

**Strengths of CIM Wheel:**

- This CIM Wheel represents different resources required for the complete implementation of the CIM.
- The second Rim form out side defined the main CIM implementation required three main functional in evolvement.

1. Manufacturing planning & control
2. Product process ,&
3. Factory automation.

- The outer Rim shows the management & recourse requirement of the CIM implementation.
- It can also helpful to find out the Island requiring for the complete CIM.

**Weakness of the CIM Wheel:**

- The main & the major weakness of the CIM Wheel is it does not Shows the way of integration
- It is also doesn't represent the complete connection of the different island.
- We can not clarify in which sequence we have to plan for implementation of the CIM.
- The existing CIM Wheel is not being time constrained or not giving articulation process constituents or weight age for the same.

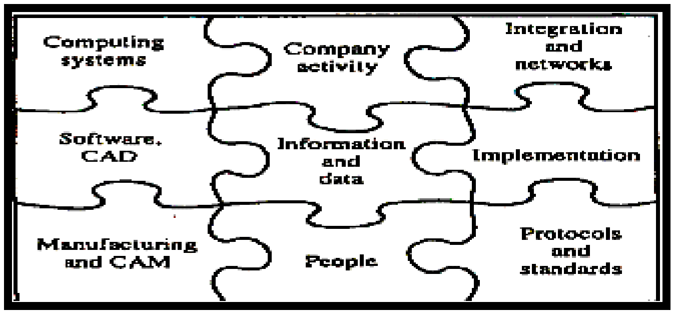



**Fig.3:The CIM Jigsaw**

**CIM Enterprise Wheel:**

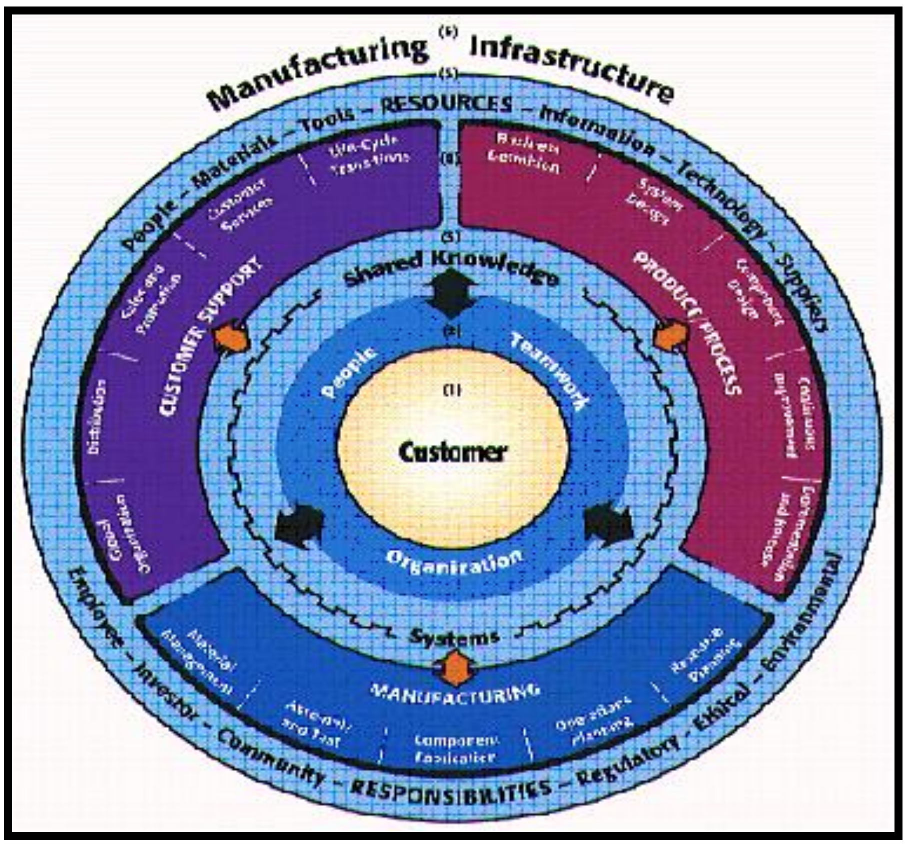



**Fig.4: The New Manufacturing Enterprise Wheel Suggested by Society of Manufacturing Engineers, Dearborn, Michigan**

## CIM Enterprise Wheel:

- 1985 - The Computer and Automated Systems Association of the Society of Manufacturing Engineers (CASA/SME) published its vision of enterprise-wide teaming--the CIM Enterprise Wheel
- 1992 - New Manufacturing Enterprise Wheel. This updated vision preserves the understanding gained from the previous CIM Enterprise Wheel. The old Wheel looked primarily at automation and integration inside the enterprise. The new Wheel looks outside as well. It adds understanding in these six areas:
- The central role of a customer-oriented mission and vision to strive for continuous improvement.
- The importance of teams and human networking in the new manufacturing environment.
- The continuing importance of computer tools, now increasingly distributed and networked. This includes tools to support networking and concurrent engineering.
- A focus on key processes and best practices throughout the enterprise, from marketing through design, manufacturing, and customer support.
- Recognition of the move away from bureaucratic structures, to leaner and more agile organizations.
- The need to integrate an understanding of the external environment, including customers, competitors, suppliers, and the global manufacturing infrastructure.

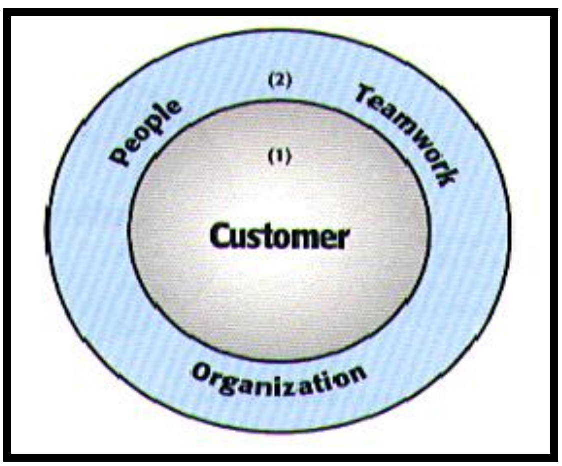



**Fig.5: Wheel-people**

- CIE - computer integrated enterprise
- CIME - computer integrated manufacturing enterprise

- ***CIM means many different things to many different people.***
- "The integration of business, engineering, manufacturing and management information that spans company functions from marketing to product distribution." Harrington
- Originally, to integrate what had already been computerized.
- shop floor processes
- manufacturing engineering planning of those processes
- Production planning and control of both the shop floor and the materials used.

**Wheel - Six Elements:**

- The new Manufacturing Enterprise Wheel describes six fundamental elements for competitive manufacturing:
- The central role of the customer and evolving customer needs.
- The role of people and teamwork in the organization.
- The revolutionary impact of shared knowledge and systems to support people and processes.
- Key processes from product definition through manufacturing and customer support.
- Enterprise resources (inputs) and responsibilities (outputs).

**Wheel - customer centered:**

A customer-centered mission provides a clear direction to align activities and empowers the work of teams in the new manufacturing enterprise.

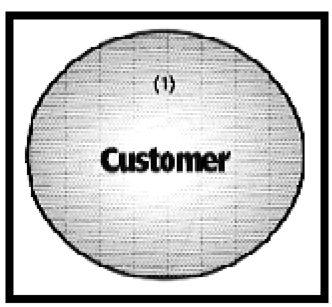



**Fig.6: Wheel - customer centered**

- The central role of people in the organization forms the inner circle of the Wheel. The enterprise is only as strong as its people, organization, and culture.

**Wheel - 15 Processes:**

PRODUCT/PROCESS DEFINITION:

1) Business Definition
2) System Design
3) Component Design
4) Continuous Improvement
5) Documentation and Release
MANUFACTURING (Service)
6) Resource Planning
7) Operations Planning
8) Component Fabrication
9) Assembly and Test
10) Material Management
CUSTOMER SUPPORT:
11) Global Organization
12) Distribution
13) Sales and Promotion
14) Customer Services
15) Life-Cycle Transitions

Wheel - Manufacturing Infrastructure: Infrastructure separates top manufacturing regions and countries from others.

- workforce
- investment
- transportation
- communication
- suppliers
- schools
- research
- government support

**Similarities between both wheels:**

- In middle rim both of the wheel shows the product ,processes and manufacturing facilities requires for the CIM implementation.
- Both wheels try to explain the resources required to getting complete CIM.
- The most of the island related to manufacturing & design in both wheel are similar.

**Differences between both wheels:**

- The CIM Wheel more emphasis on information system, design & manufacturing & business. Segment where as the CIM Enterprise wheel emphasis on customer satisfaction, knowledge management, business design and business global.

- The CIM Wheel is also concentrate on the factory automation side that portion was not included in the CIM Enterprise wheel.

- In CIM Wheel there is no point to taking in account the customer satisfaction, where as in the CIM enterprise wheel customer satisfaction was taken as a key factor for CIM.
- Organizational goals were set out in the CIM enterprise wheel; where as in CIM wheel only operational and financial matter can be clear out only.

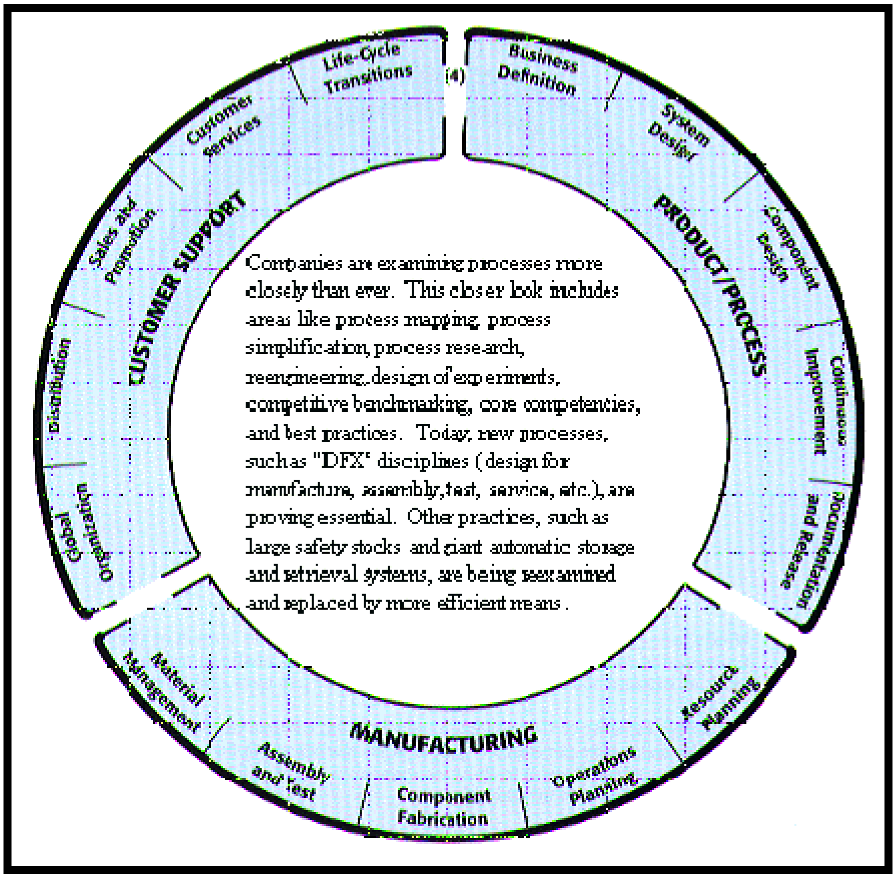



**Fig.7: Wheel – Processes**

## Benefits of CIM:

A reduction in inventory translates into higher profits.

Tangible Benefits → higher profits, less direct labor, increased machine use, reduced scrap & rework, increased factory capacity, reduced inventory, shortened new product development time, decreased warranty costs.

Intangible Benefits→ higher employee morale, safer working environment, improved customer image, greater scheduling flexibility, greater ease in recruiting new employees, increased job security, more opportunities for upgrading skills.

CIM - to coordinate and organize data

- functional - about organization (still important)
- product - about parts
- operational - plan or instructions
- performance - reporting on performance

CIM - to meet competitive pressures

- to reduce lead times
- to reduce costs
- to reduce inventory (or need for)

CIM – others: to eliminate paper

- automate communication
- simultaneous engineering (IPD)
- Because it is possible?
- To reduce communication time

**CIM I & II :** Computer-interfaced manufacturing & Computer integrated manufacturing

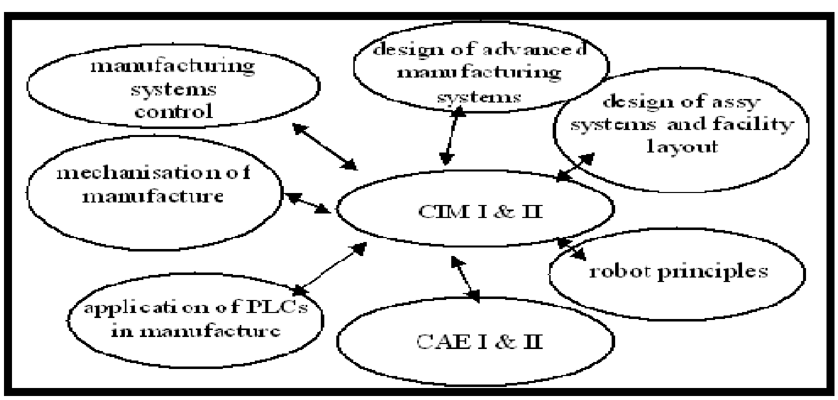



**Fig.9: CIM-I & II**

- Manufacturing Planning & Control
  - MRPII, MRP, CRP, shop floor control, inventory Control, …
- Manufacturing Engineering
  - CAD/CAM, CAPP, coding & Classification, …

- Manufacturing Processes
  - NC/CNC/DNC, FMS, robots, material handling Systems, …
- Indirect Elements:

- Sales order processing (& marketing)
- Finance & accounting

LSI/VSI → CIM-1 → Data interfaced management environment

PARELLEL PROCESSING → CIM-2 → Networked management environment

## Integration in CIM:

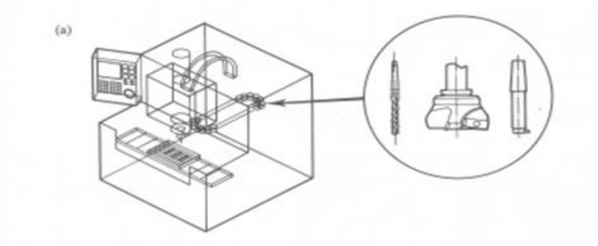



Figure 1.5 Integration: (a) a single machine **integrates** the functions of drilling, milling and boring.

