KINGS ENGINEERING COLLEGE
An Autonomous Institution
Affiliated to Anna University, Chennai

DEPARTMENT
OF
MECHANICAL ENGINEERING

Regulation 2021

IV Year – VII Semester

ME3792 - COMPUTER INTEGRATED MANUFACTURING

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REGULATIONS 2021

IV YEAR/ VII SEMESTER

ME3792 **COMPUTER INTEGRATED MANUFACTURING**

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COURSE OBJECTIVES

1. To provide the overview of evolution of automation, CIM and its principles.
2. To learn the various Automation tools, include various material handling system.
3. To train students to apply group technology and FMS.
4. To familiarize the computer aided process planning in manufacturing.
5. To introduce to basics of data transaction, information integration and control of CIM.

UNIT – I INTRODUCTION 9

Introduction to CAD, CAM, CAD/CAM and CIM - Evolution of CIM – CIM wheel and cycle – Production concepts and mathematical models – Simple problems in production models – CIM hardware and software – Major elements of CIM system – Three step process for implementation of CIM – Computers in CIM – Computer networks for manufacturing – The future automated factory – Management of CIM – safety aspects of CIM– advances in CIM

UNIT – II AUTOMATED MANUFACTURING SYSTEMS 9

Automated production line – system configurations, work part transfer mechanisms – Fundamentals of Automated assembly system – System configuration, Part delivery at workstations – Design for automated assembly – Overview of material handling equipments – Consideration in material handling system design – The 10 principles of Material handling. Conveyor systems – Types of conveyors – Operations and features. Automated Guided Vehicle system – Types &applications – Vehicle guidance technology – Vehicle management and safety. Storage system performance – storage location strategies – Conventional storage methods and equipments – Automated storage/Retrieval system and Carousel storage system Deadlocks in Automated manufacturing systems – Petrinet models – Applications in Dead lock avoidance – smart manufacturing – Industry 4.0 - Digital manufacturing – Virtual manufacturing

UNIT – III GROUP TECHNOLOGY AND FMS 9

Part families – Visual – Parts classification and coding – Production flow analysis – Grouping of parts and Machines by rank order clustering method – Benefits of GT – Case studies. FMS – Components – workstations – FMS layout configurations – Computer control systems – FMS planning and implementation issues – Architecture of FMS – flow chart showing various operations in FMS – Machine cell design – Composite part concept, Holier method, Key machine concept – Quantitative analysis of FMS – Bottleneck model – Simple and complicated problems – Extended Bottleneck model - sizing the FMS — FMS applications, Benefits.

UNIT – IV PROCESS PLANNING 9

Process planning – Activities in process planning, Informations required. From design to process planning – classification of manufacturing processes – Selection of primary manufacturing processes – Sequencing of operations according to Anteriorities – various examples – forming of Matrix of Anteriorities – case study. Typical process sheet – case studies in Manual process planning. Computer Aided Process Planning – Process planning module and data base – Variant process planning – Two stages in VPP – Generative process planning – Flow chart showing various activities in generative PP – Semi generative process planning- Comparison of CAPP and Manual PP.

UNIT – V PROCESS CONTROL AND DATA ANALYSIS 9

Introduction to process model formulation – linear feedback control systems – Optimal control – Adaptive control –Sequence control and PLC& SCADA. Computer process control – Computer process interface – Interface hardware – Computer process monitoring – Direct digital control and Supervisory computer control - Overview of Automatic identification methods – Bar code technology –Automatic data capture technologies.- Quality management (SPC) and automated inspection

TOTAL :45 PERIODS

OUTCOMES: At the end of the course the students would be able to

1. Discuss the basics of computer aided engineering.
2. Choose appropriate automotive tools and material handling systems.
3. Discuss the overview of group technology, FMS and automation identification methods.
4. Design using computer aided process planning for manufacturing of various components
5. Acquire knowledge in computer process control techniques.

TEXT BOOKS:

1. Shivanand H K, Benal M M and Koti V, Flexible Manufacturing System, New Age, 2016.
2. CIM: Computer Integrated Manufacturing: Computer Steered Industry Book by August-Wilhelm Scheer

REFERENCES:

1. Alavudeen and Venkateshwaran, Computer Integrated Manufacturingll, PHI Learning Pvt. Ltd., New Delhi, 2013.
2. Gideon Halevi and Ronald D. Weill, Principles of Process Planningll, Chapman Hall, 1995.
3. James A. Retrg, Herry W. Kraebber, Computer Integrated Manufacturingll, Pearson Education, Asia,3rdEdition,2004.
4. Mikell P. Groover, Automation, Production system and Computer integrated Manufacturing, Prentice Hall of India Pvt. Ltd., 4thEdition, 2014.
5. Radhakrishnan P, Subramanian S and Raju V, CAD/CAM/CIM, New Age International Publishers, 3rd Edition, 2008.

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ME3792 COMPUTER INTEGRATED MANUFACTURING

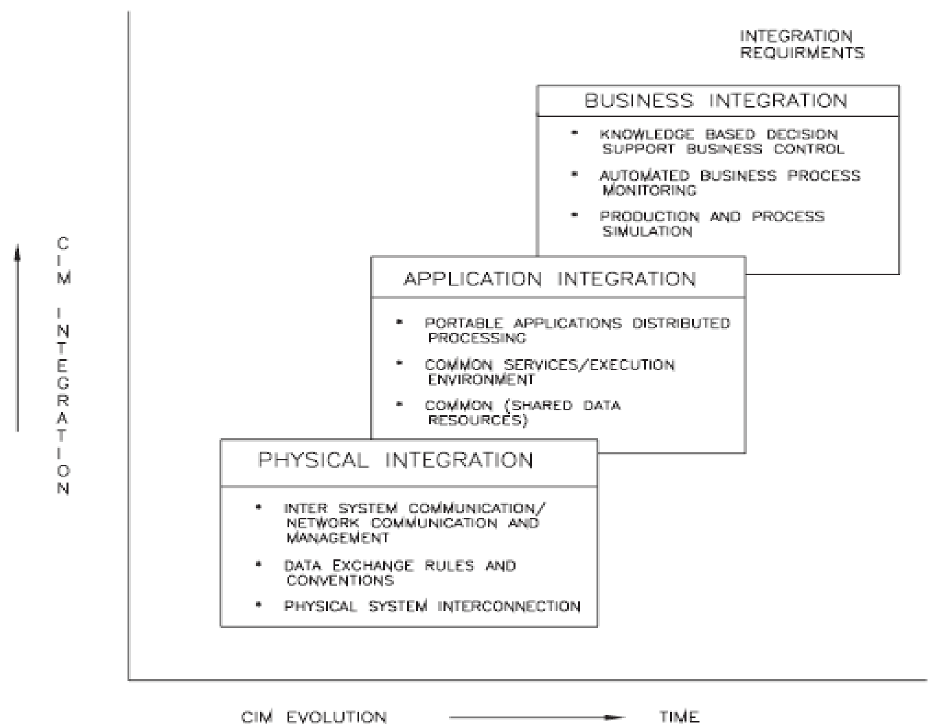
UNIT –I **INTRODUCTION**

INTRODUCTION TO **CAD, CAM, CAD/CAM** and **CIM**

- ✓ It defines CAD as using computers to assist in the design process.
- ✓ CAM is defined as using computers to plan, manage and control manufacturing operations.
- ✓ CIM attempts complete automation of all manufacturing processes under computer control by integrating CAD, CAM and other business aspects.

EVOLUTION OF **CIM**

- ✓ CIM is an integration process leading to the integration of the manufacturing enterprise.
- ✓ A Graph indicates different levels of this integration that can be seen within an industry.
- ✓ Dictated by the needs 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 and retrieval systems, CAD/CAM based design etc. are the examples of islands of automation i.e. a sort of computer based automation achieved completely in a limited sphere of activity of an enterprise.
- ✓ This involves data exchange among computers, NC machines, robots, gantry systems etc.
- ✓ Therefore the integration process has started bottom up. The interconnection of physical systems was the first requirement to be recognized and fulfilled.

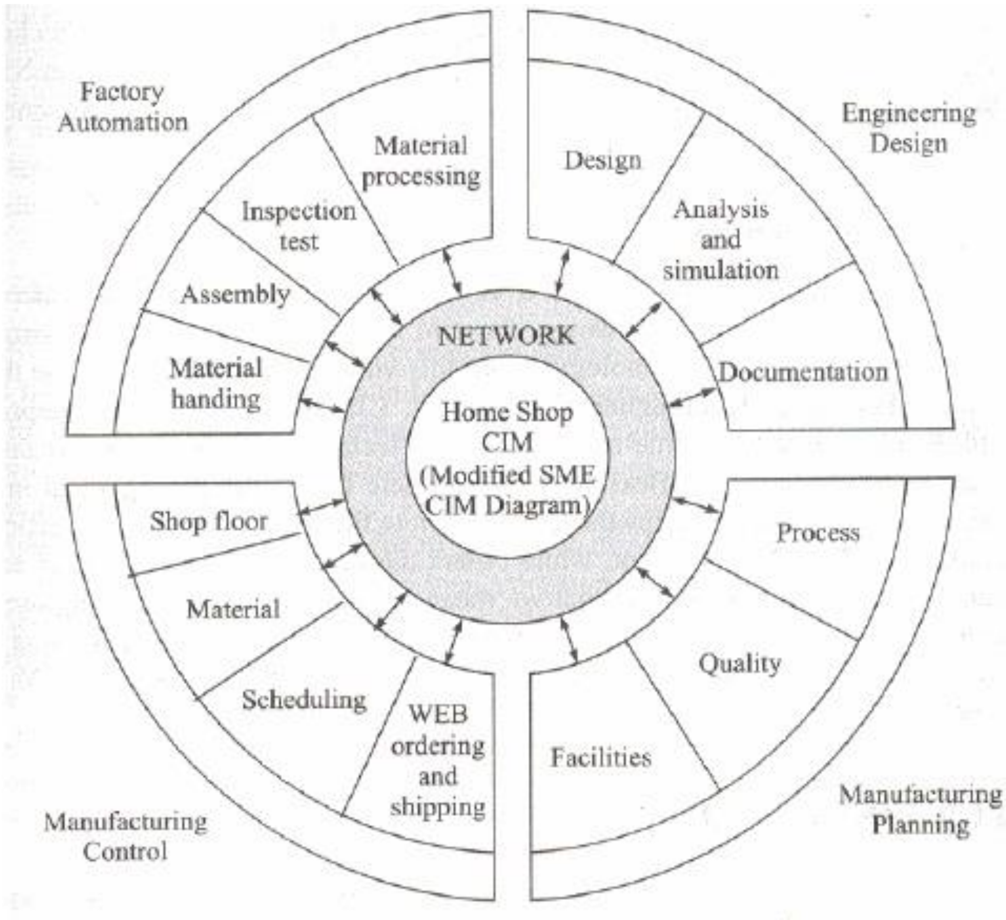


- ✓ The next level of integration, application integration in graph is concerned with the integration of applications, the term applications being used in the data processing sense.
- ✓ The applications are those which are discussed in section 1.4 under the heading CIM hardware and software.

- ✓ Application integration involves supply and retrieval of information, communication between application users and with the system itself.

- ✓ Thus the application integration level imposes constraints on the physical integration level. There has to be control of the applications themselves also.

CIM **WHEEL** AND **CYCLE**



CIM **WHEEL**

Factory Automation:

- ✓ Factory automation equipment further enriches the database with equipment and process data, resident either in the operator or the equipment to carry out the production process.

- ✓ In CIM system this consists of computer controlled process machinery such as CNC machine tools, flexible manufacturing systems (FMS), Computer controlled robots, material handling systems, computer controlled assembly systems, flexibly automated inspection systems and so on.

Engineering Design:

- ✓ The design department of the company establishes the initial database for production of a proposed product.

- ✓ In a CIM system this is accomplished through activities such as geometric modeling and computer aided design while considering the product requirements and concepts generated by the creativity of the design engineer.

- ✓ Configuration management is an important activity in many designs. Complex designs are usually carried out by several teams working simultaneously, located often in different parts of the world.

- ✓ The design process is constrained by the costs that will be incurred in actual production and by the capabilities of the available production equipment and processes.

- ✓ The design process creates the database required to manufacture the part.

Manufacturing Planning:

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

- ✓ Planning involves several subsystems dealing with materials, facility, process, tools, manpower, capacity, scheduling, outsourcing, assembly, inspection, logistics etc. In a CIM system, this planning process should be constrained by the production costs and by the production equipment and process capability, in order to generate an optimized plan.

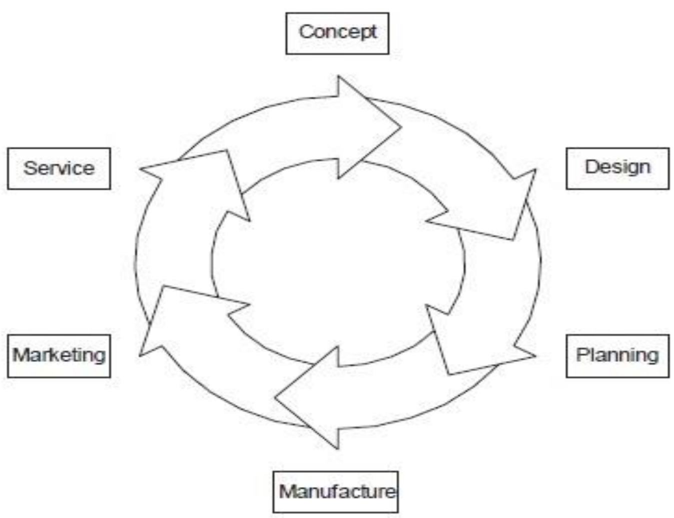
Manufacturing control:

- ✓ Computer-Integrated Manufacturing (CIM) is a method of using computers to control an entire production process, including engineering, production, and marketing.

- ✓ CIM systems use automation technologies to link functional areas like design, analysis, and inventory control with factory floor functions like materials handling and management.

- ✓ This allows for direct control and monitoring of all operations simultaneously, which can improve efficiency, quality, and flexibility in production.

- ✓ Computer Integrated Manufacturing, known as CIM, is the phrase used to describe the complete automation of a manufacturing plant, with all processes functioning under computer control with digital information tying them together.



CIM **CYCLE**

- ✓ The product development cycle starts with developing the product concept, evolving the design, engineering the product, manufacturing the part, marketing and servicing.

- ✓ The idea of a product may come from a patent, suggestion of the customers, feedback of the sales and service department, market research carried out by the marketing department or from the R&D department itself.

- ✓ customers, feedback of the sales and service department, market research carried out by
- ✓ the marketing department or from the R&D department itself.

- ✓ The next stage is the conceptualization of the product. The cost at which the product could be sold in the market is decided and the overall design in terms of shape, functional specifications, ergonomics, aesthetics etc are considered in detail and finalized at this stage.

- ✓ The work of product development is then taken to the next stage by the design department who carefully designs each assembly and each component of the assembly.

- ✓ Detailed design analysis and optimization is carried out at this stage. A design may have several variants. For example, a passenger car may have what is called a stripped down version with the bare minimum options and luxury versions with several add on functionalities.

- ✓ Between these two extreme versions, there will be a number of models or variants to meet the needs of customers with different paying capacities. In a similar way, a satellite launch vehicle may be designed for different payloads. A fighter aircraft may have different versions. A refrigerator will have to be marketed with different capacities.

- ✓ The design department creates these designs through a top down approach or a bottom up approach. In top down approach, the entire assembly is designed first and individual designs are done latter. In bottom up approach, the component design is done first and the product is realized by assembling the components suitably. The design also will involve preparation of detail drawings.

CIM **HARDWARE** AND **SOFTWARE**

CIM **Hardware** comprises the following:

I. Manufacturing equipment such as CNC machines or computerized work centers, robotic work cells, DNC/FMS systems, work handling and tool handling devices, storage devices, sensors, shop floor data collection devices, inspection machines etc.

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

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

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

MAJOR **ELEMENTS OF CIM** SYSTEM

Major elements of a CIM system are:

1. Marketing
2. Product Design
3. Planning
4. Purchase
5. Manufacturing Engineering
6. Factory Automation Hardware
7. Warehousing
8. Logistics and Supply Chain Management
9. Finance
10. Information Management

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

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

iii. Planning: The planning department takes the database established by the design department and enriches it with production data and information to produce a plan for the production of the product. Planning involves several subsystems dealing with materials, facility, process, tools, manpower, capacity, scheduling, outsourcing, assembly, inspection, logistics etc. In a CIM system, this planning process should be constrained by the production costs and by the production equipment and process capability, in order to generate an optimized plan.

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

v. 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. In CIM, this requires activities like CNC programming, simulation and computer aided scheduling of the production activity. This should include online dynamic scheduling and control based on the real time performance of the equipment and processes to assure continuous production activity. Often, the need to meet fluctuating market demand requires the manufacturing system flexible and agile.

vi. 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. In CIM system this consists of computer controlled process machinery such as CNC machine tools, flexible manufacturing systems (FMS), Computer controlled robots, material handling systems, computer controlled assembly systems, flexibly automated inspection systems and so on.

vii. Warehousing: Warehousing is the function involving storage and retrieval of raw materials, components, finished goods as well as shipment of items. In today's complex outsourcing scenario and the need for just-in-time supply of components and subsystems, logistics and supply chain management assume great importance.
viii. Finance: Finance deals with the resources pertaining to money. Planning of investment, working capital, and cash flow control, realization of receipts, accounting and allocation of funds are the major tasks of the finance departments.

THREE STEP PROCESS FOR **IMPLEMENTATION OF CIM**

There are three steps involved in implementing CIM successfully. They are

- Assessment of the enterprise
- Simplification
- Implementation with performance measures

Assessment of the enterprise:

Assessment focuses on three areas,

- Technology
- Human resources
- Systems

Technology assessment is done to determine the current level of technology and process sophistication present in manufacturing, Employee's readiness for adoption of CIM automation across the enterprise is determined by Human resource assessment and finally systems assessment is done to understand why the production systems function as they do. Every assessment is an internal self-study. After the assessment, the capabilities, strengths and weaknesses of all three areas are found and documented.

Simplification:

Simplification is the process of eliminating waste. It is also defined as follows, Simplification is a process that removes waste from every operation or activity to improve the productivity and effectiveness of the department and organization.

Every operation, move or a process that does not add any value to the product is called a waste. In a material timeline from raw material to final product, only material under processing add value to the part, other operations like moving, waiting in queue, waiting for process and inspection doesn't add value to the part, these are called cost-added operations. All avoidable cost-added operations must be eliminated.

Examples:

- Replacing a forklift with conveyor.
- Elimination of transportation by moving the production machines closer.

Implementation with performance measures:

Implementing CIM is done with performance measures. After measuring performance of various areas in an enterprise, the specifications are changed according to requirement. This performance measures are done reputedly until the desires success rate is achieved. Finally, the required hardware and software are acquired and installed.

COMPUTER NETWORKS FOR MANUFACTURING:

Hierarchy of Computers in Manufacturing

- The functional configuration of the integrated computer system in a manufacturing firm is discussed.
- The configuration is a hierarchical one, similar to the management structure in the firm.
- The hierarchical structure is achieved by using a local area network (LAN) in the factory.

- The hierarchical arrangement depicted here is a management oriented structure indicating various levels of responsibility, some of which are sub ordinate to others.
- It represents the command structure that exists between the computers and computer driven devices in the factory.
- The various computers in the hierarchy are tied together by communication links to form a distributed computer system.
- The individual links provide a computer communications network to forward data and information up through the various levels from the manufacturing operations all the way to the corporate computer level
- In the opposite direction, product designs, process plans, production schedules, machine commands and so on, are passed down to the individual production cells.
- The hierarchy allows for the design engineering and manufacturing engineering functions to be included with in the computer network.
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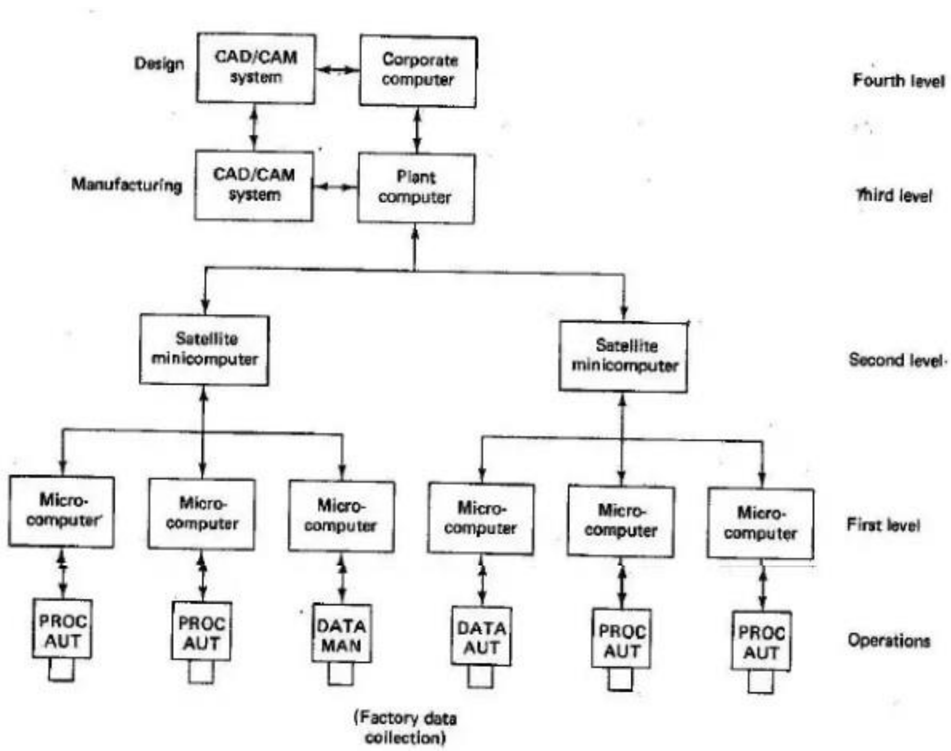
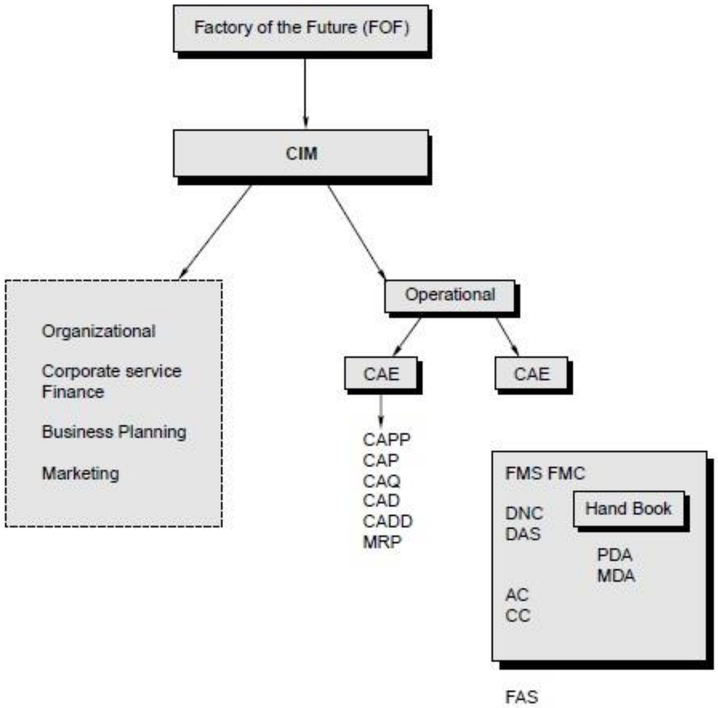


THE **FUTURE AUTOMATED FACTORY**



CAPP	Computer Aided Process Planning	FMS	Flexible Manufacturing System
CAP	Computer Aided Planning	FMC	Flexible Manufacturing Cell
CAQ	Computer Aided Quality Control	FAS	Flexible Manufacturing Assembly
CAD	Computer Aided Design	DNC	Direct Numerical Control
CADD	Computer Aided Design and Drafting	DAS	Data Acquisition System
MRP	Materials Resource Planning PDA	Production Data	
CIM	Computer Integrated Manufacturing	AC	Area Control
CC	Cell Control		

ADVANCES IN **COMPUTER INTEGRATED MANUFACTURING**

In order to make manufacturing systems adapt to the new global competitive market environment, many advanced networked manufacturing concepts and approaches have been proposed by scholars, such as virtual computer integrated manufacturing system (VCIM), production network, cloud manufacturing and social manufacturing.

