COMPUTER INTEGRATED MANUFACTURING & TECHNOLOGY

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COURSE CONTENT

Unit No.	Chapter No.	Chapter Content
1	1	INTRODUCTION
1	2	GROUP TECHNOLOGY
1	3	ROBOT TECHNOLOGY
2	4	NUMERICAL CONTROL (NC) AND COMPUTERIZED NUMERICAL CONTROL (CNC)
2	5	FLEXIBLE MANUFACTURING SYSTEM

Text Books –

1. CNC Programming by Dr. S. K. Sinha (Golgotia Publication)
2. Flexible Manufacturing Cells and System by William W Luggen (Prentice Hall)
3. Computer Numerical Control by P. Radhakrishnan (New Central Book Agency)
4. Computer Integrated Manufacturing by S. Kant Vajpayee (Prentice Hall)
5. Computer Aided Manufacturing By Rao (McGraw Hill)
6. CAD/CAM by Groovers & Zimmers (Pearson)

CHAPTER 1: INTRODUCTION

CONTENT

CIM CONCEPT: INTRODUCTION

CIM :- Computer Integrated Manufacturing

We can simply get a meaning:-

"Manufacturing is done with an aid of Computer Technology"

But above statement defines 'CAM' (Computer Aided Manufacturing)

What is difference then (between CAM and CIM !!) ?

As CAD covers all design and drafting functions, CAM covers all manufacturing and quality functions similarly.....

CIM integrates all virtual or physical activities those require to transform a raw thing into quality product including CAD and CAM.

CIM CONCEPT: DEFINITION

Definition:

" It covers the entire range of enterprise's functions (such as design, development, manufacturing, business, Information and communication) with aiding computer technologies to operate entire organization as a whole"

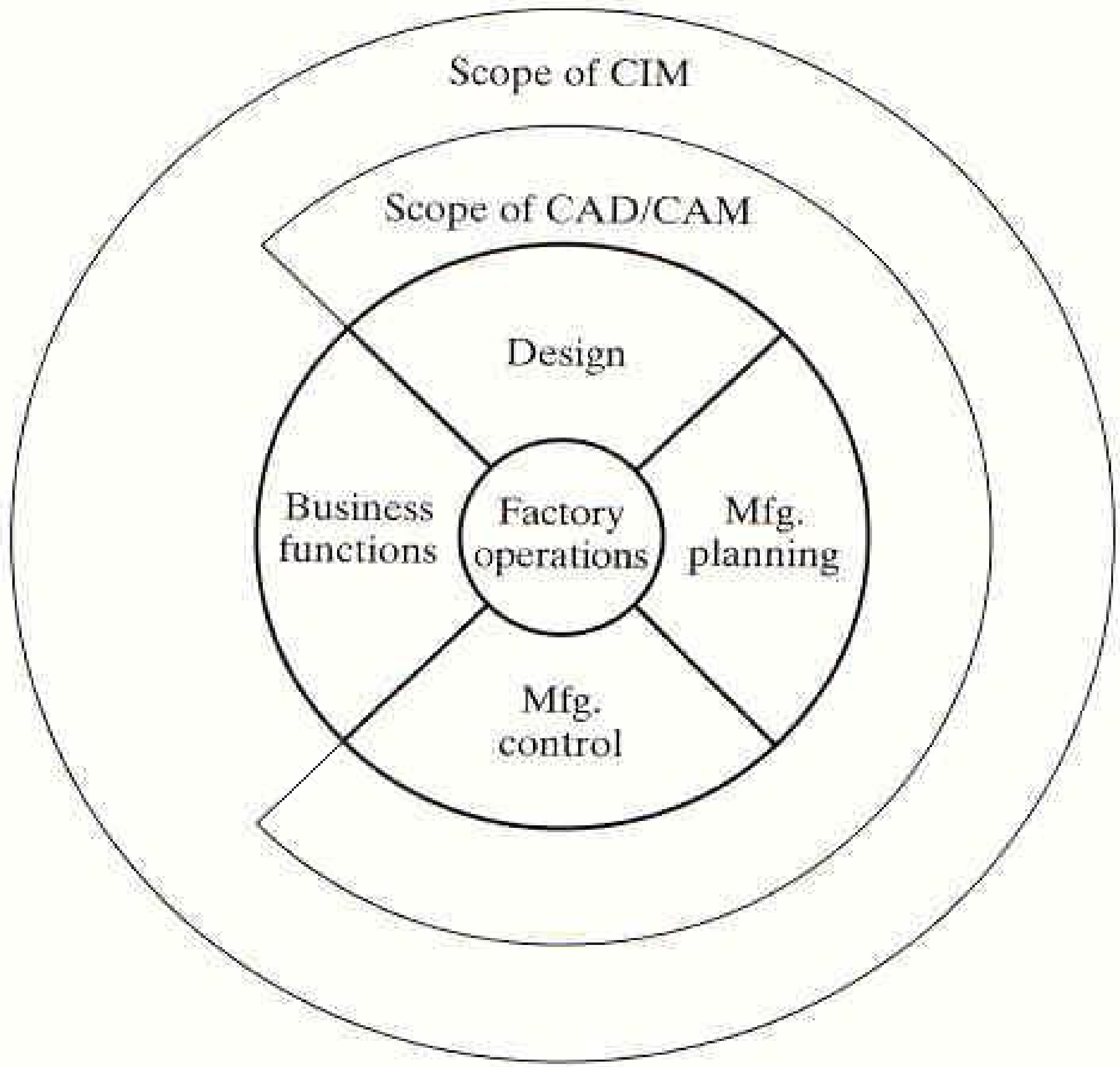
OR

"CIM includes all activities from the perception of a need for a product; through the conception, design, and development of the product; and on through production, marketing, and support of the product in use. Every action involved in these activities uses data, whether textual, graphic, or numeric."

CIM CONCEPT: OBJECTIVES

- Waste reduction
- Increase manufacturing efficiency
- Greater productivity
- Inventory reduction
- Optimum batch size
- Improved quality
- Fewer rejection
- Increase utilization of labour and equipments
- Reduction in total manufacturing lead time
- Reduction in total manufacturing cost
- Less idle time
- Improved flexibility

SCOPE OF CIM


Scope of CIM
Scope of CAD/CAM
Design
Business functions
Factory operations
Mfg. planning
Mfg. control

SCOPE OF CIM

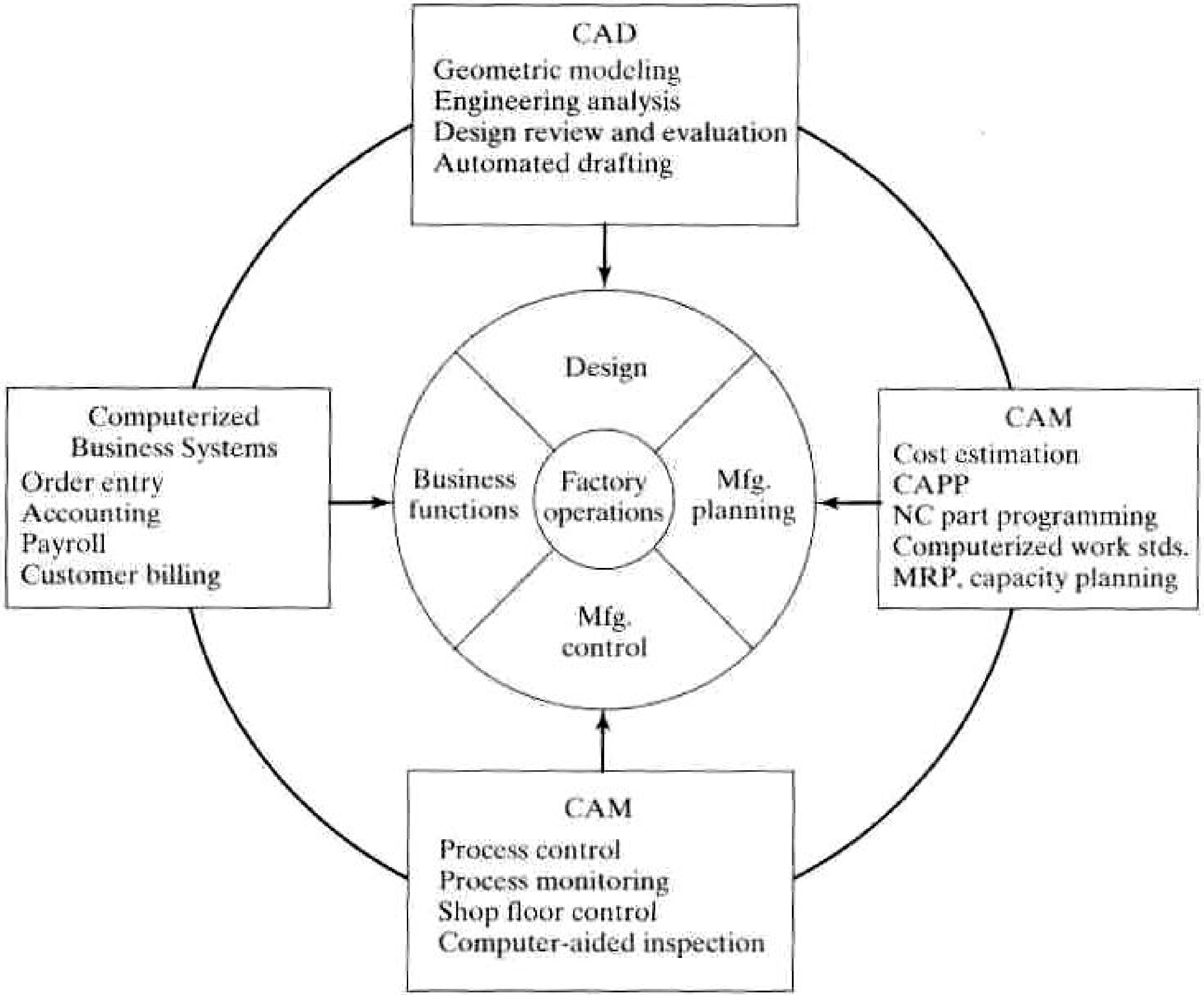
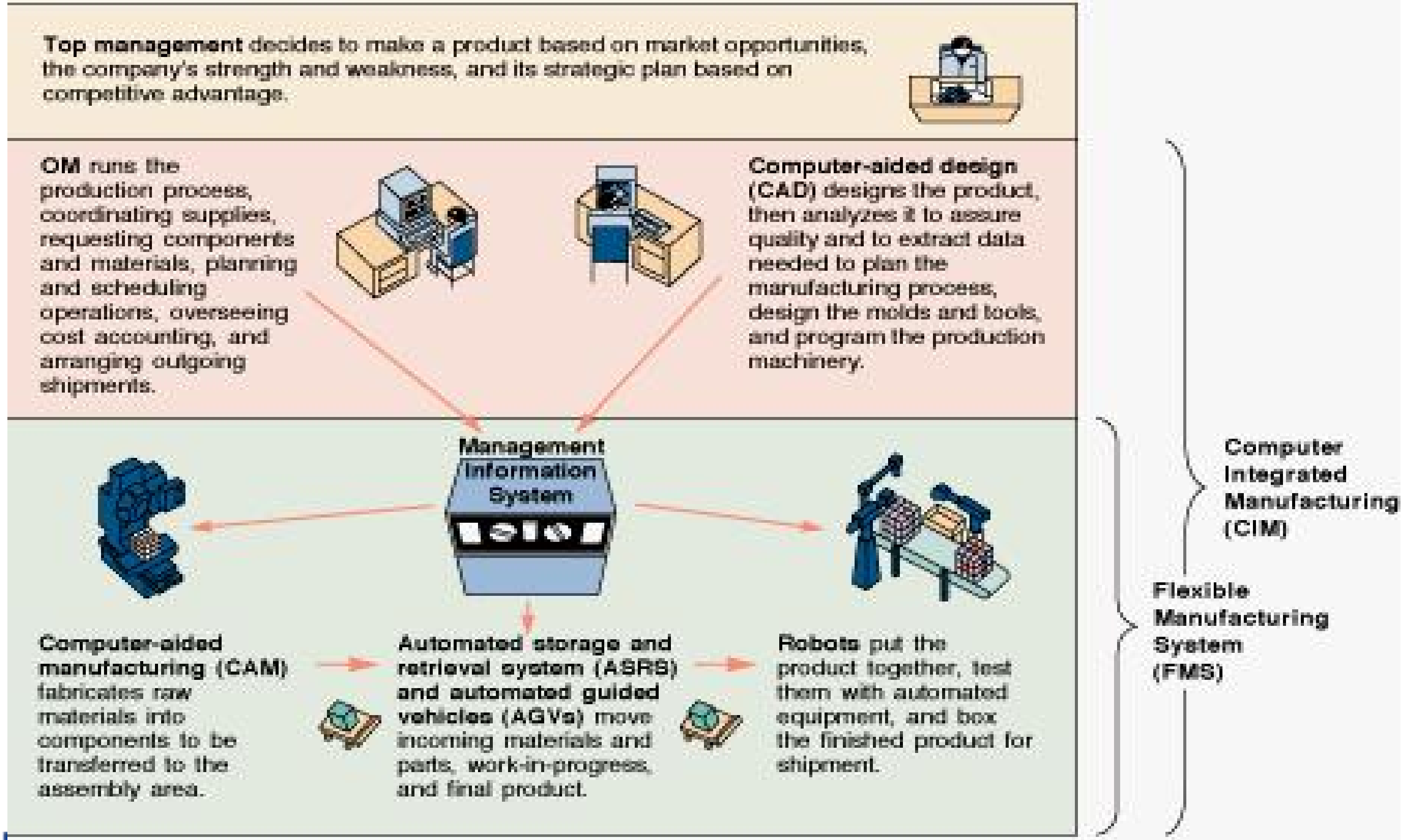


Figure 24.8 Computerized elements of a CIM system.

SCOPE OF CIM



Top management decides to make a product based on market opportunities, the company's strength and weakness, and its strategic plan based on competitive advantage.
OM runs the production process, coordinating supplies, requesting components and materials, planning and scheduling operations, overseeing cost accounting, and arranging outgoing shipments.
Computer-aided design (CAD) designs the product, then analyzes it to assure quality and to extract data needed to plan the manufacturing process, design the molds and tools, and program the production machinery.
Management Information System
Computer-aided manufacturing (CAM) fabricates raw materials into components to be transferred to the assembly area.
Automated storage and retrieval system (ASRS) and automated guided vehicles (AGVs) move incoming materials and parts, work-in-progress, and final product.
Robots put the product together, test them with automated equipment, and box the finished product for shipment.
Computer Integrated Manufacturing (CIM)
Flexible Manufacturing System (FMS)

NATURE OF MANUFACTURING SYSTEMS

The term ‘Manufacturing’ covers broad spectrum of activities.

Metal working, process industries (food, chemical, oil refinements), electronic production, plastic industries, textile, etc.

According to these processes manufacturing processes are named.

This is called nature of manufacturing systems

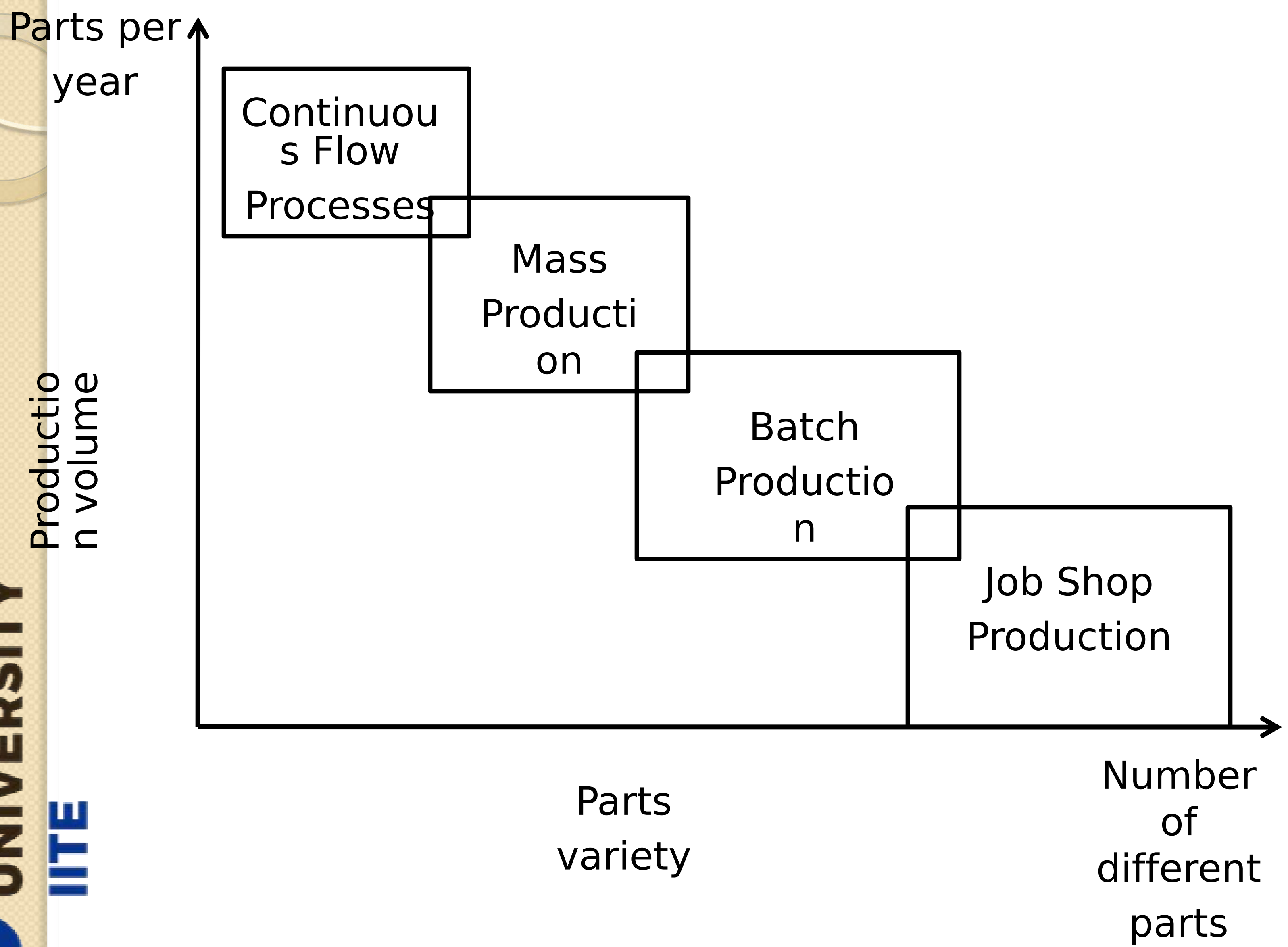
For example,

- Systems used to manufacture metal working products are called Metal working manufacturing systems