**Fig.10: Integration**

- Parts indistinguishable?
- No, seamlessly linked is what we mean
- NC/CNC Machines

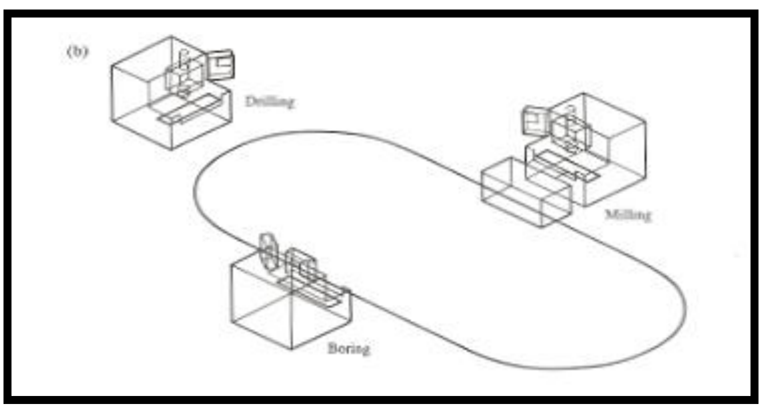



**Fig.11: Integration – linked**

## EDI - Electronic Data Interchange:

EDI : Electronic Data Interchange -

(1) The subject of electronic data exchange and sharing generally, or

(2) Electronic data and/or document interchange format (X12), particularly in a purchasing context.

EDIF : Electronic Data Interchange Format

A neutral file specification for the transfer of electronic CAD/CAM data.

EDIFACT : Electronic Data Interchange for Administration, Commerce & Trade

A standard for commercial transactions between (differing) computer systems of different commercial organizations.

Although we often talk of EDI applied to exchange of technical information it is properly used to describe commercial transactions such as the passing of invoices. Standards for EDI exist and are widely used. UN EDIFACT is becoming the accepted standard for this type of transaction. When technical information is exchanged between computer system (see the item below), this is really a sub-set of technical data sharing. In these circumstances we should use the term technical EDI, or TEDI. (Fig. 11).

*******#####*******

# QUIZ:

1. Give the elements of nc machine tool system.
2. Explain the cim wheel with neat sketch.
3. Give the benefits of cim.
4. Explain impact of cim on personnel.
5. Enlist the types of computer aided process planning and explain any one of them.

# Practical:- 02

## AIM:Introduction of FMS.

## FMS:

- FMS is an integrated approach to automating a production. The primary characteristic of an FMS is that it is a computer-controlled manufacturing system that ties together storage, manufacturing machines, inspection, tooling, and materials handling equipment. The FMS is designed to be flexible so that it can manufacture a variety of products at relatively low volumes, with minimum lead time between product changes.
- A flexible manufacturing system is highly automated GT machine cell, consisting of group of processing workstation, interconnected by automated material handling and storage system and controlled by distributed computer system. The reason the FMS is called flexible is that it is capable of processing a variety of different part, systems and quantity of production.
- An FMS relies on principle of group technology. No manufacturing system can be completely flexible. These are limits to the range of parts or products that can be made in an FMS.
- A more appropriate term for an FMS would be flexible automated system to differentiate it from manned GT machine cell or conventional transfer line.
- A Series of automatic machine tools linked to gather with an automatic material handling system, a common hierarchal digital programmed. Computer control & provision for random fabrication of parts and assemblies that falls within predetermined families.
- A flexible manufacturing system îs a group of Nc machine tools that can randomly process a group of parts having automated material handling system & central computer control to dynamically balance resource utilization so that the system can adapt automatically to changes in parts production, mixes and levels of output.
- A process under control to produce varieties of components or products within its stated capability and to a predetermined schedule.
- A technology which will help achieve leaner factories with better response times, lower unit costs, and higher quality under an improved level of management and capital control.

Capability required for Flexibility:

The capabilities that a manufacturing system must posses to be flexible are:

1. The ability to identify and distinguish arnong the different part and product systems processes required by system etc.
2. Quick change over & operating system
3. Quick change over of physical setup.

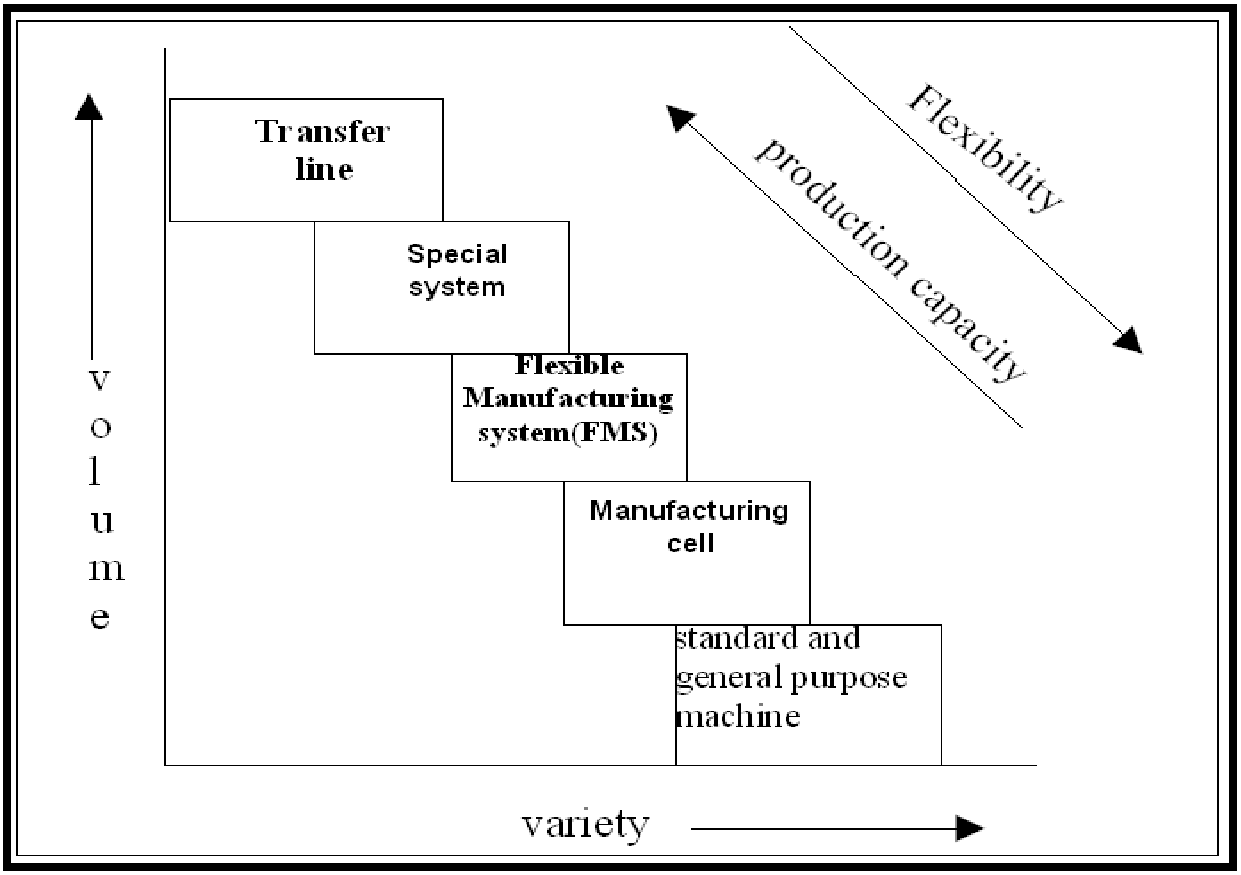
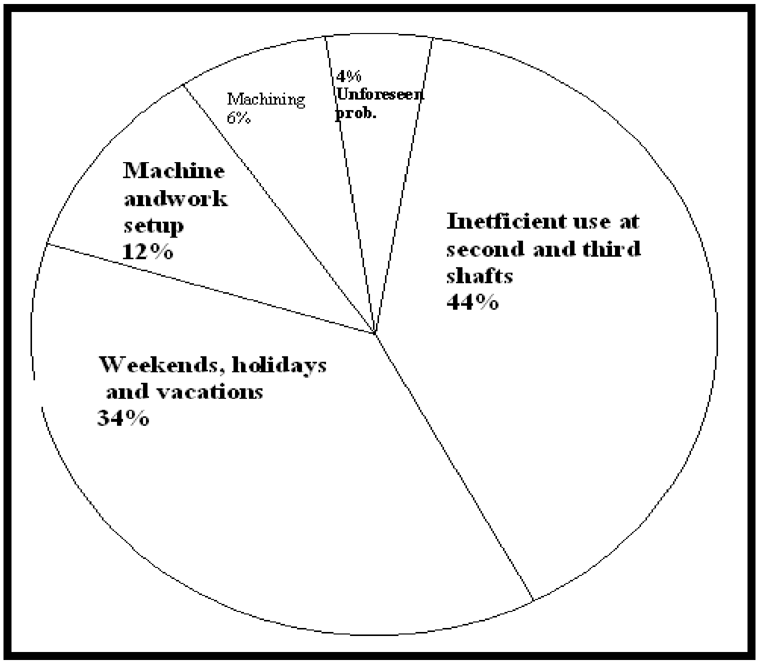



**Fig.1:General range of application solutions based on a given set of work piece volume and variety requirements.(Courtestesy of Kearney and Trecker Corp.)**

By definition, an FMS can simultaneously process a variety of workpiceces using tooling and fixturing made available at the right machine, at the right time, and in the right sequence. Fig-1 shows the different types of production systems and it can be seen from the figure that FMS fits into the intermediate range of production.

## Need of FMS:




**"Fig.2:Brakdown of 8760 available hours in a calendar to manufacturing opration.**

The key objective in manufacturing is to get the right raw materials or to the right machines at the right time.

Examples indicate the underutilization of equipment and gross infficiencies existing in a vast majority of manu facturing industries.The common day to day disturbances within overall manufacturing process consisting of:

1. priority changes
2. Eng. Design changes
3. Tooling diffulties
4. Machine brackdowns
5. processing problems
6. Lost, misplacede, and scrapped parts
7. vendor lateness

What is needed in today's competitive environment, regrdless of what products a particular company makes. This implies that:

1. There should be minimum dealy between order placement and order delivery.
2. Quality and reliability should be high.
3. operating costs should be perdictable and under control.

4. Replacement parts should be available and accessible on a quick turnaround basis.

## Objectives of FMS are:

1. Improve operational control through:
   a) Reduction in the number of uncontrollable variables
   b) Providing tools to recognize and rect quickly to deviations in the manufacturing plan
   c) Reducing dependence on human communication
2. Reduce direct labour through:
   a) Removing operators from the machining site
   b) Eliminnating dependence on highly skilled machinists
   c) Providing a catalyst to introduce and support unattended orlightly attended machine operation
3. Improve short-run reponsiveness consisting of:
   a) Engg. Changes
   b) Processing changes
   c) Machine downtime or unavailability
   d) Cutting tool failure
   e) Late material delivery
4. Improve long-run accommodations through quicker and easier assimilation of:
   a) changing product volumes
   b) New product additions and Introductions
   c) Different part mixes
5. Increase machine utilization by:
   a) Eliminating machine setup
   b) Utilizing automated features to replace manual intervention
   c) Providing quick transfer devices to keep machines in the cutting cycle
6. Reduce inventory by:
   a) Reducing lot sizes
   b) Improving inventory turnovers
   c) Providing the plannig tools for just-in-time manufacturing

## Areas of Applications of FMS:

The FMS is applicable in other manufacturing &machining:

- Assembly of equipments
- Semiconductor componet manufacturing
- Plastic injection moulding
- Sheet metal fabrication
- Welding
- Textile machinery manufacture

Such systems have proved to be practical and economical for applications with the following characteristics:

- Families of parts with similar geometric features for require similar types of equipment and processes

- A moderate number of tools and processes steps
- Moderate precision requirements

**Types of FMS: FMS has been classified in several ways. Some of these classification are still valid but the discussion in this book is restricted to basic types.**

FMS can be distinguished accordingly to the kinds of operation they perform.

1. Processing operation.
2. Assembly operation.

   Two other ways to classify FMS are by;

   1. No of machines e.g. single m/c cell, flexible manufacturing cell or flexible manufacturing system.
2. Level of flexibility e.g. dedicated FMS or random order FMS.

***FMS's Types:***

a) FMC-Flexible Manufacturing Cell:The simplest,hence most flexible types of FMS is FMC. It consists of one or more CNC machine tools, general purpose or of special design interfaced with automated material handling and tool changers.
b) FTC- Flexible Turning Cell: One of the most important advantages of CNC machines is their flixibility. The meaning of flexibility in this particular context is that these work centres enable the production of components in short batches.
c) FTL- Flexible Transfer Line: Flexible transfer lines are intended for high volume production. A part in ahigh volum production may have to undergo large number of operations.
d) FMS-Flexible Machining Systems: FMS consist of several flexible automated machine tools of the universal or special type which are flexibly interlinked by an automatic workpiece flow system so that different workpieces can be machined with the same machine configuration.This means that a FMS will be able to respond quickly to changing market and customer demands.