UNIT-II AUTOMATED **PRODUCTION LINE**

- ✓ Automated production lines are essentially advanced systems designed to streamline and optimize the manufacturing process.
- ✓ Generally, they utilize a combination of machinery, robotics, computer systems, and control software to automate various stages of production, reducing human intervention and increasing efficiency.

Steps to Creating and Implementing an Automatic Production Line

Step 1: Evaluate your current manufacturing process. ...

Step 2: Establishing automation objectives.

Step 3: Selecting the right automation technology and equipment. ...

Step 4: Designing the layout and workflow. ...

Step 5: Implementation and integration.

1. Evaluate your current manufacturing process

It's critical to first assess the current state of your production process, and especially the sequence of operations and taks involved in each cycle.

The basic principle to uphold is that automation will *only* be valuable in an already-efficient process. Automating an inefficient process will only amplify its imperfections and inefficiencies, so it will be counterproductive.

So, the initial step will provide you with a very important foundation on how you should execute and implement the automatic production line, and we'll first focus on identifying bottlenecks and inefficiencies.

2. Establishing automation objectives

In the previous section, we have discussed the importance of defining the objectives and purposes of implementing an automatic production line. In this step, we'll put it into a more concrete manner by clearly defining the desired production output.

What is the rate of production and the minimum quantity of manufactured products needed to meet customer demand and business goals?

To answer this, you may want to evaluate your market demand and its forecasted growth to plan realistic production volume according to your production cycle time and lead time. Determine the sweet spot between the production output that satisfies market demands and maintaining cost-effectiveness.

Knowing the optimal production output to target will be very helpful in designing the automatic production line.

3. Selecting the right automation technology and equipment

- ✓ **Define your automation needs.** What specific tasks do you need to automate based on the previous steps?
- ✓ **Consider different automation technologies.** There are a wide variety of automation technologies available in the market, some of the most common ones include:
  Robotics. Often used to perform repetitive but relatively simple tasks like welding, painting, assembly, etc.
  Machine vision. Can be used to perform inspections for defects, measure dimensions, etc. Often used in QC applications.
  SCADA: stands for Supervisory Control and Data Acquisition, SCADA systems are used to automatically monitor and control processes.
  PLC: stands for Programmable Logic Controller, used to automate manufacturing equipment.
- ✓ **Research and compare equipment suppliers:** once you've identified the technology you'll need, you can research and source the suppliers. Request proposals and quotations from multiple suppliers, so you can compare prices, warranties, and features.
- ✓ **Make an informed decision:** after careful evaluation, choose the automation technology that is the most ideal fit for your specific needs and budget

4. Designing the layout and workflow

To effectively design the layout of your automatic production line, you can follow these steps:

- **Define the product that will be produced:** doing so can help you determine the type of equipment and materials that will be required and the sequence of operations in the manufacturing process.

- **Identify key steps:** determine the key steps in the production process, so you can design the layout of the production line and the exact sequence of operations.

- **Design the layout of the production line:** design the layout of the workflow by considering factors such as ease of material transfers between different workstations, required proximity to raw materials, and travel distances for human operators. Your layout should consider an optimal spacial arrangement and minimal congestion.

- **Automate:** determine the optimal placement of automated equipment (conveyor belts, robotic arms, etc.) while considering optimal efficiency. If your system involves both automated and human-operated workstations, consider how you will optimize the interplay of tasks and the flow of materials between workstations to ensure efficiency.

- **Ensure safety and compliance:** evaluate the layout design for potential hazards (i.e., potential collisions, ergonomic issues, pinch points, etc.) and adjust your design as needed. Make sure the finalized layout stays compliant with industry standards and relevant regulations.

- **Test and iterate:** once you've created and implemented the initial layout design, conduct tests (virtual and/or actual) to assess the production line's effectiveness and efficiency. Evaluate the efficiency of the process and identify potential bottlenecks. Don't forget to involve your operators and stakeholders and collect feedback from them.

5. **Implementation and integration**

   - ✓ Now that you've selected the appropriate technology and have designed your workflow, the next step is to implement and integrate the system into a working production line.
   - ✓ This step will mainly involve coordinating with your technology and equipment suppliers to ensure compatibility between all hardware and software solutions.
   - ✓ Here are the basic steps to ensure a seamless integration and implementation process:

   1. **Coordinating with suppliers**
   2. **Ensuring compatibility and connectivity between solutions**

WORK PART TRANSFER MECHANISMS

- ➢ Robotic, Servo or Pneumatic Pick & Place Transfer – There are limitless variations of this method of transferring parts.
- ➢ Generally, one part is moved at a time and the motion is non-indexing and asynchronous. It is similar to the manual transfer of parts but the automated version.
- ➢ Part transfer mechanism is used to transfer a part from one place to another during machining operation. The working principle of the designed mechanism is rolling of the job with the help of gravity.
- ➢ Transfer mechanisms are commonly used in mass production to continuously move identical or similar components through an automated production line. There are different types of transfer mechanisms including linear, synchronous, and asynchronous systems that move parts continuously or intermittently.

METHODS OF **WORKPART TRANSPORT**

1. Continuous transfer
2. Intermittent or synchronous transfer
3. Asynchronous or power-and-free transfer

Continuous transfer

- With the continuous method of transfer, the work parts are moved continuously at Constant speed. This requires the work heads to move during processing in order to maintain continuous registration with the work part.
- For some types of operations, this movement of the work heads during processing is not feasible.
- It would be difficult, for example, to use this type of system on a machining transfer line because of inertia problems due to the size and weight of the work heads.
- In other cases, continuous transfer would be very practical. Examples of its use are in beverage bottling operations, packaging, manual assembly operations where the human operator can move with the moving flow line, and relatively simple automatic assembly tasks.
- In some bottling operations, for instance, the bottles are transported around a continuously rotating drum.
- Beverage is discharged into the moving bottles by spouts located at the drum's periphery.
- The advantage of this application is that the liquid beverage is kept moving at a steady speed and hence there are no inertia problems.

Intermittent or synchronous transfer

- As the name suggests, in this method the work pieces are transported with an intermittent or discontinuous motion.
- The workstations are fixed in position and the parts are moved between stations and then registered at the proper locations for processing.
- All work parts are transported at the same time and, for this reason, the term "synchronous transfer system" is also used to describe this method of work part transport.

Asynchronous or power-and-free transfer

- Asynchronous transfer systems offer the opportunity for greater flexibility than do the other two systems, and this flexibility can be a great advantage in certain circumstances.
- In-process storage of work parts can be incorporated into the asynchronous systems with relative ease. Power-and-free systems can also compensate for line balancing problems where there are significant differences in process times between stations.
- Parallel stations or several series stations can be used for the longer operations, and single stations can be used for the shorter operations. Therefore, the average production rates can be approximately equalized.
- Asynchronous lines are often used where there are one or more manually operated stations and cycle-time variations would be a problem on either the continuous or synchronous transport systems. Larger work parts can be handled on the asynchronous systems.
- A disadvantage of the power-and-free systems is that the cycle rates are generally slower than for the other types.

TRANSFER MECHANISMS

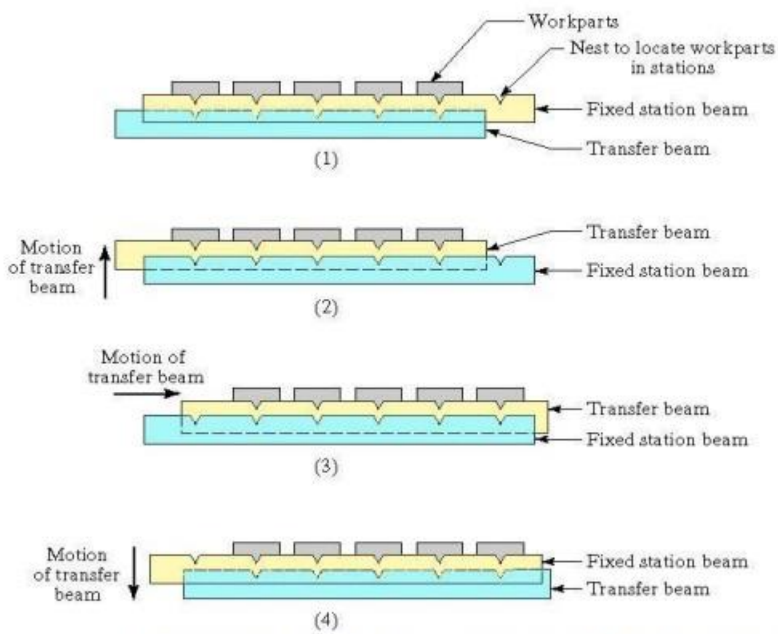
- There are various types of transfer mechanisms used to move parts between stations.
- These mechanisms can be grouped into two types: those used to provide linear travel for **in-line machine**s, and those used to provide **rotary motion for dial indexing machines**.

Linear transfer mechanisms

We will explain the operation of three of the typical mechanisms; the **walking beam transfer bar system**, the powered **roller conveyor system**, and the **chain-drive conveyor system**. This is not a complete listing of all types, but it is a representative sample.

Walking beam transfer bar system,

→ With the walking beam transfer mechanism, the work-parts are lifted up from their workstation locations by a transfer bar and moved one position ahead, to the next station.
→ The transfer bar then lowers the pans into nests which position them more accurately for processing.
→ For speed and accuracy, the motion of the beam is most often generated by a rotating camshaft powered by an electric motor or a roller movement in a profile powered by hydraulic cylinder.



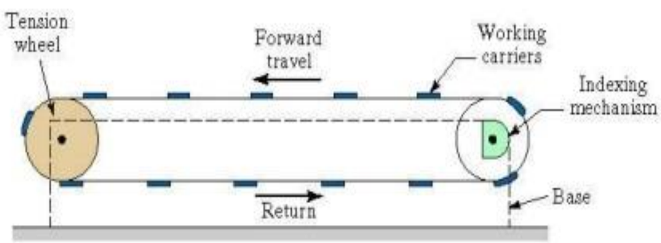
walking beam transfer system, showing various stage during transfer stage

Powered roller conveyor system

→ This type of system is used in general stock handling systems as well as in automated flow lines. The conveyor can be used to move pans or pallets possessing flat riding surfaces.
→ The rollers can be powered by either of two mechanisms. The first is a belt drive, in which a flat moving belt beneath the rollers provides the rotation of the rollers by friction.
→ A chain drive is the second common mechanism used to power the rollers.
→ Powered roller conveyors are versatile transfer systems because they can be used to divert work pallets into workstations or alternate tracks.

Chain-drive conveyor system

- → In chain-drive conveyor system either a chain or a flexible steel belt is used to transport the work carriers.
- → The chain is driven by pulleys in either an "over-and under" configuration, in which the pulleys turn about a horizontal axis, or an "around-the-corner" configuration, in which the pulleys rotate about a vertical axis.
- → This general type of transfer system can be used for continuous, intermittent, or non synchronous movement of work parts.
- → In the non synchronous motion, the work parts are pulled by friction or ride on an oil film along a track with the chain or belt providing the movement.
- → It is necessary to provide some sort of final location for the work parts when they arrive at their respective stations



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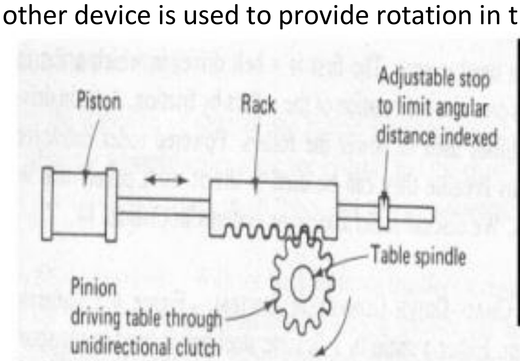
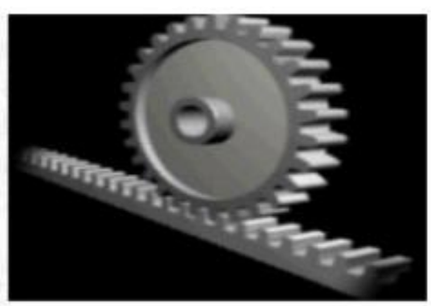
Rotary transfer mechanisms

Rack and pinion:

- → This mechanism is simple but is not considered especially suited to the high-speed operation often associated with indexing machines.
- → uses a piston to drive the rack, which causes the pinion gear and attached indexing table to rotate, A clutch or other device is used to provide rotation in the desired direction.





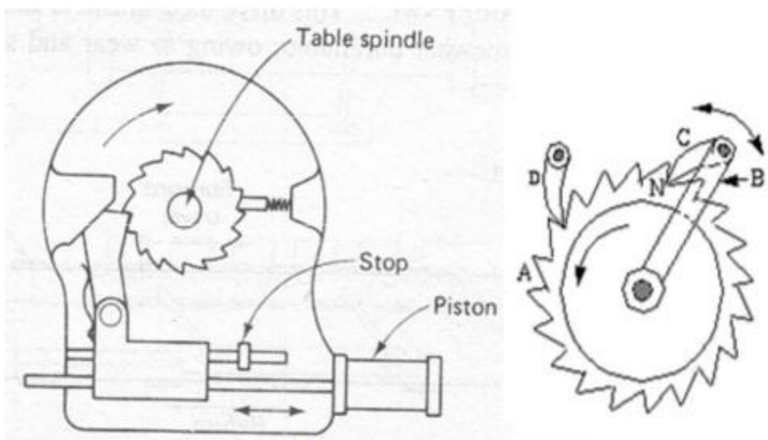
Ratchet and pawl:

→ A ratchet is a device that allows linear or rotary motion in only one direction, while preventing motion in the opposite direction.

→ Ratchets consist of a gearwheel and a pivoting spring loaded finger called a pawl that engages the teeth.

→ Either the teeth, or the pawl, are slanted at an angle, so that when the teeth are moving in one direction, the pawl slides up and over each tooth in turn, with the spring forcing it back with a 'click' into the depression before the next tooth.

→ When the teeth are moving in the other direction, the angle of the pawl causes it to catch against a tooth and stop further motion in that direction.



Rachet and pawl mechanism

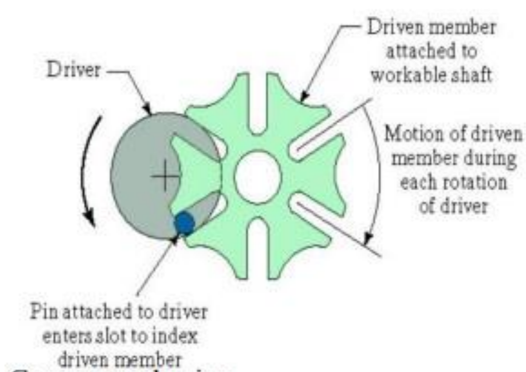
Geneva mechanism:

→ The two previous mechanisms convert a linear motion into a rotational motion. The Geneva mechanism uses a continuously rotating driver to index the table

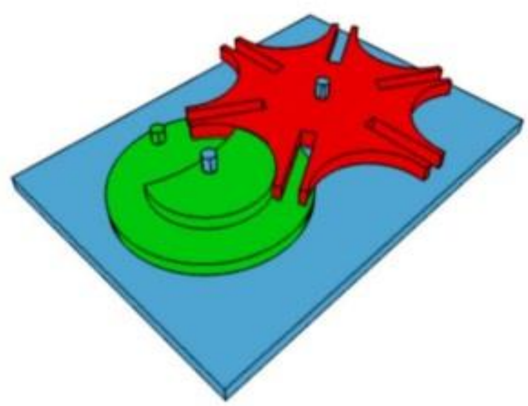
→ If the driven member has six slots for a six-station dial indexing machine, each turn of the driver will cause the table to advance one-sixth of a turn.

→ The driver only causes movement of the table through a portion of its rotation. For a six-slotted driven member, 120° of a complete rotation of the driver is used to index the table.

→ The other 240° is dwell. For a four-slotted driven member, the ratio would be 90° for index and 270° for dwell. The usual number of indexing per revolution of the table is four, five, six, and eight.



Geneva mechanism

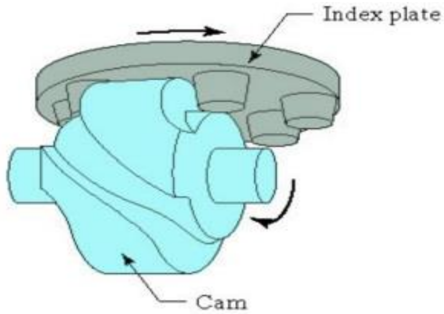


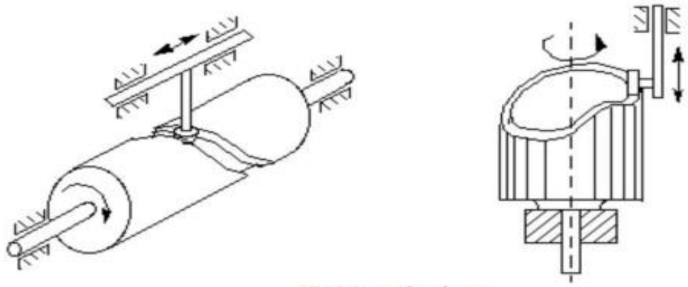
CAM Mechanisms:

→ Various forms of cam mechanism, an example of which is illustrated in Figure 18, provide probably the most accurate and reliable method of indexing the dial.

→ They are in widespread use in industry despite the fact that the cost is relatively high compared to alternative mechanisms.

→ The cam can be designed to give a variety of velocity and dwell characteristics.





CAM mechanisms

FUNDAMENTALS OF **AUTOMATED ASSEMBLY SYSTEM**

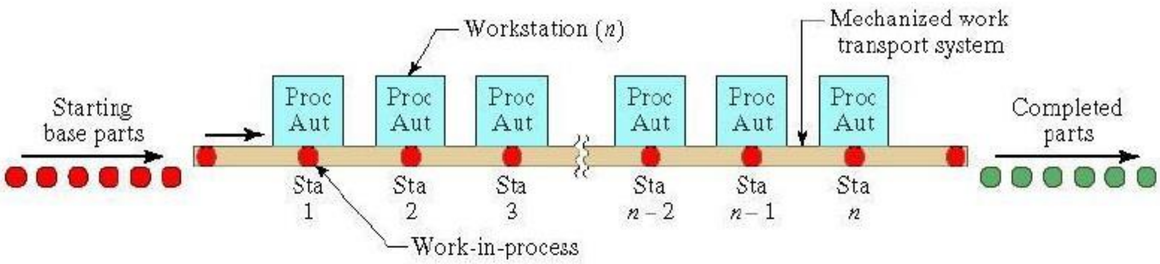
Automated assembly technology should be considered when the following conditions exist:

- → High product demand. Automated assembly systems should be considered for products made in millions of units (or close to this range).
- → Stable product design. In general, any change in the product design means a change in workstation tooling and possibly the sequence of assembly operations. Such changes can be very costly.
- → A limited number of components in the assembly.
- → The product is designed for automated assembly.

Types of automated assembly system

1. In-line type

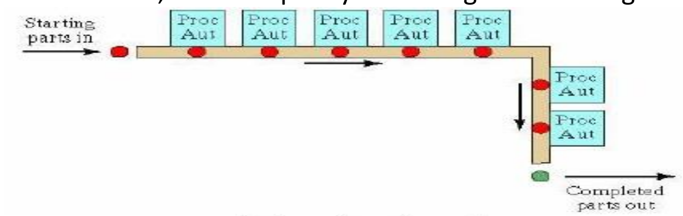
- → The in-line configuration consists of a sequence of workstations in a more-or-less straight-line arrangement.
- → An example of an in-line transfer machine used for metal-cutting operations
- → The objectives of the use of flow line automation are, therefore:
    1. To reduce labor costs
    2. To increase production rates
    3. To reduce work-in-process
    4. To minimize distances moved between operations
    5. To achieve specialization of operations
    6. To achieve integration of operations



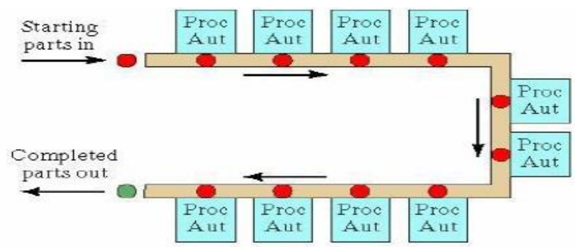
2. **Segmented In-Line Type**

→ The segmented in-line configuration consists of two or more straight-line arrangement which are usually perpendicular to each other with L-Shaped or U-shaped or Rectangular shaped as shown in figure .

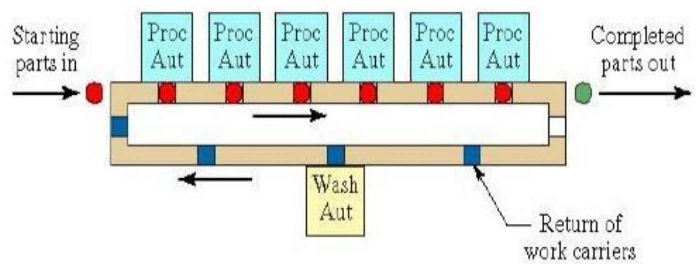
→ The flow of work can take a few 90° turns, either for work pieces reorientation, factory layout limitations, or other reasons, and still qualify as a straight-line configuration.



L-shaped configuration



U-shaped configuration



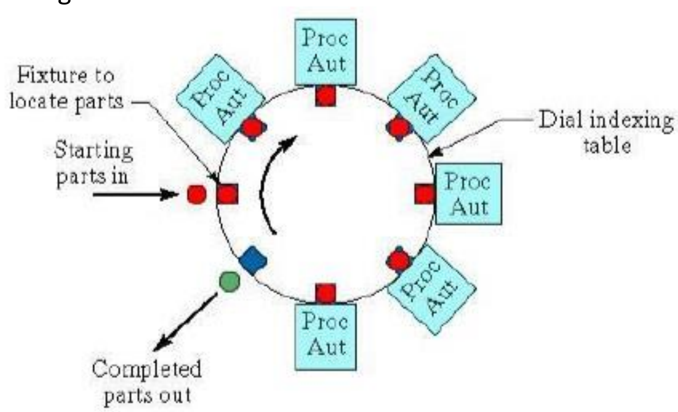
Rectangular-shaped configuration

3. **Rotary type**

→ In the rotary configuration, the work parts are indexed around a circular table or dial. The workstations are stationary and usually located around the outside periphery of the dial.

→ The parts ride on the rotating table and arc registered or positioned, in turn, at each station for its processing or assembly operation.