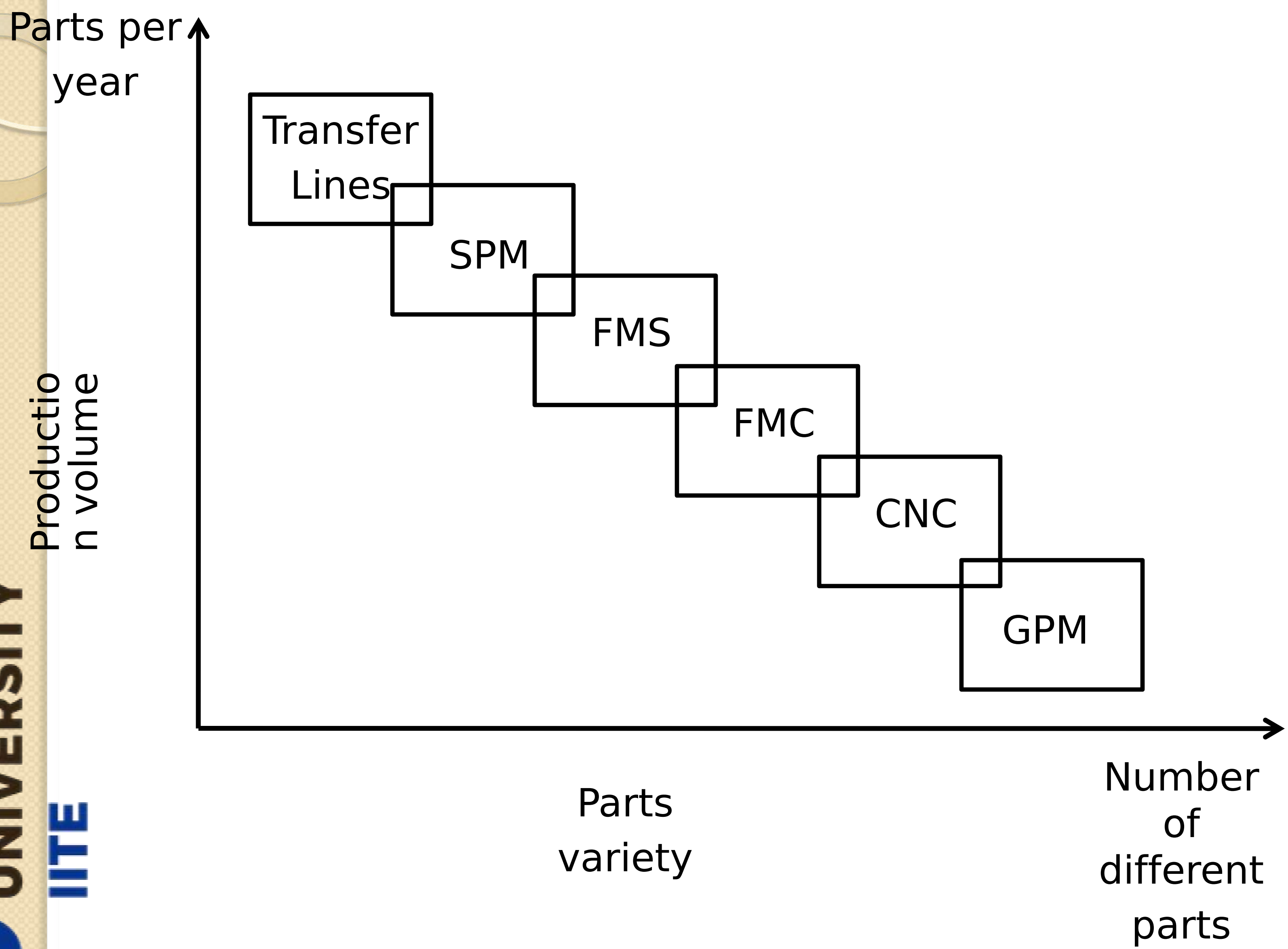
NATURE OF MANUFACTURING SYSTEMS

- Manufacturing Systems
  - Production Systems
    - Production Machines
    - In-process Quality control systems
    - Work piece handling
    - Quality Control
  - Material Handling systems
    - Manually Operated
    - Semi-automated
    - Fully automated
  - Data Management Systems
    - Information
    - Data Storage
    - Data Retrieval
    - Marketing & Feedback
  - Storage & Retrieval Systems
    - Inventory Management
    - Material Storage
    - Material Retrieval
  - Dispatch, Coding and shipment systems
    - Packaging
    - Coding & Data Management
    - On way and delivery

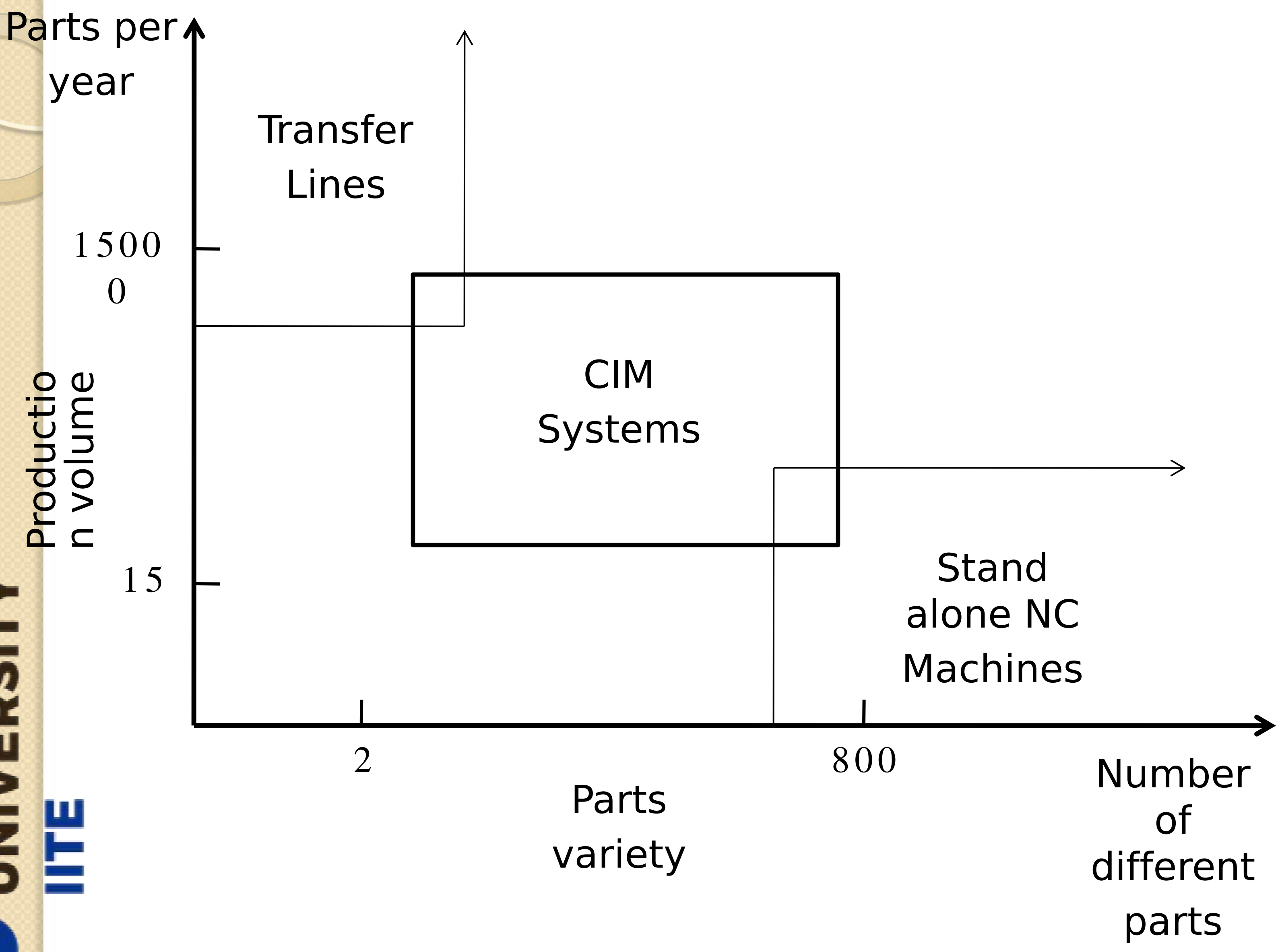
TYPES OF MANUFACTURING SYSTEMS



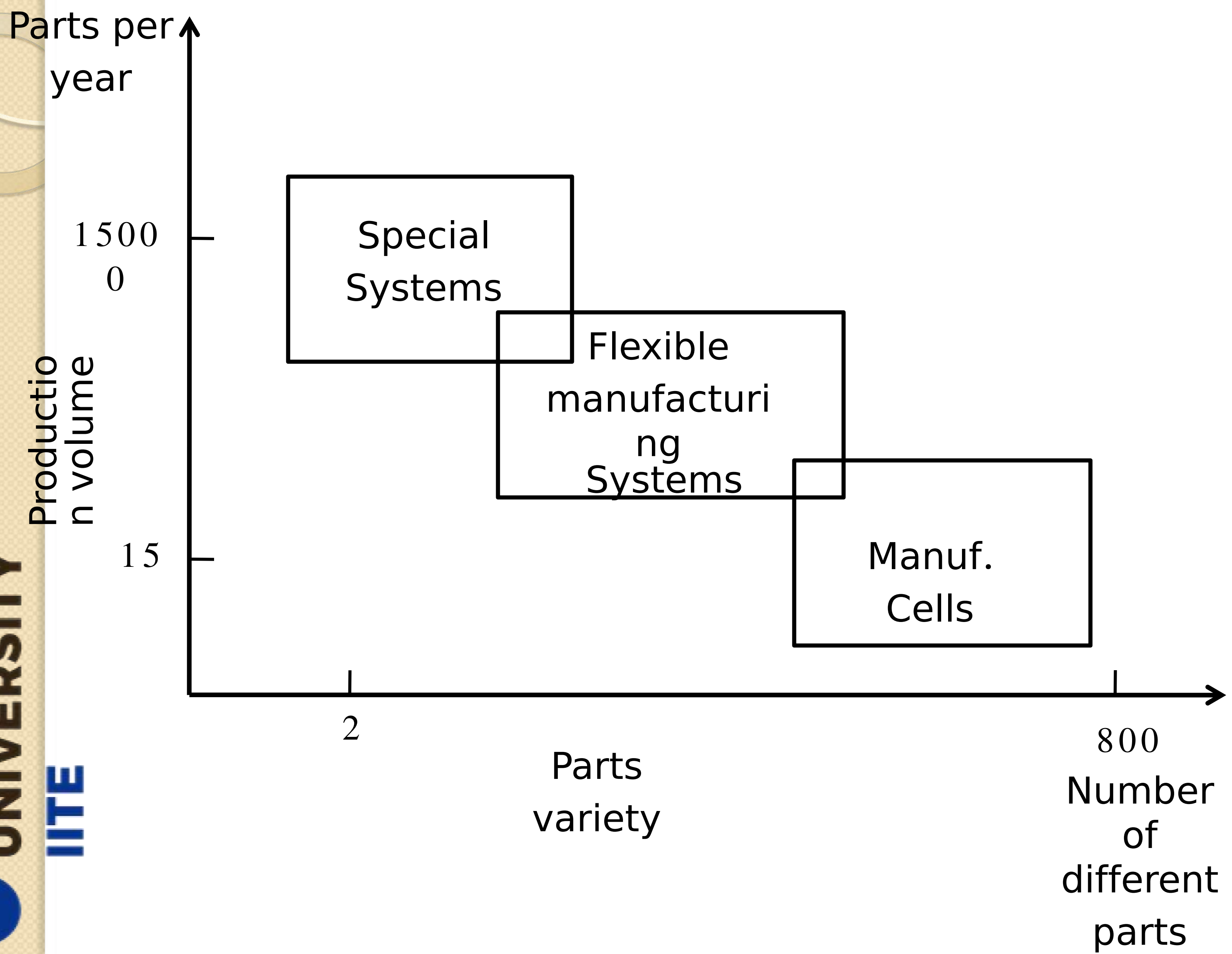
TYPES OF MANUFACTURING SYSTEMS



TYPES OF MANUFACTURING SYSTEMS



TYPES OF MANUFACTURING SYSTEMS



EVOLUTION OF CIM

CIM is considered a natural evolution of technology of CAD/CAM which by itself evolved by integration of CAD and CAM

MIT first developed CAD and CAM both to meet design and manufacturing requirement of aerospace industries after WW2.

Air force of USA first approached MIT to develop suitable control system, drives and programming technique for machine tools using electronic control.

First major innovation in machine control is Numerical Control (NC) in 1952. It was a hardwired system using integrated chips (IC)

EVOLUTION OF CIM

To program IC; a paper tape with punched code is used as an input.

In late 60's a main frame computer is used to feed and control coded tape to a group of machines was called Direct Numerical Control (DNC)

As complexity of functions to be performed by NC controlled machines, a separate mini computer is provided with machine to store and feed programmed instruction in 70's.

That was a starting era of CNC controlled machines. Further more NC were designed around microprocessors resulted in Compact CNC

EVOLUTION OF CIM

Then after different computer systems of different level of configurations are used to make a hierarchy of computer controlled machines performing complex operations with integration of NC, DNC and CNC controllers.

Manufacturing engineers also started computers for inventory control, demand forecasting, production planning and control.

CNC technology also adopted with integrated operation of measuring machines which were named after as CMM (coordinate measuring machine). This gave birth to automated inspection activities.

Development in Robot technology also used then after for machine loading, material handling, welding, painting and assembly.

EVOLUTION OF CIM

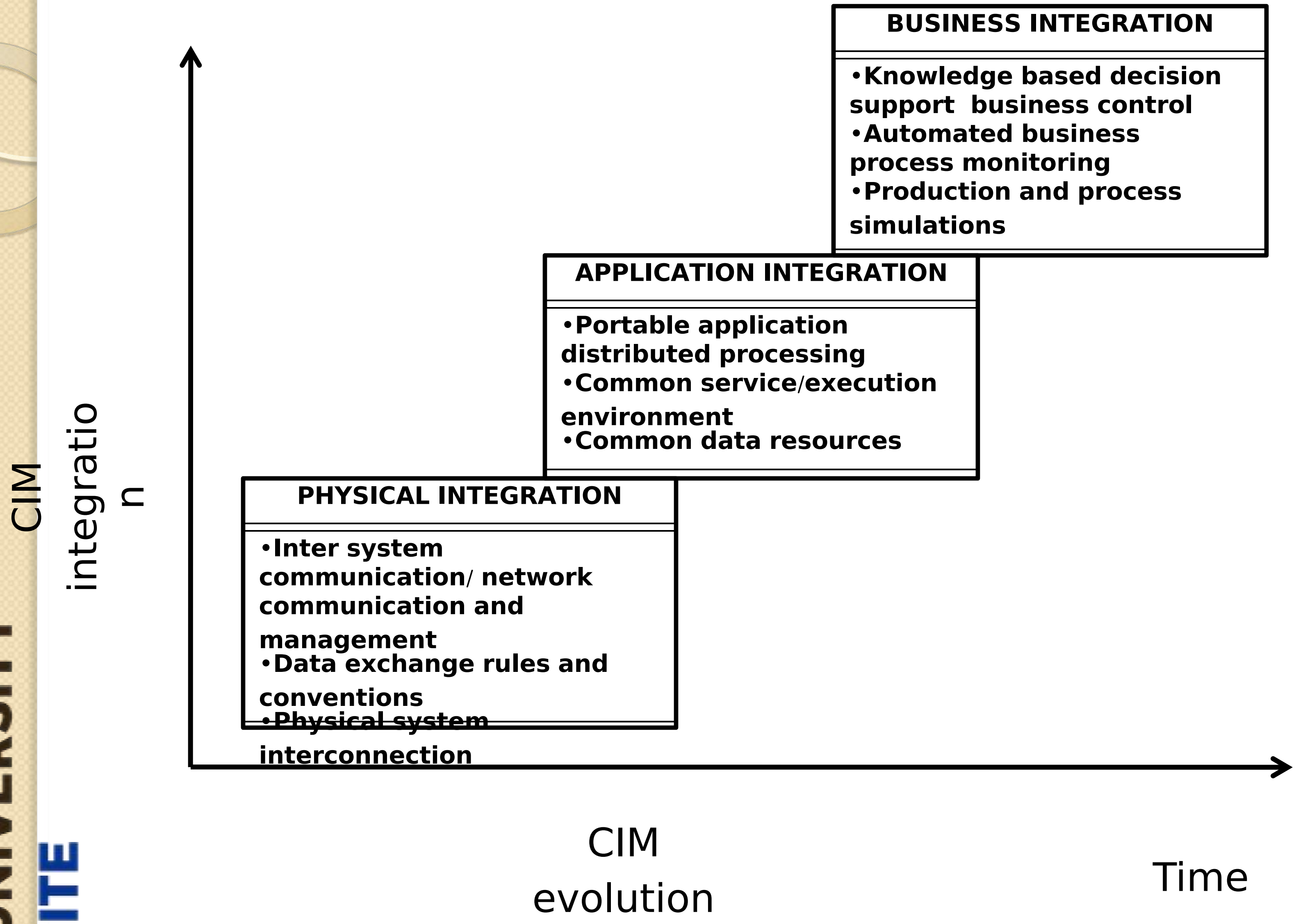
All these developing technologies bought together and build up an automated manufacturing cells called ‘Flexible Manufacturing Cells’

This idea was adopted for whole manufacturing system is now called as ‘Flexible Manufacturing Systems’.