**Types of FMS:** The basic classification of FMS is according to the level of flexibility designed into the system. This method of classification can be applied to systems with any number of workstations, but its application seems most common with FMCs and FMSs. Two categories are distinguished here:

- Dedicated FMS
- Random-order FMS

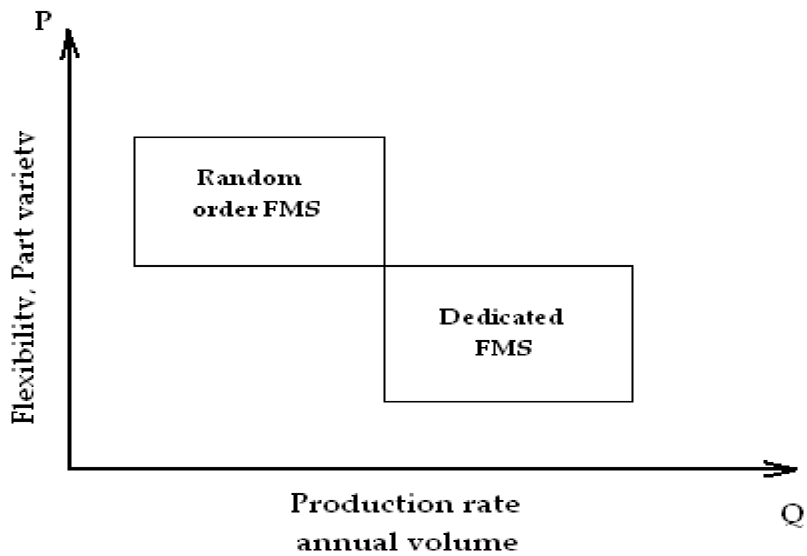



**Fig. 3 Comparison of dedicated and random-order FMS types**

Dedicated FMS:

A dedicated FMS is designed to produce a limited variety of part styles, and the complete universe of parts to be made on the system is known in advanced. The term *Special manufacturing System* has also been used in reference to this FMS type. The part family is likely to be based on product commonality rather than geometric similarity. The product design is considered stable, and so the system can be designed with a certain amount of process specialization to make the operations more efficient. Instead of using general-purpose machines, the machines can be designed for the specific processes required to make the limited part family, thus increasing the production rate of the system. In some instances, the machine sequence may be identical or nearly identical for all parts produced, and so a transfer line may be appropriate, in which the workstations process the necessary flexibility to process the different parts in the mix. Indeed, the term *flexible transfer line* is sometimes used for this case. The dedicated FMS is less flexible but more capable of higher production rate.

Random-order FMS:

A random-order FMS is more appropriate when the part family is large, there are substantial variations in part configurations, there will be new part designs introduced into the system and engineering changes in parts currently produced, and the production schedule is subject to change from day-to-day. To accommodate these variations, the random-order FMS must be more flexible than the dedicated FMS. It is equipped with general-purpose machines to deal with the variations in product and is capable of processing parts in various sequences (random-order). A more sophisticated computer control system is required for this FMS type. The random-order FMS is more flexible but at the price of lower production rates.

| Flexibility Criteria (Tests of Flexibility) | | | | |
|---|---|---|---|---|
| **System Type** | **Part variety** | **Schedule Change** | **Error Recovery** | **New Part** |
| Dedicated FMS | Limited. All parts known in advanced. | Limited changes can be tolerated. | Limited by sequential processes. | No. New part introductions difficult. |
| Random-order FMS | Yes, Substantial part variations possible. | Frequent and significant changes possible. | Machine redundancy minimizes effect of machine breakdowns. | Yes. System designed for new part introductions. |

**Table 1. Flexibility criteria applied to the three types of manufacturing cells and systems**

Further, more general classification on the basis of:

**(a) Machine tools:**

- General purpose or specialized
- Automatic tool changing capabilities
- Tool magazines (capacity, removability and tool changing needs)

**(b) Material handling system:**

- Type (conveyor, carousel, tow-line with carts, network of wire-guided carts, stand-alone robot carts)
- Part movement equipment (palletized and/or fixtured)
- Tool transportation system (manual or automatic with parts)

**(c) Storage areas for in process inventory:**

- Central buffer storage
- Decentralized buffer at each machine tool
- Local storage

**(d) Computer control:**

- Distribution of decision
- Architecture of the information system
- Types of decisions (input sequence, priority rules, part to cart assignment, cart traffic regulation)
- Control of part mix (periodic input, feedback based priority rules)

## FMS compared to other types of manufacturing approaches:

## (Types of FMS Continue….)

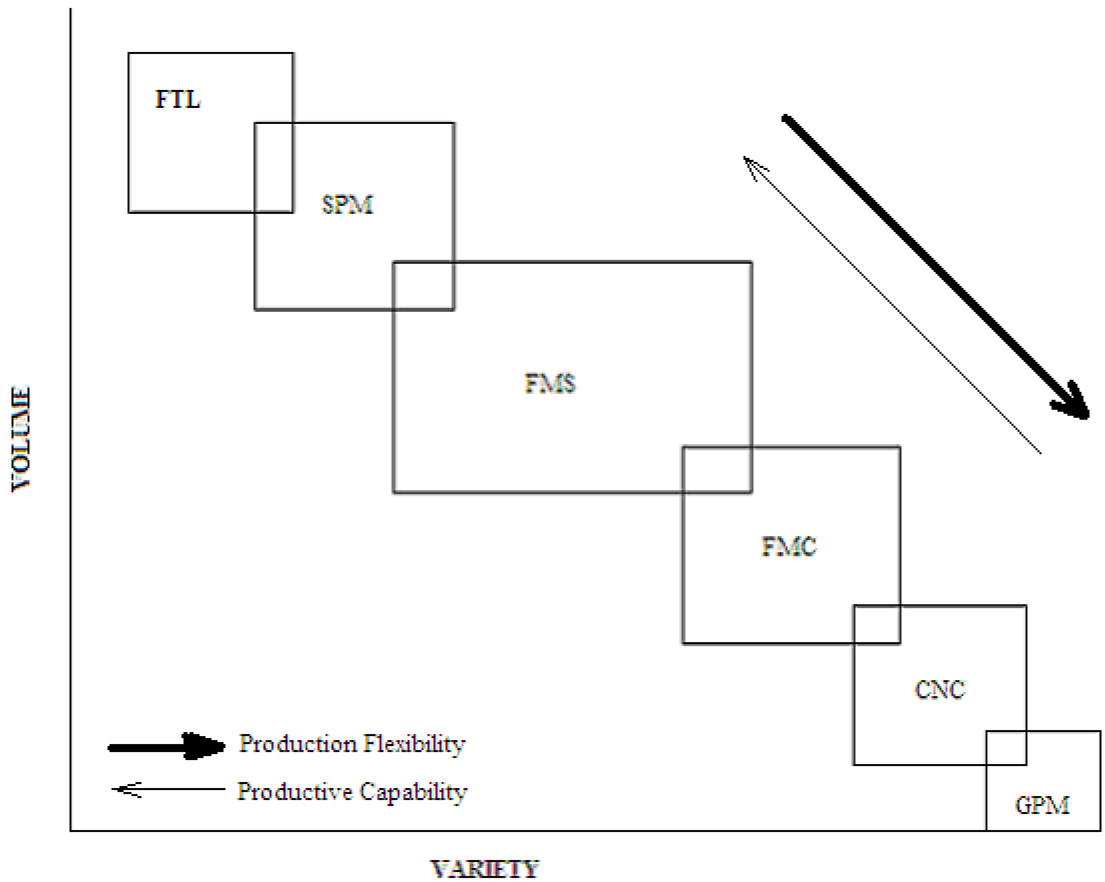



**Fig. 4 Types of Production Systems**

Where,

GPM – General Purpose Machine tools

CNC – Computer Numerically Control

FMC – Flexible Manufacturing Cells

FMS – Flexible Manufacturing Systems

SPM – Special Purpose Machine tools

FTL – Flexible Transfer Line

**General Purpose Machine tools (GPM):**

One-off and low volumes of production are normally carried out by conventional general purpose machine tools. When the number of parts in a production run is more it is called batch production. A batch production shop is best suited for very small quantities of many different types of parts. The very nature of production makes the operation of a job shop less efficient than an automated production line. Since the job shop must be provided the greatest degree of flexibility, most of its operations are manual.

**Computer Numerically Control (CNC):**

Computer Numerically Control (CNC) machine tools paves the way for introducing flexible automation on the shop floor. The technology of computer numerical control is today applied to a large spectrum of material processing equipment. During the last decade, CNC technology has improved tremendously. The clear graphics enable tool path and process simulation prior to actual machining. With the incorporation of 32-bit controls, modern CNC systems handles large amounts of information faster. Some of the benefits of 32-bit controls in CNC are in the areas of sculptured shapes, sophisticated internal commands, faster editing and conversational programming, new machine features, and more. CNC machine tools provide higher variety of products compared to other types of production systems excepting GPM. Product volume of CNC is comparatively higher than that of the GPM.

**Flexible Machining Cells (FMC): (Type I FMS)**

The simplest, hence most flexible type of FMS is a flexible machining cell. It consists of one or more CNC machine tools, general purpose or of special designed interfaced with automated material handling and tool changers. FMC's are capable of automatically machining a wide range of different work pieces. They are usually employed in one off and small batch production as independent machining centers, but are frequently the starting point for FMS.

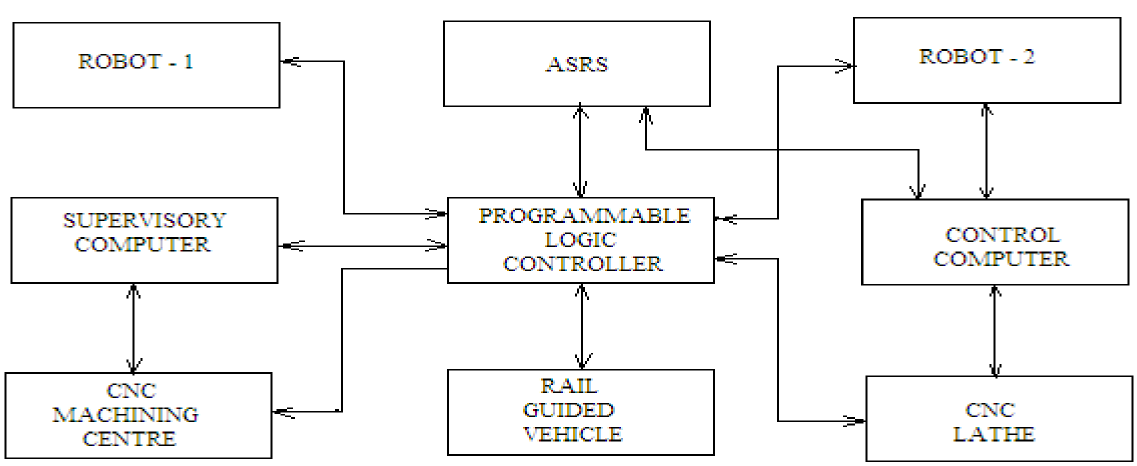



**Fig. 5 Flexible Manufacturing Cell**

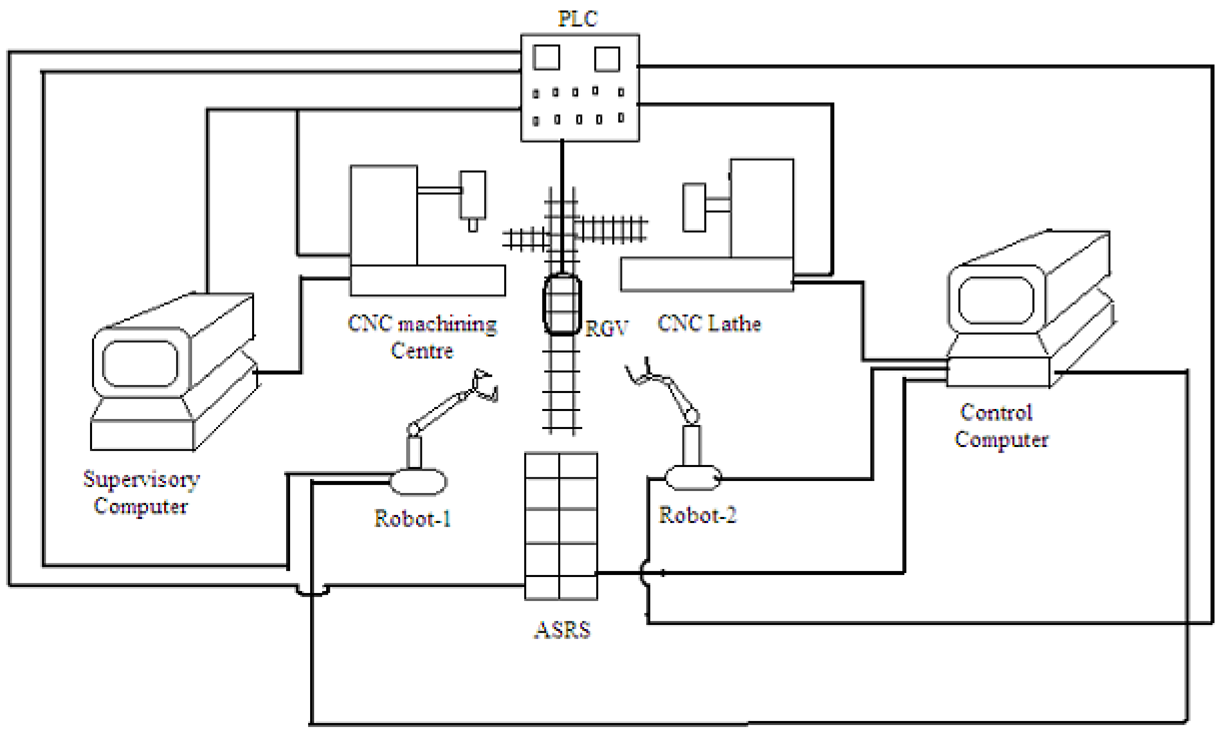



**Fig. 6 Flexible manufacturing cell layout**

A turning centre fitted with a gantry loading and unloading system and pallets for storing work pieces and finished parts is a typical flexible turning cell. If the turning centre is incorporated with post process metrology equipment like Renishaw probes or inductive measuring equipment for automatic offset correction, the efficiency of the system improves. Automatic tool changes, tool magazines, block tooling, automatic tool offset measurement, automatic chuck change and chuck jaw change etc. help to make the cell to be more productive.