→ This type of equipment is often referred to as an indexing machine or dial index machine and the configuration is shown in Figure

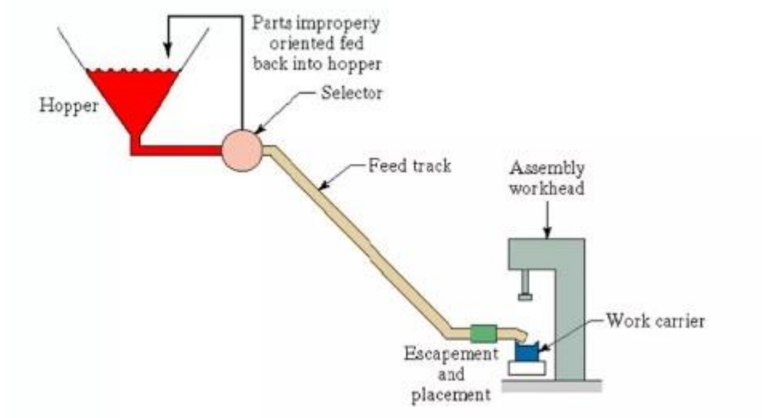


Rotary configuration

PART DELIVERY AT WORKSTATIONS

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

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



Vibratory Bowl Feeder

Most versatile of hopper feeders for small parts

Consists of bowl and helical track

- ✓ Parts are poured into bowl
- ✓ Helical track moves part from bottom of bowl to outlet

Vibration applied by electromagnetic base

- ✓ Oscillation of bowl is constrained so that parts climb upward along helical track

Selector and /or Orientor

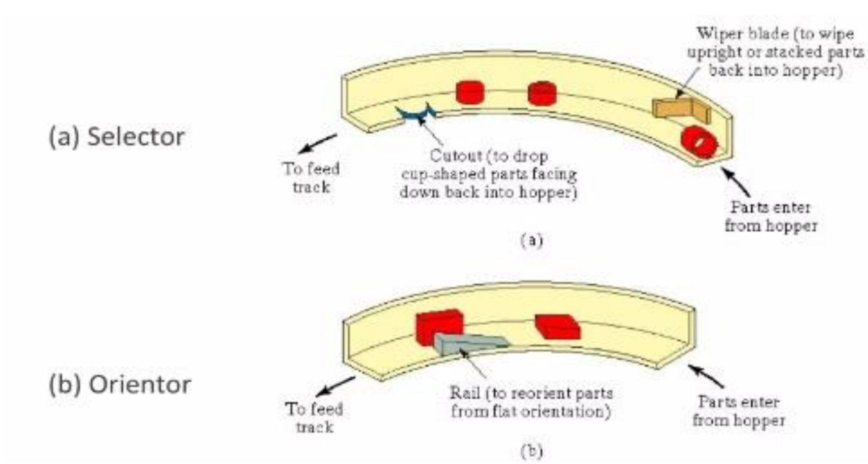
Purpose to establish the proper orientation of the components for the assembly work head

Selector

- ✓ Acts at a filter
- ✓ Only parts in proper orientation are allowed to pass through to feed track

Orientor

- ✓ Allows properly oriented parts to pass
- ✓ Reorients parts that are not properly oriented



Feed track

Moves parts from hopper to assembly work head

Categories:

- ✓ Gravity – hopper and feeder are located at higher elevation than work head
- ✓ Powered – uses air or vibration to move parts toward work head

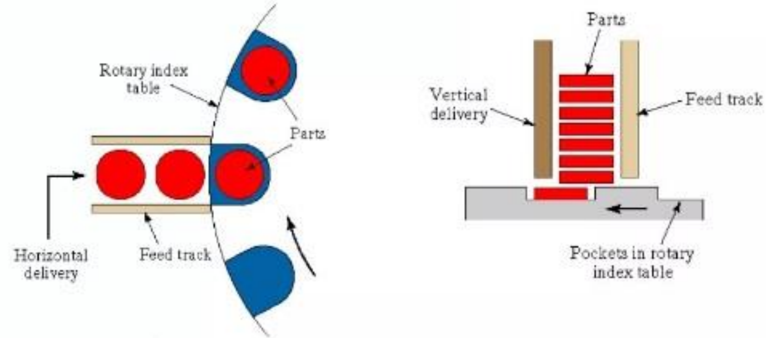
Escapement and Placement Devices

Escapement device:

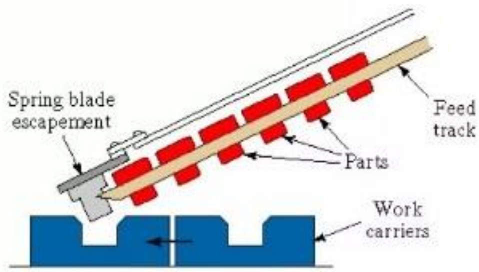
- ✓ Removes parts from feed track at time intervals that are consistent with the cycle time of the assembly work head

Placement device:

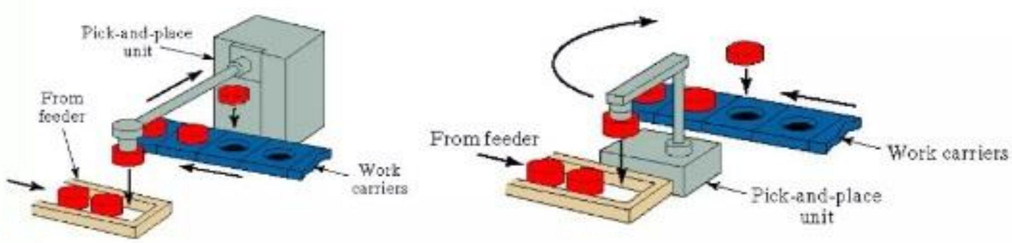
- ✓ Physically places the parts in the correct location at the assembly workstation
- ✓ Escapement and placement devices are sometimes the same device, sometime different devices



(a) Horizontal and (b) vertical devices for placement of parts onto dial-indexing table



Escapement of rivet-shaped parts actuated by work carriers



Two types of pick-and-place mechanisms for transferring base parts from feeders to work carriers

DESIGN FOR **AUTOMATED ASSEMBLY**

- ✓ A design for automated assembly is most often a simpler design that can reduce (manufacturing) system complexity, thus directly lowering costs for both the system and the end product. Proof of the savings possible through assembly automation systems is.
- ✓ Automated assembly refers to the use of mechanized and automated devices (conveying, fixturing, part feeding, pressing, soldering, plastic welding, dispensing, screwing, riveting, inspection and product ID) to perform the various functions in an assembly line or cell.

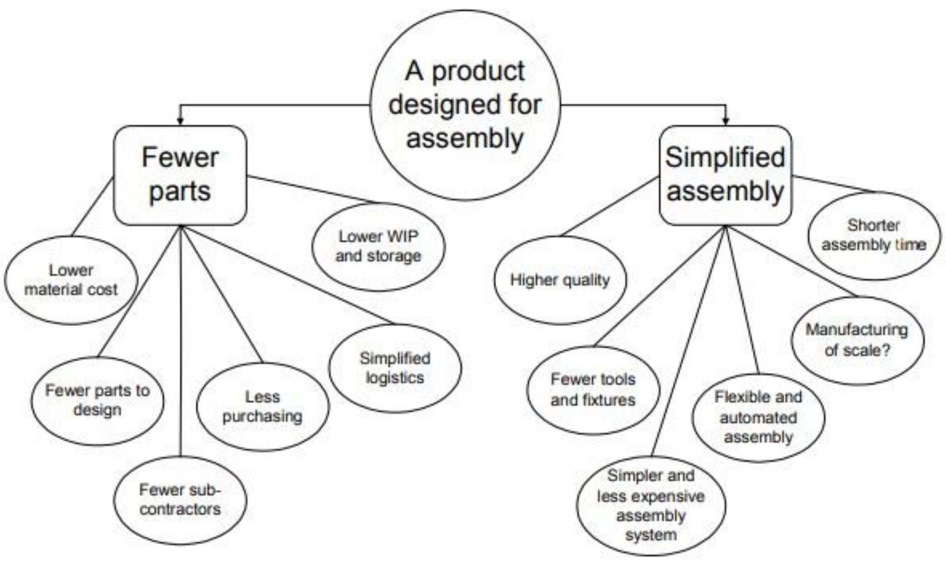
- ✓ Many of the DFA methods available today are focused on manual assembly. There are several aspects that are different in comparison between manual and automatic assembly.

- ✓ For example, the human being is very flexible in movement, speed, force, vision and in the ability to feel if an operation is correct and perhaps change it.

- ✓ These aspects are not as simple for a mechanical assembly unit or a robot. Therefore, there is a need to simplify the product in order to enable assembly with mechanical units. These simplifications may seem evident and just common sense, but still, when taken all into consideration, it is important to remember these many aspects. With a good producibility design, automation projects can be successful (Miyakawa, 1990a).

- ✓ A successful product design project includes low manufacturing system costs, which preferably are analysed early in the product design stage.

Short term- Initial goals for implementing DFA are often cost based, typically:
• Reduced number of components
• Reduced assembly time
• Reduced manufacturing and assembly costs
Long term- When applying DFA on more than one product there are potential long term goals for the whole company, such as:
• Improved product quality
• An environment for concurrent engineering



OVERVIEW OF **MATERIAL HANDLING EQUIPMENTS**
- ✓ Materials handling is loading, moving and unloading of materials.
- ✓ To do it safely and economically, different types of tackles, gadgets and equipment are used, when the materials handling is referred to as mechanical handling of materials.
- ✓ Materials handling as such is not a production process and hence does not add to the value of the product.
- ✓ It also costs money; therefore it should be eliminated or at least reduced as much as possible.
- ✓ However, the important point in favour of materials handling is that it helps production.
- ✓ Depending on the weight, volume and throughput of materials, mechanical handling of materials may become unavoidable.

The essential requirements of a good materials handling system may be summarized as:

i. Efficient and safe movement of materials to the desired place.
ii. Timely movement of the materials when needed.
iii. Supply of materials at the desired rate.
iv. Storing of materials utilising minimum space.
v. v. Lowest cost solution to the materials handling activities.

Functional scope of materials handling within an industry covers the following:

i. Bulk materials as well as unit materials handing. Bulk handling is particularly relevant in the processing, mining and construction industries. Unit materials handling covers handling of formed materials in the initial, intermediate and final stages of manufacture.
ii. Industrial packaging of in-process materials, semi finished or finished goods, primarily from the point of view of ease and safety of handling, storage and transportation. However, consumer packaging is not directly related to materials handling.
iii. Handling of materials for storage or warehousing from raw materials to finished product stage.

OBJECTIVES OF MATERIAL HANDLING

- ✓ Minimize cost of material handling.
- ✓ Minimize delays and interruptions by making available the materials at the point of use at right quantity and at right time.
- ✓ Increase the productive capacity of the production facilities by effective utilization of capacity and enhancing productivity.
- ✓ Safety in material handling through improvement in working condition.
- ✓ Maximum utilization of material handling equipment.
- ✓ Prevention of damages to materials.
- ✓ Lower investment in process inventory

SELECTION OF MATERIAL HANDLING EQUIPMENTS

<u>Properties Of The Material</u>

Whether it is solid, liquid or gas, and in what size, shape and weight it is to be moved, are important considerations and can already lead to a preliminary elimination from the range of available equipment under review. Similarly, if a material is fragile, corrosive or toxic this will imply that certain handling methods and containers will be preferable to others.

<u>Layout And Characteristics Of The Building</u>

Another restricting factor is the availability of space for handling. Low-level ceiling may preclude the use of hoists or cranes, and the presence of supporting columns in awkward places can limit the size of the material handling equipment. If the building is multi-storeyed , chutes or ramps for industrial trucks may be used. Layout itself will indicate the type of production operation (continuous, intermittent, fixed position or group) and can indicate some items of equipment that will be more suitable than others. Floor capacity also helps in selecting the best material handling equipment.

<u>Production Flow</u>

If the flow is fairly constant between two fixed positions that are not likely to change, fixed equipment such as conveyors or chutes can be successfully used. If, on the other hand, the flow is not constant and the direction changes occasionally from one point to another because several products are being produced simultaneously, moving equipment such as trucks would be preferable.

<u>Cost Considerations</u>

This is one of the most important considerations. The above factors can help to narrow the range of suitable equipment, while costing can help in taking a final decision. Several cost elements need to be taken into consideration when comparisons are made between various items of equipment that are all capable of handling the same load. Initial investment and operating and maintenance costs are the major cost to be considered. By calculating and comparing the total cost for each of the items of equipment under consideration, a more rational decision can be reached on the most appropriate choice.

Nature Of Operations

Selection of equipment also depends on nature of operations like whether handling is temporary or permanent, whether the flow is continuous or intermittent and material flow pattern-vertical or horizontal.

Engineering Factors

Selection of equipment also depends on engineering factors like door and ceiling dimensions, floor space, floor conditions and structural strength.

Equipment Reliability

Reliability of the equipment and supplier reputation and the after sale service also plays an important role in selecting material handling equipments.

MATERIAL HANDING EQUIPMENTS

Broadly material handling equipment's can be classified into two categories, namely:

- → Fixed path equipments, and
- → Variable path equipments.

(a) **Fixed path equipments** which move in a fixed path. Conveyors, monorail devices, chutes and pulley drive equipments belong to this category. A slight variation in this category is provided by the overhead crane, which though restricted, can move materials in any manner within a restricted area by virtue of its design. Overhead cranes have a very good range in terms of hauling tonnage and are used for handling bulky raw materials, stacking and at times palletizing.

(b)**Variable path equipments** have no restrictions in the direction of movement although their size is a factor to be given due consideration trucks, forklifts mobile cranes and industrial tractors belong to this category. Forklifts are available in many ranges, they are manoeuvrable and various attachments are provided to increase their versatility. Material Handing Equipments may be classified in five major categories.

1. **CONVEYORS**: Conveyors are useful for moving material between two fixed workstations, either continuously or intermittently. They are mainly used for continuous or mass production operations—indeed, they are suitable for most operations where the flow is more or less steady. Conveyors may be of various types, with rollers, wheels or belts to help move the material along: these may be power-driven or may roll freely. The decision to provide conveyors must be taken with care, since they are usually costly to install; moreover, they are less flexible and, where two or more converge, it is necessary to coordinate the speeds at which the two conveyors move.

2**. INDUSTRIAL TRUCKS**: Industrial trucks are more flexible in use than conveyors since they can move between various points and are not permanently fixed in one place. They are, therefore, most suitable for intermittent production and for handling various sizes and shapes of material. There are many types of truck petrol-driven, electric, handpowered, and so on. Their greatest advantage lies in the wide range of attachments available; these increase the trucks ability to handle various types and shapes of material.

3. **CRANES AND HOISTS**: The major advantage of cranes and hoists is that they can move heavy materials through overhead space. However, they can usually serve only a limited area. Here again, there are several

types of crane and hoist, and within each type there are various loading capacities. Cranes and hoists may be used both for intermittent and for continuous production.

4. **CONTAINERS**: These are either 'dead' containers (e.g. Cartons, barrels, skids, pallets) which hold the material to be transported but do not move themselves, or 'live' containers (e.g. wagons, wheelbarrows or computer self-driven containers). Handling equipments of this kind can both contain and move the material, and is usually operated manually.

5. **ROBOTS**: Many types of robot exist. They vary in size, and in function and maneuverability. While many robots are used for handling and transporting material, others are used to perform operations such as welding or spray painting.

PRINCIPLES OF MATERIAL HANDLING

Following are the principles of material handling:
1. **Planning principle:** All handling activities should be planned.
2. **Systems principle:** Plan a system integrating as many handling activities as possible and co-ordinating the full scope of operations (receiving, storage, production, inspection, packing, warehousing, supply and transportation).
3. **Space utilization principle:** Make optimum use of cubic space.
4. **Unit load principle:** Increase quantity, size, weight of load handled.
5. **Gravity principle:** Utilize gravity to move a material wherever practicable
6. **Material flow principle:** Plan an operation sequence and equipment arrangement to optimise material flow.
7. **Simplification principle:** Reduce combine or eliminate unnecessary movement and/or equipment.
8. **Safety principle:** Provide for safe handling methods and equipment.
9. **Mechanization principle:** Use mechanical or automated material handling equipment
10. **Standardization principle:** Standardize method, types, size of material handling equipment.
11. **Flexibility principle:** Use methods and equipment that can perform a variety of task and applications 12. **Equipment selection principle:** Consider all aspect of material, move and method to be utilised.
13. **Dead weight principle:** Reduce the ratio of dead weight to pay load in mobile equipment.
14. **Motion principle:** Equipment designed to transport material should be kept in motion.
15. **Idle time principle:** Reduce idle time/unproductive time of both MH equipment and man power.
16. **Maintenance principle:** Plan for preventive maintenance or scheduled repair of all handling equipment.
17. **Obsolescence principle:** Replace obsolete handling methods/equipment when more efficient method/equipment will improve operation.
18. **Capacity principle:** Use handling equipment to help achieve its full capacity.
19. **Control principle:** Use material handling equipment to improve production control, inventory control and other handling.
20. **Performance principle:** Determine efficiency of handling performance in terms of cost per unit handled which is the primary criterion.

CONVEYOR SYSTEMS

Different classes of conveyors forming the conveyor group is by far the most frequently used materials handling equipment primarily for conveying bulk materials in process industries and also for conveying certain types of unit loads in large quantities.

Classification of Conveyor Systems:

Conveyors

A. Belt Conveyor
1. flat
2. trough
3. closed
4. metallic
5. portable
6. telescoping

B. Chain Conveyor
1. apron or pan
2. slat
3. cross-bar or arm
4. car type/pallet
5. en-mass
6. carrier chain and flat-top
7. trolley
8. power and free
9. suspended tray or swing-tray

C. Haulage Conveyor
(A special class of chain conveyor in which load is pushed or pulled and the weight is carried by stationary troughs, surfaces or rail.)
1. drag chain
2. flight
3. tow
   (a) over-head
   (b) flush-floor
   (c) under-floor

D. Cable Conveyor

E. Bucket Conveyor
1. gravity discharge
2. pivoted bucket
3. bucket elevator (also included under III)

F. Roller Conveyor
1. gravity
2. powered/driven
3. portable

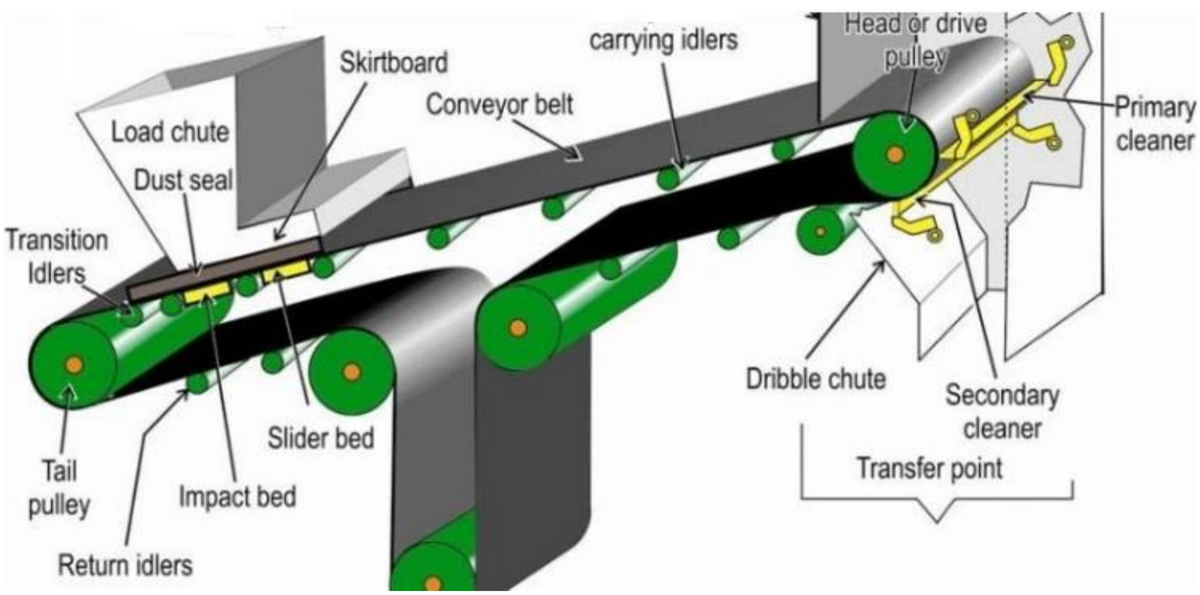
G. Screw Conveyor

H. Pneumatic Conveyor
1. pipe line
2. air-activated gravity (air slide)
3. tube

I. Hydraulic Conveyor

Flat Belt Conveyor:

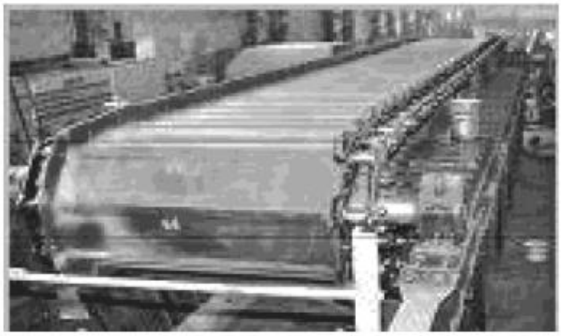
In this conveyor, the active side of belt remains flat supported by cylindrical rollers or flat slider bed. The conveyor is generally short in length and suitable for conveying unit loads like crates, boxes, packages, bundles etc. in manufacturing, shipping, warehousing and assembly operations. Flat belts are conveniently used for conveying parts between workstations or in an assembly line in mass production of goods.



Chain Conveyors:

The term chain conveyor means a group of different types of conveyors used in diverse applications, characterized by one or multiple strands of endless chains that travel entire conveyor path, driven by one or a set of sprockets at one end and supported by one or a set of sprockets on the other end. Materials to be conveyed are carried directly on the links of the chain or on specially designed elements attached to the chain.

The load carrying chain is generally supported on idle sprockets or guide ways. The endless chains are kept taught by suitable chain tensioning device at the non-driven end.



HAULAGE CONVEYORS:

Haulage conveyor is a special group of chain conveyors. As the name implies, the material is dragged, pushed or towed by means of a chain or chains, making use of flights or surfaces which are parts of the chain themselves. The weight of the material is generally carried by stationary troughs, surfaces, or wheeled trucks/dollies on rails/floor. In certain designs, the chain may be replaced by cables. These conveyors are run at slow speed (15 to 60 mpm) and being built for heavy duty need little maintenance. However, the chains undergo wear under heavy tension and work in one direction only.

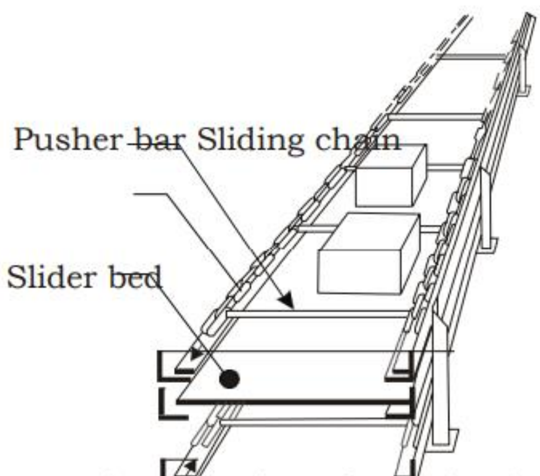
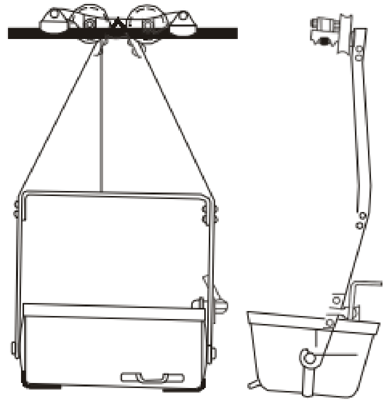


Fig. Schematic view of a pusher-bar drag conveyor

CABLE CONVEYORS:

These conveyors form a distinct group of materials handling equipment to transport people and bulk materials in load carrying buckets, using overhead moving cables and/or wire ropes and are com- posed of one or more spans from the loading point to the discharge point/points covering long distances upto several kilometers. These conveyors are also known as ropeways or aerial tramways

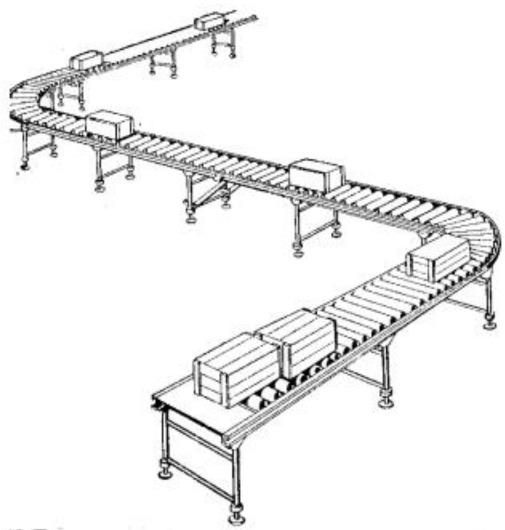


ROLLER CONVEYORS:

A roller conveyor supports unit type of load on a series of rollers, mounted on bearings, resting at fixed spacings on two side frames which are fixed to stands or trestles placed on floor at certain intervals. A roller conveyor essentially coveys unit loads with at least one rigid, near flat surface to touch and maintain stable equilibrium on the rollers, like ingots, plates, rolled stock, pipes, logs, boxes, crates, moulding boxes etc. The spacing of rollers depend on the size of the unit loads to be carried, such that the load is carried at least by two rollers at any point of time. Roller conveyors are classified into two groups according to the principle of conveying action.