On the other hand development of computer technology, evolution of CAD used to develop complex geometric modeling, virtual analysis, simulation and lastly Virtual reality raised an urge to bridge manufacturing systems with design facilities.

Meanwhile business and corporate professionals also get an expertise on usage of computer and computer networks to communicate with another professional explore the circle of cutting edge technologies in

EVOLUTION OF CIM



CIM BENEFITS

- Reduction in manufacturing lead time
- Reduction in work–in–process inventory
- Maximum utilization of labour and equipments
- Improved communication among various elements of CIM
- Reduction in total manufacturing and operating cost
- More flexibility in manufacturing operations
- Better process scheduling

CIM COUNTER-BENEFITS

- Reduction in manufacturing lead time
- Reduction in work-in-process inventory
- Maximum utilization of labour and equipments
- Improved communication among various elements of CIM
- Reduction in total manufacturing and operating cost
- More flexibility in manufacturing operations
- Better process scheduling

ROLE OF MANUFACTURING ENGINEERS

Manufacturing Industries strive to reduce cost of the product continuously to remain competitive in the globe.

In addition, improve quality and performance level on a continuing basis with in-time delivery.

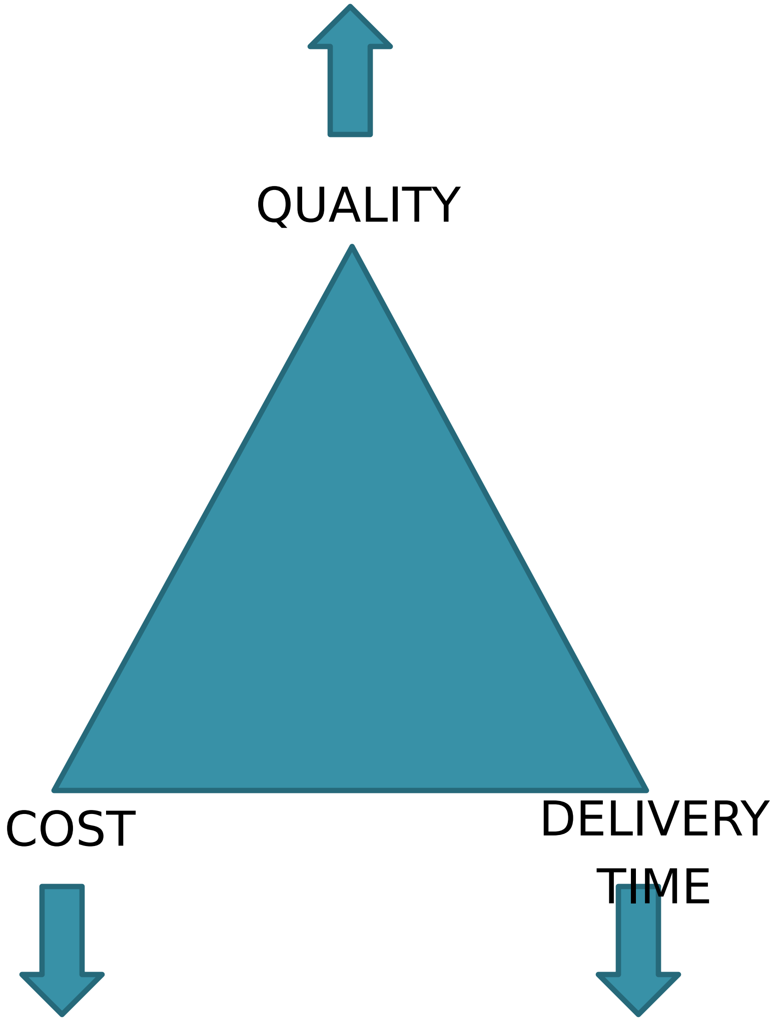
Role of manufacturing engineer found crucial to fulfill the above aspects.

Engineer required to achieve the following objectives:

- Reduce inventory
- Lower cost
- Reduce waste
- Improve quality
- Increase flexibility in product change, production change, process change, equipment change and personnel change

Above stated objectives are challenges in manufacturing for a manufacturing engineer.

ROLE OF MANUFACTURING ENGINEERS



CIM WHEEL

Because of the complexity of CIM, some organizations that promote the understanding and implementation of CIM have found it useful to define CIM graphically.

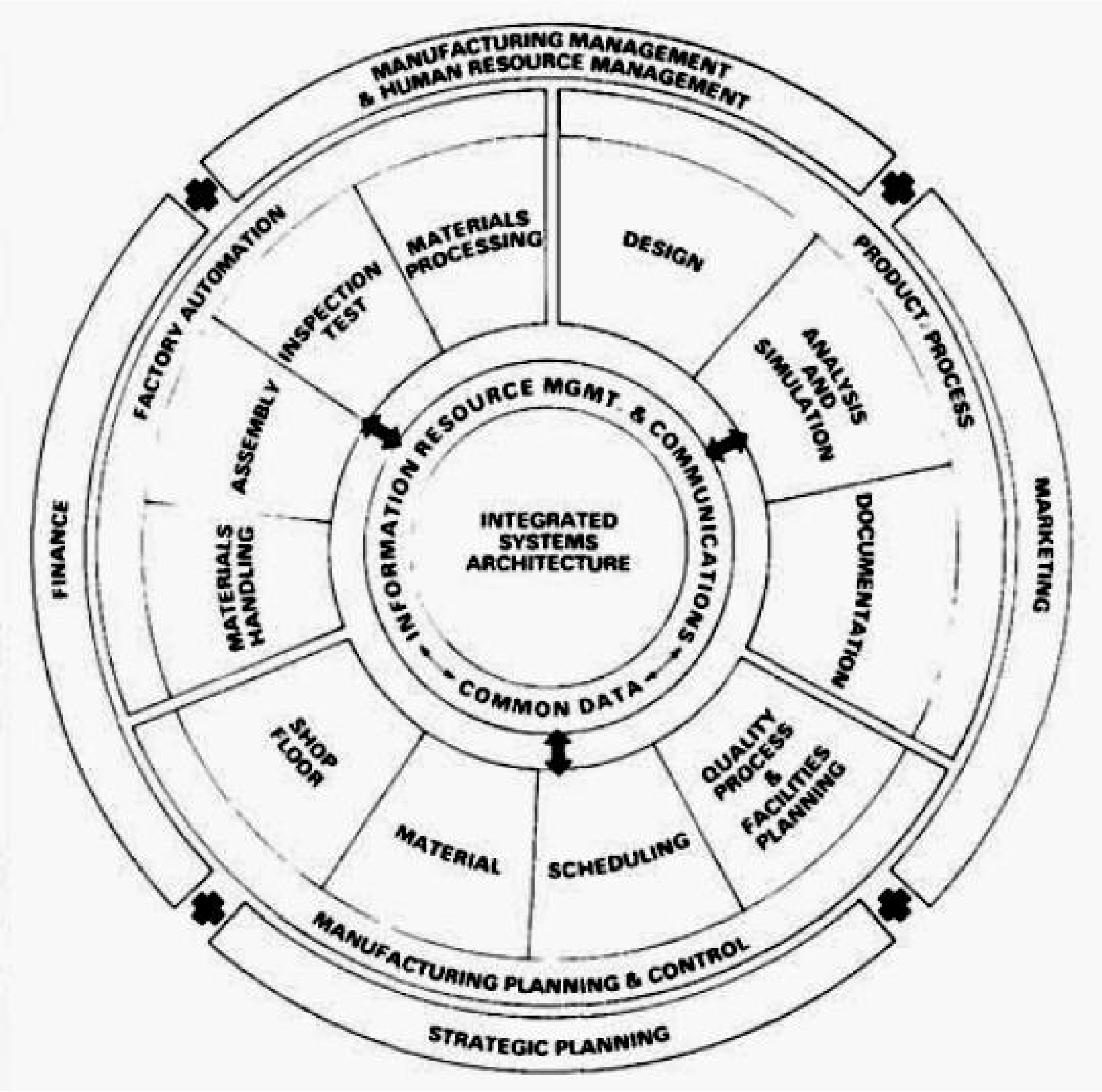
One of the most inclusive representations is the CIM Wheel developed by the Computer and Automated Systems Association of the Society of Manufacturing Engineers

The CIM Wheel is composed of five fundamental dimensions:

(1) general business management,
(2) product and process definition,
(3) manufacturing planning and control,
(4) factory automation, and
(5) information resource management.

Each of these five dimensions is a composite of other more specific manufacturing processes that have shown a natural affinity to each other

CIM WHEEL


MANUFACTURING MANAGEMENT
& HUMAN RESOURCE MANAGEMENT
FACTORY AUTOMATION
PRODUCT/PROCESS
FINANCE
MARKETING
MANUFACTURING PLANNING & CONTROL
STRATEGIC PLANNING
MATERIALS PROCESSING
DESIGN
INSPECTION TEST
ANALYSIS AND SIMULATION
ASSEMBLY
DOCUMENTATION
MATERIALS HANDLING
SHOP FLOOR
MATERIAL
SCHEDULING
QUALITY PROCESS & FACILITIES PLANNING
INFORMATION RESOURCE MGMT. & COMMUNICATIONS
COMMON DATA
INTEGRATED SYSTEMS ARCHITECTURE

CIM WHEEL

The general business management family of processes is arrayed around the periphery of the Wheel.

Although seen as an integral part of the manufacturing enterprise, this family of processes was viewed as being the primary link between the rest of the enterprise and the outside world.

The general business management family of applications includes a wide range of automated processes from general and cost accounting to marketing, sales, order entry, human relations, decision support, program scheduling, cost status reporting, and labor collection.

The second, third, and fourth families have been arrayed as thirds of the inner circle of the CIM Wheel.

At the heart of CIM information resource management is the concept of data management.

CHAPTER 2: GROUP TECHNOLOGY CONTENT

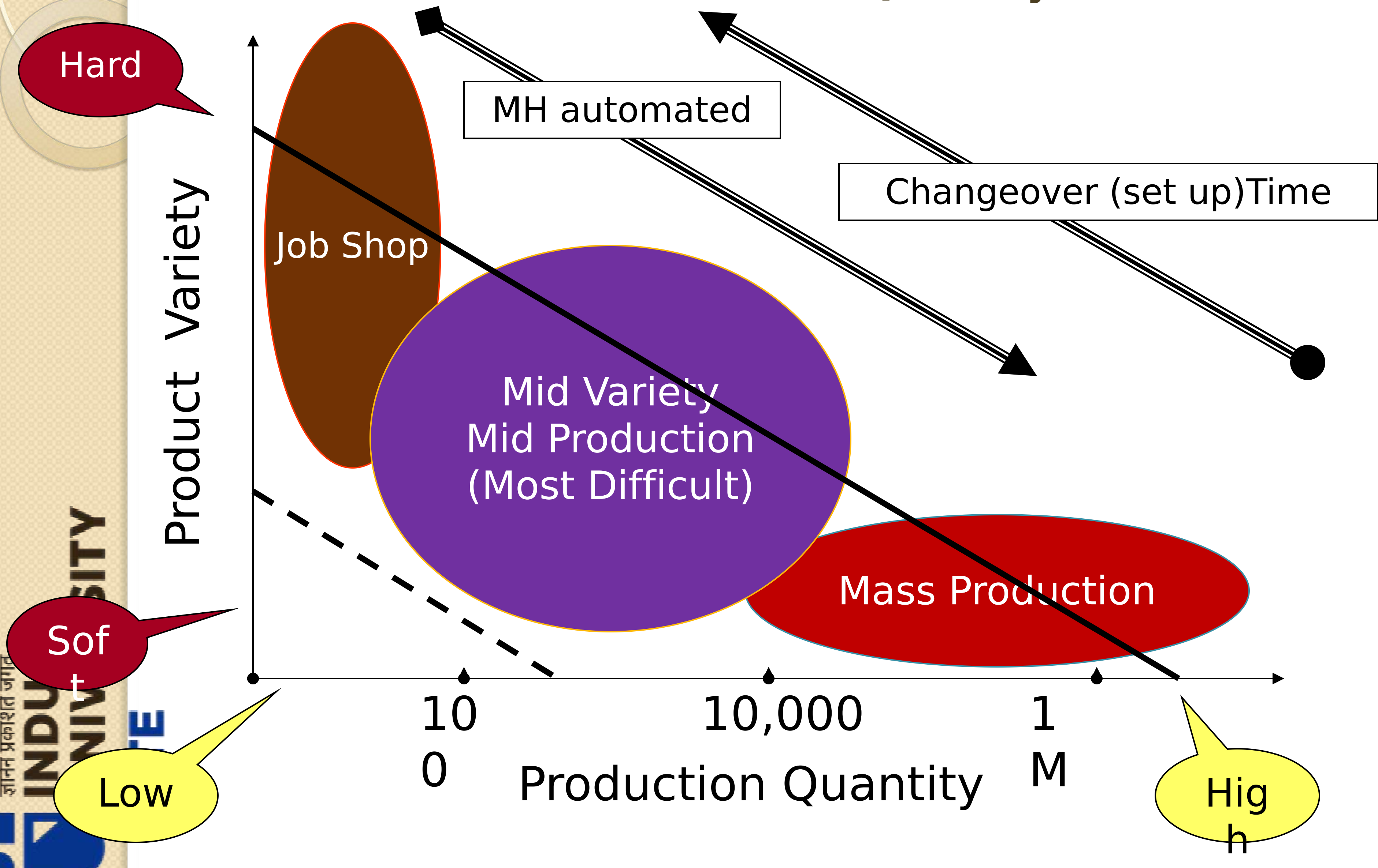
Introduction
Part families
Part classification & Coding
Machining cells
Benefits of Group Technology

INTRODUCTION

- It is manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in design and production.
- Similar parts are arranged into part families.
- For Example, A plant producing 10,000 different parts may be group the majority of these parts into 50 to 60 different families.
- Each family would posses similar design and manufacturing characteristics.
- So processing of each member of given family would be similar, and this result in manufacturing efficiency.
- Efficiency achieved by reduced setup times, lower in-process inventories, better scheduling, improved tool control, and use of standard process plan.

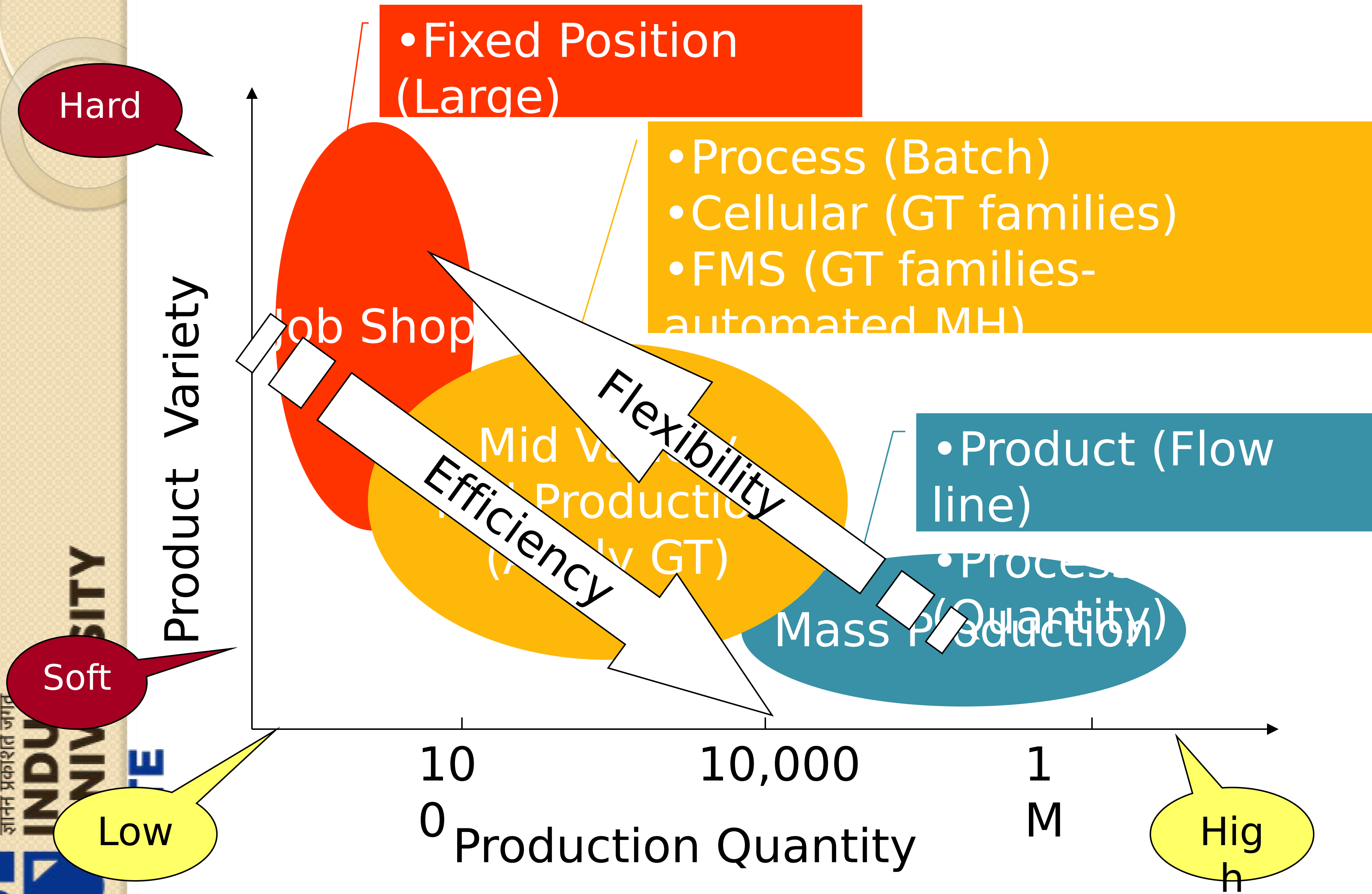
INTRODUCTION

Product Variety v/s Production Quantity



INTRODUCTION

Types of Production Plant (facilities) and Layout



INTRODUCTION: CLASSIFICATION

Group Technology classification is based on part families

Part families are classified based on various attributes

Geometric attributes

or

production process attributes

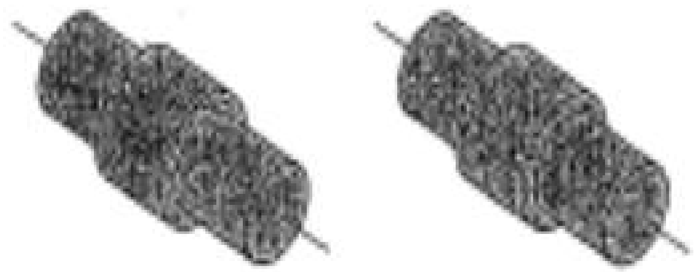
- Part Family
  - Design attributes
    - Shape
    - Size
  - Manufacturing attributes
    - Types of operations
      - Process Method
      - Holding Methods
      - Tooling type
      - Process condition
    - Sequences
    - Numbers of operations

PART FAMILIES: DEFINITION

- Definition: It is a collection of parts that are similar either because of geometrical shape and size or because of processing steps required in their manufacturing.
- The parts within the family are different, but their similarities are close enough to merit their identification as members of particular part family.
- There are two major types of part family:
  - Design Part Family
  - Manufacturing Part Family

PART FAMILIES: DESIGN PART FAMILY

- The two parts shown in fig. are similar from a design viewpoint but quite different in term of manufacturing.
- So the two parts consist a part of design family but not in manufacturing family.