One or two horizontal machining centers with modular fixturing, multiple pallets, advanced tool management system, automatic tool changer, automatic head changer or automatic magazine changer, robots or other material handling systems to facilitate access of the jobs to the machine also constitute a flexible machining cell.

An FMC also comprise a turning centre, machining centre and pick and place robots or other material handling systems. Fig. 5 shows flexible manufacturing cell. Fig.6 indicates the flexible manufacturing cell layout. This consists of a CNC lathe, a machining centre, a small automatic storage and retrieval system, two robots for loading and unloading the machines and a small rail guided vehicle to carry the component from one machine tool to another. The system is controlled by a PLC and a couple of personal computer.

## Flexible Machining System (FMS): (Type II FMS)

A large portion of the manufacturing industry involves the intermediate level of batch operations that lead themselves to the FMS approach. FMS thus basically attempts to efficiently automate batch manufacturing operations. They are an alternative that fits in between the manual job shop and hard automation. FMS is best suited for applications that involve an intermediate level of flexibility and low or medium quantities.

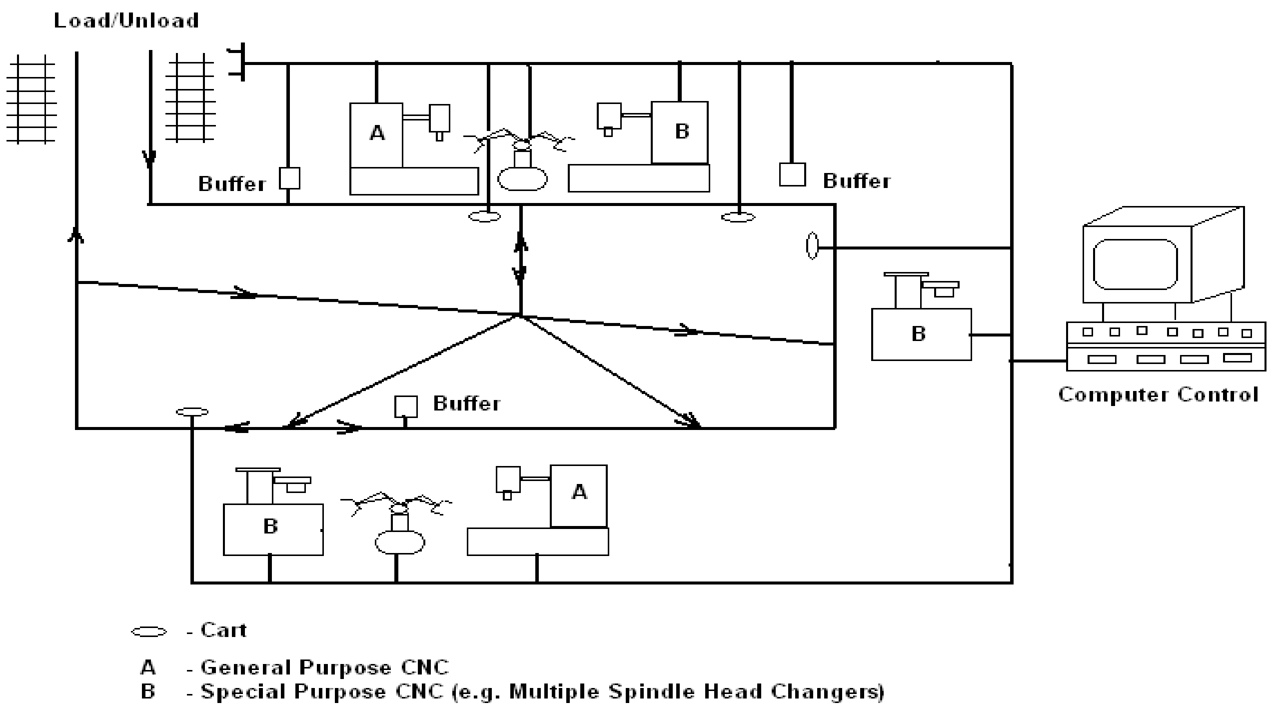



**Fig. 7 Flexible Machining System Layout**

Fig.7 shows the flexible machining system layout. Flexible machining Systems consist of several flexible automated machine tools of the universal or special type which are flexibly interlinked by an automatic work-piece flow system so that different work-pieces can be machined with the same machine configuration. The characteristic feature is the external interlinkage of the machines, unrestricted by cycle considerations. Different machining times at the individual stations are compensated for by central or decentralized work-piece buffer stores. Flexibility is applied to machines because of CNC control and flow of products from one machine to another which is possible through flexible transport system.

Flexibility is characterised by the system's ability to adapt to changes in the volumes in the product mix and of the machining processes and sequences. This means that a FMS will be able to respond quickly to changing market and customer demands.

A typical FMS layout is illustrated in fig. 8. Study the figure until you locate all the elements in the FMS. The FMS shown in fig.8 is designated to produce a family of machined metal parts that can be manufactured with three-axis vertical machining centers. Five machining centers are required to meet the production demands; locate them in the figure. Raw material for the parts is delivered to the automatic work changers (number 5 in the fig.) and is located onto pallets or fixtures that will hold the material for one or more milling operations. Frequently, a partially finished part will be removed from one fixture and placed on another in a different orientation for additional machining. The pallets or fixtures are delivered to the correct machining center cell by the computer-controlled cart or automatic guided vehicle (AGV). The vehicles have no person on board for navigation and use a current-carrying wire embedded into the floor and electronics on the cart for path, direction, and speed control.

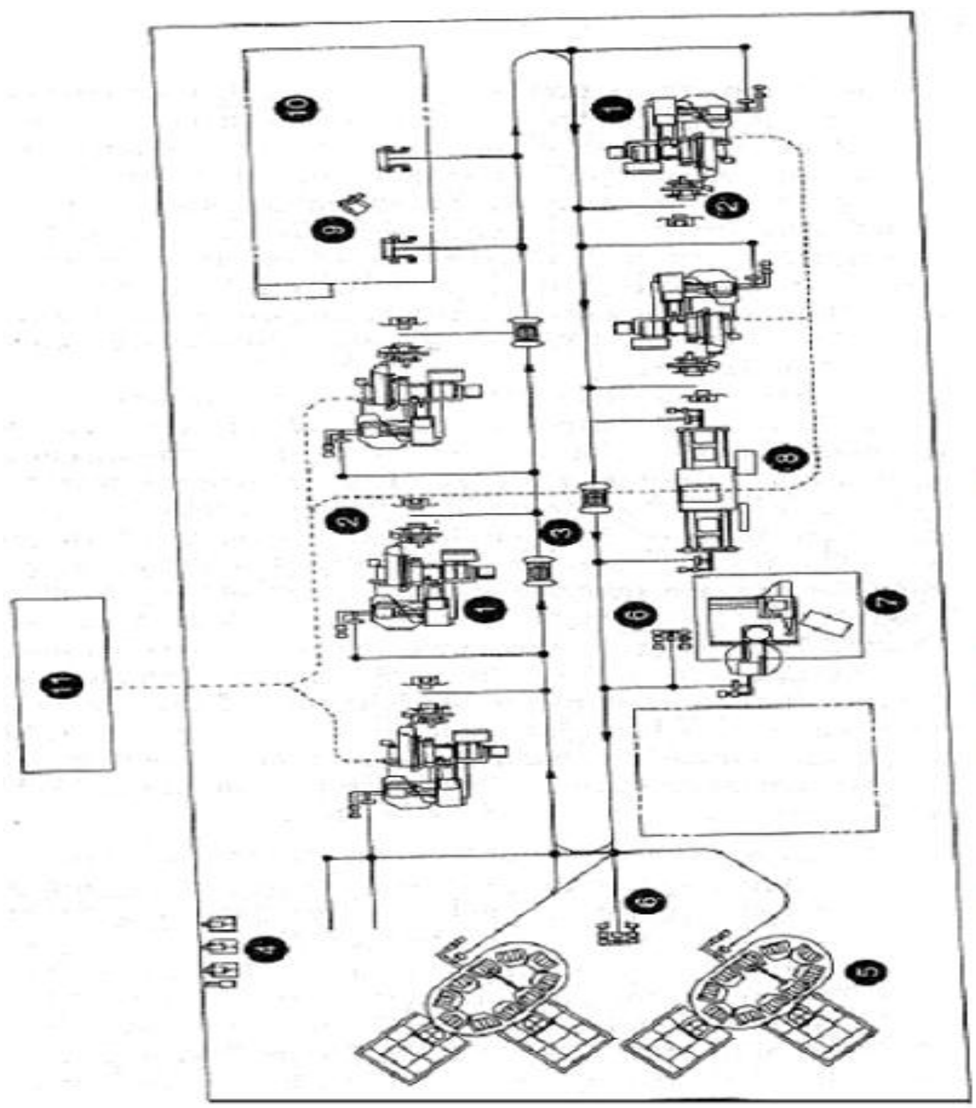



Fig.8 Example of Flexible Manufacturing System
(Source: Courtesy Cincinnati Milacron, Inc.)

**(1)** Five Milacron 5-axis T-30 CNC machining Centers, 90 tools each.

**(2)** Five tool interchange stations, one per machine, accepting tool delivery via chart

**(3)** Three computer-controlled carts, with wire-guided path

**(4)** Cart maintenance station

**(5)** Two automatic work-changers, 10 pallets each, with dual load/unload positions with 90º tilt, 360º rotation.

**(6)** Two material review stands, for on demand part inspection.

**(7)** Inspection module, with LK Tool Co. Metre Four Micro-vector horizontal arm coordinate measuring machine.

**(8)** Automatic part washing station

**(9)** Toll chain load/unload, tool gage, and calibration gage stands

**(10)** Elevated computer room, with DEC VAX 8200 central computer

**(11)** Centralized chip/coolant collection/recovery system, with dual flume

--------------------- Flume path

The material handling AGVs are also used to deliver tools from the setup and calibration area (9 in the fig.) to the tool interchange stations (2) in the fig.). From the tool interchange stations, tools are changed automatically on the machining centers to match the requirements of the parts to be produced. Finished parts still mounted to the pallets are delivered by the AGV system to the parts washing station (8 in the fig.) prior to inspection and shipping. To track the quality of finished parts, the AGV delivers machined parts to the coordinate measuring machine (7 in the fig.) for automatic inspection or to the manual inspection stations (6 in the fig.). A centralized chip and coolant recovery system collects metal removed in machining and filters the cutting fluid used in the cells. The cells in the FMS are under area computer control from a central computer (10 in the fig.).

**Special Purpose Machine tools (SPM):**

Special purpose machine tools are made for specific applications. Special types of parts or components are made on them. In which required operations and sequence of operations are predefined. These are also computer controlled. This type of machined are specially designed for particular type of product, which is not possible to make on other general purpose machines. In this type of production system the variety of product is less but the volume of product is higher.

**Flexible Transfer Line (FTL): (Type III FMS)**

Flexible Transfer Lines are intended for high volume production. A part in a high volume production may have to undergo large number of operations. Each operation is assigned to and performed on only one machine. This results in a fixed route for each part through the system. The material handling system is usually a pallet or carousel or conveyor. In addition to general purpose machines, it can consist of SPM’s , robots and some dedicated equipment. Scheduling to balance the machine loads is easier. Unlike conventional transfer lines, a number of different work-pieces can be manufactured on the FTL. The resetting procedure is largely automated.

**Flexible Transfer Multi-line: (Type IV FMS)**

In this type of FMS, multiple flexible transfer lines (type III FMS) are interconnected. This type of FMS having the following type of characteristics:

- Less process flexibility
- Increased routing flexibility
- Achieve best of type II and type III
- Flexibility is increases form type III FMS to type II FMS
- Type III FMS is generally used in U. S. A. and type II FMS is generally used in Japan.

## *FMS Components:*

Work station:

The processing or assembly equipment used in an FMS depends on type of work accomplished by the system.

a) Load/unload station: it is the physical interface between the FMS and rest of the factory. Raw work parts enter the system at a point and finished part exit the system from here.
b) Machhing system: The predominant machining stations in the FMS are CNC machine tools.
c) Other processing station: the FMS concept has been applied to other processing operations.
d) Assembly: Some FMS are designed to perform assembly operation using variable programmed robots especially in electronics components factory.
e) Other station and equipments: Here we mean machines that need not necessarily do convențional manufacturing like material removal; assembly etc, and instead deal with other thing,s like possibly on-line testing; barcode reading and stamping etc. Other stations at which the FMS can be incorporate are inspection, measurement, cleaning.

Material Handlinq and storage system:

These are the support systems of an FMS, which can be cleverly used to speed up improve productivity of the system.

They must do following functions:

- Random independent movemenî of work parts between workstations.
- Handle a variety of work part configurations.
- Temporary storage.
- Convenient access for loading & unloading work parts.
- Compatible with computer control.

Material handling Equipment;

The types of material handling system used to transfer parts between stations in an FMS include variety of material transfer equipments and robots. The m/t handling function in an FMS is often shared between two systems.

(1)A primary handling system.
(2)Secondary handling system.

## Difference between cell & FMS:

| CELL | FMS |
|---|---|
| Low Flexibility | High Flexibility |
| Small stored part program inventory and accessibility | Large stored part program inventroy and accessibility |
| Limited on-line computing power and decision-making software | High on-line computing power and decision-making software |
| Low to moderate equipment and resource costs | High equipment and resource costs |
| Limited flexibility and variety of parts produced | High flexibility and variety of parts produced |
| Low to medium preparation and implementation requirements | High preparation and implementation requirements |
| Benefits narrow but easily identified and quantified | Benefits broad but hard to identify and quantify |
| Moderate justification complexity and difficulty with mid-management approval required | Difficult and complex justification process with high-level approval required |
| Moderate level of management commitment and support required | High level of management commitment and support required |
| Low staffing and training impact | High starting and training impact |
| Moderate effect on other internal operations and organizations | High effect on other internal operations and organizations |
| Short planning to implementation cycle | Long planning to implementation cycle |
| Low to moderate risk and complexity,minimal facility changes | High risk and complexity, many facility changes or new facility required |
| Quick and practical learning curve and | Lenthy and involveed learningcurve and |

| | |
|---|---|
| implementation cycle | implementation cycle |
| Generally no tool delivery:limits system scope and flexibility | Generally tool delivery and tool management: opens systems scope and flexibility |
| Phased cellular growth may take too long and obsolete equipment before full integration | FMS complete system and total part spectrum planned and implemented in turnkey installation. |
| Possibility of violating cell integrity by „stripping out" underutilized equipment to handle excess capacity during times of peak load conditins. | Not likely to violating FMS integrity and strip out equipment due to inherent flexibility and centrilized computer control of the system. |

## FMS layout configuration:

The material handling system establishes the FMS layout. Most layout

configurations found in today's FMS can be divided into five categories.