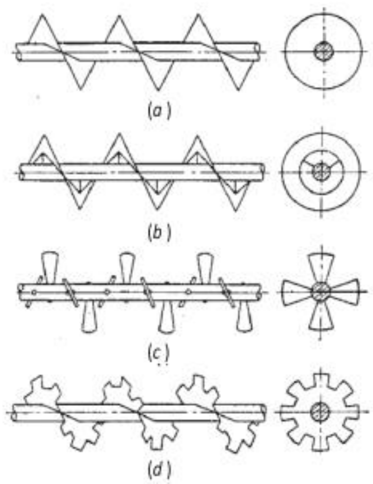
These are:

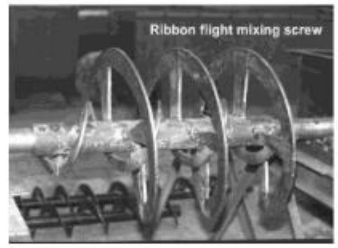
1. Unpowered or Idle Roller Conveyor.
2. Powered or Live Roller Conveyor.



SCREW CONVEYORS:

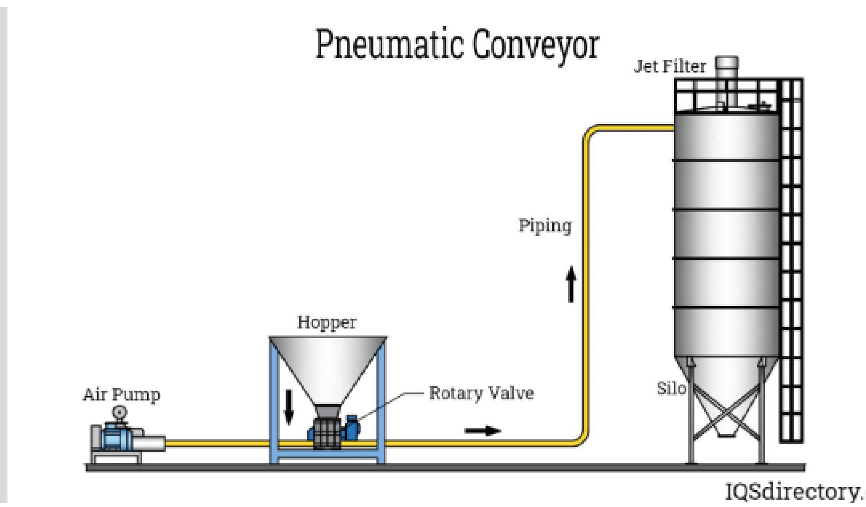
A screw conveyor consists of a continuous or interrupted helical screw fastened to a shaft which is rotated in a U-shaped trough to push fine grained bulk material through the trough. The bulk material slides along the trough by the same principle a nut prevented from rotating would move in a rotating screw. The load is prevented from rotating with screw by the weight of the material and by the friction of the material against the wall of the trough. A screw conveyor is suitable for any pulverized or granular non viscous material, and even at high temperature. The conveyor is particularly suitable for mixing or blending more than one materials during transportation, and also for controlling feed rate of materials in a processing plant. Abrasion and consequently certain amount of degradation of the material is unavoidable, hence it is not suitable for brittle and high abrasive materials. It is also not suitable for large-lumped, packing or sticking materials.





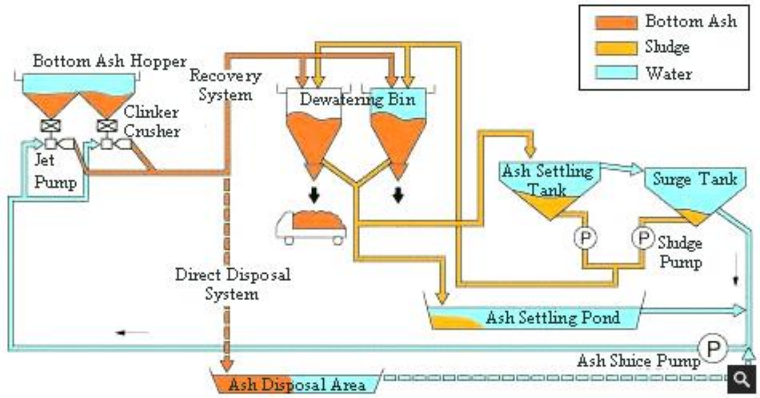
PNEUMATIC CONVEYORS:

Pneumatic conveying is the process of conveying granular / powdered materials by floating the materials in a gas, primarily air, and then allowing it to flow to the destination through a closed pipe. The operating principle common to all types of pneumatic conveying is that motion is imparted to the material by a fast moving stream of air. Thus any pneumatic conveyor consists of an air supply equipment (blower or compressor), pipelines, product storages, air lock feeders and dust filters.



HYDRAULIC CONVEYORS:

Moving bulk materials along pipes or channels (troughs) in a stream of water is called Hydraulic conveying. The mixture of materials and water is termed as pulp. Pump is used for conveying of pulp through pipe under pressure. In channels the conveying takes place down the inclination due to gravity. A hydraulic conveying system generally consists of a mixer where the material and water is mixed to form the requisite pulp. Depending on starting size of the bulk material, the materials may have to be crushed / ground in a crushing plant and screening facility. The prepared pulp is then pumped by a suitable pumping and piping system. In certain installation a suitable recovery system may be incor- porated at the delivery end for dewatering the material. Hydraulic conveyors are used in many industries, mining operations and construction works. Some of the popular uses are to dispose ash and slag from boiler rooms, deliver materials from mines and sand and water to fill up used mines, to remove slag from concentration plants, to quench, granulate and convey furnace slag to disposal points, to move earth and sand in large construction projects and for land filling etc.



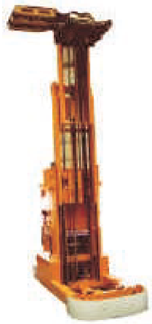
AUTOMATIC GUIDED **VEHICLES**

- AGV is one of the widely used types of material handling device in an FMS. These are battery-powered vehicles that can move and transfer materials by following prescribed paths around the shop floor.
- They are neither physically tied to the production line nor driven by an operator like forklift. Such vehicles have on-board controllers that can be programmed for complicated and varying routes as well as load and unload operations.
- The computer for the materials handling system or the central computer provides overall control functions, such as dispatching, routing and traffic control and collision avoidance.
- AGV's usually complement an automated production line consisting of conveyor or transfer
- systems by providing the flexibility of complex and programmable movement around the manufacturing shop.

TYPES OF AGVS

Automated guided vehicle systems: consists of the computer, software and technology that are the "brains" behind the AGV. Without computer software systems and communications networks, only the simplest AGV functions can be performed.
Camera guided AGVs: are used when precise guidance accuracy is needed, such as in crowded environments and smaller sized facilities. An on-board camera focuses and guides the AGV while performing.
Forked AGVs :are used to pick up and deliver various loads, such as pallets, carts, rolls and others. These can be manually driven as well as used automatically, and have the ability to lift loads to many levels.
Inertial guided AGVs: use a magnet sensing device, a gyroscope that measures the unit's heading and a wheel odometer that calculates the distance traveled. Magnets mounted beneath the floor are detected by the on-board magnetic sensing device and combine with the first two readings to give an accurate positional location.
Large chassis/unit load AGVs :are used to transport heavier loads with various transfer devices such as roller beds, lift/lower mechanisms and custom mechanisms.
Laser guided AGVs :use mounted laser scanners that emit a laser and reflect back from targets. The vehicle's location can be determined based on distance to the target and time of reflection information.
Optical guided AGVs :use a latex-based photosensitive tape on a facility's floor for guidance. Distance is measured by use of wheel odometers, which establish stop locations for the AGV along the course.
Outrigger AGVs :have two horizontal stabilizing legs (outriggers) to provide lateral support, and are used to handle pallets, rolls and racks.
Small chassis AGVs :are able to maneuver through crowded workplaces through laser sensing, while transporting smaller loads.
Smart vehicle AGVs: are capable of determining their own traffic control and routing without necessitating a central controller.
Tug/tow AGVs :are used to pull trailers and are usually manned by an operator who adds and removes the trailers at designated stops. These can follow a basic loop or a more complicated path.

Wire guided AGVs :use a charged wire that is buried beneath the floor for proper guidance and has a small antenna composed of metal coils mounted on their bottoms. The stronger the field between the buried wire and antennae, the higher the voltage induced to the coils.

VEHICLE **GUIDANCE TECHNOLOGY**

Types of Vehicle Guidance Technologies (Types of AGV Guidance System)

There are many AGV guidance technologies/methods available and their selection will depend on need, application, and environmental constraints.

The-various types of vehicle guidance technologies/methods are:

1. Electromagnetic guidance (or wire guided) system
2. Tape (or paint strips) guidance system
3. Laser guidance system
4. Rectangular coordinate guidance system
5. Optical guidance system
6. Inertial guidance system
7. Image recognition guidance system
8. GPS guidance system
9. Ultrasonic guided system
10. Vision guided system

1. Wire guidance system,
2. Paint strips system, and
3. Self-guided (or autonomous) vehicles.

I. Wire Guidance System (Imbedded Guide Wires Technology)

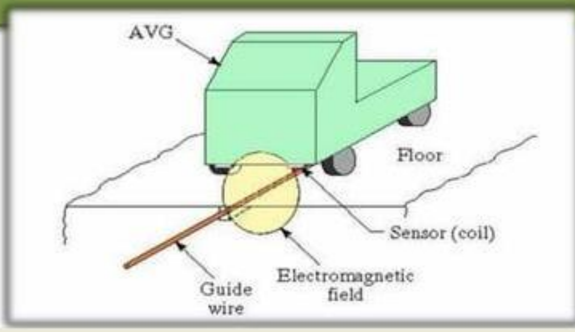
Thé wire guidance system is the most commonly used vehicle guided technology in the manufacturing shop.

Construction:

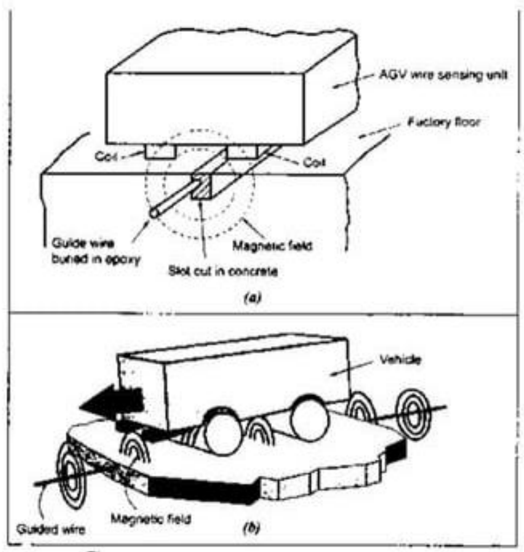
- In this wire guidance system, the control wire is embedded in the factory floor along which the AGV is to transverse.
- For this purpose, a rectangular slot is cut into the concrete floor and the wire is placed in position with the rest of the slot being filled with epoxy, as shown in Fig.

Wired Navigation

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



The wire embedded is actually in many segments depending upon the required path of travel.



Working principle:

- Wire guidance is based on the fact that an electrical conductor through which an AC current is flowing will create an electromagnetic field around itself as shown in Fig. Since the field is stronger closer to the wire, the AGV is able to steer itself using an antenna that detects the strength of the field.
- More than one AGV can be located on a single wire, and different guide wires can carry electricity at different frequencies, which enables a single system to control AGVs on different paths.

- The guiding antenna consists of two coils that straddle the guide Wire. The difference in electrical voltage between the two coils will create the steering signal.
- The steering signal indicates to the steering motor which direction to turn.
- As long as the antenna coils are centered over the guide wire, there is no difference in voltage, and the steering signal will be zero.
- If the vehicle begins to move away from centre, then the voltage will rise in one coil on the antenna and drop in the other coil which will change the steering signal and cause the vehicle to steer in one direction or the other.
- Guide wires are also used for indicating position of the AGV with respect to its target, pick up point, or drop off point. The vehicle position is updated using a cross antenna that detects guide wires that are perpendicular to the guide path From these perpendicular guide wires, the controller or supervisor can trace the location of the AGV.

Advantages and disadvantages of wire guidance system:

Advantages:

The advantages of employing wire guidance technology for guiding the AGV are:

(i) Simple and highly reliable.
(ii) High accuracy.
(iii) It is not influenced by sound, light, snow, ice, dirt, etc.
(iv) Low cost.
(v) No pollution and damage.

Disadvantages:

The disadvantages of wire guidance technology are:

1. It is inflexible. Thus the method should not be used wherever frequent changes in the path are required.
2. This method is not suitable when the floor is uneven and not suitable for embedding wire.
3. Metal encumbrances in the floor may influence the operation.
4. Additional sensors are necessary for longitudinal information.
5. Guide wires must' be installed permanently and changing the .AGV becomes costly and disruptive to the manufacturing process.
6. Overtime the guide wires will become brittle and break when this happens the wire will have to be dug out and new wire will have to laid.

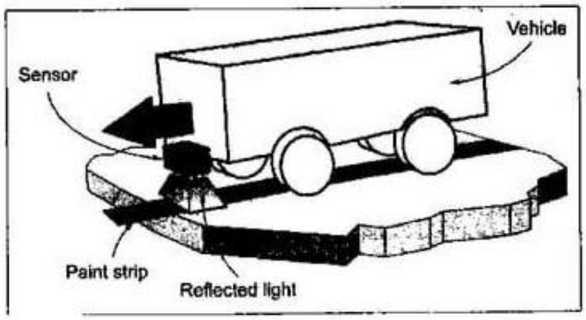
2. Paint Strips Guidance System

In this method, the paint strips are used to define the pathway and the AGV uses optical sensors to follow the painted strip.

✓ The strips can be painted, taped or sprayed onto the floor.

Working principle:

- This type of system uses a line of fluorescent particles or dye to indicate the path for the vehicle to follow.
- Sensors on the vehicle are used to detect reflected light to indicate to the vehicle its position in relation to the specified path, as shown in Fig.4.20.



Typical paint strip guidance system

Information codes can also be set on the path and the sensor will 'read' the codes and perform the action instructed by the code such as: stop, turn left, turn right, slow down, etc.

Advantages and disadvantages of paint strip guidance system

Advantages:

The advantages of paint strip guidance system over the wire guidance system as follows:

- The paint strip guidance systems are particularly advantageous in environments with high electrical interference, where embedded wires cannot be used. Also useful in environment where guide wires in the floor surface is not practical.
- A new path can be laid out or painted with very little expense.
- It is also easy to repair a path if it is damaged.

Disadvantages:

The disadvantages of paint strip guidance system are given

1. The paint strips wear out in a high traffic area.
2. These systems must have a clean environment, and the path must Clear of all obstructions including a piece of paper.

VEHICLE MANAGEMENT

There are two aspects of management and coordination of unmanned vehicles. They are:

1. Traffic control, and
2. Vehicle dispatching.

1. Traffic Control

✓ The purpose Of traffic control in an automated guided vehicle system is to minimise interference between vehicles and to prevent collisions.

Methods of traffic control: There are three methods for traffic control:

I. Forward-sensing (or on-board vehicle sensing) control,

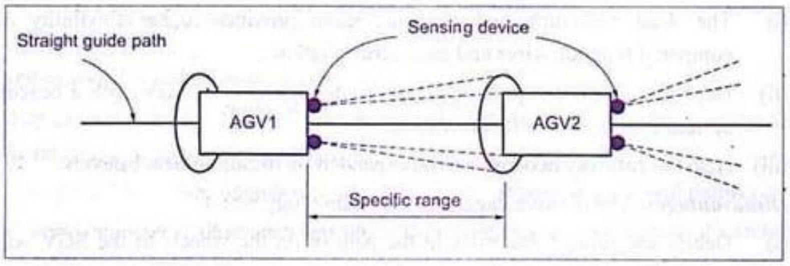
2. Zone-sensing control, and

3. Combinational control.

1. Forward-Sensing Control (Or On-Board Vehicle Sensing)

✓ In forward-sensing control, also called on-board vehicle sensing, the AGV is equipped with obstruction detecting sensors that can identify another AGV in front of it, and slow down or stop.

Sensor types used in this control include optical and ultrasonic devices that cause the AGV to stop when the presence of another vehicle is detected



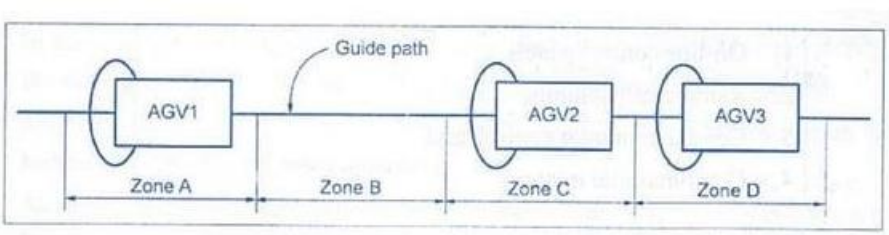
As shown in Fig., there is a specified range or distance that must be maintained between AGVs. The sensing device continuously "look" forward to sense any object that falls within the specified range. If one vehicle gets too close to another vehicle, then the sensors will detect that vehicle and cause the one in the rear to stop. The movement of vehicle occurs again only when the obstacle is removed.

2. Zone-sensing Control

✓ The zone-sensing control is the most widely used in which the guide path areas of the shop floor are divided into zones. Only one AGV is allowed in a zone at a given time. v/

✓ In zone-sensing control, the central computer keeps track of the entire guide path, which is divided into zones. Once an AGV enters a zone, that zone becomes blocked for other AGVs.

✓ Fig. illustrates a typical zone-sensing control system.



- It may be noted that the zone length is generally enough to hold one AGV plus additional space allowance for safety and other considerations.
- When a zone is full, it activates a block on the zone until it becomes free zone again.
- For instance, in Fig., zones A, C and D are blocked and zone B is free. The AGV2 is blocked from entering zone D by AGV3, but the AGV2 and AGVI are free to enter zone B.

3. Combinatorial Control

In combinatorial control, both the forward-control sensing and zone-sensing controls are selectively used to obtain the benefits of both strategies.

Vehicle Dispatching

- ✓ For an effective functioning of AGVS, AGVs must be dispatched in a timely manner, as and when they are needed.
- Dispatching methods: The vehicle dispatching can be achieved using any of the following four methods.

    1. On-line control panels,
    2. Remote call stations,
    3. Central computer control, and
    4. Combinatorial method.

Safety Features Provided for AGV's

- Movement speeds of less-than-walking-pace: This ensures that the AGV does not injure personnel by overtaking them unawares as they walk along the guide path.
- Automatic stopping of the vehicle: This is initiated if it strays a short distance from the guide-path. This off-set distance is called the acquisition distance.
- Obstacle detection sensor on the vehicle; This on-board sensor is used to detect obstacles along the path ahead, including humans.
- Emergency bumper: All commercial AGVs are equipped with safety devices such as emergency bumpers. When the bumper makes contact with an object, the AGV is programmed to brake automatically.
- Additional features: Other available safety devices that may be found on AGVs include warning lights and warning bells.

AUTOMATED STORAGE AND **RETRIEVAL SYSTEMS (AS/RS)**

- Automated Storage and Retrieval Systems (ASRS) are means to high density, hands free buffering of materials in distribution and manufacturing environments.
- There are several classes of Automated Storage and Retrieval (AS/RS) that are characterized by weight and size handling characteristics.

Unit Load AS/RS
Mini Load AS/RS
Carousel AS/RS

Unit Load AS/RS

→ Unit Load AS/RS machines are generally pallet-handling systems with capacities that vary much like lift trucks.

→ Unit load AS/RS Systems are often quite tall and sometimes support the building shell that contains them.

→ The density, security and labor/machinery savings they provide, make them a good choice in a variety of applications from cold storage to general warehousing.

Mini Load AS/RS

→ Mini Load AS/RS—operating on the same principles as the Unit Loads these mini load machines handle smaller and lighter loads.

→ These typically range from metal trays and totes to shipping cartons. Mini loads may be used in traditional stockroom applications but are also well suited as buffers to support manufacturing processes and shipping systems.

Carousel AS/RS

→ Carousel AS/RS, the industrial carousel may be integrated with a specific purpose robotic inserter/ extractor for small load buffering. Very often, carousel AS/RS is applied in lights-out stockroom.

→ This technology finds itself at the heart of systems varying widely in application from the food industry to the manufacturing floor.

INDUSTRY 4.0

What is Industry 4.0 ?

- Industry 4.0 is a concept related to the fourth industrial revolution (4IR) which is associated with the advancements of cyber-physical systems. It describes the rise of automated systems and data exchange technology with in the manufacturing industries.

- Industry 4.0 examples

  1. The Internet of Things
  2. The Industrial Internet of Things (IIoT)
  3. Artificial Intelligence

The Evolution of Industry from 1.0 to 4.0

❑ Industry 1.0

- Mechanical production facilities were introduced to the world in the late 18th century, paving the way for steam-powered machines to help workers in manufacturing. The concept of Industry 1.0 is also deemed as the beginning of industry culture.

❑ Industry 2.0

- Industry 2.0 began at the start of the 20th century with the development of machines running on electrical energy. The first assembly line was built during this era, further streamlining the process of mass production.

The Evolution of Industry from 1.0 to 4.0

- ❑ Industry 3.0
  - Industry 3.0 was centralized around the advances in the electronics industry in the last few decades of the 20^{th} century. As expected, the automation of machines and introduction of advanced software systems has evolved over the years as advancements are made in the electronics and IT industries.
- ❑ Industry 4.0
  - Industry 4.0 as a concept was introduced in the 1990s as the internet and telecommunications transformed the way we connected and exchanged information. This technology merged the boundaries of the physical and virtual world further to manufacturing, introducing of new technologies into the industry.

How is Industry 4.0 used in manufacturing ?