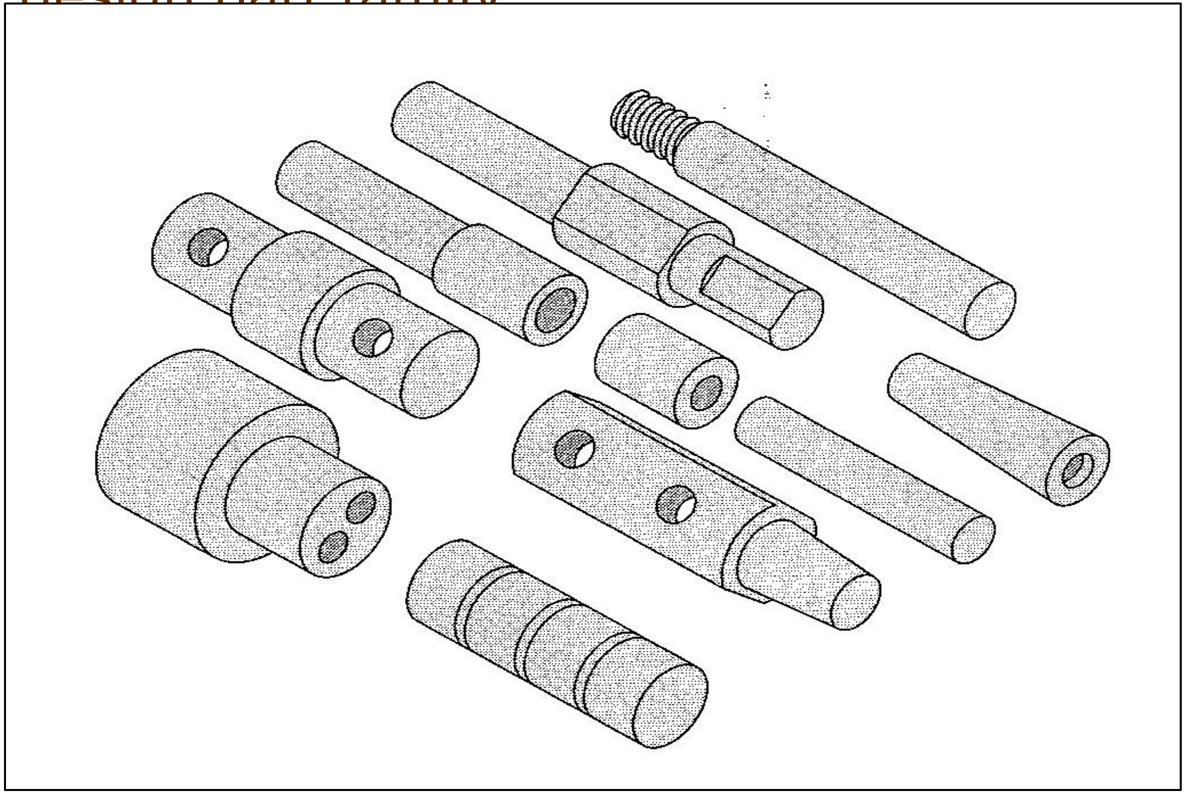


(a) (b)

Figure 15.1 Two parts of identical shape and size but different manufacturing requirements: (a) 1,000,000 pc/yr, tolerance = ±0.010 in, material = 1015 CR steel, nickel plate; and (b) 100 pc/yr, tolerance = ±0.001 in, material = 18 – 8 stainless steel.

PART FAMILIES : MANUFACTURING PART

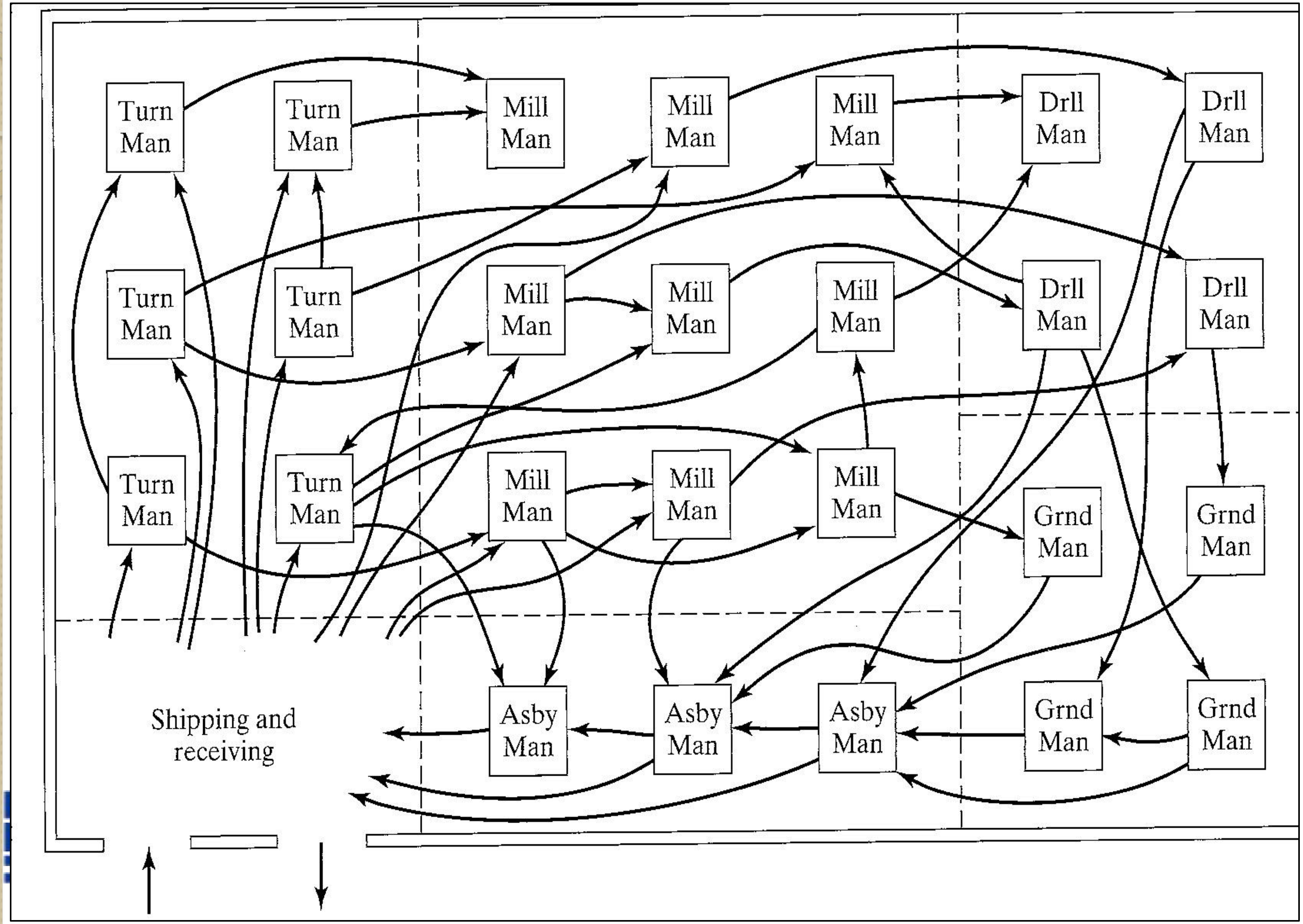
- The parts shown in the fig. might consist a part family in manufacturing, but their geometry characteristics do not permit them to be grouped as a design part family



PART FAMILIES : REASONS FOR USING

- The fig. in next slide shows a process-type layout for batch production in machine shop. The various machine tools are arranged by function.
- There is a lathe section, milling machine section, drill section. During machining, the work piece must move between sections, perhaps the same section visited several times.
- This result in,
  - Increased Material handling movements
  - Large in-process inventory
  - More setups than necessary
  - Long manufacturing lead time
  - And high running and capital cost.

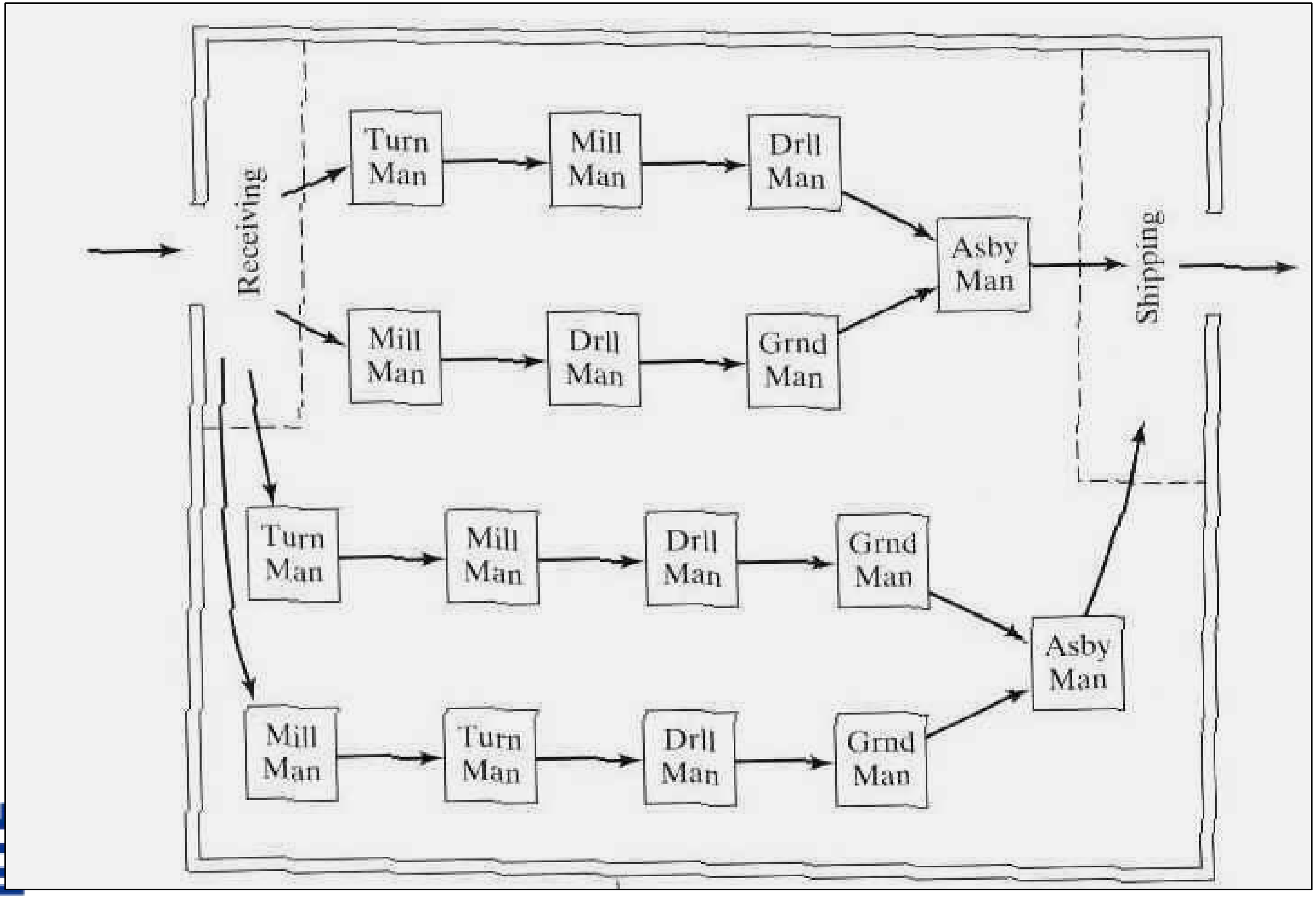
PART FAMILIES : REASONS FOR USING



PART FAMILIES : REASONS FOR USING

- Fig. in next slide shows production shop of equivalent capacity, but machines are arranged into cells.
- Each cell is organized to specialize in the manufacture of a particular part family.
- Advantages are,
  - Reduced work piece handling,
  - Lower setup times, less in-process inventory,
  - Less floor space, shorter lead time.

PART FAMILIES : REASONS FOR USING



PARTS CLASSIFICATION & CODING

Hurdles in implementing Group Technology:

- The main single obstacle in changing over to group technology from a traditional production shop is the problem of grouping parts into families.
- Three general methods for solving this problems.

1. **Visual Inspection**

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

PARTS CLASSIFICATION & CODING

2. **Production Flow Analysis**

- PFA was developed by J. L. Burbidge.
- It is a method of identifying part families and associated machine tool grouping by analyzing the route sheets for part produced in a given shop.
- It group together the parts that have similar operation sequence and machine routings.
- Disadvantages, it accept the existing route sheet, with no consideration given whether these process plan are logical or not.

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PARTS CLASSIFICATION & CODING

3. Parts Classification & Coding

- Part classification and coding system can be grouped into three types

1. Design attribute group
2. Manufacturing attribute group
3. Combined attribute group

Part design attributes:

- Basic external shape
- Basic internal shape
- Rotational or rectangular shape
- Length-to-diameter ratio
- Aspect ratio
- Material type
- Part type
- Major dimensions
- Minor Dimensions
- Tolerances
- Surface finish

Part Manufacturing attributes:

- Major processes
- Minor operations
- Operation sequence
- Major dimensions
- Surface finish
- Machine tool
- Production cycle time
- Batch size
- Annual production
- Fixtures required
- Cutting tools

PARTS CLASSIFICATION & CODING

Classification and coding schemes

Name of system	Country Developed	Characteristics
TOYODA	Japan	Ten digit code
MICLASS	The Netherlands	Thirty digit code
TEKLA	Norway	Twelve digit code
BRISCH	United Kingdom	Based on four to six digit primary code and a number of secondary digits
DCLASS	USA	Software based system without any fixed code structure
NITMASH	USSR	A hierarchical code of ten to fifteen digits and a serial number
OPITZ	West Germany	Based on a five digit primary code with a four digit secondary code

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PARTS CLASSIFICATION & CODING

Coding structure

- It consist of a sequence of symbols that identify the parts design or manufacturing attributes.
- The symbols in the code can be all numeric, all alphabetic, or combination of both types.
- Most common classification and coding system use number digits only.
- Three basic structures of codes used in GT application.
    - Hierarchical structure
    - Chain-type structure
    - Hybrid structure, combination of hierarchical and chain-type.

PARTS CLASSIFICATION & CODING

Coding structure

- In hierarchical structure, the interpretation of each succeeding symbol depends on the value of the preceding symbols.
- Other name of this structure is monocode and tree structure.
- In chain-type structure, the interpretation of each symbol in the sequence is fixed and does not depend on the value of preceding digits.
- Another name of this structure is polycode. The problem tend to polycode is they are long.
- The use of polycode allows for convenient identification of specific part attributes.
- This can help in recognize parts with similar processing requirements.

PARTS CLASSIFICATION & CODING

Coding structure

- The difference, example, take two digit code 15 or 25,
- The first digit stand for general part shape. The symbol 1 means round work part and 2 means flat rectangular geometry.
- In hierarchical code structure, the interpretation of the second digit would depend on the value of the first digit. If preceded by 1, the 5 might indicate some L/D ratio, and if preceded by 2, the 5 might be specify some overall length.
- In chain-type code structure, the symbol 5 would be interpreted the same way regardless of the value of the first digit.