(1)In- line layout.
(2)Loop layout
(3)Ladder layout
(4)Open field layout
(5)Robot controlled cell
Computer control system:

The FMS includes a distributed computer system that is interfaced to the workstation, material handling system and other hardware components. A typical FMS computer system consists of a central computer and other components. The various control requirements are:

1. Workstation control
2. Distribution of control instruction to work station
3. Production cycle
4. Shuttle control
5. Traffic control
6. W/p monitoring
7. Tool control
8. Performance monitoring & reporting
9. Diagnostics

Human resources;

One additional component in the FMS is human labor. The use of manpower in

FMS is attributed to the following functions

- Loading/unloading
- Changing & setting tools

- Maintenance & repair
- NC part programming
- Overall management of system

## FMS Benefits:

A number of benefits expected in successful FMS application.

- Increase machine utilization.
- Fewer machine required.
- Less factory floor space required.
- Lower manufacturing lead limes.
- Reduced inventory requirements.
- Reduced direct labor requirements & higher productivity.
- so for high productivity for all batch sizes, large or small
- shorter throughput times
- lower storage costs
- reduced labour if not altogether avoiding labour
- reduced handling
- flexible production system to incorporate product changes
- at short notice to meet customer's specific requirements.
- tunity for unattended production

## Quiz:

1 Define Flexible Manufacturing System.

2 Give The Objectives Of Fms.

3 Give Benefits Of Cim.

4 Give The Difference Between Fms And Fmc

5 Explain Random Fms And Dedicated Fms

6. Enlist The Fms Layout And Explain Any One Of Them

7. list types of automobile guided vehicles and explain any one of them

# Practical no : 3

**AIM: - Flexibility in FMS and its measurements**

***FLEXIBILITY***

Flexibility means to produce reasonably priced customized products of high quality that can be quickly delivered to customers.

Different approaches to flexibility and their meanings are shown Table 1.

**Table 1**

| **Approach** | **Flexibility meaning** |
|---|---|
| **Manufacturing** | • The capability of producing different parts without major retooling<br>• A measure of how fast the company converts its process (es) from making an old line of products to produce a new product<br>• The ability to change a production schedule, to modify a part, or to handle multiple parts |
| **Operational** | • The ability to efficiently produce highly customized and unique products |
| **Customer** | • The ability to exploit various dimension of speed of delivery |
| **Strategic** | • The ability of a company to offer a wide variety of products to its customers |
| **Capacity** | • The ability to rapidly increase or decrease production levels or to shift capacity quickly from one product or service to another |

So, **what is flexibility in manufacturing?**

There are three levels of manufacturing flexibility.

**(a) Basic flexibilities**

- Machine flexibility
- Material handling flexibility

- Operation flexibility

**(b) System flexibilities**

- Volume flexibility
- Expansion flexibility
- Routing flexibility
- Process flexibility
- Product flexibility

**(c) Aggregate flexibilities**

- Program flexibility
- Production flexibility
- Market flexibility

***FLEXIBILITY IN FMS***

**[1] Machine Flexibility**:

"Ease of making change required to produce a given set of part type."

**Depends on Factors**:

- Setup or change over time.
- Ease of machine reprogramming ( ease with which part program can be downloaded to machine).
- Tool storage capacity of machines.
- Skill and versatility of workers in the system.

**Measures:**

- Time to replace worn-out or broken cutting tools.
- Time to change tools in a tool magazine.
- Time to assemble or mount the new fixtures.
- Machine tool setup time
  - Tool preparation
  - Part positioning and releasing
  - NC part program change over

**How to attain machine flexibility?**

- By using sophisticated tool-loading and part loading devices(technological progress)
- Minimize tool changes (proper operation assignment)
- Bring the part and required tool together to the machine (technological capability)

**[2] Process Flexibility:**

"Ability to produce a given set of part types in several ways"

**Depends on Factors:**

- Machine flexibility
- Skills of workers

**Measures:**

- The number of part types that can be simultaneously processed without using batches.

**How to attain process flexibility?**

- By using machine flexibility
- By using Multi-purpose, adoptable, and CNC machining centers

**[3] Product Flexibility:**

"Ability to change over to new set of products economically and quickly."

**Depends on Factors:**

- How closely the new part design matches the existing part family
- Off-line part program preparation
- Machine flexibility

**Measures:**

- The time required from one part mix to another

**How to attain product flexibility?**

- By using an efficient and automated production planning and control system which containing
  (i) Automatic operation assignment procedure

  (ii) Automatic pallet distribution calculation capability

- By using machine flexibility

**[4] Routing Flexibility:**

"Ability to handle breakdowns(machines, tools, etc)."

- Either a part type can be processed via. Several routes

  **OR**

- Equivalently, each operation can be performed on more than one machine

**Routing flexibility is of two types:**

(i) Potential:- part route are fixed but parts are automatically rerouted when a breakdown occurs

(ii) Actual:- identical parts are actually processed through different routes, independent of breakdown.

**Depends on Factors:**

- Similarity of parts in the mix.
- Similarity of workstation.
- Duplication of workstation.

- Cross training of manual workers.
- Common tooling.

**Measures:**

- Robustness of FMS (Continuity of production)

**How to attain routing flexibility?**

- By allowing automated and automatic rerouting of parts(Potential routing flexibility)
- Pooling machines into machine groups
- Duplicating operation assignment (Actual routing flexibility)

**[5] Volume Flexibility:**

"Ability to operate an FMS profitable at different production volume"

**Depends on Factors:**

- Level of manual labor performing production
- Amount invested in capital equipment

**Measure:**

- Smallest volumes for all part types that allow the system run profitably

**How to attain volume flexibility?**

- By using multi purpose machines
- Layout not dedicated to a particular process
- By using sophisticated, automated materials handling system, e.g. intelligent carts (not fixed-route conveyors)
- Through routing flexibility

**[6] Expansion Flexibility:**

"Ease of modularly expanding a system"

**Depends on Factors:**

- Expense of adding workstation
- Ease with which layout can be expanded
- Type of part handling system used
- Ease with which properly trained workers can be added

**Measures:**

- How long the FMS can become

**How to attain volume flexibility?**

- Non-dedicated, non-process driven layout
- Flexible materials handling system containing wire guided carts

**[7] Operation Flexibility:**

"Ability to interchange the ordering of (some) operations for each part type."

**Depends on Factors:**

- Machine flexibility
- Interchangeability of operation
- Sequence of operation

**Measures:**

- Ability and extent of not pre-determining the order of all operations, each on a particular machine (type)

**How to attain volume flexibility?**

- Design a decision system to make decision in real-time determining the ‘next’ operation and the ‘next’ machine, depending on the system state (idle, busy, bottleneck) of various elements of FMS
- Through machine flexibility

**[8] Production Flexibility:**

“The universe of part types that the FMS can produce”

**Depends on Factors:**

- Machine flexibility of individual station
- Range of machine flexibilities of all stations in the system

**Measures:**

- Level of existing technology

**How to attain volume flexibility?**

- Increase the level of technology
- Increase the versatility of the machine tools
- All previous flexibilities

**QUIZ:**

1. Define Flexibility. Explain Process Flexibility, Machine Flexibility, Product Flexibility, Production Flexibility, Routine Flexibility, expansion flexibility

2 Explain As/Rs System with Neat Sketch.

# Practical:- 04

## Aim:-Selection of FMC according to lambtechnicon method

## According to Lamb Technicon, Eight factors contributes to flexibility

**(1) Setup** **: -** Ease and short duration changeover of tools, fixtures, programs, and other issues affected by the changeover between parts.

**(2) Process** **: -** The ability to produce part in more than one way; also the mix of part the system can cope with.

**(3) Convertibility** **: -** The ability to change the system to handle new parts that may be similar or different.

**(4) Routing** **: -** The ability to continue producing in the event of breakdowns.

**(5) Volume** **: -** The ability to match market volume demands profitably.

**(6) Expandability** **: -** The ability to expand the facilities and cost-effectively.

**(7) Operation** **: -** The ability to shift the order of operation.

**(8) Production** **: -** The range of parts that can be produced.

The flexibility points are obtained by multiplying the weighting for each criterion with the score and adding the result .The throughputs and capital costs for the candidate FMCs (or other flexible equipment) are compared with their flexibility points Usually, the ratio between the capital cost and throughput is considered .the FMC(or flexible equipment ) with smallest ratio and an acceptable value of flexibility points is selected.

**Problem 1:- Consider the five FMCs of A, B, C, D, E and F for candidate system .The eight factors considered with their weightings reflecting the company's needs, which are shown in following table 1 .Systems are judged and rated on a scale of 1 to 10 for each factor . The one scoring the highest total is the most flexible.**

| CRITERION | WEIGHTING PERCENTAGE % | A | B | C | D | E |
|---|---|---|---|---|---|---|
| Setup | 20 | 8 | 3 | 7 | 6 | 9 |
| Process | 5 | 7 | 0 | 5 | 10 | 8 |
| Convertibility | 15 | 8 | 10 | 9 | 5 | 10 |
| Routing | 10 | 3 | 8 | 4 | 8 | 7 |
| Volume | 15 | 5 | 7 | 10 | 6 | 9 |
| Expandability | 20 | 4 | 7 | 9 | 7 | 8 |
| Operation | 5 | 9 | 8 | 6 | 8 | 10 |
| Production | 10 | 4 | 6 | 8 | 7 | 9 |

**Table-1**

**Which of the FMC should be selected out of Five FMCs ?**

**Solution:-**

First of all, finding out of the flexibility points for all FMCs as following:

**For FMC A:-**

Flexibility points= (20x8 ) + ( 5x7 ) + ( 15x8 ) + ( 10x3 ) + ( 15x5 ) + ( 20x4 ) + ( 5x9 ) + ( 10x4 )

= 160 + 35 + 120 + 30 + 75 + 80 + 45 + 40
= 585

**For FMC B:-**

Flexibility points= (20x3 ) + ( 5x0 ) + ( 15x10 ) + ( 10x8 ) + ( 15x7 ) + ( 20x7 ) + ( 5x8 ) + ( 10x6 )

= 60 + 00 + 150 + 80 + 105 + 140 + 40 + 60

= 635

**For FMC C:-**

Flexibility points= (20 x7) + ( 5x5 ) + ( 15x9 ) + ( 10x4 ) + ( 15x10 ) + ( 20x9 ) + ( 5x6 ) + ( 10x8 )

= 140 + 25 + 135 + 40 + 150 + 180 + 30 + 80

= 780

**For FMC D:-**

Flexibility points= (20x6) + ( 5x10 ) + ( 15x5 ) + ( 10x8 ) + ( 15x6 ) + ( 20x7 ) + ( 5x8 ) + ( 10 x 7 )

= 120 + 50 + 75 + 80 + 90 + 140 + 40 + 70

= 665

**For FMC E:-**

Flexibility points= (20x9) + ( 5x8 ) + ( 15x10 ) + (10x 7 ) + (15 x 9 ) + (20x 8 ) + ( 5x10 ) + ( 10x 9 )

= 180 + 40 + 150 + 70 + 135 + 160 + 50 + 90

= 875

**Result Table:-**

| **FMC** | **Flexibility Point** |
|---|---|
| A | 585 |
| B | 635 |
| C | 780 |
| D | 665 |
| E | 875 |

Here, from above result; We get the maximum flexibility points with the FMC,E so the **FMC,E** is selected for the candidate system .

**Problem-2:- The XYZ Company is deciding to purchase the FMC. They have three option of different FMCs; Say P, Q and R. The weighting of eight factors, as shown in table-2, in percentage are 15, 10, 5, 20, 10, 15, 10, and 5 respectively. Find the best suitable FMC for the company system, Use the data given in the following table-2.**

| **CRITERION** | **P** | **Q** | **R** |
|---|---|---|---|
| Setup | 8 | 3 | 7 |
| Process | 7 | 0 | 5 |
| Convertibility | 8 | 10 | 9 |
| Routing | 3 | 8 | 4 |
| Volume | 5 | 7 | 10 |
| Expandability | 4 | 7 | 9 |
| Operation | 9 | 8 | 6 |
| Production | 4 | 6 | 8 |

**TABLE-2**

**Which of the FMC should be selected out of Five FMCs based on flexibility points ?**

**Solution:-**

First of all finding out the flexibility points for all FMCs as following:

**For FMC P:-**

Flexibility points= (15 x8) + (10 x7 ) + ( 5 x 8 ) + (20 x 3 ) + ( 10x5 ) + ( 15x 4 ) + (10x 9 ) + (5 x 4 )

= 120 + 70 + 40 + 60 + 50 + 60 + 90 + 20

= 510

**For FMC Q:-**

Flexibility points= (15 x3 ) + ( 10x 0 ) + ( 5x10 ) + ( 20x8 ) + ( 10x7 ) + ( 15x7 ) + ( 10x8 ) + ( 5x6 )

= 45 + 60 + 50 + 160 + 70 + 105 + 80 + 30

= 540

**For FMC R:-**

Flexibility points= (15x7) + ( 10x5 ) + ( 5x9 ) + ( 20x 4 ) + ( 10x10 ) + ( 15x9 ) + ( 10 x 6 ) + ( 5x 8 )

= 105 + 50 + 45 + 80 + 160 + 135 + 60 + 40
= 615

Here, from above result ; we get the maximum flexibility points with the FMC,R so the **FMC,R** is selected for the candidate system.