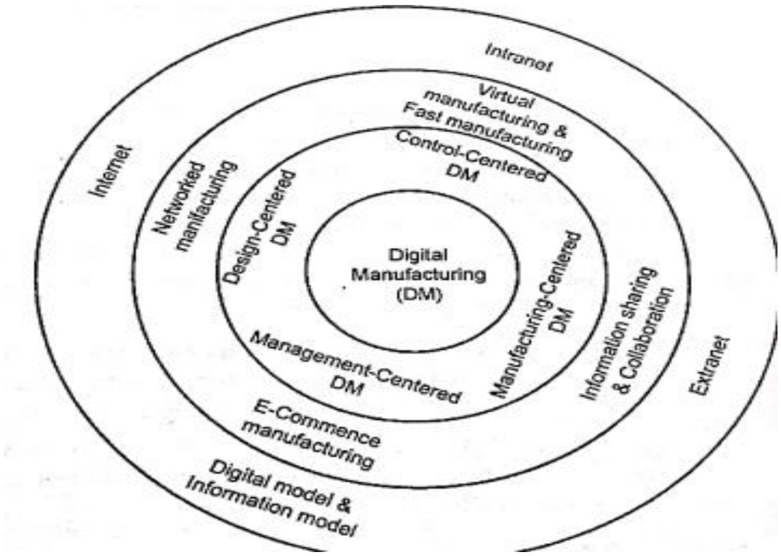
- ❑ Supply Chain Management
  - Industry 4.0 technologies allow businesses to have greater insight, control, and data visibility over their supply chain. Smart manufacturing means companies can deliver products and services faster, cheaper, and with better quality.
- ❑ Predictive Maintenance
  - Industry 4.0 solutions and a connected factory floor can be used to predict potential downtime in machinery before it occurs and also sense problems before they arise and can even provide insight on how to solve issues before they become a problem.

How is Industry 4.0 used in manufacturing ?

- ❑ Tracking and Optimization
  - Industry 4.0 related technology makes it easier for businesses to track inventory, quality, and optimization opportunities related to logistics. Connected manufacturing and the IoT provides employees with visibility over company assets worldwide. Standard asset management tasks such as asset transfers, disposals, reclassifications, and adjustments can be streamlined and managed centrally and in real-time.

DIGITAL MANUFACTURING

Digital manufacturing is the use of an integrated, computer-based system comprised of simulation, 3D visualization, analytics and collaboration tools to create product and manufacturing process definitions simultaneously.



Digital manufacturing can be broken down into three dimensions:

(a) Product Life Cycle,

(b) Smart Factory, and

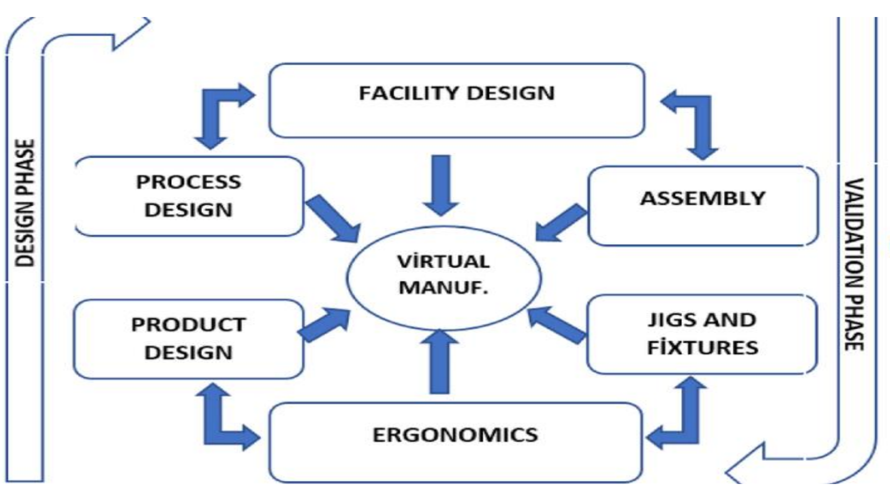
(c) Value Chain Management.

→ The Product Life Cycle starts with an engineering design definition and follows through sourcing, production and service life.

→ Digital manufacturing is an integrated approach to manufacturing that uses computer technologies to improve manufacturing operations.

VIRTUAL MANUFACTURING

Virtual manufacturing is a computer-based technology for defining, simulating, and visualizing the manufacturing process early in the design stage, when some, if not all, manufacturing-related issues can be detected and addressed.



UNITS-III GROUP TECHNOLOGY AND FMS

PART **FAMILIES**

- ✓ A part family is a collection of parts which are similar either because of geometry and size or because similar processing steps are required in their manufacture.
- ✓ The parts within a family are different, but their similarities are close enough to merit their identification as members of the part family.
- ✓ The major obstacle in changing over to group technology from a traditional production shop is the problem of grouping parts into families. There are three general methods for solving this problem.

i. Visual inspection

ii. Production flow analysis

iii. Parts classification and coding system

PARTS CLASSIFICATION **AND** CODING **SYSTEMS**

Parts classification and coding systems can be grouped into three general types:

i. Systems based on design attribute

ii. Systems based on part manufacturing attributes

iii. Systems based on both design and manufacturing attributes

Part Design Attributes

→ Basic (External/Internal) shape
→ Axisymmetric/Prismatic/sheet metal
→ Length/diameter ratio
→ Material
→ Major dimensions
→ Minor dimensions
→ Tolerances
→ Surface finish

Part Manufacturing Attributes

→ Major process of manufacture
→ Surface treatments/coatings
→ Machine tool/processing equipment
→ Cutting tools
→ Operation sequence
→ Production time
→ Batch quantity
→ Production rate
→ Fixtures needed

If we take a look at a machine tool manufacturing industry, large part families can be grouped as:

1. Heavy parts - beds, columns etc.
2. Shafts, characterized by large L/D ratios
3. Spindles (long shafts, screw rods included)
4. Non-rounds (small prismatic parts)
5. Gears, disc type parts (whose L/D ratios are small)

Some of the **coding systems** that have been successfully implemented in process planning are given below:

→ OPITZ system
→ The CODE system
→ The KK-3 system
→ The MICLASS system
→ DCLASS system
→ COFORM (coding for machining)

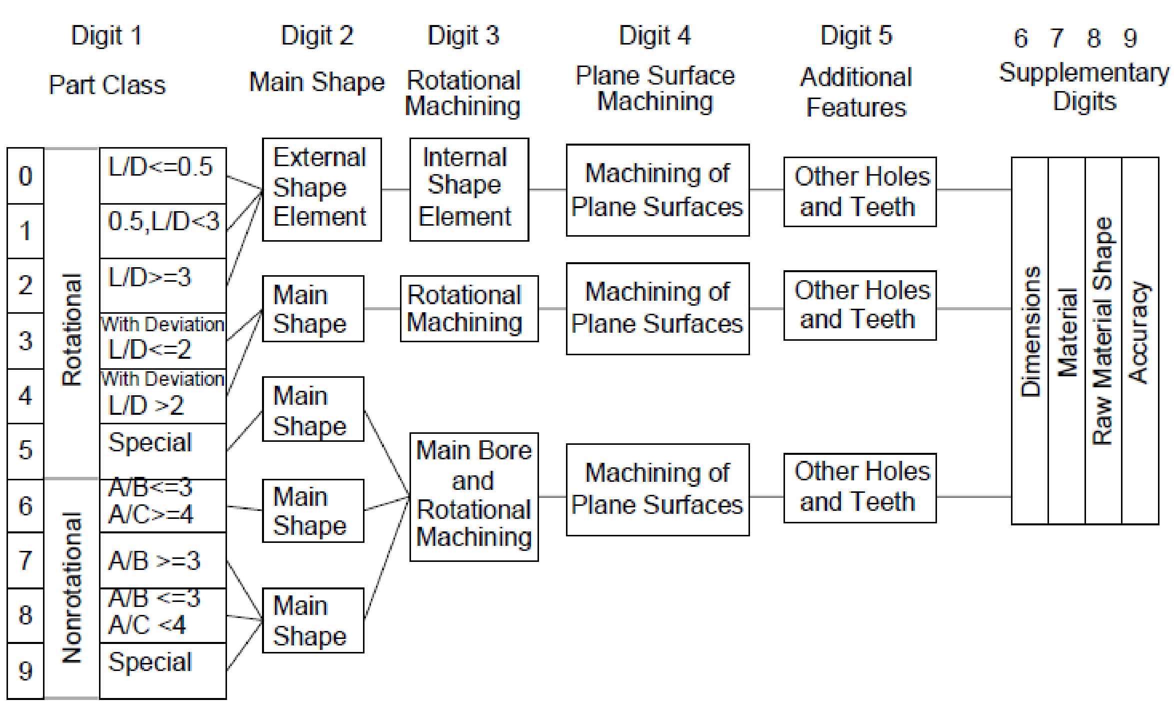
When implementing a parts classification and coding system, most companies can purchase a commercially available package or develop a system for their own specific use. Commercial systems have the advantage of less lead time in implementation. Brief treatment of some commercial systems is given in subsequent sections.

OPITZ CLASSIFICATION SYSTEM

The Opitz coding system uses the following digit sequence:

12345 6789 ABCD

- The basic code consists of nine digits, which can be extended by adding four more digits. The first nine digits are intended to convey both design and manufacturing data.
- The general interpretation of the nine digits is indicated in Fig . The first five digits, 12345, are called the "form code" and describe the primary design attributes of the part.
- The next four digits, 6789, constitute the "supplementary code". It indicates some of the attributes that would be of use to manufacturing (work material, raw work piece shape, and accuracy).
- The extra four digits, "ABCD", are referred to as the "secondary code" and are intended to identify the production operation type and sequence. The secondary code can be designed by the firm to serve its own particular needs. In the form code, the first digit identifies whether the part is a rotational or a non rotational part.
- It also describes the general shape and proportions of the part. Fig shows the specification scheme. For the rotational work pieces, the coding of the first five digits is given in Fig.



	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		Smoothing Shape Elements		No Hole, No Break Through	No Surface Machining	No Auxiliary Holes
1		0.5<L/D<3	Stepped one end or Smooth	No Shape Elements	Smooth or Stepped on One End	No Shape Elements	Surface Plane/ Curved	Axial, Not on Pitch Circle Dia
2		L/D > 3		Thread		Thread	External Plane Surface, Circular Graduation	Axial on Pitch Circle Diameter
3				Groove		Groove	External Groove and/or Slot	Radial, Not on Pitch circle Dia.
4			Stepped Both Ends	No Shape Elements	Stepped Both Ends	No Shape Elements	External Spline (Polygon)	Radial, on Pitch Circle Dia.
5	Non rotational Parts			Thread		Thread	External Plane Surface/Slot Spline	Axial and/ Radial and/ other Direction
6				Groove		Groove	Internal Plane Surface or Slot	Spur Gear Teeth
7				Functional Cone		Functional Cone	Internal Spline (Polygon)	Bevel Gear Teeth
8				Operating Speed		Operating Speed	Internal or Slot/ External Polygon	Other Gear Teeth
9				All Others		All Others	All Others	All Others

THE MICLASS SYSTEM

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

The component attributes coded in the first 12 digits of the MICLASS number are as follows:

1st digit	Main shape
2nd and 3rd digits	Shape elements
4th digit	Position of shape elements
5th and 6th digits	Main dimensions
7th digit	Dimension ratio
8th digit	Auxiliary dimension
9th and 10th digits	Tolerance codes
11th and 12th digits	Material codes

One of the unique features of MICLASS system is that parts can be coded using a computer interactively. To classify a given part design, the user responds to a series of questions asked by the computer. The number of questions depends on the complexity of the part. For a simple part, as few as seven questions are needed to classify the part. For an average part, the number of questions ranges between 10 and 20. On the basis of responses

THE CODE SYSTEM

- → The CODE system is a parts classification and coding system developed and marketed by Manufacturing Data System, Inc (MDSI), of Ann Arbor, Michigan. Its most universal application is in design engineering for retrieval of part design data, but it also has applications in manufacturing process planning, purchasing, tool design, and inventory control.
- → The code number has eight digits. For each digit, there are 16 possible values (zero through 9 and A through F) which are used to describe the parts 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 cylinder, flat, block, or other. The interpretation of the remaining digits forms a chain-type structure. Hence the CODE system possesses a hybrid structure.

BENEFITS OF GROUP TECHNOLOGY

When group technology is applied, a manufacturing company will typically realize the following benefits:

Product engineering -

- Reduce part proliferation
- Help design standardization
- Provide manufacturing feed back

Manufacturing engineering -

- Process selection
- Tool selection
- Machine purchases
- Material handling

Production engineering -

- Reduce lead time
- Reduce delays
- Reduce set-up time
- Improve product quality

Production planning and control

- Group scheduling
- Stock accountability
- Reduce expediting
- Improved product design
- Reduced materials handling

Other benefits

- Increased productivity
- Improved accuracy in estimation of costs
- Greater standardization and variety reduction
- Reduced set up times
- Better product delivery (Helps to implement just-in-time (JIT) manufacturing)
- Reduced cost of purchasing
- Improved plant efficiency

PRODUCTION FLOW ANALYSIS

- Production flow analysis is a method in which part families are identified and machine tools are grouped based on the analysis of the sequence of operations for the various products manufactured in the plant.
- Parts, which may not be similar in shape but require similar sequence of operations, are grouped together to form a family.
- The resulting families are then used to design or establish machine cells. PFA employs clustering algorithms to manufacturing cells.
- After gathering the needed data, i.e. the part number and machine routing for every product, the computer is employed to sort out the products into groups, each of which contains parts that require identical process routings and is called a pack.
- Each pack is given an identification number, and packs having similar routings are grouped together. Next zoning is used to identify the machine tools form rational machine cell.

GROUPING OF PARTS **AND** MACHINES **BY RANK ORDER CLUSTERING METHOD**

The steps in using the Rank Order Clustering Algorithm are as follow:

1. Assign **binary weights $BW_i = 2^{m-i}$** to each **row *i*** of the machine-part indicator matrix, where m is the number of machines and n is the number of parts.
2. Determine the **decimal equivalent (DE)** of the binary value of each **column *j*** using the formula:

3. Rank the columns in decreasing order of their DE values. Break ties arbitrarily.. Rearrange the columns based on this ranking. If no rearrangement is necessary, stop. Otherwise, go to step 4.
4. For each rearranged **column *j*** of the matrix, assign **binary weights $BW_j = 2^{n-j}$.**
5. Determine the **decimal equivalent (DE)** of the binary value of each **row *i*** using the formula:

6. Rank the rows in decreasing order of their DE values. Break ties arbitrarily. Rearrange the rows based on this ranking. If no rearrangement is necessary, stop. Otherwise, go to step 1.

Let's assign the codes below to represent all the Parts and Machines:

Pump Parts:	***Machines:***
P1: Pocket	M1: Sawing Machine
P2: Upper Swage	M2: Turning Machine
P3: Lower Swage	M3: Milling Machine
P4: Upper Discriminator	M4: Horizontal Boring Machine
P5: Lower Discriminator	M5: Drilling Machine
P6: Body Pipe	M6: Honing Machine
	M7: Deburring Machine

(Types of Products)

(Types of Machines/Equipment)

	P1	P2	P3	P4	P5	P6
M1	**1**	**0**	**0**	**0**	**0**	**0**
M2	**0**	**1**	**1**	**1**	**0**	**0**
M3	**0**	**0**	**1**	**1**	**1**	**0**
M4	**1**	**0**	**0**	**0**	**0**	**1**
M5	**0**	**1**	**1**	**0**	**0**	**0**
M6	**1**	**0**	**0**	**0**	**0**	**1**
M7	**0**	**1**	**0**	**0**	**1**	**0**

To begin: Arrange the machines and products into a matrix as shown on the left.

Enter a '**1**' for a product (P) that is processed by a machine (M).

Enter a '**0**' for a product (P) that is not processed by a machine (M).

	P1	P2	P3	P4	P5	P6	
M1	1	0	0	0	0	0	2^6
M2	0	1	1	1	0	0	2^5
M3	0	0	1	1	1	0	2^4
M4	1	0	0	0	0	1	2^3
M5	0	1	1	0	0	0	2^2
M6	1	0	0	0	0	1	2^1
M7	0	1	0	0	1	0	2^0

Assign Binary Weights to each row *i*

Step 1: Assign binary weight **$BW_i = 2^{m-i}$** to each **row *i*** of the matrix, where ***m*=7** (the number of machines).

	P1	P2	P3	P4	P5	P6	
M1	1	0	0	0	0	0	64
M2	0	1	1	1	0	0	32
M3	0	0	1	1	1	0	16
M4	1	0	0	0	0	1	8
M5	0	1	1	0	0	0	4
M6	1	0	0	0	0	1	2
M7	0	1	0	0	1	0	1
DE of the binary values of each column *j*	74	37	52	48	17	10	

e.g. DE_2= 64x0 + 32x1+ 16x0 + 8x0 + 4x1+ 2x0 + 1x1
= 0+ 32 +0+0+ 4 +0+ 1 = 37

Step 2: Calculate the **decimal equivalent (DE)** of the binary values of each **column *j*** using the formula:

$$DE_j = \sum_{i=1}^{m} (BW_i)(a_{ij})$$

	P1	P2	P3	P4	P5	P6	
M1	1	0	0	0	0	0	64
M2	0	1	1	1	0	0	32
M3	0	0	1	1	1	0	16
M4	1	0	0	0	0	1	8
M5	0	1	1	0	0	0	4
M6	1	0	0	0	0	1	2
M7	0	1	0	0	1	0	1
	74	37	52	48	17	10	
Rank of DE values	1	4	2	3	5	6	

Step 3: Rank the columns in decreasing order of their DE values.

	P1	P3	P4	P2	P5	P6
M1	1	0	0	0	0	0
M2	0	1	1	1	0	0
M3	0	1	1	0	1	0
M4	1	0	0	0	0	1
M5	0	1	0	1	0	0
M6	1	0	0	0	0	1
M7	0	0	0	1	1	0
	74	52	48	37	17	10
Columns re-arranged in order of Rankings →	1	2	3	4	5	6

Step 4: Re-arrange the columns in the running order of the rankings.

	P1	P3	P4	P2	P5	P6
M1	1	0	0	0	0	0
M2	0	1	1	1	0	0
M3	0	1	1	0	1	0
M4	1	0	0	0	0	1
M5	0	1	0	1	0	0
M6	1	0	0	0	0	1
M7	0	0	0	1	1	0
	2^5	2^4	2^3	2^2	2^1	2^0

← Assign Binary Weights to each column *j*

Step 5: Assign binary weight $BW_j = 2^{n-j}$ to each **column** ***j*** of the matrix, where ***n*=6** (the number of parts).

	P1	P3	P4	P2	P5	P6	
M1	1	0	0	0	0	0	32
M2	0	1	1	1	0	0	28
M3	0	1	1	0	1	0	26
M4	1	0	0	0	0	1	33
M5	0	1	0	1	0	0	20
M6	1	0	0	0	0	1	33
M7	0	0	0	1	1	0	6
	32	16	8	4	2	1	

↑ DE of the binary values of each row *i*

Step 6: Calculate the **decimal equivalent (DE)** of the binary values of each **row** ***i*** using the formula:

$$DE_i = \sum_{j=1}^{m} (BW_j)(a_{ij})$$

e.g. DE_6= 32x1 + 16x0 + ... + 1x1
= 32 + 1 = 33

	P1	P3	P4	P2	P5	P6	DE value	Rank
M1	1	0	0	0	0	0	32	3
M2	0	1	1	1	0	0	28	4
M3	0	1	1	0	1	0	26	5
M4	1	0	0	0	0	1	33	1
M5	0	1	0	1	0	0	20	6
M6	1	0	0	0	0	1	33	2
M7	0	0	0	1	1	0	6	7
	32	16	8	4	2	1		

Rank of DE values

Step 7: Rank the rows in decreasing order of their DE values.

	P1	P3	P4	P2	P5	P6	DE value	Rank
M4	1	0	0	0	0	1	33	1
M6	1	0	0	0	0	1	33	2
M1	1	0	0	0	0	0	32	3
M2	0	1	1	1	0	0	28	4
M3	0	1	1	0	1	0	26	5
M5	0	1	0	1	0	0	20	6
M7	0	0	0	1	1	0	6	7

Rows re-arranged in order of Rankings

Step 8: Re-arrange the rows in the running order of the rankings.

	P1	P3	P4	P2	P5	P6	Binary weight
M4	1	0	0	0	0	1	2^6
M6	1	0	0	0	0	1	2^5
M1	1	0	0	0	0	0	2^4
M2	0	1	1	1	0	0	2^3
M3	0	1	1	0	1	0	2^2
M5	0	1	0	1	0	0	2^1
M7	0	0	0	1	1	0	2^0

Assign Binary Weights to each row *i*

Step 9: Assign binary weight $BW_i = 2^{m-i}$ to each **row** ***i*** of the matrix, where ***m*=7** (the number of machines).

(Note that this is a repeat of step 1 again)

	P1	P3	P4	P2	P5	P6	
M4	1	0	0	0	0	1	64
M6	1	0	0	0	0	1	32
M1	1	0	0	0	0	0	16
M2	0	1	1	1	0	0	8
M3	0	1	1	0	1	0	4
M5	0	1	0	1	0	0	2
M7	0	0	0	1	1	0	1
DE of the binary values of each column *j* →	112	14	12	11	5	96	

Step 10: Calculate the **decimal equivalent (DE)** of the binary values of each **column *j*** using the formula:

$$DE_j = \sum_{i=1}^{m} (BW_i)(a_{ij})$$

	P1	P3	P4	P2	P5	P6	
M4	1	0	0	0	0	1	64
M6	1	0	0	0	0	1	32
M1	1	0	0	0	0	0	16
M2	0	1	1	1	0	0	8
M3	0	1	1	0	1	0	4
M5	0	1	0	1	0	0	2
M7	0	0	0	1	1	0	1
	112	14	12	11	5	96	
Rank of DE values →	1	3	4	5	6	2	

Step 11: Rank the columns in decreasing order of their DE values.

	P1	P6	P3	P4	P2	P5
M4	1	1	0	0	0	0
M6	1	1	0	0	0	0
M1	1	0	0	0	0	0
M2	0	0	1	1	1	0
M3	0	0	1	1	0	1
M5	0	0	1	0	1	0
M7	0	0	0	0	1	1
	112	96	14	12	11	5
Columns re-arranged in order of Rankings →	1	2	3	4	5	6

Step 12: Re-arrange the columns in the running order of the rankings.

	P1	P6	P3	P4	P2	P5
M4	1	1	0	0	0	0
M6	1	1	0	0	0	0
M1	1	0	0	0	0	0
M2	0	0	1	1	1	0
M3	0	0	1	1	0	1
M5	0	0	1	0	1	0
M7	0	0	0	0	1	1
	2^5	2^4	2^3	2^2	2^1	2^0

← Assign Binary Weights to each column *j*

Step 13: Assign binary weight **$BW_j = 2^{n-j}$** to each **column *j*** of the matrix, where ***n*=6** (the number of parts).

	P1	P6	P3	P4	P2	P5	DE
M4	1	1	0	0	0	0	48
M6	1	1	0	0	0	0	48
M1	1	0	0	0	0	0	32
M2	0	0	1	1	1	0	14
M3	0	0	1	1	0	1	13
M5	0	0	1	0	1	0	10
M7	0	0	0	0	1	1	3
	32	16	8	4	2	1	

DE of the binary values of each row *i*

Step 14: Calculate the decimal equivalent (DE) of the binary values of each row i using the formula:

$$DE_i = \sum_{j=1}^{m} (BW_j)(a_{ij})$$

	P1	P6	P3	P4	P2	P5	DE	Rank
M4	1	1	0	0	0	0	48	1
M6	1	1	0	0	0	0	48	2
M1	1	0	0	0	0	0	32	3
M2	0	0	1	1	1	0	14	4
M3	0	0	1	1	0	1	13	5
M5	0	0	1	0	1	0	10	6
M7	0	0	0	0	1	1	3	7
	32	16	8	4	2	1		

Step 15: Rank the rows in decreasing order of their DE values.

Since the ranking is now neatly arranged in order, stop the process. We can now identify the groupings.