PARTS CLASSIFICATION & CODING

Coding structure

- For example, it might indicate overall part length, or whether the part is rotational or rectangular.
- Most commercial parts coding systems used in industry are combination of the two structure, means hybrid structure.
- Hybrid codes are typically constructed as a series of short polycode.
- Within these shorter chains, the digits are independent, but one or more symbols in the complete code number are used to classify the part population into groups, as in the hierarchical structure.

PARTS CLASSIFICATION & CODING

Three parts classification and coding system

- When implementing a parts classification and coding system, most companies elect to purchase a commercially available package rather than develop their own.

- Iyong ham recommends the following factors to be considered in selecting a parts coding and classification system.

- Objective:

  The user should first define the objective for the system.

  Will it be used for part-family-design or part-family manufacturing or both？

PARTS CLASSIFICATION & CODING

Three parts classification and coding system

- Scope and application:

  What departments in the company will use the system？

  What specific requirements do these department have？

  What kinds of information must be coded？

  How wide a range of product must be coded？How complex are the parts, shapes, processes, tooling, and so on？

- Costs and time:

  The company must considered the cost of installation, training, and maintenance for their part classification and coding system. Will their be consulting fees, and how much？

  How much time required for install the system and train the staff to operate and maintain it？

PARTS CLASSIFICATION & CODING

Three parts classification and coding system

- Adaptability to other systems:

  Can system be readily adapted to the existing company computers systems and data base?

  Can it be readily integrated with other existing company procedure?

- Management problems:

  - It is important that all involved management personnel be informed and supportive of the system. Also, will there be any problems with the union?

PARTS CLASSIFICATION & CODING

Three parts classification and coding system

- Three classification and coding systems which are widely recognized among people familiar with GT:

  Opitz system

  MICLASS system

  CODE system

PARTS CLASSIFICATION & CODING

Opitz System

- This system was developed by H. Opitz of the university of Aachen in West Germany.
- It represents one of the pioneering efforts in the GT area and is perhaps the best known of the classification and coding schemes.
- The Opitz coding system uses the following digit sequence

12345 6789 ABCD

- The basic code consist nine digits, which can be extended by adding four more digits.

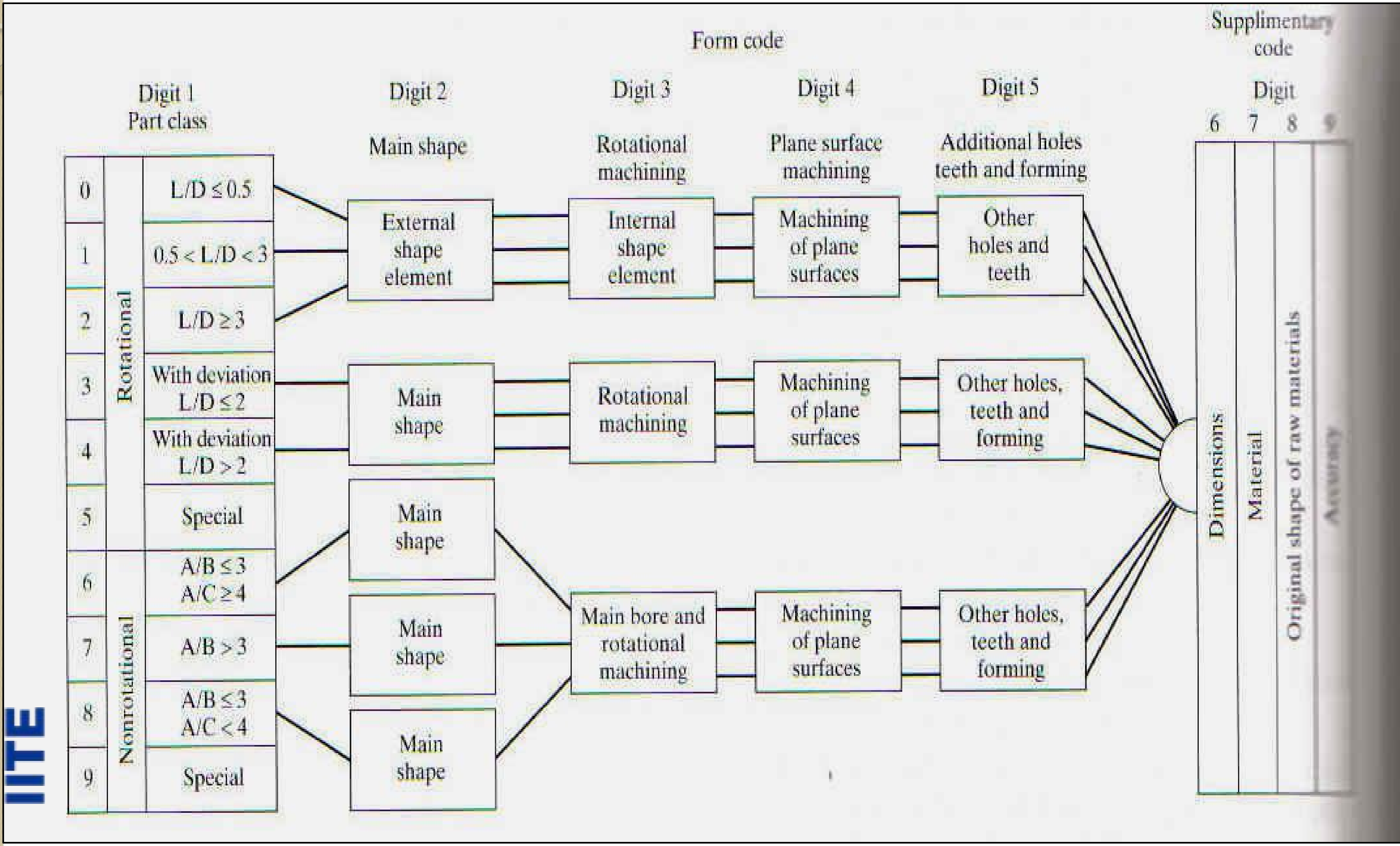
PARTS CLASSIFICATION & CODING

Opitz System

- The first nine digits are intended to convey both design and manufacturing data.
- The first five digit “12345” are called “form code”. And describe the primary design attributes of the part.
- The next four digit 6789, called “supplementary code”.
- It indicates some of the attributes that would be of use to manufacturing(dimensions, work material, starting raw material shape and accuracy.)
- The extra four digit code, ABCD, called “secondary code” and are intended to identify the production operation type and sequence.

PARTS CLASSIFICATION & CODING

Opitz System



PARTS CLASSIFICATION & CODING

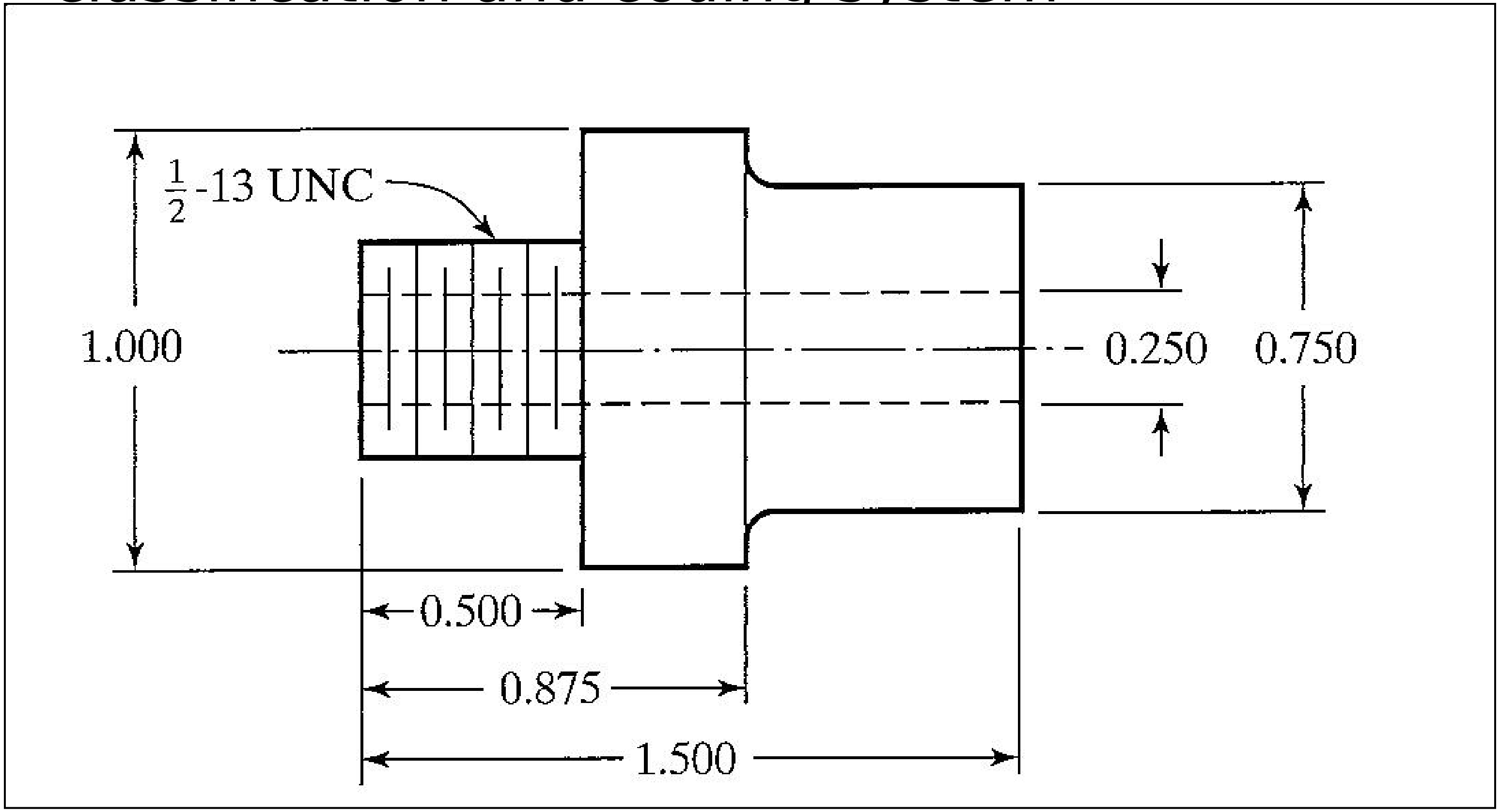
Opitz System

	Digit 1		Digit 2		Digit 3		Digit 4	Digit 5	
	Part class		External shape, external shape elements		Internal shape, internal shape elements		Plane surface machining	Auxiliary holes and gear teeth	
0	Rotational parts	L/D ≤ 0.5		Smooth, no shape elements		No hole, no breakthrough	No surface machining	No gear teeth	No auxiliary hole
1		0.5 < L/D < 3	Stepped to one end or smooth	No shape elements	Smooth or stepped to one end	No shape elements	Surface plane and/or curved in one direction, external		Axial, not on pitch circle diameter
2		L/D ≥ 3		Thread		Thread	External plane surface related by graduation around the circle		Axial on pitch circle diameter
3				Functional groove		Functional groove	External groove and/or slot		Radial, not on pitch circle diameter
4			Stepped to both ends	No shape elements	Stepped to both ends	No shape elements	External spline (polygon)		Axial and/or radial and/or other direction
5				Thread		Thread	External plane surface and/or slot, external spline		Axial and/or radial on PCD and/or other directions
6	Nonrotational parts			Functional groove		Functional groove	Internal plane surface and/or slot	With gear teeth	Spur gear teeth
7				Functional cone		Functional cone	Internal spline (polygon)		Bevel gear teeth
8				Operating thread		Operating thread	Internal and external polygon, groove and/or slot		Other gear teeth
9				All others		All others	All others		All others

PARTS CLASSIFICATION & CODING

Opitz System

For given rotational part in Figure, determine the form code in the Opitz parts classification and coding system



PARTS CLASSIFICATION & CODING

Opitz System

L/D = 1.5 Digit 1 =1

External shape: stepped on both ends with screw thread on one end

Digit 2 = 5

Internal shape Digit 3 = 1

Plane surface matching: Digit 4 = 0

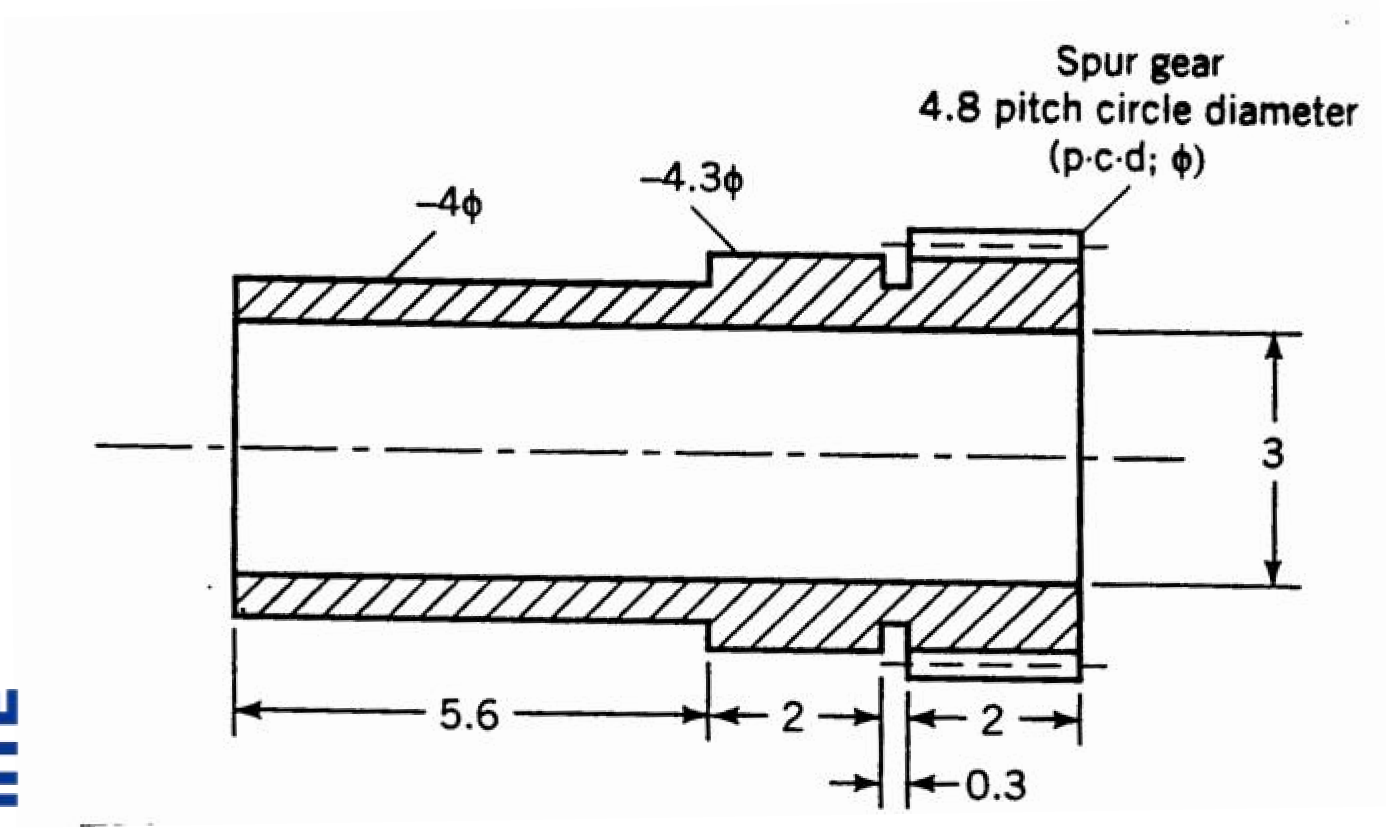
Auxiliary holes Digit 5 = 0

Opitz system code: 15100

PARTS CLASSIFICATION & CODING

Opitz System

Given the rotational part design in Figure, determine the form code in the Opitz parts classification and coding system



PARTS CLASSIFICATION & CODING

Opitz System

L/D = 1.98 here 0.5<L/D <3.

Digit 1

External shape ; stepped with one side with a functional groove- Digit 3

Internal shape – through hole

Digit 1

Plane surface machining

Digit 0

Aux. holes and gear teeth- spur gear

Digit 6

PARTS CLASSIFICATION & CODING

MICLASS (Multi Class) System

- Metal Institute Classification System– developed by TNO Netherlands Orgn. for applied Scientific research.

- The MICLASS system was developed to help automate and standardize a number of design, production, and management function. These includes:
  - Standardization of engineering drawings
  - Retrieval of drawings according to classification number
  - Standardization of process routing
  - Automated process planning
  - Selection of parts for processing on particular group of machine tools.
  - Machine tool investment analysis.

PARTS CLASSIFICATION & CODING

MICLASS (Multi Class) System

- The MICLASS classification number can range from 12 to 30 digits.
- The first 12 digits are a universal code that can be applied to any part.
- Up to 18 additional digits can be used to code data that are specific to particular company or industry.
- For Example-Lot size, piece time, cost data, and operation sequence might be included in the 18 supplementary digits.
- First 12 digits universal code, next 18 supplementary

PARTS CLASSIFICATION & CODING

MICLASS (Multi Class) System

- 12 digits are mandatory used to classify the Engineering & Manufacturing characteristics of a part
  - 1 - main shape (rotational / non-rotational)
  - 2 &3 - shape elements (holes, slots, grooves)
  - 4 - position of shape elements
  - 5&6 - main dimensions
  - 7 - dimension ratio
  - 8 - auxiliary dimension
  - 9&10 - tolerance cods

PARTS CLASSIFICATION & CODING

MICLASS (Multi Class) System

- To classify a given part design, the user respond to a series of question asked by computer. The number of question depends on the complexity of the part.
- For a simple part, as few as seven question are needed to classify the part.
- For an average part, the number of question ranges between 10 to 20. On the basis of the responses to its question, the computer assigns a code number to the part.
- TNO, is international organization, the program was written to converse in any of four languages: English, French, German or Dutch.
- Also it can operate in either inches or metric, or both.