**Problem-3:-** **The following data pertains to three FMCs available in the market . Which of these should be selected ?**

| CRITERION | A | B | C |
|---|---|---|---|
| Cost (Rs In Lacks) | 10 | 8 | 14 |
| Throughputs (In Hundred)<br>Flexibility Score<br>(Scale based on 1-10) | 200 | 250 | 385 |
| Setup | 4 | 6 | 8 |
| Process | 5 | 7 | 3 |
| Convertibility | 6 | 3 | 2 |
| Routing | 2 | 8 | 4 |
| Volume | 3 | 4 | 5 |
| Expandability | 5 | 4 | 3 |
| Operation | 9 | 8 | 7 |
| Production | 7 | 8 | 9 |

**TABLE-3**

**The weighting percentage for the flexibility factor is 15, 20, 5, 10, 20, 10, 15 and 5 respectively**

# Practical:- 05

**AIM: Increasing of Unutilized Workstation Capacity of a Complex FMS by Quantitative Analysis using Bottleneck model.**

**Problem: 1 Bottleneck model on a simple problem:**

A flexible machining system consists of two machining workstations and a load/unload station. Station 1 is the load/unload station and having single server. Station 2 performs milling operations and consists of two servers (two identical CNC milling machines).station 3 has one server that performs drilling (one CNC drill press). The stations are connected by a part min. The FMS produces two parts, A and B. The part mix fractions and process routings for the two parts are presented in the table-1 below. The operation frequency $f_{ijk}$ = 1.0 for all operations. Determine:

(a) Maximum production rate of the FMS,
(b) Corresponding production rates of each product,
(c) Utilization of each station, and
(d) Number of busy servers at each station.

| Part j | Part Mix $P_j$ | Operation k | Description | Station i | Process Time $t_{ijk}$(min) |
|---|---|---|---|---|---|
| | | 1 | Load | 1 | 4 |
| | | 2 | Mill | 2 | 30 |
| A | 0.4 | 3 | Drill | 3 | 10 |
| | | 4 | Unload | 1 | 2 |
| | | 1 | Load | 1 | 4 |
| B | 0.6 | 2 | Mill | 2 | 40 |
| | | 3 | Drill | 3 | 15 |
| | | 4 | Unload | 1 | 2 |

Table-1

**Solution:**

(a) **To compute the FMS production rate**, we first need to compute workloads at each station, so that the bottleneck station can be identified.

**WLi =Σ Σ $t_{ijk}$ $f_{ijk}$ $P_j$ …………………….. (eq.2)**

Where WLi = average workload for station i (min)

$T_{ijk}$ = processing time for operation k in process plan j at station i (min)

$F_{ijk}$ = operation frequency for operation k in part j at station i; and

$P_j$ = part mix fraction for part j.

WL1 = [(process time for laod & unload,$t_{ijk}$)( part mix for A,Pj)( Operation frequency, $f_{ijk}$)]+[( process time for laod & unload,tijk)( part mix for A,Pj)( Operation frequency, $f_{ijk}$)]

WL1 = (4+2)(0.4)(1.0)+(4+2)(0.6)(1.0)

**WL1 = 6.0 min**

WL2 = [( Process time for mill, tijk)(Part mix for A, Pj)(operation frequency,fijk)] + [(Process time for mill, tijk)(Part mix for B, Pj)(operation frequency,fijk)]

WL2 = (30)(0.4)(1.0) + (40)(0.6)(1.0)

**WL2 = 36.0 min**

WL3 = [( Process time for drill, tijk)(Part mix for A, Pj)(operation frequency,fijk)] + [(Process time for drill , tijk)(Part mix for B, Pj)(operation frequency,fijk)]

**WL3 = 13.0 min**

The ststion routing for both parts is same : 1 → 2→ 3 → 1

Now, the workload of the handling system,

WLn+1 = nt tn+1 ………………………………………….( eq.4)

Where WLn+1 = workload of the handling system(min),

nt = mean number of transports

tn+1 = mean transport time per move(min)

WLn+1= 3(3)

WLn+1= 9 min

Now the production rate for material handling system,

WL4 = [(Workload of handling system, WLn+1)(Part mix for A, Pj)(Operation frequency, fijk)]+[ (Workload of handling system, WLn+1)(Part mix for B, Pj)(Operation frequency, fijk)

WL4 = (9.0)(4.0)(1.0) + (9.0)(0.6)(1.0)

WL4 = 9.0 min

The bottleneck station is identified by finding the largest WLi/si ration.

Here, servers for station 1, s1 = 1
servers for station 2, s2 = 2
servers for station 3, s3 = 1
servers for station 4, s4 = 4 (Station 4: The part handling system)

For station 1, WL1/S1 = 6.0/1 = 6.0 min.
For station 2, WL2/S2 = 36.0/2 = 18.0 min.
For station 3, WL3/S3 = 13.0/1 = 13.0 min.
For station 4, WL4/S4 = 9.0/4 = 2.25 min. (Station 4 : The part handling system)

The maximum ratio occurs at station 2, so it is the bottleneck station that determines the maximum production rate of all parts made by the system.

Rp* = (s*/WL*)

Where Rp* = maximum production rate of all part styles produced by the system, which is determined by the capacity of the bottleneck station (pc/min),

s* = number of servers at the bottleneck station =2

WL* = workload at the bottleneck station (min/pc) =36.0

Rp* = (s*/WL*)

Rp* = 2/36.0

Rp* = 0.05555 pc/min = 3.333 pc/hr

**(b) To determine production rate of each product**, multiply Rp* by its respective part mix fraction.

Rpj* = (Rp*)Pj = (s*/WL*)Pj………………….(eq.6)

Where, Rpj = maximum production rate of part style j (pc/hr), and

Pj = part mix fraction for part style j.

RpA* = 3.333 (0.4) = 1.333 pc/hr

RpB* = 3.333 (0.6) = 2.000 pc/hr

(c**) The utilization of each station can be computed by**

Ui = (WLi/si)(Rp*) = (WLi/si)(s*/WL*)…………………….(eq.7)

Where , Ui = utilization of station I,

WLi = workload of station I (min/pc),

Si = number of servers at station i ,and

Rp* = overall production rate (pc/min).

U1 = (WL1/s1) (Rp*) = (6.0/1)(0.05555) = 0.333 (33.3%)

U2 = (WL2/s2) (Rp*) = (36.0/2)(0.05555) = 1.000 (100%)

U3 = (WL3/s3) (Rp*) = (13.0/1)(0.05555) = 0.722 (72.2%)

U4 = (WL4/s4) (Rp*) = (9.0/4)(0.05555) = 0.125 (12.5%)

(d) **mean number of busy servers at each station is determined by**

BSi = WLi(Rp*) = WLi(s*/WL*)……………………………(eq.10)

Where , BSi = number of busy servers on average at station i, and

WLi = workload at station i.

BS1 = WL1(Rp*) = 6.0 (0.05555) = 0.333

BS2 = WL2(Rp*) =3 6.0 (0.05555) = 2.000

BS3 = WL3(Rp*) = 13.0 (0.05555) = 0.722

BS4 = WL4(Rp*) = 9.0 (0.05555) = 0.50

**Verification of results without using bottleneck model :**

We designed the preceding example so that most of the results could be verified without using the bottleneck model.

For example, it is fairly that station 2 us the limiting station, even with two servers. The

Processing times at this station are more than twice those at station 3. Given that station 2 is the bottleneck, let us try to verify the maximum production rate of the FMS. To do this, the reader should note that the processing times at station 2 are t2A2 =30 min. and t2B2 =40 min. note also that the part mix fractions are PA =0.4 and PB =0.6. This means that for every unit of B produced, there are (0.4/0.6) = (2/3) units of part A. the corresponding time to process 1 unit of B and (2/3) unit of At station 1 is

(2/3)(30)+ (1) (40) = 20+40 = 60 min.

Sixty minutes is exactly the amount of processing time each machine has available in an hour. (This is no coincidence; we designed the problem so this would happen.) With two servers (two CNC mills), the FMS can produce parts at the following maximum rate:

$R_p^*$ = 2 [(2/3) +1] = (4/3) + (2) = 2(1.6666) = 3.333 pc/hr

This is the same result obtained by the bottleneck model.

Given that the bottleneck station is working at 100% utilization, it is easy to determine the utilization of the other stations. At time needed to load and unload the output of the two servers at station 2 is

3.333 (4+2) = 20.0 min.

As a fraction of 60 min. in an hour, this gives a utilization of U1 = (20/60) =0.333.

At station 3, the processing time required to process the output of the two servers at station 2 is

(4/3) (10) + (2) (15) = 43.333 min

As a fraction of the 60 min, we have U3 = (43.333/60) = 0.772.

Using the same approach on the part handling system, we have

(4/3) (9) + (2) (9) = 30.0 min

As a fraction of 60 min., this is 30/60 = 0.50.

However, since there are four server (four work carriers), this fraction is divided by 4 to obtain, U4 = (0.50/4) = 0.125.

These are the same utilization values as in our example using the bottleneck model.

**Problem: 2 Bottleneck model on a more complicated problem**

An FMS consists of four stations. Station 1 is a load/unload station with one server. Station 2 performs milling operations with three servers (three identical CNC milling machines). Station 3 performs drilling operation with two server (two identical CNC drill presses). Station 4 is an inspection station with one server that performs inspection on a sampling of the parts. The stations are connected by a part Handling system that has two work carriers (with two servers) and whose mean transport time = 3.5 min. The FMS produce four parts, A, B, C and D. The part mix fraction and process routing for the four parts are presented in the table below. Note that the operation frequency at inspection station (f4jk) is less then 1.0 to account for the fact that only fractions of the part are inspected. Use the data given table-1. Determine:

(a) Maximum production rate of the FMS,
(b) Corresponding production rate of each part,
(c) Utilization of each station in the system, and
(d) The overall FMS utilization.

| Part j | Part Mix Pj` | Operation k | Description | Station i | Process Time tijk (min) | Frequency Fijk |
|---|---|---|---|---|---|---|
| A | 0.1 | 1 | Load | 1 | 4 | 1 |
| | | 2 | Mill | 2 | 20 | 1 |
| | | 3 | Drill | 3 | 15 | 1 |
| | | 4 | Inspect | 4 | 12 | 0.5 |
| | | 5 | Unload | 1 | 2 | 1 |
| B | 0.2 | 1 | Load | 1 | 4 | 1 |
| | | 2 | Drill | 3 | 16 | 1 |
| | | 3 | Mill | 2 | 25 | 1 |
| | | 4 | Drill | 3 | 14 | 1 |
| | | 5 | Inspect | 4 | 15 | 0.2 |
| | | 6 | Unload | 1 | 2 | 1 |
| C | 0.3 | 1 | Load | 1 | 4 | 1 |
| | | 2 | Drill | 3 | 23 | 1 |
| | | 3 | Inspect | 4 | 8 | 0.5 |
| | | 4 | Unload | 1 | 2 | 1 |
| D | 0.4 | 1 | Load | 1 | 4 | 1 |
| | | 2 | Mill | 2 | 30 | 1 |
| | | 3 | Inspect | 4 | 12 | 0.333 |
| | | 4 | Unload | 1 | 2 | 1 |

Table-1

**Problem 3:-Increasing Unutilized Station capacity:**

Use the data of example 2,in which $u_2$ =82.9 %. Determine the production rate of part D that will increase the utilization of station 2 to 100 %. Also find the new part mix fraction.

**Solution:-**

Utilization of a workstation is calculated by,

$U_2=(WL_2/S_2)(Rp^*)$

$=(WL_2/ 3)(0.1389)$

Settingthe utilization of station 2 (U2) to 1.0(100 %), we can solve the corresponding WL2 value.

Therefore, $WL_2=(U_2)(S_2)/(Rp^*)$

$=(1.0)(3)/(0.1389)$

$=21.6$

This compares with the previous workload value (WL2)of **19.0 min** computed in problem 2. A portion of the workload for both value is accounted for by parts A and B.

This portion is,

WL2(A+B) = (t2A2)(f2A2)(PA)+(t2B3)(f2A3)(PA)

=(20)(1.0)(0.1)+(25)(1.0)(0.2)

=7.0 min

The remaining portion of the workload are due to part D.

For the workload at 100% utilization ,WL2(D) = 21.6-7.0 = 14.6 min

For the workload at 87.9% utilization ,WL2(D)= 19.0-7.0 =12.0 min

We can now use the ratio of these values to calculate the new (increased) production rate for part D:

RpD=($WL_2$(D)for 100% utilization /$WL_2$ (D) for 87.9% utilization )*(RpD previous value)

=(14.6/12.0)(3.333)

=(1.2167)(3.333)

=**4.055 pc/hr**

Production rates of the other three producs remoin the same as before . Accordingly, the Production rate of all parts increases tonthe following :

Rp*=0.833+1.667+2.500+4.055

= **9.055 pc/hr**

Although the production rates of the other three products are unchanged ,The increase in Production rate for part D alters relative part mix fraction .The new values are :

PA=(RpA*)/(Rp*) = (0.833)/(9.055) = **0.092**

PB=(RpB*)/(Rp*) = (1.667)(9.055) = **0.184**

PC=(RpC*)/(Rp*) = (2.500)(9.055) = **0.276**

PD=(RpD*)/(Rp*) = (4.055)(9.055) = **0.448**

# Practical:- 06

**AIM**: Introduction of GT and part family forming using different method.

## GT (Definition)

- Group technology is a manufacturing concept in which similar parts are identified and grouped together in groups or families to take their advantages of their similarities in manufacturing and design.
- The groups of the parts are called as the part families.
- Group technology is an operations management philosophy based on the reorganization that similarities occur in the design and manufacturing of discrete parts.

## Objective of GT

- To improve productivity
- To improve costing accuracy
- To improve customer services
- To improve variety of the products
- To improve effectiveness of machine
- To reduce overall cost
- To reduce work movement
- To reduce overall production cost
- To reduce work movement
- To reduce overall production time

## Obstacle to the application of GT

- Implementation of GT requires a large cost in rearranging the plant into group.
- There is no accepted GT standard so there is no common implementation approach, and implementation is often difficult.
- Installing a coding and classification system requires a large amount of time and effort.
- If Communication between design engineering and manufacturing is not proper then it is may cause the delay in the manufacturing.
- Defect in the coding system may cause the defect in the machining.
- There are large numbers of GT codes.
- It is not suitable when very wide varieties of products are carried out.