Group 1:	Group 2:
P1, P6	P2, P3, P4, P5
M1, M4, M6	M2, M3, M5, M7

The following grouping, as derived from the Rank Order Clustering Algorithm, shall be presented to Dominic for consideration:

Group 1		Group 2	
Product Family 1	**Machine Cell 1**	**Product Family 2**	**Machine Cell 2**
P1: Pocket	**M1:** Sawing Machine	**P2:** Upper Swage	**M2:** Turning Machine
P6: Body Pipe	**M4:** Horizontal Boring Machine	**P3:** Lower Swage	**M3:** Milling Machine
	M6: Honing Machine	**P4:** Upper Discriminator	**M5:** Drilling Machine
		P5: Lower Discriminator	**M7:** Deburring Machine

FLEXIBLE MANUFACTURING SYSTEM (FMS)

A flexible manufacturing system (FMS) is an arrangement of machines ... interconnected by a transport system. The transporter carries work to the machines on pallets or other interface units so that work-machine registration is accurate, rapid and automatic. A central computer controls both machines and transport system.

BASIC COMPONENTS OF FMS

The basic components of FMS are:

1. Workstations
2. Automated Material Handling and Storage system.
3. Computer Control System

1. Workstations:

In present day application these workstations are typically computer numerical control (CNC) machine tools that perform machining operation on families of parts. Flexible manufacturing systems are being designed with other type of processing equipments including inspection stations, assembly works and sheet metal presses. The various workstations are

(i) Machining centers
(ii) Load and unload stations
(iii) Assembly work stations
(iv) Inspection stations
(v) Forging stations
(vi) Sheet metal processing, etc.

2. Automated Material Handling and Storage system:

The various automated material handling systems are used to transport work parts and subassembly parts between the processing stations, sometimes incorporating storage into function. The various functions of automated material handling and storage system are

(i) Random and independent movement of work parts between workstations
(ii) Handling of a variety of work part configurations
(iii) Temporary storage
(iv) Convenient access for loading and unloading of work parts
(v) Compatible with computer control

3. Computer Control System:

It is used to coordinate the activities of the processing stations and the material handling system in the FMS.

The various functions of computer control system are:

(i) Control of each work station

(ii) Distribution of control instruction to work station

(iii) Production control

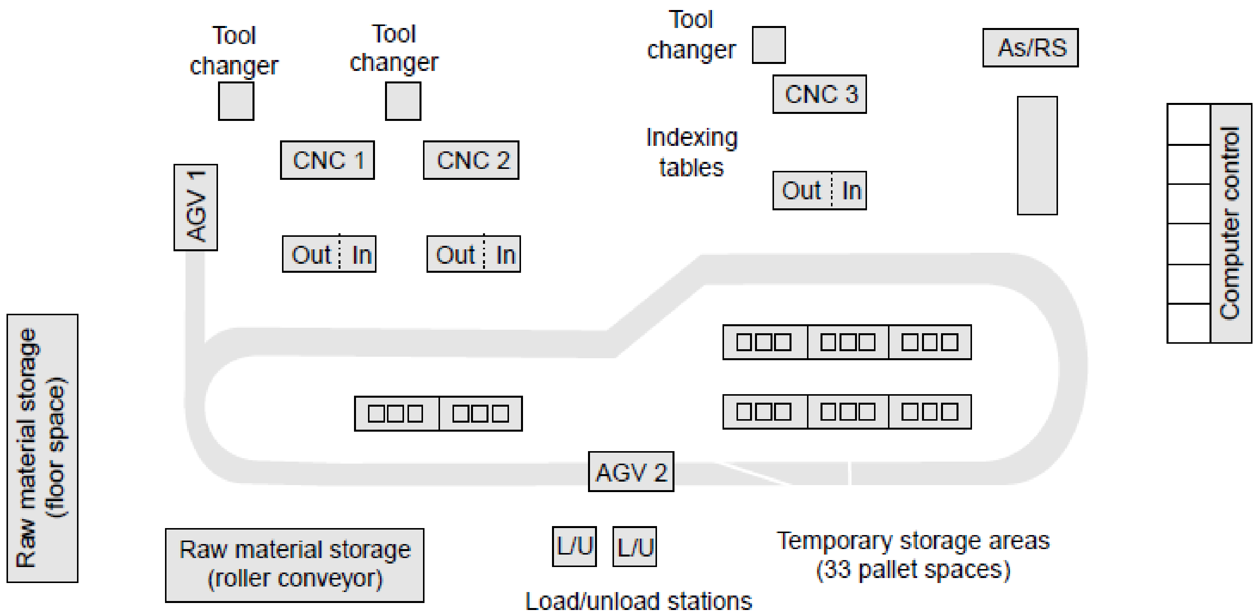
(vi) Traffic control

(v) Shuttle control

(vi) Work handling system and monitoring

(vii) System performance monitoring and reporting

The FMS is most suited for the mid variety, mid value production range.



Flexible manufacturing system

FMS LAYOUT **CONFIGURATIONS**

An FMS may include a configuration of interconnected workstations with computer terminals that process the end-to-end creation of a product. Functions may include loading and unloading, machining and assembly, storing, quality testing, and data processing.

The material handling system establishes the FMS layout. Most layout configurations FMSs can be divided into five categories:

(1) inline layout,

(2) loop layout

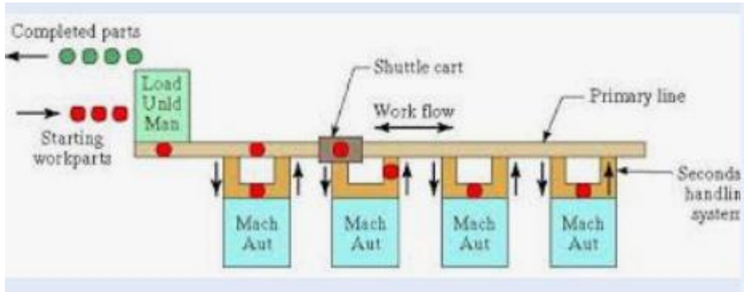
(3) ladder layout.

(4) open field layout,

(5) robot-centered cell.

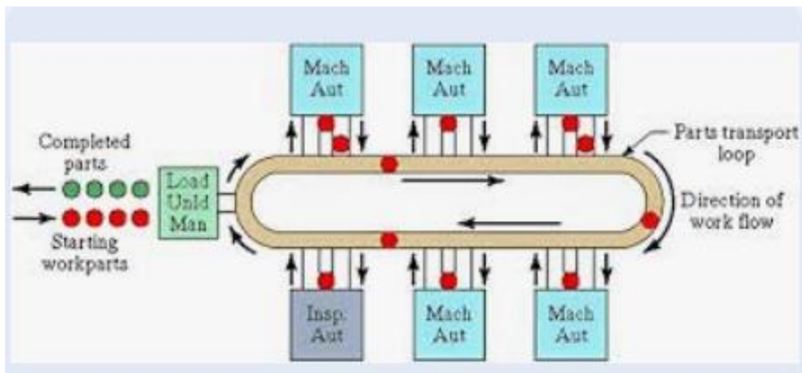
Progressive or Line type:

The machines and handling system are arranged in a line as shown in the Fig. It is most appropriate for a system in which the part progress from one workstation to the next in a well defined sequence with no back flow. The operation of this type of system is very similar to transfer type. Work always flows in unidirectional path as shown in Fig.



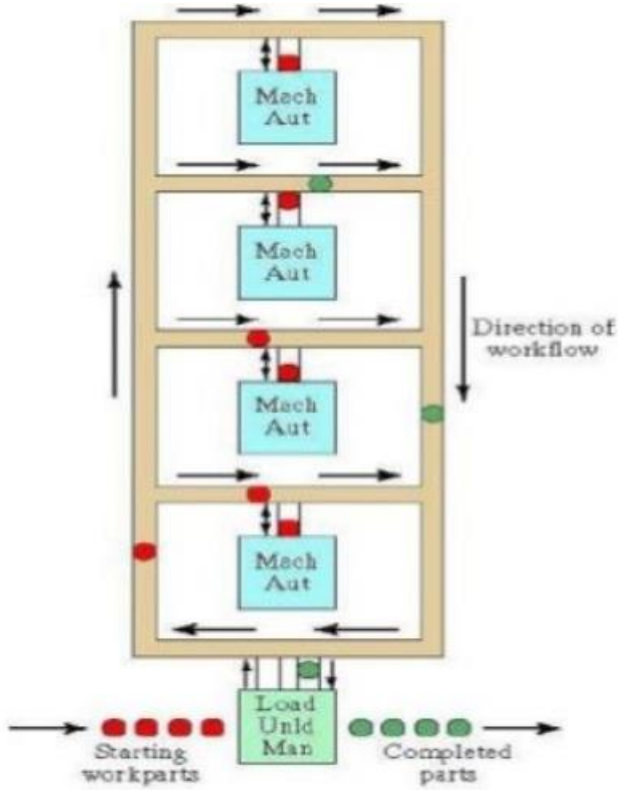
2. Loop Type:

The basic loop configuration is as shown in Fig. The parts usually move in one direction around the loop, with the capability to stop and be transferred to any station. The loading and unloading station are typically located at one end of the loop Fig.



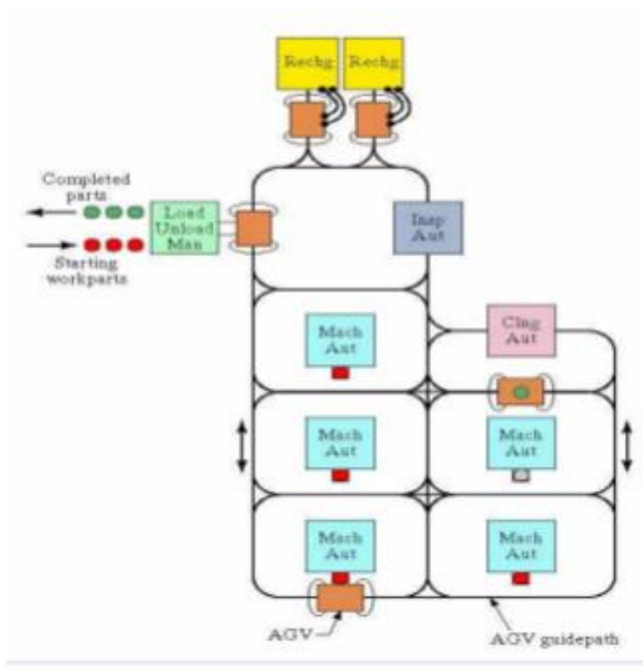
3. Ladder Type:

The configuration is as shown in Fig. The loading and unloading station is typically located at the same end. The sequence to the operation/transfer of parts from one machine tool to another is in the form of ladder steps as shown in Fig.



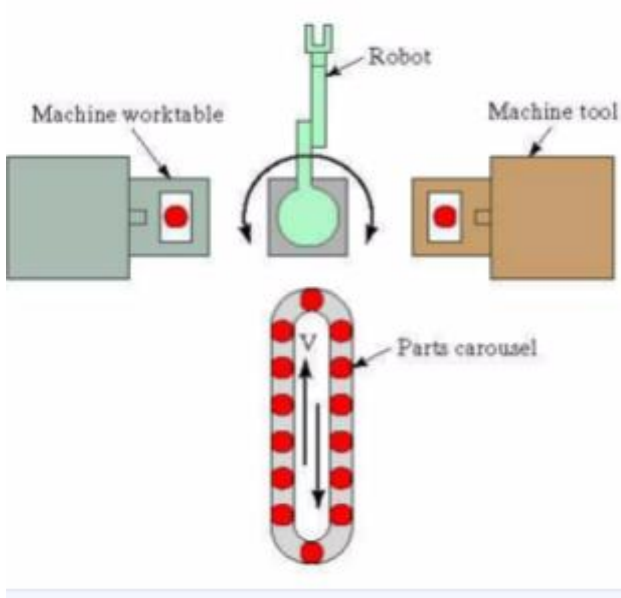
4.**Open Field Type:**

The configuration of the open field is as shown in Fig. The loading and unloading station is typically located at the same end. The parts will go through all the substations, such as CNC machines, coordinate measuring machines and wash station by the help of AGV's from one substation to another.



5. Robot Centered Type:

Robot centered cell is a relatively new form of flexible system in which one or more robots are used as the material handling systems as shown in Fig. Industrial robots can be equipped with grippers that make them well suited for handling of rotational parts.



FMS PLANNING **AND** IMPLEMENTATION **ISSUES**

Implementation of an FMS represents a major investment and commitment by the user company. It is important that the installation *of* the system be preceded by thorough planning and design, and that its operation be characterized by good management of all resources: machines, tools, pallets, parts, and people. Our discussion of these issues is organized along these lines:

(1) FMS planning and design issues and

(2) FMS operational issues.

→ **FMS planning and design issues**

The initial phase of FMS planning must consider the parts that will he produced by the *sys*tem. The issues are similar to those in GT machine cell planning

Part family considerations. Any FMS must be designed to process a limited range of part (or product) styles. The boundaries of the range must be decided. In effect, the part family that will be processed 011the FMS must be defined. the definition of part families to be processed un the FMS can be based on product commonality as well as on part similarity. The term *product commonality* refers 10 different components used on the same product. Many successful FMS installations arc designed to accommodate part families defined by this criterion. This allows all of the components required to assemble a given product unit to be completed just prior to beginning of assembly,

Processing requirements. The types of parts and their processing requirements determine the types of processing equipment that will be used in the system. In machining applications. Non-rotational parts are produced by machining centers, milling machines, and like machine tools: rotational parts are machined by turning centers and similar equipment.

Physical characteristics *of the work parts,* The size and weight of the parts determine the size of the machines at the workstations and the size of the material handling system that must be used

Production volume, Quantities to be produced by the system determine how many machines Will be required. Production volume is also a factor in selecting the most appropriate type of material handling equipment for the system.

→ **FMS operational issues.**

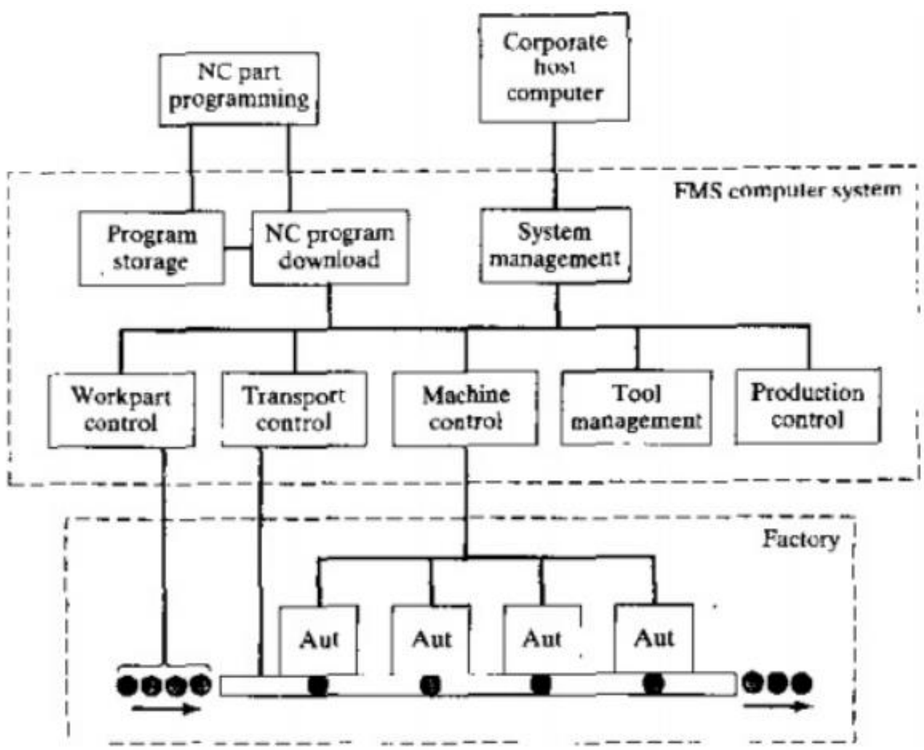
Scheduling: and dispatching. Scheduling of production in the FMS is dictated b)' the master production schedule. Dispatching is concerned with launching of parts into the system at the appropriate times. Several of the problem areas below are related to the scheduling issue.

Machine loading. This problem is concerned with allocating the operations and tooling resources among the machines in the system to accomplish the required production schedule.

Part routing. Routing decisions involve selecting the routes that should be followed by each part in the production mix to maximize use of workstation resources.

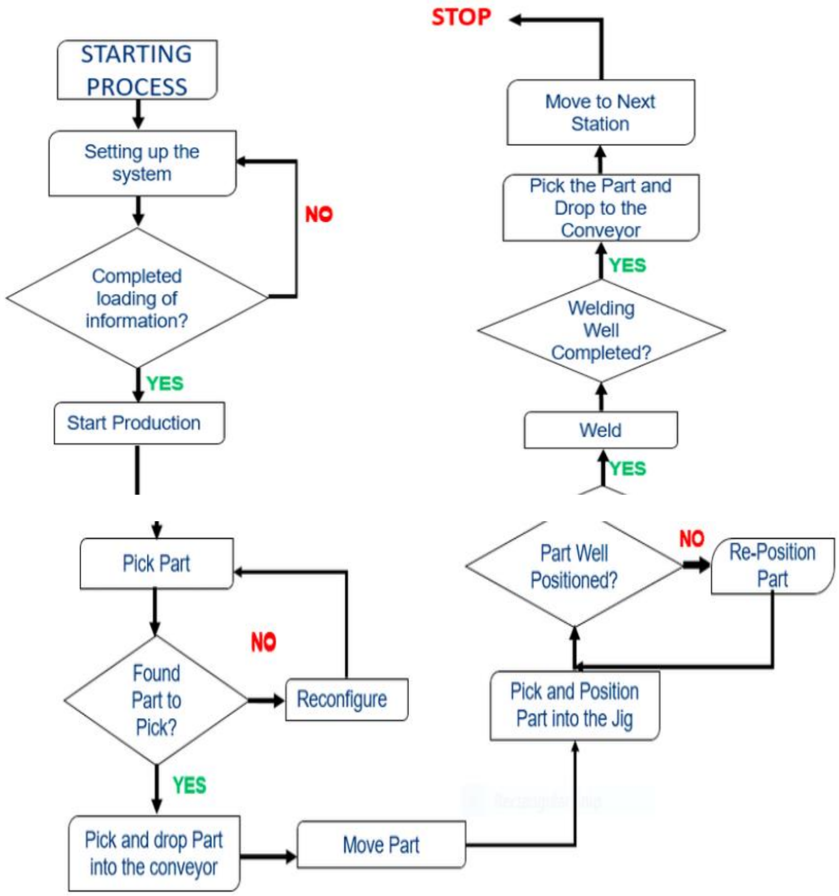
Part grouping. This IS concerned with the selection of groups of part types for simultaneous production, given limitations on available tooling and other resources a' workstations.

ARCHITECTURE **OF FMS**



Control software for an FMS is normally tailored on a specific plant; this causes long development times and high costs; hence the impossibility to have the software at the early stage of the system design and the difficulty of modifying the software during the working phase. The paper describes a software architecture that allows the interactive definition of an FMS model and, at the same time, automatically builds the control and emulation software. These, together. constitute an off-line detailed simulator that may be used for plant optimization. When the plant is completely set up, the control software is also available: when the plant is functioning, the simulation software may be used as on-line simulator for the decision rules optimization.

FLOW CHART SHOWING VARIOUS OPERATIONS IN FMS



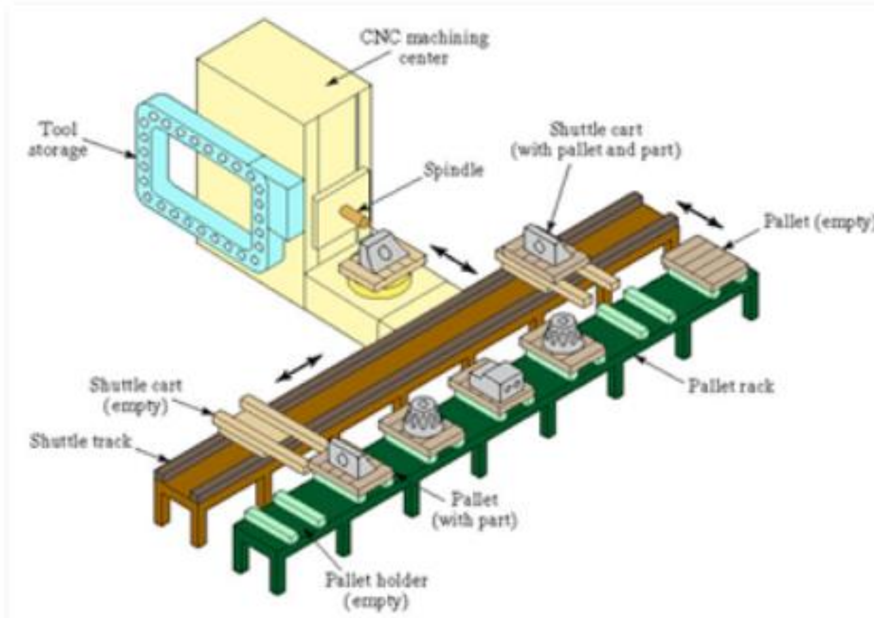
MACHINE CELL **DESIGN**

Machine Cell Design The Machine Cell Design can be classified based on the number of machines and the degree to which the material flow is mechanized between the machines. The most common types include single-machine cells, multi-machine cells, and worker-machine cells.

→ Single Machine Cell (SMC)

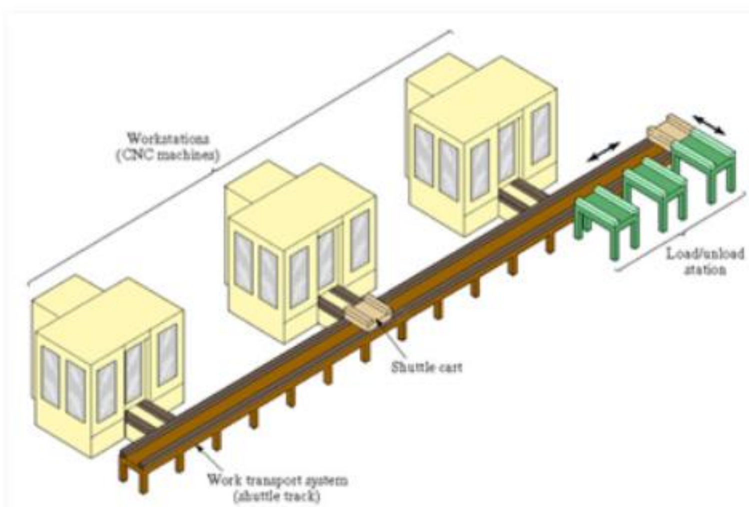
• A single machine cell consists of one CNC machining center combined with a parts storage system for unattended operation.

• Completed parts are periodically unloaded from the parts storage unit, and raw work parts are loaded into it.



→ Multi-Machine Cells

- Part size must be controlled through probe measurement of the part, automated in-process or postprocessor gauging, and automatic compensation of the machine for changes.
- Multi-machine cells are either serviced by a material-handling robot or parts are palletized in a two- or three-machine, in-line system for progressive movement from one machining station to another



UNIT -IV PROCESS PLANNING

PROCESS PLANNING

Process planning is the relation between design and manufacturing. Process planning consists in defining the sequence of the steps that should be taken to make the product. Process planning is referring to the engineering and technological issues of how to make it.

PROCESS PLANNING ACTIVITY

The process planning activity can be divided into the following steps:

- Selection of processes and tools
- Selection of machine tools/Manufacturing equipment
- Sequencing the operations
- Grouping of operations
- Selection of work piece holding devices and datum surfaces (set ups)
- Selection of inspection instruments
- Determination of production tolerances
- Determination of the proper cutting conditions
- Determination of the cutting times and non-machining times (setting time, inspection time) for each operation
- Editing the process sheets.