PARTS CLASSIFICATION & CODING

CODE System

- The CODE system is a part classification and coding system developed by manufacturing data systems, Inc.(MDSI) of Ann arbor, Michigan.
- Its most universal application is in design engineering.
- The code number has eight digit.
- For each digit there are 16 possible values (0 through 9 and A through F) which are used to describe the part's design and manufacturing characteristics.
- The initial digit position indicates the basic geometry of the part and is called the Major Division of the CODE system.
- This digit would be used to specify whether the shape was a cylinder, flat piece, block, or other.

PARTS CLASSIFICATION & CODING

CODE System

- The remaining seven digit depends on the value of the first digit, but remaining digits form a chain-type structure.
- The second and third digit provide additional information regarding basic geometry and principal manufacturing process for the part.
- Digit 4,5 and 6 specify secondary manufacturing processes such as threads, grooves, slots, and so forth.
- Digit 7 and 8 are used to indicate the overall size of the part by classifying it into one of 16 size ranges for each of two dimensions.

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MACHINE CELLS

GT Machine Cell

- Group of machines arranged to produce similar part families.
- These group is called Machine Cells
- This cellular arrangement of production equipment is designed to achieve an efficient work flow within the cell.
- It also result in labor and machine specialization for the particular part families produced by the cell.
- This assembly raises the productivity of the cell.

MACHINE CELLS

Types of GT Machine Cell

1. Single machine cell
2. Group machine layout
3. Flow line design

- Single machine approach can be used for work parts whose attributes allow them to be mad on basically one type of process, such as turning or milling.

- The group machine cell layout is a cell design in which several machines are used together, with no provision for parts movement between the machines.

MACHINE CELLS

Types of GT Machine Cell

- The cell contains the machines needed to produce a certain family of parts, and the machines are organized with the proper fixtures, tools and operators to efficiently produce the parts family.

- The flow line cell design is a group of machines connected by a conveyor systems.

- This design approaches the efficiency of an automated transfer line, the limitation of the flow line layout is that all the parts in the family must be processed through the machines in the same sequence.

BENEFITS OF GROUP TECHNOLOGY

- When GT applied, the company will typically realize benefits in the following areas:
  - Product design
  - Tooling and setups
  - Materials handling
  - Production and inventory control
  - Employee satisfaction
  - Process planning procedures

BENEFITS OF GROUP TECHNOLOGY

Product Design Benefits of GT

- When a new part design is required, the engineer or draftsman can spend few minutes to figure the code of the required parts.
- Then the existing part design that match the code can be retrieved to see if one of them will serve the function desired.
- The few minute searching the design file with the use of the coding system may save several hours of the designer's time.
- It improves cost estimating procedures and helps to promote design standardization

BENEFITS OF GROUP TECHNOLOGY

Tooling and setups Benefits of GT

- In tooling, an effort is made to design group jigs and fixtures that will accommodate every member of a part family.

- Work holding devices are designed to use special adapter which convert the general fixtures into one that can accept each part family member.

- The machine tools in GT do not require drastic changeover in setup because of the similarity in the work parts processes on them.

- Hence, setup time saved, and it becomes more feasible to try to process parts in an order so as to achieve minimum setup changeover.

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BENEFITS OF GROUP TECHNOLOGY

Material Handling Benefits of GT

- It reduce work part move and waiting time.
- It lend themselves to efficient flow of materials through shop.
- Process planning procedures
- The time and cost of process planning function can be reduced through GT.
- A new part design is identified by its code number and belonging to a certain parts family.

BENEFITS OF GROUP TECHNOLOGY

Production and Inventory control Benefits of GT

- Production scheduling is simplified with GT.
- In effect grouping of machine cells reduces the number of production centers schedules.
- Grouping of parts into families reduces the complexity and size of the part scheduling problem.
- It can reduce,
- 70% reduction in production times
- 62% reduction in work-in-process inventories
- 82% reduction in overdue orders.

BENEFITS OF GROUP TECHNOLOGY

Employee Satisfaction Benefits of GT

- The machine cell allows parts to produced from raw material to finished state by a small group of workers.

- The workers are able to visualize their contributions to the firm more clearly.

- Another benefit of GT is that more attention tends to be given to product quality.

- Work part quality is more easily traced to a particular machine cell in GT.

****

CHAPTER 3: ROBOT TECHNOLOGY
CONTENT

- Introduction
- Industrial Robots
- Robot’s Physical Configurations

INTRODUCTION

Robot can be defined,

"A robot is a programmable, multi-functional manipulator designed to move material parts, tools, or special devices through variable programmed motions for the performance of variety of tasks"

INDUSTRIAL ROBOT

An Industrial Robot is a general purpose, programmable machine possessing certain anthropomorphic characteristics.

The most anthropomorphic or human like characteristic of a robot is its arm.

This arm with robot's capacity to be programmed, makes it ideally suited to a variety of production tasks, machine loading, spot welding, spray painting and assembly.

Robot can be programmed to perform a sequence of mechanical motions and it can repeat that motion sequence over and over until reprogrammed to perform another job.

INDUSTRIAL ROBOT

An industrial robot shares many attributes in common with a numerical control machine tool.

The same NC technology can be used to operate or actuate mechanical robot’s arm.

Robot is much lighter and portable equipment than NC machine tool.

Application of robot is more flexible and general rather than machine tool which is specific one.

Although programming of robot is different than NC machines as machine tools are programmed ‘off–line’ and robot is programmed ‘on–line’

ROBOT'S PHYSICAL CONFIGURATION

Industrial robot may be available in a variety of shape and sizes.

They are capable of various arm manipulations and they posses different motion systems.

These different variations are depend upon configuration of operation that robot performs.

Commercially available industrial robots have one of the four configuration stated below:

- Polar coordinate configuration
- Cylindrical coordinate configuration
- Jointed arm configuration
- Cartesian coordinate configuration

ROBOT’S PHYSICAL CONFIGURATION

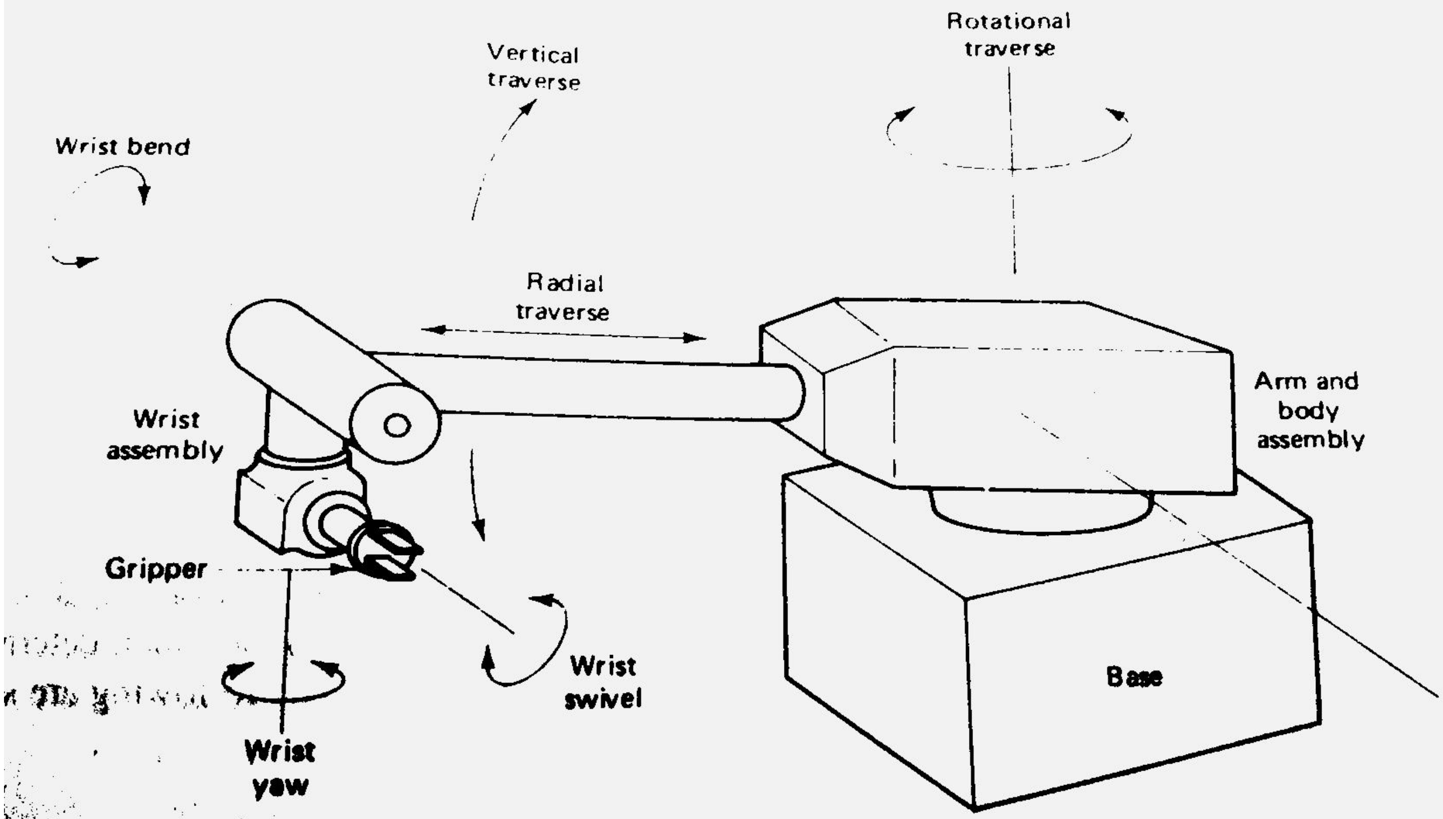
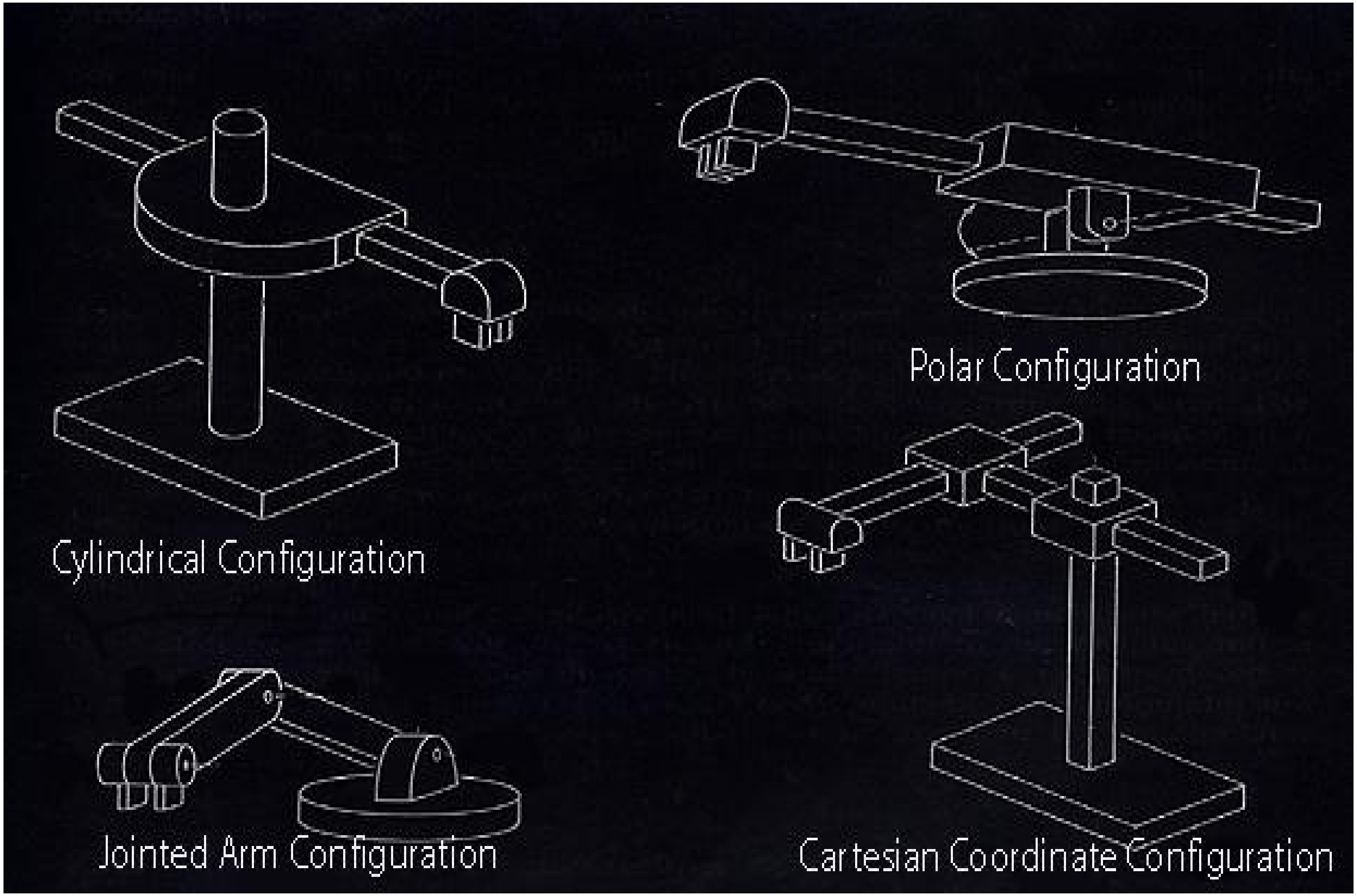
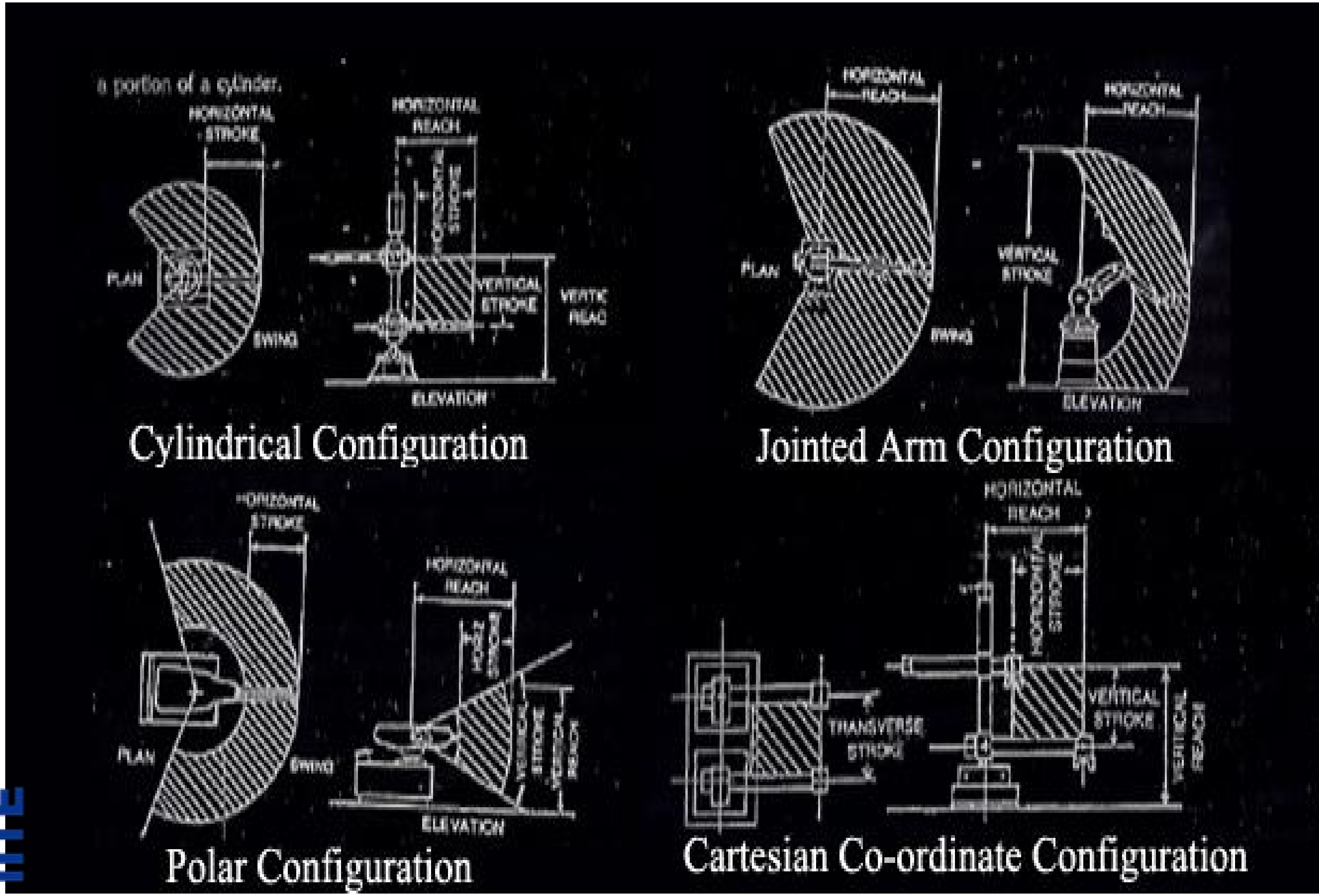


FIGURE 10.6 Typical six degrees of freedom in robot motion.

ROBOT'S PHYSICAL CONFIGURATION



ROBOT’S PHYSICAL CONFIGURATION



CHAPTER 4: NUMERICAL CONTROL & COMPUTERIZED NUMERICAL CONTROL

CONTENT

Introduction
Numerical controls
Evolution of controllers
Components of NC/CNC system
Specification of CNC system
Classification of NC/CNC machines
Constructional details of CNC machines
NC/CNC tooling
Fundamental of Manual Part Programming
Types of format
Word Address format
Manual part programming for operations: Drilling/Lathe/Milling
Subroutines/Do loops/Canned cycles

INTRODUCTION

Efficiency is the term associated with every business, resulting in profit making.