**Types of layout**

There are two types of lay out.

1. Process layout
2. GT layout

**1. Process layout**

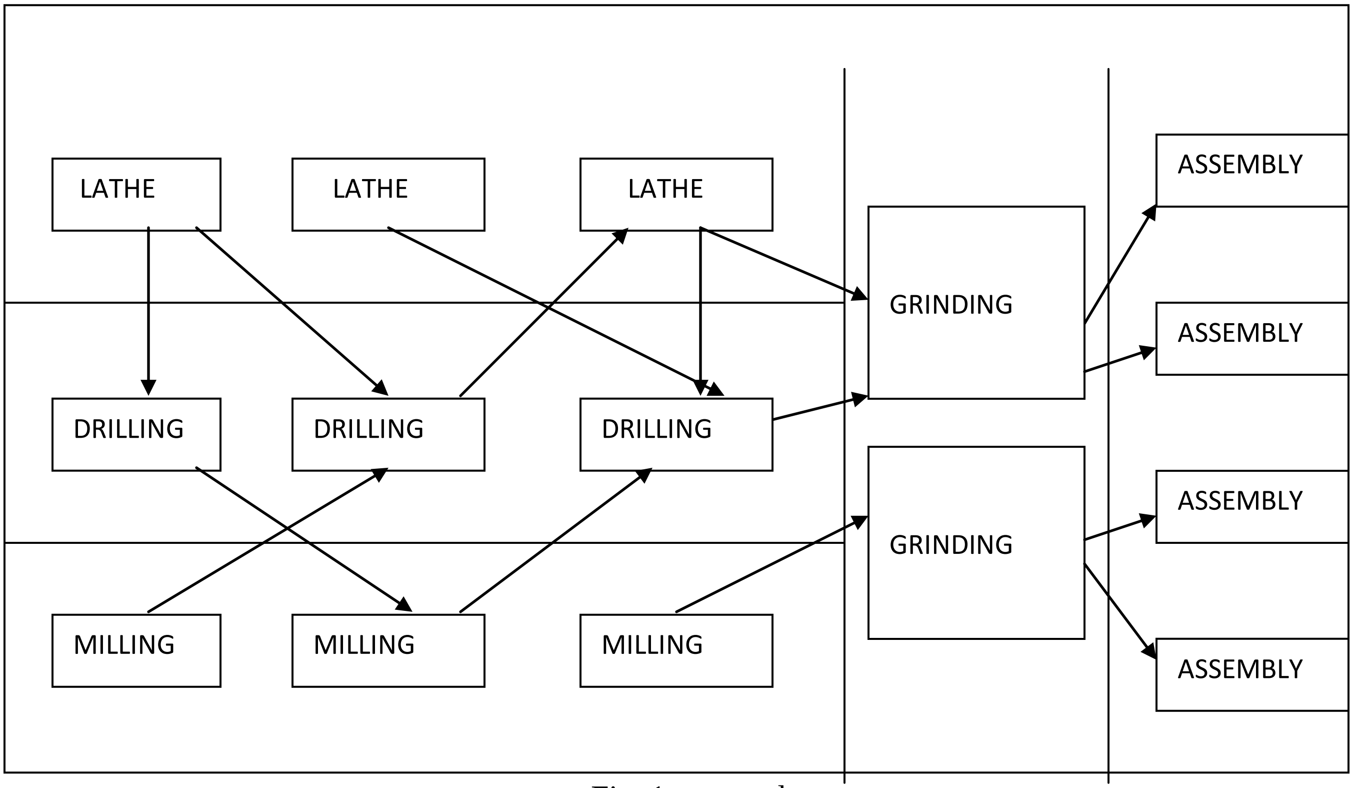



Fig. 1 process layout

- Consider a process layout as shown in figure 1 .machines are arranged in the group. All the lathes are arranged in the same raw, all the drilling machines and milling machines are also arranged in the one section.
- During the manufacturing of parts has to move in between the sections.
- It will result in the high material handling and material movement.

**2. GT layout**

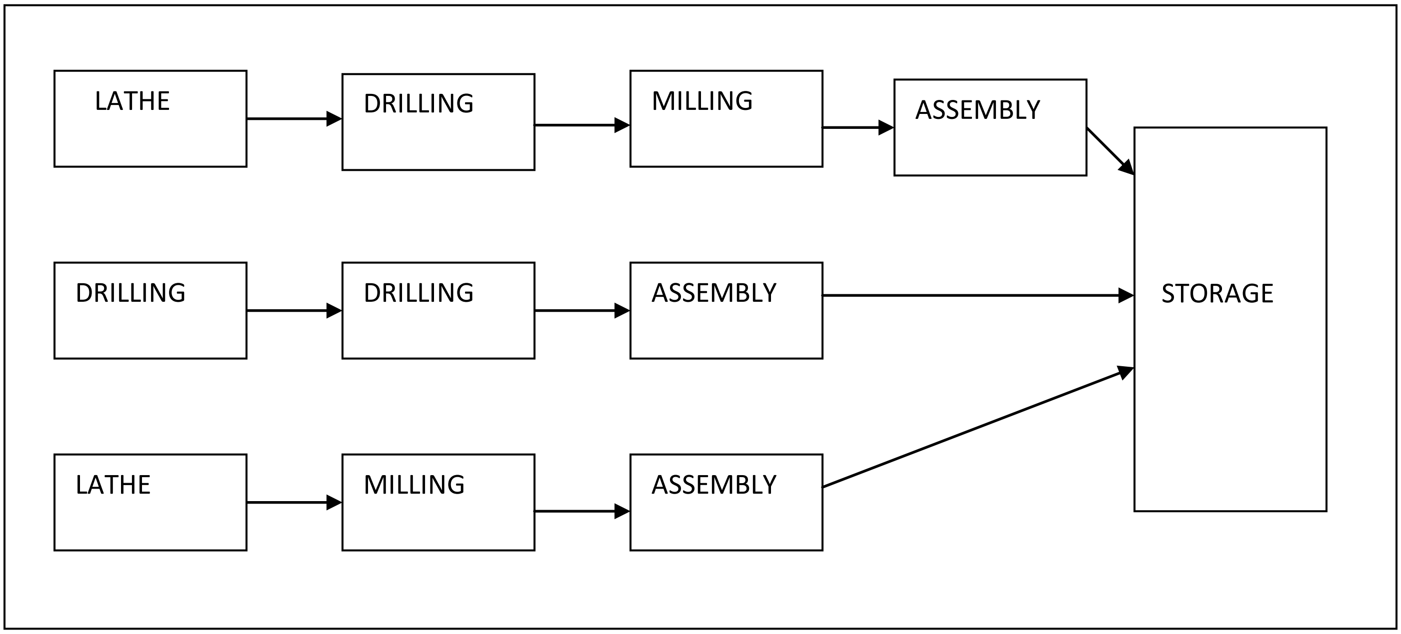



Fig. 2 GT layout

- Now in the GT layout the machines are arranged as per their groups or cell require to manufacture a part.
- The layout is shown in the figure 2.
- The number of machines are same but there will be a large reduction in the time as the material transfer reduces.

## Part family

The group of parts or component is called part family. This group is carried out to reduce the over all manufacturing cost and to improve the productivity. The parts are grouped according to their similarities. These similarities are of two types.

1. **Design attributes.**
2. **Manufacturing attributes.**

In the design attributes the parts are families' according to shape, size, surface roughness, raw material, etc.

In manufacturing attributes the parts are families' according to different process such as milling, drilling, turning etc.

**Example on part family formation**

The examples are on the basis of the design part family, and manufacturing part family.

1. **Design part family.**

   As shown in figure 3 there are two parts which are differing in area and other geometry but they require drilling operation of different size so, it is included in the design part family.

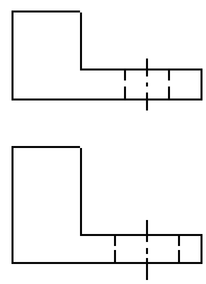


Fig 3 Design part family

2. **Manufacturing part family.**

   As shown in the figure 4 there are two parts different in the geometric aspect but both the parts require the same operation of drilling +.05mm. Though the parts have different geometry they have same manufacturing characteristic this is called as the manufacturing part family.

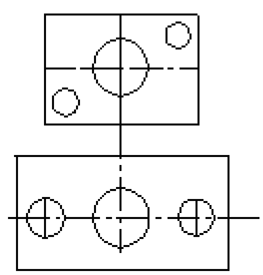


Fig 4 Manufacturing part family

# Methods for grouping part into family

1. **Visual inspection**

The visual inspection method is the least classification of parts into families by looking at either the physical parts or photographs and arranging them into sophisticated and least expensive method. It involves the similar groupings. This method is generally considered to be the least accurate among the three.

2. **Parts Classification and coding system**

The second method, production flow analysis, was developed by tool groupings by analysing the route sheets of parts produced in a given shop. It groups together the parts that have similar operation sequences and machine routings. J.L.burbidge. PFA is a method of identifying part families and associated machine the disadvantage of PFA is that it accepts the validity of existing rout sheets, with no consideration given to whether these process plans are logical or consistent. The PFA approach does not seem to be used much at all in the US.

2. **Production flow analysis (PFA)**

PFA is the method by which the operation sequence and the routing of

- a part through the machine and work station in the plant.
- The route sheet is given below in fig.5. In the route sheet the numbers indicate the operations require.
- Now the parts which require same operation are arranged in the same group.

| **Machine** | **Part Number** | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** |

- Here 1, 7, 9,11,4,6,16 require the same operation so they are grouped same and 2, 8,10,15,14 and 3, 13,12,5 are also grouped same as shown in the fig. 6

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lathe** | **X** | **X** | | **X** | | **X** | **X** | **X** | **X** | **X** | **X** | | | **X** | **X** | **X** |
| **Milling** | **X** | | **X** | **X** | **X** | **X** | **X** | | **X** | | **X** | **X** | **X** | | | **X** |
| **Drilling** | **X** | **X** | **X** | **X** | | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | |
| **Grinding** | **X** | **X** | **X** | | **X** | | **X** | **X** | **X** | **X** | **X** | | **X** | | **X** | **X** |

Fig 5 Route sheet data before grouping.

| **Machine** | **Part Number** | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **7** | **9** | **11** | **4** | **6** | **16** | **2** | **8** | **10** | **15** | **14** | **3** | **13** | **12** | **5** |
| **L** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | | | | | | | | | |
| **M** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | | | | | | | | | |
| **D** | **X** | **X** | **X** | **X** | **X** | **X** | | | | | | | | | | |
| **G** | **X** | **X** | **X** | **X** | | | **X** | | | | | | | | | |
| **L** | | | | | | | | **X** | **X** | **X** | **X** | **X** | | | | |
| **D** | | | | | | | | **X** | **X** | **X** | **X** | **X** | | | | |
| **G** | | | | | | | | **X** | **X** | **X** | **x** | | | | | |
| **M** | | | | | | | | | | | | | **X** | **X** | **X** | **X** |
| **D** | | | | | | | | | | | | | **X** | **X** | **X** | |
| **G** | | | | | | | | | | | | | **X** | **X** | | **X** |

Fig.6 Route sheet data after grouping.

## Quiz

1. Explain the group technology in brief and give the objectives of it

2. Explain the part family.

3 enlist the methods of grouping the parts in to part families and explain any two of them.

4 explain hierarchical code and hybrid code structure.

5 explain optiz part classification and coding system

6. Limitations of group technology

# Practical: - 07

**AIM:- Grouping Parts & Machines By Rank Order Clustering**

The rank order clustering technique, first proposed by King 26 , is specifically applicable in production flow analysis. It is an easy & easy-to-use algorithm for grouping machines into cells. In a starting part machine incidence matrix that might be compiled to document the part routings in a machine shop, the occupied locations in the matrix are organized in seemingly random fashion. Rank order clustering works by reducing the part machine incidence matrix to a set of a diagonalized blocks that represent part families & associated machine groups. Starting with part incidence matrix , the algorithm consists of the following steps :---

1) In each row of matrix , read the series of 1's & 0's (blank entries = 0's) from left to right as a binary number. Rank the rows in order of decreasing value. In case of a tie , rank the rows in the same order as they appear in the current matrix.

2) Numbering from top to bottom, is the current order of rows the same as the rank order determined in the previous step? If yes, go to step 7. If no go to the following steps.

3) Reorder the rows in the part machine incidence matrix by listing them in the decreasing rank order , starting from the top.

4) In each column of the matrix , read the series of 1's & 0's (blank entries = 0's) from top to bottom as a binary number. Rank the columns in the order of decreasing value . In case of a tie , rank the columns in the same order as they appear in the current matrix.

5) Numbering from left to right , is the current order of columns the same as the rank order determined in the previous step? If yes, go to step 7. If no go to the following steps.

6) Reorder the columns in the part machine incidence matrix by listing them in the decreasing rank order , starting with the left columns Go to step 1.

7) Stop.
For readers accustomed to evaluating binary numbers in step 1 & 4., it might be helpful to convert each binary no. into its decimal equivalent. It is as follows:- $1 * 2^8 + 0 * 2^7 + 0 * 2^6 + 1 * 2^5 + 0 * 2^4 + 0 * 2^3 + 0 * 2^2 + 1 * 2^1 + 0 * 2^0 = 256 + 32 + 2 = 290$. It should be mentioned that decimal conversion becomes impractical for large no. of parts found in practice, & comparison of the binary nos. is preferred.