INFORMATION REQUIRED FOR PROCESS PLANNING

The detailed instructions for making a part or a component. It includes such information as the operations, their sequence, machines, tools, speeds and feeds, dimensions, tolerances, stock removed, inspection procedures and time standards

- Parts list
- Annual demand/batch size
- Accuracy and surface finish requirement (CAD Database)
- Equipment details (Work centre Database)
- Data on cutting fluids, tools, jigs & fixtures, gauges
- Standard stock sizes
- Machining data, data on handling and setup

DESIGN TO PROCESS PLANNING

→ Process planning is concerned with planning the conversion or transformation processes needed to convert the materials into finished products.
→ Process planning consists of two parts – Process design and Operations design.
→ Process Design is concerned with the overall sequences of operations required to achieve the product specifications.
→ Process planning specifies the type of work stations that are to be used, the machines and the equipments necessary & the quantities in which each is required.
→ Process planning is concerned with planning the conversion or transformation processes needed to convert the materials into finished products. ™Process planning consists of two parts – Process design and Operations design.
→ Process Design is concerned with the overall sequences of operations required to achieve the product specifications.
→ Process planning specifies the type of work stations that are to be used, the machines and the equipments necessary & the quantities in which each is required.

CLASSIFICATION OF MANUFACTURING PROCESSES

Repetitive manufacturing:

- → involves producing the same product repeatedly in large quantities.
- → Repetitive manufacturing is a type of manufacturing process that involves the production of a high volume of identical or similar products continuously. This type of manufacturing is typically used for products that have a high demand and require a standardized production process like water bottles.

Discrete manufacturing:

- → involves producing individual, unique items with specific requirements and characteristics.
- → Discrete manufacturing is a type of manufacturing process that involves the production of distinct, identifiable items that are usually produced in relatively low volumes. These items are often complex and may require multiple stages of production involving different processes, materials, and equipment.
- → It is used to produce a wide range of products, including electronics, automobiles, appliances, furniture, toys and more.

Job shop manufacturing:

- → involves producing custom-made products in small quantities according to customer specifications.
- → The job shop type of manufacturing process involves the production of small batches of customized or specialized products, often one-of-a-kind items, that require unique processes and skills to produce. These products are typically designed to meet the specific needs of individual customers and are often made to order or based on requirements.
- → Job shop manufacturing is often used in industries such as aerospace, automotive, and medical equipment manufacturing, where customized, specialized products are in high demand. It is characterized by its flexibility and the variety of products it can produce.

Continuous Process manufacturing:

- → involves producing products through a continuous and uninterrupted process, such as in the chemical or oil industries.
- → The continuous process manufacturing type of manufacturing process involves a product produced continuously without interruption or the need for starting and stopping. This means that the raw materials, equipment, and labour are all dedicated to the production of the product continuously.
- → The continuous process is typically used in the production of chemicals, fertilizers, power stations, oil, gas, and paper. Here the raw materials are continuously fed into the production equipment, and the product is continuously produced until it is ready for packaging or distribution. This means that the process is not stopped, and production is not interrupted during the production cycle.

Batch Process manufacturing:

- → involves producing products in specific quantities and batches, such as in the food or pharmaceutical industries.
- → The batch process production type of manufacturing process involves a specific quantity of a product produced at one time, known as a batch. In this process, the raw materials, equipment, and labour are all dedicated to the production of the batch until it is complete.
- → The batch process is commonly used in the production of food, pharmaceuticals, cosmetics, and other products that require specific formulations or have short shelf

lives. Manufacturing using a batch method is frequently used in the manufacture of food, newspapers, books, and medications.

SEQUENCING OF OPERATIONS ACCORDING TO ANTERIORITIES

Here are some factors to consider when sequencing operations:

- **Precedence**

  There are different types of precedence that can be used to classify operations, including dimensional, geometric, datum, technological, and economic.

- **Due dates**

  Some tasks may have due dates, and penalties may be incurred if a task is not finished on time.

- **Priority**

  There are many rules for prioritizing operations, including:

  - ❖ First In, First Out (FIFO): The first item inputted into the process is the first to be outputted
  - ❖ Shortest Processing Time (SPT): Prioritizes items that can be produced and finished the fastest
  - ❖ Earliest Due Date (EDD): Prioritizes items that are due to be completed the soonest
  - ❖ Least Slack (LS): Prioritizes items that have the least disparity between their deadline and expected processing time

- **Machine idle time**

  Johnson's algorithm minimizes the idle time of machines by ensuring that the same sequence of jobs is processed on each machine

- **Other factors to consider include**

  - ❖ Progress status of the operation
  - ❖ Setup time
  - ❖ Pattern recognition
  - ❖ Selection of datum
  - ❖ Connection between machining surfaces and type of operations
  - ❖ Machining tools

TYPICAL PROCESS SHEET

A typical process sheet consists of the following sections:

- Product/system description: what to produce or install
- Process description: what stages are involved in product/system manufacturing/installation
- Procedures & instructions: how to produce/install the product/system
- Labor & technology: who will produce/install the product/system and what tools & equipment will be used
- Budget: what amount of funds is required to implement the process

Manual process planning

Manual process planning, also known as man-variant process planning, is a method for selecting the processes needed to make a finished part. It's the most common type of process planning

In manual process planning, a planner will:

- Use engineering drawings to define part requirements
- Consider the capabilities and availability of machines and processes
- Select a combination of processes to produce the part
- Consider criteria like production costs, time, and machine utilization

Manual process planning is based on the planner's experience and knowledge of the production facilities, equipment, and processes. There are two approaches to manual process planning:

- Workbook approach: Uses predetermined sequences
- Traditional approach: Relies on the planner's experience to determine operations

Some advantages of manual process planning include low cost and flexibility. However, it can also be labor intensive, lead to excessive paperwork, and lack consistency.

1.Traditional approach

- ❖ In traditional process planning systems, the process plan is prepared manually. The task involves examining and interpreting engineering drawing.
- ❖ Making decisions on machining process selection, equipment selection, operations sequence, and shop practices.
- ❖ The manual process plan is very much dependent on the skill, judgment and experience of the process planner. That‟s Why, if different planners were asked to develop a process plan for the same part, they would probably come up with different plans.

The traditional process planning usually involves the following three stages, are;

Stage 1: The process planner interprets the component/product drawing using his own experience and intuition. Taking into account the type of resources available, he decides on how the component / product should be made. He lists the sequence of operations to be carried out in order to manufacture the product.

Stage 2: The process planner refers the manual to decide on tools, feeds, speeds. etc., for each element of each operation, Also the specific operation setup times and operation times for each operation are calculated using the manual.

Stage 3: Finally, the resulting process plan is documented as a routing sheet.

2. Workbook Approach

- ❖ The workbook approach is a modified version of traditional approach of process planning that uses the developed workbook for preparing route sheet.
- ❖ In this approach, the workbooks of predetermined sequence of operations for possible elements of operations of components / products arc developed.
- ❖ Once the drawing interpretation is carried out, the suitable predetermined sequence of operations are selected from the developed workbook and the details are documented in the route sheet.

Advantages of Manual Process Planning

The advantages of employing manual process planning are as follows:

- → Manual process planning is very much suitable for small scale companies with few process plans to generate.
- → This method is highly flexible.
- → This requires low investment costs.

COMPUTER AIDED PROCESS PLANNNG

In order to overcome the drawbacks of manual process planning, the computer-aided process planning (CAPP) is used.

- ➢ With the use of computers in the process planning, one can reduce the routine clerical work of manufacturing engineers.
- ➢ Also, it provides the opportunity to generate rational, consistent and optimal plans.
- ➢ In addition, CAPP provides the interface between CAD and CAM.

Benefits of CAPP

The benefits of implementing CAPP include the following

- ➢ Process rationalization and standardization: CAPP leads to more logical and consistent process plans than manual process planning.
- ➢ Productivity improvement: As a result of standard process plan, the productivity is improved (due to more efficient utilization of resources such as machines, tooling, stock material and labour).
- ➢ Product cost reduction: Standard plans tend to result in lower manufacturing

costs and higher product quality.

- ➢ Reduction in time: As a result of computerizing the work, a job that used to lake several days, is now done in a few minutes.
- ➢ Reduced clerical effort and paper work

- Improved legibility: Computer-prepared route sheets are neater and easier to read than manually prepared route sheets.
- Faster response to engineering changes: Since the logic is stored in the memory of the computer.

Approaches of CAPP

The two basic approaches or types of CAPP system are

1. Retrieval CAPP system
2. Generative CAPP system

Retrieval CAPP system

- A retrieval CAPP system, also called a variant CAPP system, has been widely used in machining applications.
- The basic idea behind the retrieval CAPP is that similar parts will have similar process plans.
- In this system, a process plan flit a new part is created by recalling, Identifying aid retrieving an existing plan for a similar part and making the necessary modifications for the new part.

Procedure for Using Retrieval CAPP System

A retrieval CAPP system is based on the principles of group technology (GT) and past classification and coding. In this system, for each part family a standard process plan (i.e., route sheet) is prepared and stored in computer files. Through classification and coding, a code number is generated. These codes are often used to identify the part (amity and the associated standard plan. The standard plan is retrieved edited for the new part.

Advantages of Retrieval CAPP system

- Once a standard plan has been written, a variety of parts can be planned.
- Comparatively simple programming and installation (compared with generative CAPP systems) is required to implement a planning System.
- The system is understandable, and the planner has control of the final plan.
- It is easy to learn and easy to use.

Drawbacks of Retrieval CAPP System

- The components to be planned are limited to similar components previously planned.

- Experienced process planners are still required to modify the standard plan for the specific component.

GENERATIVE CAPP SYSTEMS

- In the generative approach, the computer Is used to synthesize or generate each individual process plan automatically and without reference to any prior plan.

- A generative CAPP system generates the process plan based on decision logics and pre -coded algorithms, The computer stores the rules of manufacturing and the equipment capabilities (not any group of process plans).

- When using a system, a specific process plan for a specific part can be generated without army involvement of a process planner.

- The human role in running the system includes: (i) inputting the GT code of the given part design, and (ii) monitoring the function.

Components of a Generative CAPP System

The various components of a generative system are:

a. A part description, which identifies a series of component characteristics, including geometric features, dimensions, tolerances and surface condition.

b. A subsystem to define the machining parameters, for example using look-up tables and analytical results for parameters.

c. A subsystem to select and sequence Individual operations. Decision logic is used to associate appropriate operations with features of a component, and heuristics and algorithms are used to calculate operation steps, times and sequences.

d. A database of available machines and tooling.

e. A report generator which prepares the process pIan report

CAPP Advantages of Generative

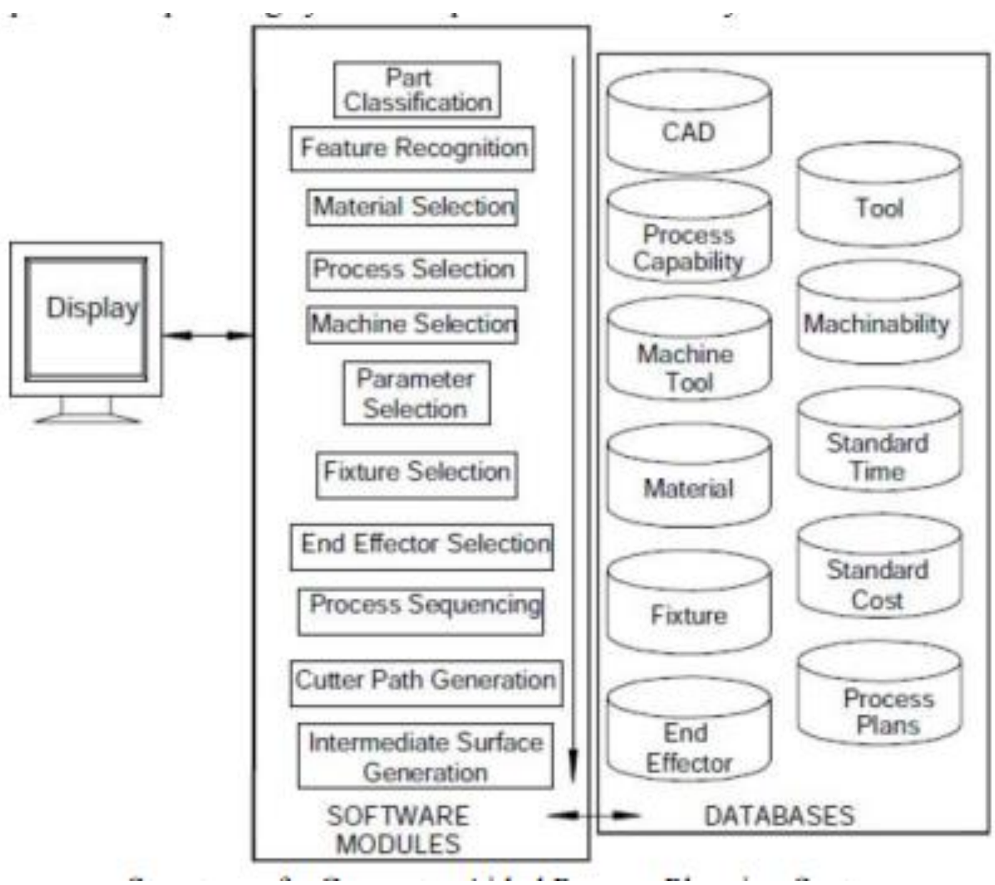
The generative CAPP has the following advantages:

i. It can generate consistent process plans rapidly.
ii. New components can be planned as easily as existing components.
iii. It has potential for integrating with an automated manufacturing facility to provide detailed control information.

Drawbacks of Generative CAPP System:

The generative approach is complex and very difficult to develop.

Process planning module and data base



Variant process planning

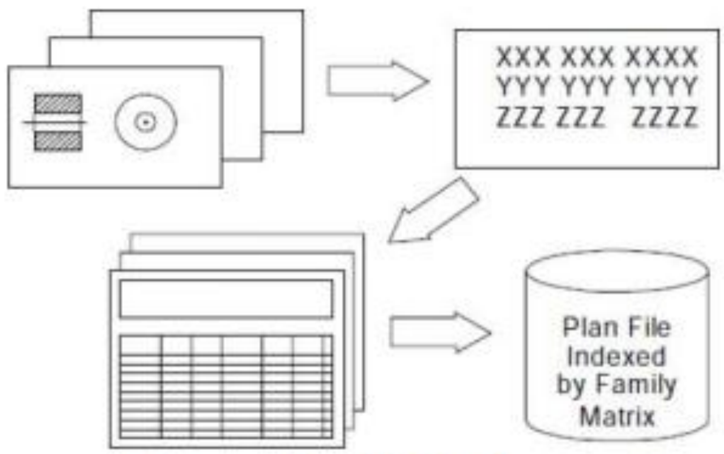
A variant process planning system uses the similarity among components to retrieve the existing process plans. A process plan that can be used by a family of components is called a standard plan. A standard plan is stored permanently with a family number as its key. A family is represented by a family matrix which includes all possible members.

The variant process planning system has two operational stages:

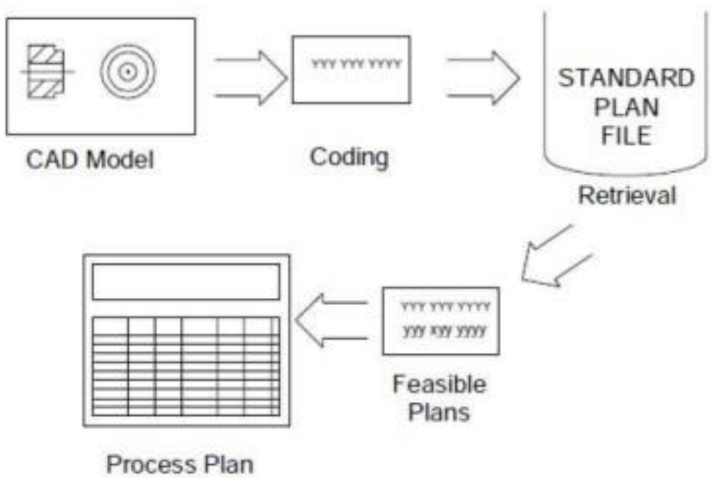
• A preparatory stage

• A production stage.

During the preparatory stage, existing components are coded, classified, and subsequently grouped into families. The process begins by summarizing process plans already prepared for components in the family. Standard plans are then stored in a data base and indexed by family matrices(Fig.).



The operation stage occurs when the system is ready for production. An incoming part is first coded. The code is then input to a part family search routine to find the family to which the component belongs. The family number is then used to retrieve a standard plan. Some other functions, such as parameter selection and standard time calculations, can also be added to make the system more complete (Fig). This system is used in a machine shop that produces a variety of small components.



Part Search and Retrieval

Design Of Variant Process Planning System

The following are the sequences in the design of a variant process planning system:

i. Family formation
ii. ii. Data base structure design
iii. iii. Search algorithm development and implementation
iv. iv. Plan editing and Process parameter selection/updating

i. **Family Formation**

Part family classification and coding were discussed earlier. This is based on the manufacturing features of a part. Components requiring similar processes are grouped into the same family. A general rule for part family formation is that all parts must be related. Then, a standard process plan can be shared by the entire family. Minimum modification on the standard plan will be required for such family members.

ii. **Data Base Structure Design**

The data base contains all the necessary information for an application, and can be accessed by several programs for specific application. There are three approaches to construct a data base: hierarchical, network, and relational.

iii. **Search Procedure**

The principle of a variant system is to retrieve process plans for similar components. The search for a process plan is based on the search of a part family to which the component belongs. When, the part family is found, the associated standard plan can then be retrieved. A family matrix search can be seen as the matching of the family with a given code. Family matrices can be considered as masks. Whenever, a code can pass through a mask successfully, the family is identified.

iv. **Plan Editing and Parameter Selection**

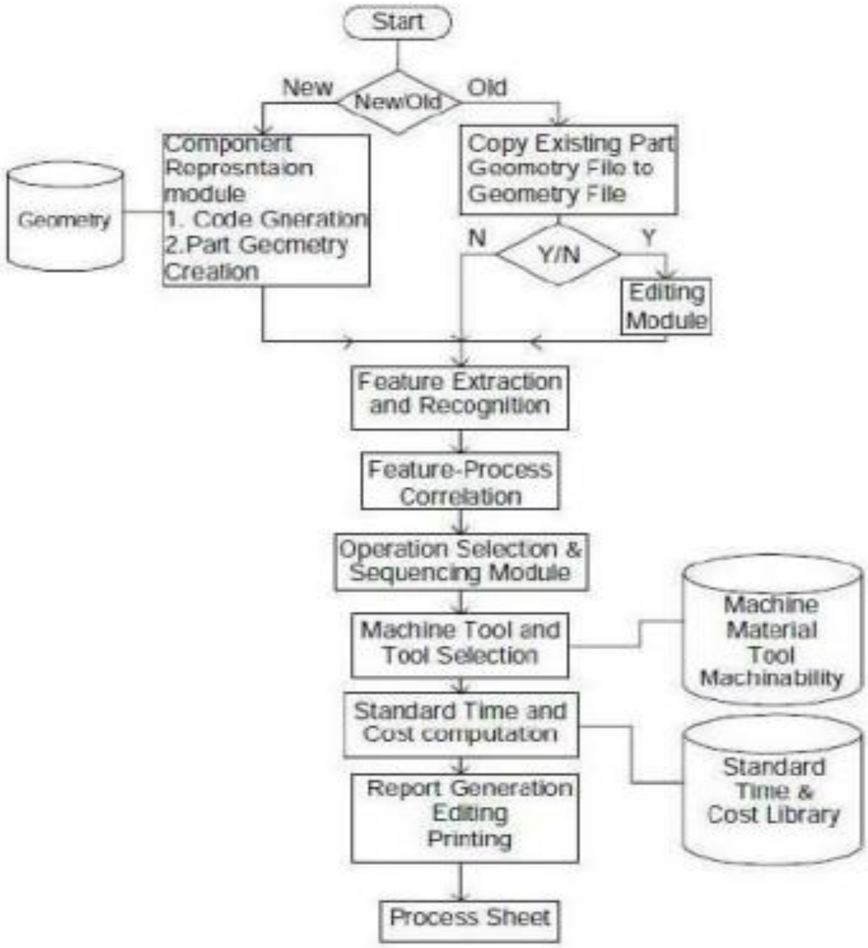
Before a process plan can be issued to the shop, some modification of the standard plan may be necessary, and process parameters must be added to the plan. There are two types of plan editing: One is the editing of the standard plan itself in the data base, and the other is editing of the plan for the component. For editing a standard plan, the structure of the data base must be flexible enough for expansion, additions, and deletions of the data records. A complete process plan includes not only operations but also process parameters. The data in the process parameter files are linked so that we can go through the tree to find the speed and feed for an operation. The parameter file can be integrated into variant planning to select process parameters automatically.

GENERATIVE PROCESS PLANNING

- ✓ Generative process planning is a system that synthesizes process information in order to create a process plan for a new component automatically. Inagenerativeplanningsystem,processplansarecreatedfrominformationavailable in manufacturing data base without human intervention.
- ✓ Upon receiving the design model, the system can generate the required operations and operation sequences for the component.
- ✓ Knowledge of manufacturing must be captured and encoded into efficient software. By applying decision logic, a process planner’s decision making can be imitated.
- ✓ Other planning functions, such as machine selection, tool selection, process optimization, and so on, can also be automated using generative planning techniques.

THE GENERATIVE PLANNING HAS THE FOLLOWING ADVANTAGES:

i. It can generate consistent process plans rapidly.
ii. New process plans can be created as easily as retrieving the plans of existing components.
iii. It can be interfaced with an automated manufacturing facility to provide detailed and up-to-date control information



The generative part consists of:

• Component representation module

• Feature extraction module

• Feature process correlation module

• Operation selection and sequencing module

• Machine tool selection module

• Standard time / cost computation module

• Report generation module

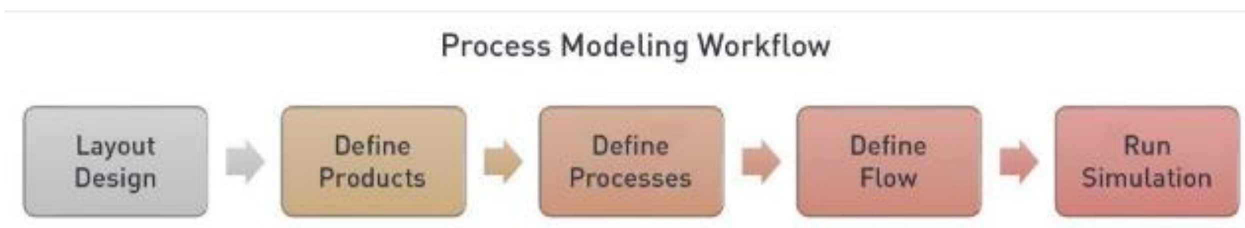
UNIT -V PROCESS CONTROL AND DATA ANALYSIS

Introduction to Process Model Formulation

Process Modeling concept

The Process Modeling workflow was designed to resemble how real-world production design is done in practice. It consists of the following 5 steps:

- Layout design.
- Define products, their visualization, structure and properties.
- Define processes, like machines, workstations, inventories and buffers using task statements.
- Define flow by creating sequences of processes that products must complete.
- Run simulation, collect KPIs, make necessary changes to achieve your goals.



1. **Layout Design**

The first step in the workflow is to design or configure the physical layout of the production system. This can be created using simulation-ready components from the Catalog and/or CAD data, which you can import directly into the software. Equipment should be placed in the correct position and orientation, and stations, walkways, buffers, fixtures, and spacing requirements should all be factored into the design.

For our reference cell, we've created a layout with 2 processes: machining and painting. We're using a robot to load/unload parts in the lathe and a human to manually perform the painting at a workbench. We've also added some conveyors to help transport products between processes.

2. **Define Products**

A Product is an entity that goes through a certain process in a layout. Products that undergo processes can be defined in this phase. From the Product Type Editor, you're able to configure and manage the following:

Product flow group; which is the collection of product types sharing the same production flow sequence. Let's name the first flow group as Flow Group #1.

Product type name; this can be a short description of the product like cylinder, car tire, motor plate, etc. In this case, the product is a 'Lathe Part' so let's keep this name.