For the context of Machining; If we ask a machinist to remake a part on machine tool, he will need a complied information about part such as detailed sketch, type of material, machining process, cutting speed, feeds, tools, etc.

Complexity of a product increases the time to produce a component, as more time is required to reading the drawing and checking dimensions.

Today industry demands faster production in harder and tougher material to unprecedented tolerances, conventional machine tools can not meet these demands.

INTRODUCTION

The solution to this problem is, NUMERICAL CONTROL, as it supports 85% of market demands.

Numerical control is nothing, but relatively new process of organizing the information required for a process resulting in automation.

Automation is essential for implementation of Computer Integrated Manufacturing. Automation in production process may be achieved by one of the following strategies:

- Industrial Process Control (IPC)
- Computer Aided Data Processing (CADP)
- Special Purpose Manufacturing Machines (SPMM)
- Numerical Control (NC)

NUMERICAL CONTROL

Numerical Control (**NC**) :

It is a type of control system used for operating a machine automatically by a coded set of instruction in form of NUMERICALS.

or

It is a method of automatically operating a manufacturing machine based on a code letters, numbers and special characters.

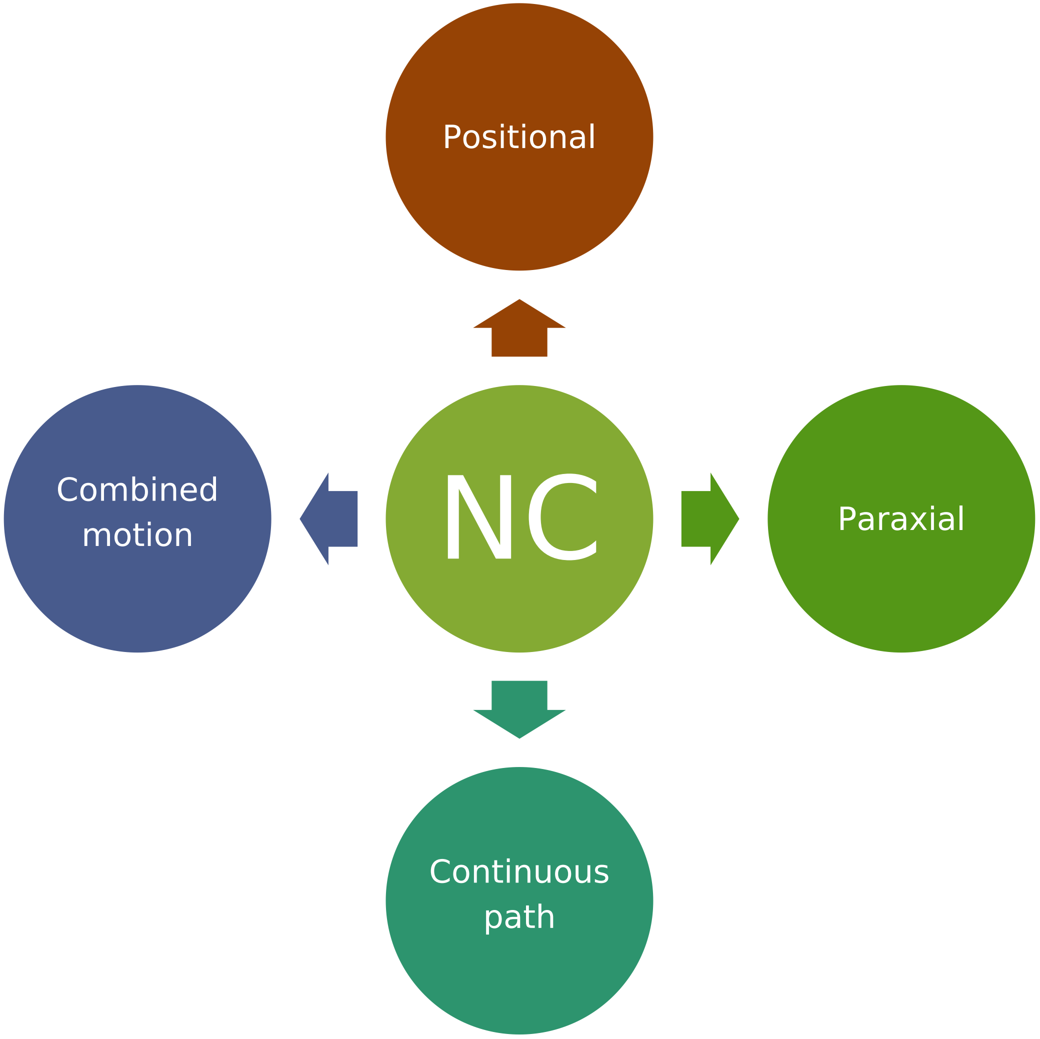
or

It is a technique by which a machine or process can be automated through a series of coded instructions consisting of numbers and other symbols

Computerized Numerical Control (**CNC**):

NUMERICAL CONTROL

Types of NC controls



INTRODUCTION

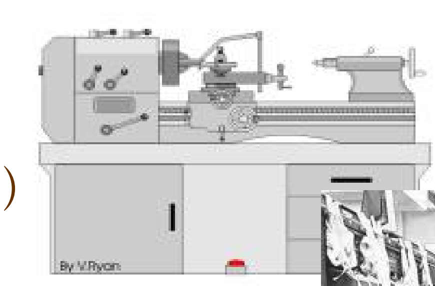
Introduction to NC & CNC

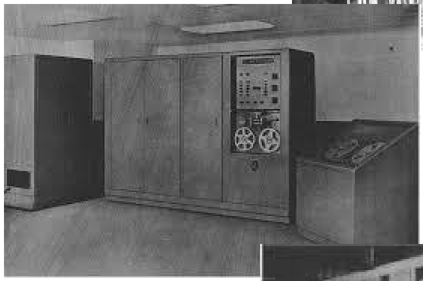
1. **Positional (point to point)**
   1. Drilling
      1. Vertical column, coordinate table machines (2P or 2PL)
      2. Gantry type (2PL)
   2. Boring
      1. Vertical e.g. Jig Borer (2PL)
      2. Horizontal (2PL)
2. **Paraxial (Straight line)**
   1. Milling
   2. Lathes
   3. Machining Centers
3. **Continuous path (Contouring)**
   1. Lathes
   2. Milling M/c (2CL, 3C, 4C, 4CL)
   3. Routers
   4. Grinding Machines
   5. Machining Centers (2CL to 6C)
4. **Combined Motion Control**

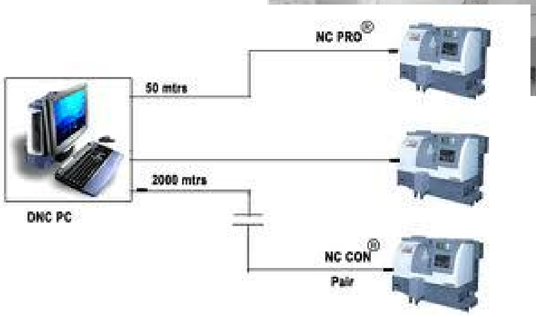
EVOLUTION OF CONTROLLERS

Introduction to NC & CNC

1. In 1775, John Wilkinson- cannon boring machine (lathe)
2. In 1881, Eli Whitney- milling machine.
3. In 1947, Mr. John Parsons began experimenting for using 3-axis curvature data to control the machine tool motion for the production for aircraft components.
4. In 1949, parsons- first NC machine.
5. In 1951, MIT was involved in the project.
6. In 1955, after refinements NC became available in Industry
7. Today, modern machinery are CNC milling machines and lathes.





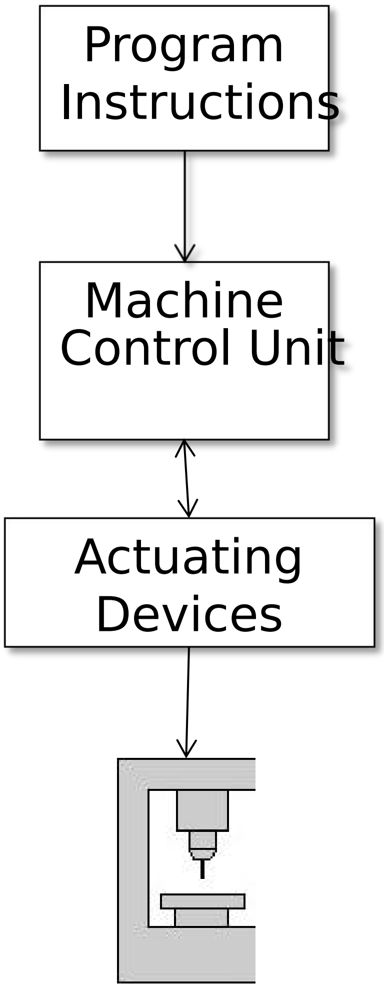


COMPONENTS OF **NC** MACHINE SYSTEM

The **program** of instructions is the detailed step by step set of instructions which tells the machine what to do.

Machine Control Unit (**MCU**) consists of electronics and hardware that read and interpret the program of instructions and convert it into binary codes causes mechanical actions of the machine tool.

The third basic component of an NC system is the **machine tool** or other controlled process. It is part of the NC system which performs useful work.



COMPONENTS OF **CNC** MACHINE SYSTEM

Same as in NC m/c part program is series of instructions, composed of letters, numbers & symbols, which tells the machine what to do.

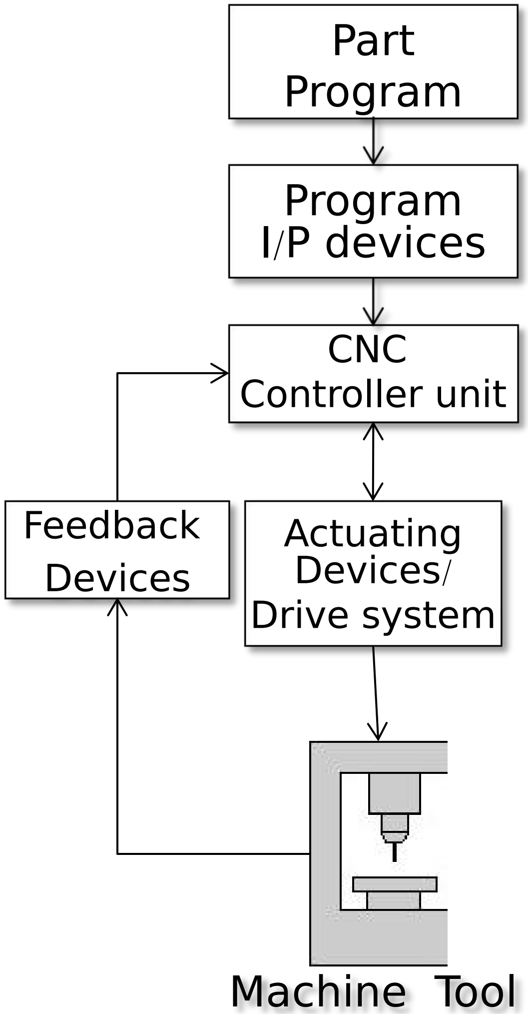
Input devices in CNC are Computer interface, flash drives and communication portals/routers

Machine Control Unit (MCU) consists of electronics and hardware that read and interpret the program of instructions and convert it into binary codes.

The basic component of an CNC system is the actuating devices which causes physical movements in machine tool.

Machine tool is part of the CNC system which performs useful work.

Feed back devices are used to retrieve physical position in form of electronic signals of various movable components



SPECIFICATION OF **CNC** SYSTEMS

Sr. No.	Nature of Configuration	Specification
1	Number of controlled axes	Two/Four/Eight, etc
2	Interpolation	Linear/circular/parabolic or cubic/cylindrical
3	Resolution	1. Input resolution (feedback) 2. Programming resolution
4	Feed rate	1. Feed/min 2. Feed/revolution
5	Rapid traverse rate	1. Feed rate override 2. Feed/min
6	Operating modes	Manual/Automatic/MDI(editing)/Input/output/Machine data set-up/Incremental, etc
7	Type of feedback	1. Digital (rotary encoders with train of pulses) 2. Analog (transducers, etc.) 3. Both
8	Part program handling	1. Number of characters which can be stored 2. Part program input devices 3. Output devices 4. Editing of part program

SPECIFICATION OF **CNC** SYSTEMS

Sr. No.	Nature of Configuration	Specification
9	Part programming	1. Through MDI 2. Graphic simulation 3. Blue print programming 4. Background editing 5. Menu driven programming 6. Conversational programming
10	Compensations	1. Backlash 2. Lead screw pitch error 3. Temperature 4. Cutter radius compensation 5. Tool length compensation
11	Programmable logic controller (PLC)	1. Built-in (integrated)/External 2. Type of communication with NC 3. Number of inputs, outputs, timers, counters and flags 4. User memory 5. Program organization 6. Programming Languages
12	Thread cutting/Tapping	Types of threads that can be cut
13	Spindle control	1. Analog /Digital control 2. Spindle orientation 3. Spindle speed overrides 4. RPM/min: constant surface speed

SPECIFICATION OF **CNC** SYSTEMS

Sr. No.	Nature of Configuration	Specification
14	Other features	1. Inch/metric switchover 2. Polar coordinate inputs 3. Mirror imaging 4. Scaling 5. Coordinate rotation system 6. Custom macros 7. Built-in fixed cycles 8. Background communication 9. Safe zone programming 10. Built-in diagnostics, safety function, etc. 11. Number of universal interfaces 12. Number of active serial interfaces 13. Direct numerical control interface 14. Network interface capability

CLASSIFICATION OF NC/CNC MACHINES

Based on Motion Control

- Point to Point
- Paraxial
- Contouring (Continuous path control)
- Combined motion control.

Based on Control Loops

- Open Loop
- Semi Closed loop
- Closed loop

Based on number of axis controlled by machine

- 2 Axis
- 3 Axis
- 6 Axis, etc.

Based on Circuitry technology

- Analog circuit
- Digital circuit

CLASSIFICATION OF NC/CNC MACHINES

Based on Positioning Method Used

- Absolute
- Incremental
- Mixed

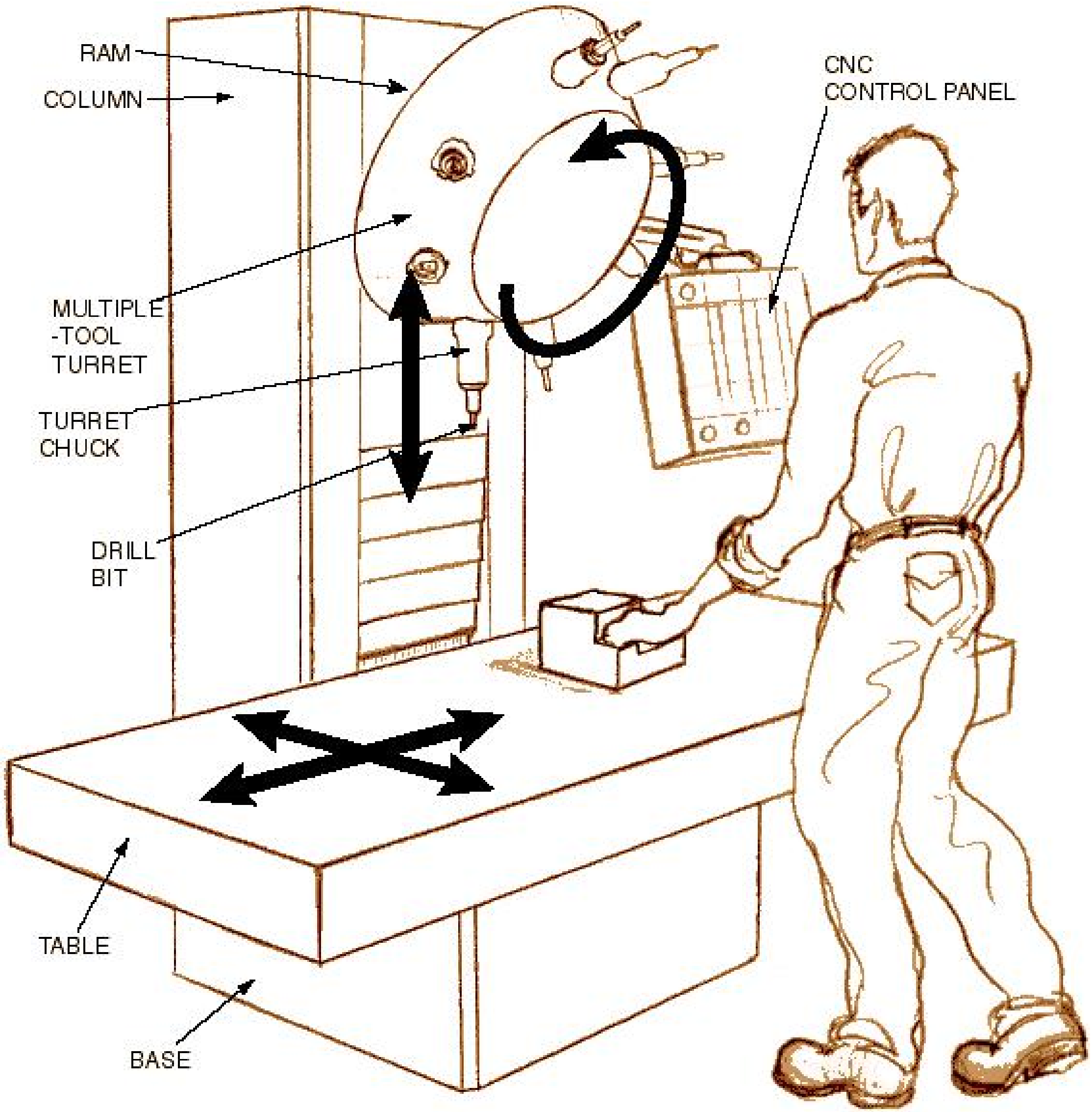
Based on Types of axis controlled by Machine