******************** **Problem Description:** ******************

**Apply The R.O.C. Tech. To The Part Machine Incidence Matrix As Shown In Table.**

| MACHINES | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 3 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 4 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 6 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 7 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |

**<u>Step 1</u>** :- Read series of 0's & 1's & convert it into its binary equivalent.

**<u>Step 2</u>** :- Reorder the rows in descending order diff. from original matrix.

| Binary | $2^8$ | $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ | **Decimal Equal** | **Rank nos** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MACHINES | A | B | C | D | E | F | G | H | I | | |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | **290** | **1** |
| 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | **17** | **7** |
| 3 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | **81** | **5** |
| 4 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | **136** | **4** |
| 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **258** | **2** |
| 6 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | **65** | **6** |
| 7 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | **140** | **3** |

**Step:- 3** Read series of 0's & 1's in respective column & convert it into its binary equivalent

**Step:- 4** Reorder the columns in descending order diff. from original matrix

| MACHINES | A | B | C | D | E | F | G | H | I | Binary |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | **$2^6$** |
| | | | | | | | | | | |
| 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | **$2^5$** |
| | | | | | | | | | | |
| 7 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | **$2^4$** |
| | | | | | | | | | | |
| 4 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | **$2^3$** |
| | | | | | | | | | | |
| 3 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | **$2^2$** |
| | | | | | | | | | | |
| 6 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | **$2^1$** |
| | | | | | | | | | | |
| 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | **$2^0$** |
| | | | | | | | | | | |
| **Decimal** | **96** | **24** | **6** | **64** | **5** | **24** | **16** | **96** | **7** | |
| | | | | | | | | | | |
| **Rank** | **1** | **4** | **8** | **3** | **9** | **5** | **6** | **2** | **7** | |

**Step:- 5 & 6** :--

Preceding from step 6 back to steps 1 & 2 we see that reordering of rows & columns provide descending value & algorithm is concluded **(step 7).** A solution is given in the following table.

| MACHINES | A | H | D | B | F | G | I | C | E |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | | | | | | |
| 5 | 1 | 1 | 0 | | | | | | |
| 7 | | | | 1 | 1 | 1 | | | |
| 4 | | | | 1 | 1 | 0 | | | |
| 3 | | | | | | | 1 | 1 | 1 |
| 6 | | | | | | | 1 | 1 | 0 |
| 2 | | | | | | | 1 | 0 | 1 |

This represents the ideal case because the part families & associated machine cells are completely segregated.

*********************** **Problem Description** ************************

(Overlapping Machine Requirements)

**Apply The R.O.C. Tech. To The Part Machine Incidence Matrix As Shown In Table.**

| | PARTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| MACHINES | A | B | C | D | E | F | G | H | I |
| 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 3 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 4 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 6 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 7 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |

## Practical: - 08

**Aim - Study and Demonstration on Robots.**

1) Introduction of Robot.

2) Robot anatomy. -- Joints and links

    i) Linear joint

    ii) Orthogonal joint.

    iii) Rotational joint.

    iv) Twisting joint.

    v) Revolving joint.

3) Robot configurations.-

    i) Polar configuration.

    ii) Cylindrical configuration.

    iii) Cartesian coordinate robot.

    iv) Jointed arm robot.

    v) SCARA

4) Robot drives system.

5) Accuracy and repeatability.

6) Types of robot programming.

7) Safety monitoring.

8) End effectors and sensors in robots.

9) Application of robots.

10) Programming for some robotic application

Answer:

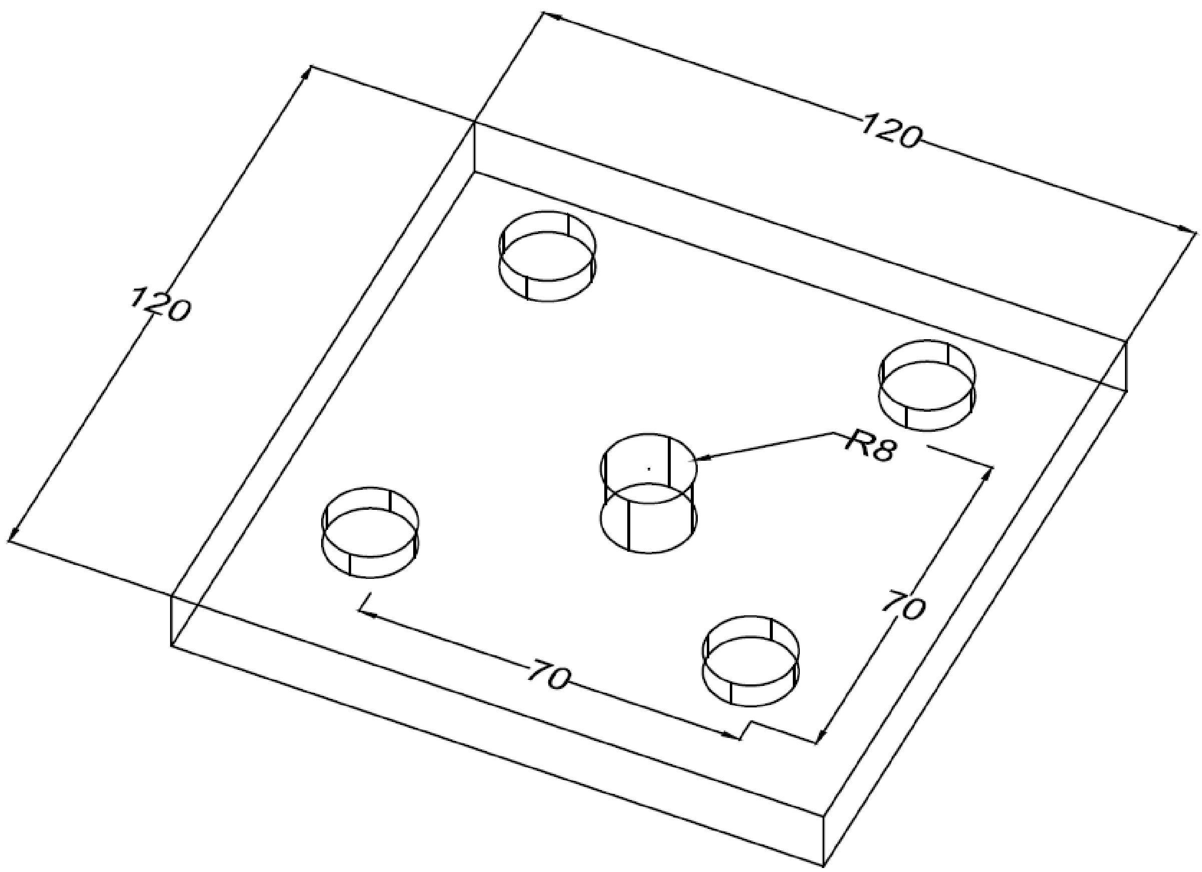
**Practical: - 09**

**Aim – Prepare Program and carryout NC Job .**

Material: New Plywood

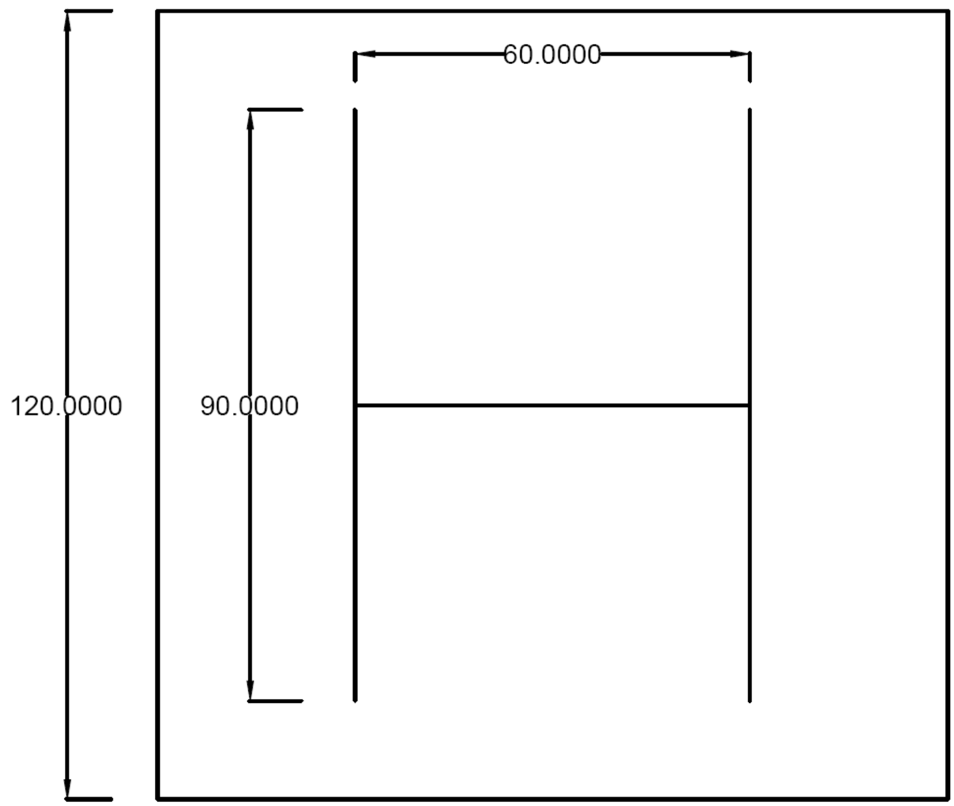
All dimension in mm.

## Part-1 Drilling Operation



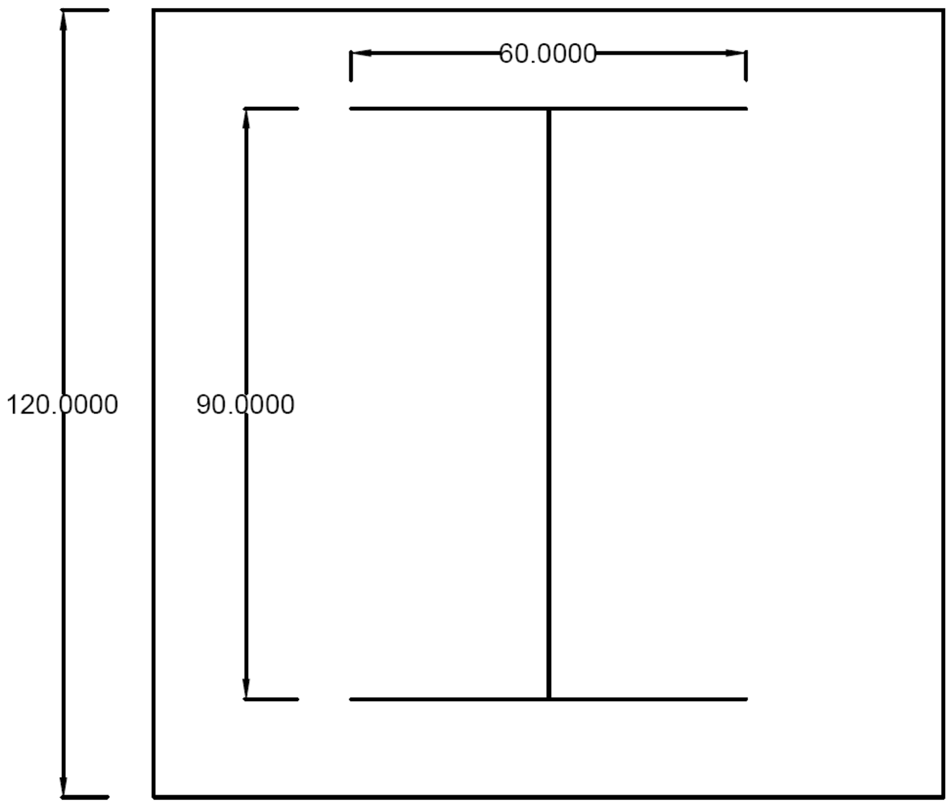

NC Programme:-

# Part-2 Cutting Operation



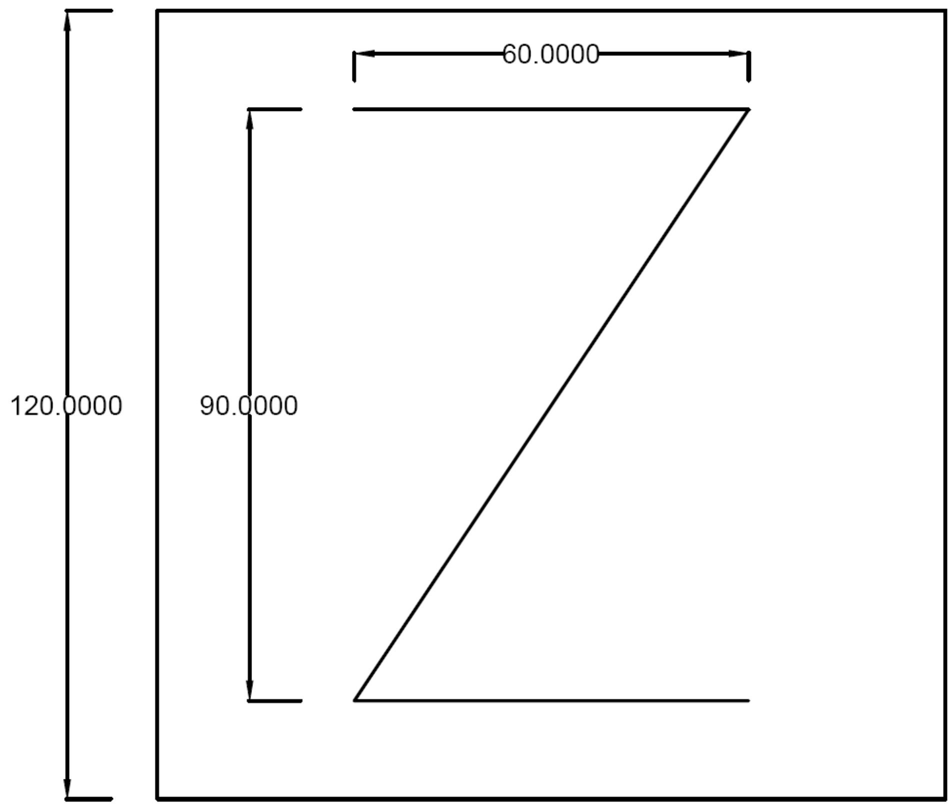

NC Programme:-

# Part-3 Cutting Operation




NC Programme:-

# Part-4 Cutting Operation




NC Programme:-