- 2P
- 2L
- 2PL
- 2C
- 2C, L
- 4C, L

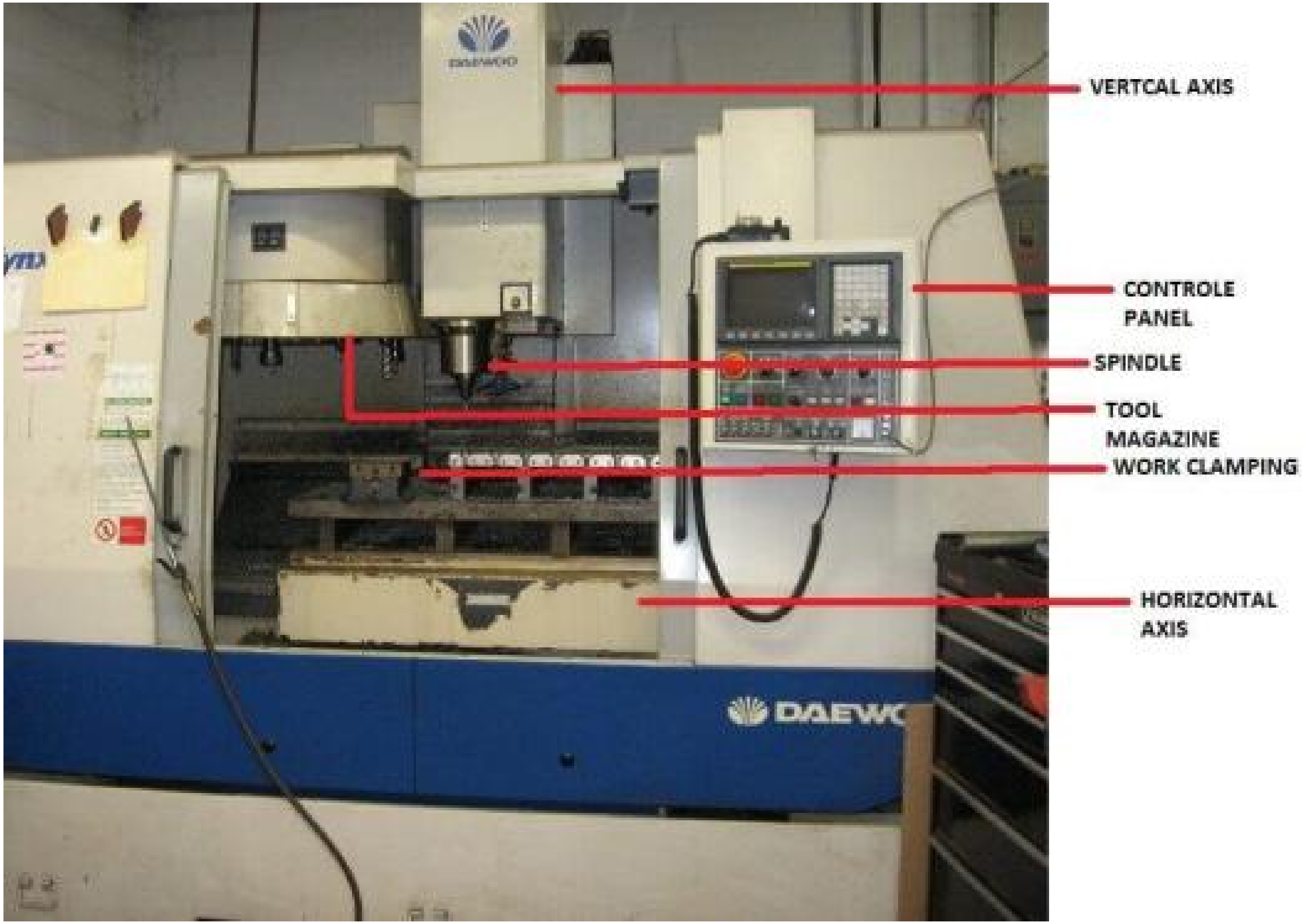
Based on Power Supply or Actuation

- Hydraulic
- Pneumatic
- Electric
- Hybrid

CONSTRUCTION DETAILS OF CNC MACHINE



CONSTRUCTION DETAILS OF CNC MACHINE



CONSTRUCTION DETAILS OF CNC MACHINE

NC coordinate system

Axis designation/ Identification

- Linear Axis
- Rotary Axis
- Machine with rotating tool
- Machine with rotating work
- Machine with non rotating tool and non rotating work

Control systems

- Analog/Digital
- Open loop/closed loop
- Linear and rotary transducer

Mechanical systems

- Slide ways
- Recirculating Ball screw and nut assembly
- Spindle

Spindle and axis drive systems

- Fluid Motors
- A.C. Electrical Motors
- D.C. Electrical Motors
- Stepper Motors
- Servo motors
- Synchros and resolvers
- Pneumatic Devices

Lubrication and cooling systems

Swarf removal systems

Safety and guarding devices

TOOLING IN NC MACHINE

Cutting tools

Based on tool material

- HSS
- HCS
- Cast alloy
- Cemented Carbide
- Ceramics
- Salons
- Diamond
- Boron Nitride

Based on cutting tool construction

- Solid tool
- Brazed tool
- Inserted bit tool

Bases of setting up a tool

- Pre-set tools
- Qualified tools
- Semi-qualified tools

TOOLING IN NC MACHINE

Holding devices for tools

Spindle tooling

- Collets, chucks with extension
- End mill adaptors
- Face mill adaptors
- Screwing end mill adaptors
- Tapping head
- Boring heads
- Shell mill adaptors

Automatic tool changer

- Turret head
- 180 degree rotating head
- Pivot insertion
- Multi axis
- Spindle direct

Flexible tooling

- Its is made up of two parts a) back end, b) adaptor

TOOLING IN NC MACHINE

Holding devices for work piece

- **Multi pallet machine attachments**
  - Linear pallet shuttle
  - Rotary pallet
- **Transfer machines**
  - Rotary transfer
  - Inline transfer
    - Straight line
    - L–type
    - U–type
    - Square type
    - Rectangular type
- **Special purpose fixtures**
- **Automatic loading and unloading devices**

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Procedure of NC

Preparing of NC coordinate drawing

↓

Process planning

↓

Part programming → 1) Manual Part Programming; 2) Computer Aided Part Programming

↓

Preparation for input devices for NC machine

↓

Verification of programme

↓

Production

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Procedure For Manual Part Programming

- **Dimensioning method used in drawing**
  - Absolute
  - Incremental
- **Axis designation**
  - X,Y, Z,
  - A, B & C
- **NC words**
- **Standard G–codes & M–codes**
- **Programming format**
- **Machine zero point setting**

FUNDAMENTAL OF MANUAL PART PROGRAMMING

NC Words

Symbol	Meaning	Example	Application
O	Program number	O25412	Its is used to identify, store, retrieve and subroutine program call for particular programme
N	Sequence number/Block Number	N21	numerical way to keep lines in proper sequence
G	Preparatory code	G00, G21	It is used to instruct machine to do machining functions
X,Y ,Z, U, V, W, a, b, c, i, j, k, p ,q, r	Dimension words	X 150	They are used to defining different movement/ interpolations coordinates and axis motion of NC controlled movable parts
M	Miscellaneous code	M03	This are the codes which instructs machine to do function rather than machining
T	Tool Number	T02	Each tool has separate number, by which it can be called up any time.
F	Feed rate	F500	Feed rate, this is a speed at which tool cuts
S	Spindle speed rate	S2500	Speed rate in revolution at which spindle rotates in CW or CCW
<EOB	End of block	;	It identifies where instruction ends in one block

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Sequence Number or Block number (N)

- Each block of the program has a sequence number which is used to identify the sequence of a block of the data in it which is ascending in numerical order
- a sequence number is displayed on a screen for operator.
- It is also useful in editing when programmer doing programming.
- It consist of character N following by three digit number starting from 000 to 999
- E.g. N093 in "N093 G81 G99 X5 Y10 Z-8 R02 M08;"

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Preparatory Code (G)

- G words are used to initiate the control commands, typically involving a cutter motion.
- In other words, it prepares the machine controller unit to perform a specific operation and interpret, the date which follows the way of this function.
- It is represented with G followed by two digit number from 00 to 99
- This comes after sequence number and tab codes.
- Two types of G codes- Modal and Non-Modal
- Modal codes are active until cancelled by a contradictory and code of same class
- Non-Modal codes are active only in particular block
- There are around 100 numbers of G codes.
- E.g. G99/G81 in “N093 G81 G99 X5 Y10 Z-8 R02 M08;”

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Dimension Words

- These are also called Coordinates–position of tool

- Linear dimension words:

  X, Y, Z: Linear dimension words for defining primary axial motion

  U, V, W: Defining secondary linear motion parallel to primary axis

  p , q, r: Third linear motion parallel to primary axis & secondary axis

- Another Dimension words:

  a, b, c: Defining angular motion around X, Y and Z

  i, j, k: Used in thread cutting operation for arc positioning

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Dimension Words

- These words are represented by an alphabets representing the axis followed by 5 or 6 digits depending up on the input resolution
- Some factors should be considered for defining dimension words are:
- All dimensions should be in mm
- Decimal point is not allowed
- Angular dimensions should be represented as a decimal fraction of revolution
- If absolute sys, all dimension words are positive
- If Incremental sys, + / – are used for direction of motion.

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Feed Rate (F)

- It is used to instruct feed rates in ‘mm/min’ or ‘mm/rev’
- It is represented by ‘F’ followed by three digit number
- i.e., F100 means feed rate is 100 mm/min or 100 mm/rev depends on G code.

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Spindle Speed Rate (S)

- It specify cutting surface speed or spindle speed during cutting operation
- It is represented by 'S' followed by three/four digit number
- i.e., S2500 means 2500 rev/min
- If speed entered is in meter/ min then speed is converted in to revolution per min and rounded to 2 digit accuracy.

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FUNDAMENTAL OF MANUAL PART PROGRAMMING

Tool Number (T)

- It is used only in the machine where automatic tool changing function is available by ATC
- It is maximum of 5 digit number with T
- i.e., T0012
- Sometimes T is also used to define tool offset with X, Y or Z co-ordinates with additional two digits after decimal point

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Miscellaneous Code (M)

- It consist of 'M' followed by two digit number.
- It controls auxiliary functions such as turning on coolant or spindle rotates in counter clockwise direction.

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Programming Format

- EIA & ISO use three types of formats for compiling of NC data into suitable blocks of information with little difference:
- WORD ADDRESS FORMAT
- TAB SEQUENTIAL FORMAT
- FIXED BLOCK FORMAT

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Word Address Format

- It uses alphabets
- Address; identifying the function of numerical data followed
- Alphabet characters are: N G XYZ S F T M
- These alphabets have specific meanings.
- Block of information is of any length and words can be arranged with out following any sequence because of word address
- No code should be repeated in every block for the same functional instruction because of ‘letter addressing’
- A typical word address format can be expressed like:

FUNDAMENTAL OF MANUAL PART PROGRAMMING

TAB sequential Format

- The sequence of code in the block are same as in word address format but alphabets are replaced by Tab codes which are inserted between two words/ digits.
- The location for each code in MCU had been fixed previously so each sequential TAB is used to recognize particular code
- If words are unchanged in next code an empty TAB shows word is missing and that is indication of unchanged address
- This format is sometimes known as interchangeable format.

TAB sequential Format

- More clarification can be explained by example:
- Suppose in Word Address:

```
N070 G81 X05764 Y04750 F473 S1500 T05  M08
<EOB|
```

- Then in Tab Sequential Format

```
|070    |81    |05764      |04750    |473   |1500   |05    |08
```

- If we need to change co-ordinate in X axis only and Y axis co-ordinate are unchanged then code is written like

```
|071     |     |            |05000    |435    |         |        |
```

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Fix Block Format

- In fixed block format the information is given in a particular sequence and block must contain fix number of characters
- No Letters, no TABs are used or none of the words can be omitted.
- If data is same it has to be repeated in next block
- In this format,
- First three digits-sequence number

  Next two digits- preparatory code

  Next 5x3 digits-X Y Z co-ordinates

  Next four digits-spindle speed

  Next three digits-feed rate

  Next two digits- tool number

  Next two digits-Miscellaneous codes

  Last one digit-end of block

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Fix Block Format

- These code format can be varied with specification of machine
- Example:
- 070 81 05764 04750 473 1500 05 08 <EOB

Seq. No. G X Y F S T M

- 071 81 05764 05000 435 1500 05 08 <EOB

- Advantage of Fix Block Format

Whole block can be read at the same instant, instead of single character

FUNDAMENTAL OF MANUAL PART PROGRAMMING

Method of writing a part program

- For writing a part program manuscript following three major steps are done in sequence:
- Write a block of set up condition, selecting a co-ordinate values (mm/ inch), Mode (Absolute/incremental), unit for other dimensions (Speed/feed)
- Prepare a program sheet where each line has a sequence number, detail of operation and X, Y, & Z co-ordinate values
- Adding basic information such as G-code, feed rates, M-

Sequence No (N)	Detail of Operation	G –Codes	Dimensional words/ Coordinates			Feed rate (F)	Spindle Speed (S)	Tool No. (T)	Miscellaneous Function (M)	EOB
			X	Y	Z					

FUNDAMENTAL OF MANUAL PART PROGRAMMING

List of G Codes

G00 – Rapid Traverse (not cutting)
G01 – Linear Interpolation
G02 – Spindle CW
G03 – Spindle CCW
G04 – Dwell
G05 – Pause (for operator intervention)
G08 – Acceleration
G09 – Deceleration
G17 – x-y plane for circular interpolation
G18 – z-x plane for circular interpolation
G19 – y-z plane for circular interpolation
G20 – turning cycle or inch data specification
G21 – thread cutting cycle or metric data specification
G24 – face turning cycle
G25 – wait for input to go low
G26 – wait for input to go high
G28 – return to reference point
G29 – return from reference point

FUNDAMENTAL OF MANUAL PART PROGRAMMING

List of G Codes

G31	– Stop on input
G33-35	– thread cutting functions
G35	– wait for input to go low
G36	– wait for input to go high
G40	– cutter compensation cancel
G41	– cutter compensation to the left
G42	– cutter compensation to the right
G43	– tool length compensation, positive
G44	– tool length compensation, negative
G50	– Preset position
G70	– set inch based units or finishing cycle
G71	– set metric units or stock removal
G72	– indicate finishing cycle
G72	– 3D circular interpolation clockwise
G73	– turning cycle contour
G73	– 3D circular interpolation counter clockwise
G74	– facing cycle contour
G74.1	– disable 360 deg arcs

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FUNDAMENTAL OF MANUAL PART PROGRAMMING

List of G Codes

G75	– pattern repeating
G75.1	– enable 360 degree arcs
G76	– deep hole drilling, cut cycle in z–axis
G77	– cut–in cycle in x–axis
G78	– multiple threading cycle
G80	– fixed cycle cancel
G81–89	– fixed cycles specified by machine tool manufacturers
G81	– drilling cycle
G82	– straight drilling cycle with dwell
G83	– drilling cycle
G83	– peck drilling cycle
G84	– taping cycle
G85	– reaming cycle / boring cycle
G86	– boring with spindle off and dwell cycle
G89	– boring cycle with dwell

FUNDAMENTAL OF MANUAL PART PROGRAMMING

List of G Codes

G90 – absolute dimension program

G91 – incremental dimensions

G92 – Spindle speed limit / datum offset

G93 – Coordinate system setting

G94 – Feed rate in inch per min

G95 – Feed rate in inch per revolution

G96 – Surface cutting speed

G97 – Rotational speed rpm

G98 – withdraw the tool to the starting point or feed per minute

G99 – withdraw the tool to a safe plane or feed per revolution

G101 – Spline interpolation

FUNDAMENTAL OF MANUAL PART PROGRAMMING

List of M Codes

- M00 – program stop
- M01 – optional stop using stop button
- M02 – end of program
- M03 – spindle on CW
- M04 – spindle on CCW
- M05 – spindle off
- M06 – tool change
- M07 – flood with coolant
- M08 – mist with coolant
- M08 – turn on accessory (e.g. AC power outlet)
- M09 – coolant off
- M09 – turn off accessory
- M10 – turn on accessory

FUNDAMENTAL OF MANUAL PART PROGRAMMING

List of M Codes

M11 – turn off accessory or tool change
M17 – subroutine end
M20 – tailstock back
M20 – Chain to next program
M21 – tailstock forward
M22 – Write current position to data file
M25 – open chuck
M25 – set output #1 off
M26 – close chuck
M26 – set output #1 on
M30 – end of tape (rewind)
M35 – set output #2 off
M36 – set output #2 on
M38 – put stepper motors on low power standby
M47 – restart a program continuously, or a fixed number of times

FUNDAMENTAL OF MANUAL PART PROGRAMMING

List of M Codes

- M71 – puff blowing on
- M72 – puff blowing off
- M96 – compensate for rounded external curves
- M97 – compensate for sharp external curves
- M98 – subprogram call
- M99 – return from subprogram, jump instruction
- M101 – move x–axis home
- M102 – move y–axis home
- M103 – move z–axis home

MANUAL PART PROGRAMMING FOR DRILLING

Point to Point machining

Procedure:

1. All align the job edges AX and AY along X and Y coordinate of machine

2. Now set the tool at point

CHAPTER 5: FLEXIBLE MANUFACTURING SYSTEM

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- Introduction
- Components of FMS
- Needs of FMS
- General consideration in FMS
- Objectives
- Types of FMS
- Advantage of FMS
- Manufacturing Cells
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- JIT (Just-in-Time) & GT (Group Technology) applied to FMS and FMC
- Automated Material Movements
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