Product properties; these can include parameters like dimensions, weight, material, etc. We want to specify that this lathe part is of 'Aluminum' material.

3D product geometry; a 3D geometry can be imported and selected as a product like in this example, where we have added 'Lathe Part' as an external CAD file.

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A process is a representation of a machine, work phase, inventory, buffer or some other production step. In Process Modeling, a Process is expressed as a set of statements, which assign certain behaviors to a product. Processes are built from statements using the Process Editor. With routines and statements, machines can be configured to behave like their real-life counterparts, such as machine doors opening and closing, processing times, product geometries changing with processes, parts attachment, and so forth.

Before defining processes, it's important to consider how products should evolve during production. In our reference cell, our products undergo two different processes.

Process #1 is Turning, where the products are lathed in a machine.

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In our reference cell, we have only one flow group (we previously named this 'Flow Group #1'), as all our products are completing the exact same route.

5. Run Simulation

When your model is set up, it's ready for simulation. Basic multimedia controls can be used to play the simulations, collect KPIs, make modifications, and export in a variety of formats.

In this article, we gave you a short introduction to the concepts and functionality behind process modeling, a major new feature in Visual Components 4.2. Process modeling introduces a simple yet powerful way to manage processes and production flow in your layout. It also provides an improved user experience by simplifying layout creation and simulation setup, streamlining the modeling and simulation workflow, and improving simulation performance.

Adaptive Control

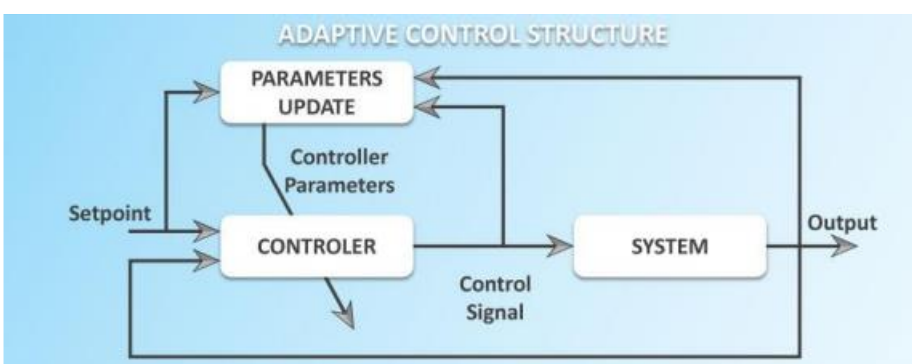
Adaptive control system adapts the parameters of the controller to changes in the parameters or structure of the controlled system in such a way that the entire system maintains optimal behavior according to the given criteria, independent of any changes that might have occurred.

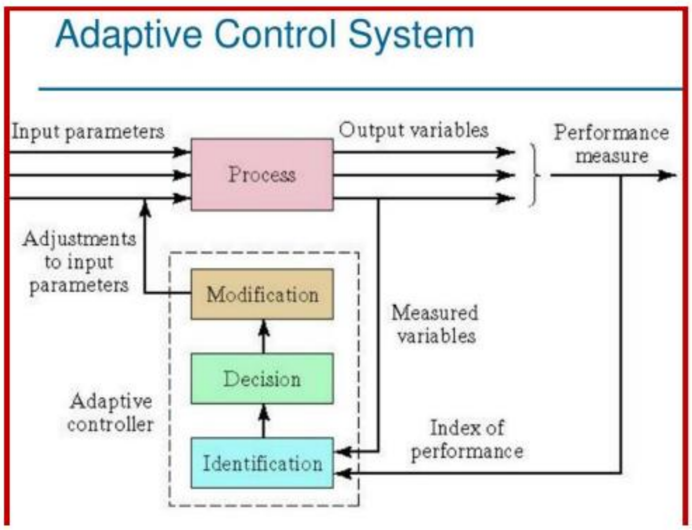
→ Adaptive control is a set of techniques that permit to adjust the value of control parameters in real time, permitting to monitor controlled variables even if plant parameters are unknown or if they change over time.

→ This control is a special kind of non-lineal control, and the process can be split in two timelines: rapid time (feedback loop) and slow time (variation of control parameters, which affects to automations).

Adaptive Control and its Applications in the Industry

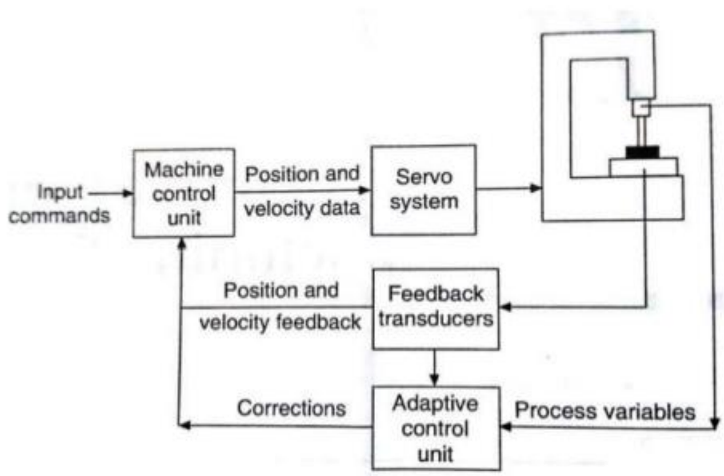
Adaptive control has been increasing its use in different sectors and industries since its beginnings in the *aerospace*, going through the control of vibrations until the use of autonomous Systems and Unmanned Aerial Systems (UAS). This is possible because its features permit to optimize the automations that are under its control, that is very attractive for industry.





Three Functions in Adaptive Control

1. Identification function – current value of IP is determined based on measurements of process variables
2. Decision function – decide what changes should be made to improve system performance
   - Change one or more input parameters
   - Alter some internal function of the controller
3. Modification function – implement the decision function
   - Concerned with physical changes (hardware rather than software)



Adaptive control machining system.

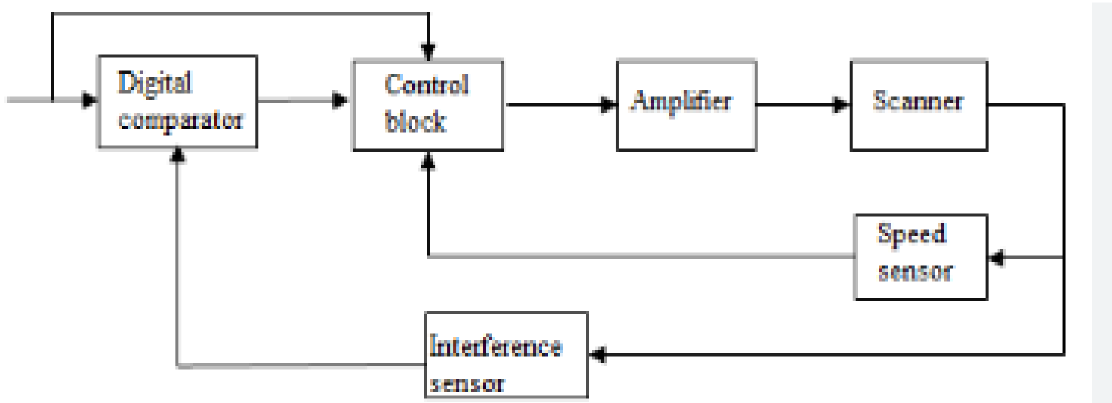
Optimal Control

Optimal feedback control modifies feedback signals to optimize an index of performance, creating a complex link between sensory signals and motor output.

Optimal feedback control (OFC) is a theory that explains how the motor system corrects movements to optimize task performance:

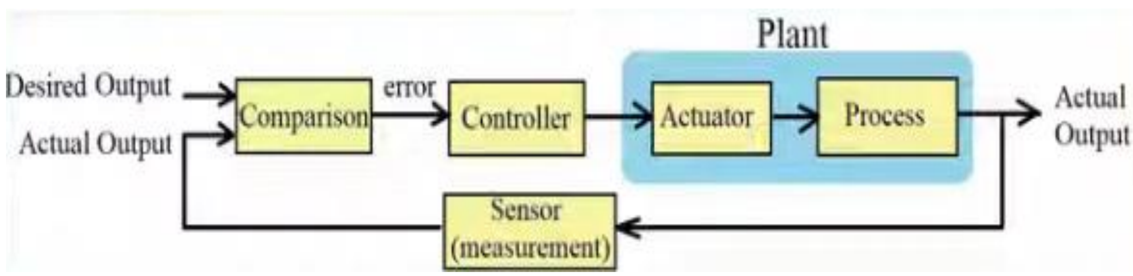
- Minimal intervention: Only corrects deviations from the average trajectory when they interfere with task performance
- Redundancy: Allows variability in task-irrelevant dimensions
- Sensory signals and motor output: Modifies feedback signals to create a complex link between sensory signals and motor output
- OFC is a leading theory of motor control that has been supported by behavioral studies in humans and other animals.
- Optimal control can also refer to a general problem of finding the best way to achieve a goal, such as minimizing fuel consumption while driving a car.

- In feedback optimizing control, the goal is to achieve optimal operation by manipulating inputs using feedback controllers. The main challenge is to determine what to control so that economic objectives can be translated into control objectives.



Linear Feedback Control Systems

Linear control are control systems and control theory based on negative feedback for producing a control signal to maintain the controlled process variable (PV) at the desired set point (SP). There are several types of linear control systems with different capabilities.



PLC& SCADA

Programmable logic controllers (PLCs) and supervisory control and data acquisition (SCADA) systems are used together in industrial automation to control, monitor, and optimize processes. They are a key part of many industrial operations, including manufacturing, energy, and water management.

Here's how PLCs and SCADA work together:

- **Data collection**: PLCs receive signals from sensors and field devices and translate the data into a format that SCADA can use.
- **Data analysis**: SCADA analyzes the data and decides if adjustments are needed.
- **Control:** SCADA sends instructions back to PLCs to enable changes.
- Maintenance: PLCs and SCADA can work together to create maintenance work orders when data crosses certain thresholds.

Here are some more details about PLCs and SCADA:

- **PLC**: PLCs perform control tasks in real time.
- **SCADA:** SCADA provides a higher level of supervision and data analysis. It's based on computers, networked data communications, and graphical user interfaces.
- **Safety:** PLCs and SCADA help reduce human interventions and manual errors, and ensure safety.
- **Remote supervision**: PLCs and SCADA allow for remote supervision.
- **Data-driven decisions**: PLCs and SCADA allow for swift data-driven decisions.

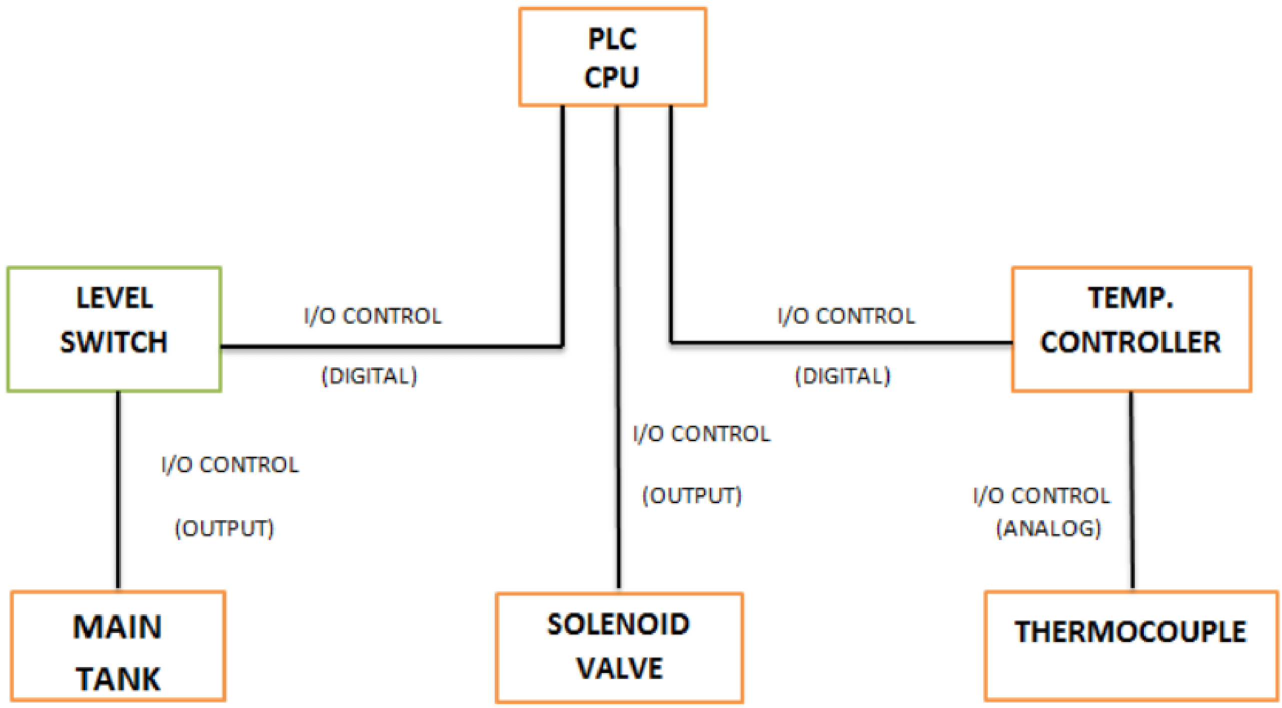
Programmable Logic Controllers (PLCs) and Supervisory Control and Data Acquisition (SCADA) systems are both used in industrial settings, and are often used together in feedback control systems:

- **PLC**

  These hardware devices are designed to control individual devices or small-scale processes in real time. PLCs are known for their reliability and ability to operate in harsh environments. They are often used to control motors, conveyor systems, and assembly lines. PLCs are an essential part of SCADA systems and are necessary for them to function.

- **SCADA**

  These software systems provide a higher level of supervision, data acquisition, and analysis for large-scale industrial processes. SCADA systems can monitor and collect information from every output of a system, and are responsible for detecting anomalies and making decisions based on the data. SCADA systems often include features such as remote access, data analytics, and integration with enterprise systems.



Block Diagram of PLC and SCADA Based Temperature and Level Controlling System

Sequence Control

Sequential control systems allow for time-discrete or event-discrete execution of sequential and parallel processes. They are used to coordinate various continuous functions as well as to control complex process sequences.

Sequence control in a feedback control system is the execution of one processing step after another, without any decision-making or looping:

- **Definition**

  Sequence control is the process of initiating, interrupting, or terminating transactions to govern the transition between them.

- **Representation**

  sequence control is represented as a sequence of statements, with each instruction executed in the order it appears.

- **Purpose**

  Sequence control systems can be used to model and analyze structures, verify properties, and implement process-specific protective functions.

- **Features**

  Sequential control systems support various operating modes, including manual control of transitions and temporary or permanent interruption of process sequences.

- **Implementation**

  Sequential control systems can be implemented using sequential function charts (SFCs).

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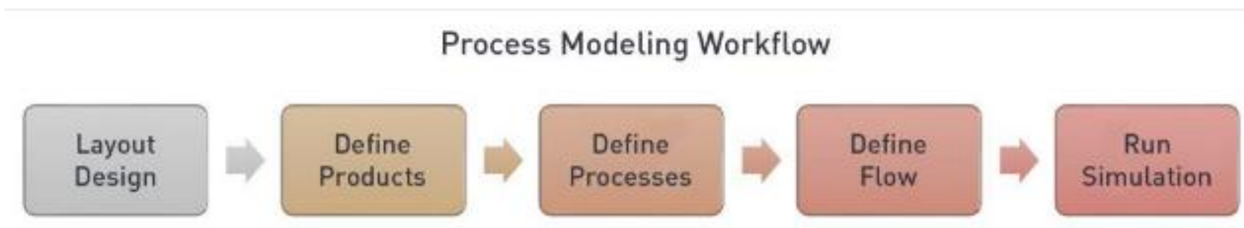

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COMPUTER PROCESS MONITORING

There are three basic classifications of computer process control monitoring, which depend on how the information is used:

1) Production management;

2) Manufacturing records

3) Maintenance

PRODUCTION MANAGEMENT

The computer can record current production levels, and can be programmed to generate reports to compare current with past production rates or to predict future production. Management would be interested in production performance measures such as:

1) Production rates;

2) Production costs;

3) Piece costs;

4) Scrap rates;

5) Worker overtime;

6) Inventory levels and their relationship to current production;

7) Production schedule overruns.

Management reports can be provided either in summary form at periodic intervals or on a real-time basis, as demanded. Other areas of importance to production management are machine utilization and efficiency, and product quality. The computer can be used to monitor and record the various parameters of the product that define its quality, and to generate reports to management that summarize this quality data. Additionally, the computer can be used to study and learn about a particular manufacturing operation, due to its capacity to collect large quantities of process data. Advancement in process technology and higher productivity are the desired outcome of this type of investigation.

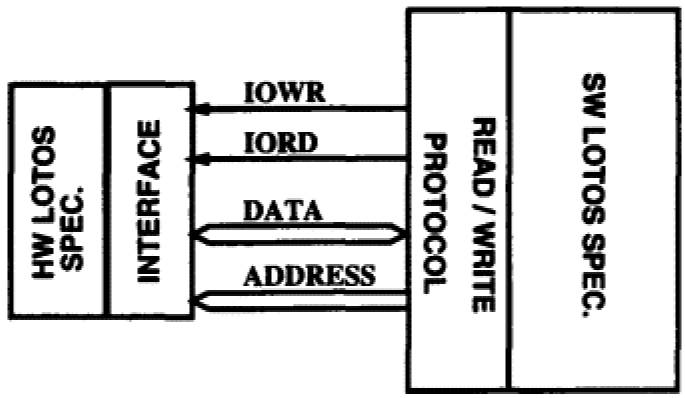
INTERFACE HARDWARE

A hardware interface specifies the plugs, sockets, cables and electrical signals that pass through each line between the CPU and a peripheral device or communications network.

The hardware interface is a layer between the VHDL(Very High Speed Integrated Circuit)generated by HARPO and the environment expected by the target architecture. It is in charge of the following tasks:

- → .Setting the input ports of the LOTOS processes on the hardware side to the values assigned from the software side. This may require some registers in which to store the values.
- → Informing the software about the values held at the output ports of the LOTOS processes on the hardware side.
- → Synchronising the read/write operations with the timing imposed by the processor

In other co-design approaches , the interface also includes a handshake protocol which passes values between the software and the hardware sides. This is not the case in our approach because, the VHDL generated by HARPO includes that protocol. In the target architecture the software accesses the hardware using a message-passing schema. The hardware side is seen by the software side as a set of special addresses in the address space. The hardware interface is accessed by the software by means of a data bus, an address bus and two control lines, one for reading operations and the other for writing operations. Each of the ports offered by the VHDL generated by HARPO has an associated address that can be accessed from the software side. When the software reads a value, the interface fetches the value from the corresponding hardware output, and puts it on the data bus. When the software writes a value, it is stored in a register whose output is connected to the desired hardware input port.



OVERVIEW OF AUTOMATIC IDENTIFICATION METHODS

1. **Data encoder**. A code is a set of symbols or signals that usually represent alpha- numeric characters. When data are encoded, the characters are translated into a machine-readable code. (For most AIDC techniques, the encoded data are not readable by humans.) A label or tag containing the encoded data is attached to the item that is to be identified.

2. **Machine reader or scanner**. This device reads the encoded data, converting them to alternative form, usually an electrical analog signal.

3. **Data decoder**. This component transforms the electrical signal into digital data and finally back into the original alphanumeric

1. Optical. Most of these technologies use high-contrast graphical symbols that can be interpreted by an optical scanner. They include linear (one-dimensional) and two- dimensional bar codes, optical character recognition, and machine vision.

2. Electromagnetic. The important AIDC technology in this group is radio frequency identification (RFID), which uses a small electronic tag capable of holding more data than a bar code. Its applications are gaining on bar codes due to several mandates from companies like Walmart and from the U.S. Department of Defense.

3. Magnetic. These technologies encode data magnetically, similar to recording tape. The two important techniques in this category are
(a) magnetic stripe, widely used in plastic credit cards and bank access cards processing., and (b) magnetic ink character recog- nition, widely used in the banking industry for check

4. Smart card. This term refers to small plastic cards (the size of a credit card) imbedded

with microchips capable of containing large amounts of information. Other terms used for this technology include chip card and integrated circuit card.

5. Touch techniques. These include touch screens and button memory.

6. Biometric. These technologies are utilized to identify humans or to interpret vocal commands of humans. They include voice recognition, fingerprint analysis, and reti- nal eye scans

BAR CODE TECHNOLOGY

A barcode system is a network of hardware and software, consisting primarily of mobile computers, printers, handheld scanners, infrastructure, and supporting software. Barcode systems are used to automate data collection where hand recording is neither timely nor cost effective.

What Is a Barcode?

At a basic level, a barcode is a square or rectangle with a combination of vertical black lines of varying thickness and height, white space and numbers that together identify specific products and their relevant information. Computers linked to scanners can read these codes and use the exact combination of bars, spaces and numbers to retrieve the data for that product.

Today, barcodes are found on not only household items that come from supermarkets or retail stores, but licenses, rental cars, checked luggage and hospital bands. In each case, they identify a product or person and encode important details.

- Barcodes encode product information into bars and alphanumeric characters, making it much faster and easier to ring up items at a store or track inventory in a warehouse.
- Besides ease and speed, bar codes' major business benefits include accuracy, inventory control and cost savings.
- There are many types of barcodes, but they all fall into two categories: linear codes, including widely used formats like UPC and EAN, and matrix codes, like QR codes.
- Bar coding has a low barrier to entry—all a business needs is a printer, scanner and basic inventory management software.

How Barcodes Work

The width of the black bars usually represents the numbers 0 or 1, while the sequence of those bars signifies a number between 0 and 9. A computer connected to the scanner has all the information on what item is associated with that unique combination of bars and spaces and may add, multiply or divide those numbers to identify the correct product, which shows up on the screen.

In a warehouse, the barcode might encode an item's size, color and other attributes, as well as its location, so the company has a detailed view of current inventory and can quickly fulfill orders or conduct physical inventory counts. In a retail setting, this information could include the product name and price that an associate needs to check out a customer. Organizations can use barcodes to track goods throughout their life cycle, from manufacture to distribution to purchase to service and repair.

Barcode Components

Barcodes must be designed in a precise, uniform way so a scanner can read them and transmit the encoded data to a computer. Using various components, a barcode may also reveal the country of origin, product category and manufacturer.

The diagram below shows the different elements of a UPC barcode, followed by an explanation of each component

- **Quiet zone:** The empty, white space on the edges of a barcode is the "quiet zone," and is necessary for the scanner to read the label.
- **Number system digit:** The first digit represents the product category on UPC codes. For example, retail products often start with 0 or 1, pharmaceuticals with 3 and coupons with 5.
- **Manufacturer code:** The first group of characters after that initial number usually identify the manufacturer. GS1,(opens in new tab) a global standards organization that regulates UPCs, assigns each manufacturer a unique code.
- **Product code:** The next set of characters identify the specific product and are created by the manufacturer.
- **Check digit:** The check digit confirms the accuracy of the data tied to that barcode and flags any potential errors

Business Benefits of Barcodes

Barcodes have taken off because they offer a clear and fast return on investment. Here are the key benefits businesses can take advantage of with barcodes:

- Accuracy:
  Barcodes eliminate manual entry of product information at receiving, meaning there are far fewer opportunities for error. Whether in a retail store or a warehouse, associates simply swipe the barcode across the scanner. Errors in barcodes themselves are extremely rare.

- Real-time data:
  Each time an employee scans a barcode, it immediately updates inventory and sales numbers in the company's enterprise resource planning (ERP) or business management system. This gives a business constant access to up-to-date data, allowing it to quickly calculate meaningful metrics ike inventory turn, value of inventory on-hand or sales per week by item.

- Reduced training:
  For the most part, barcodes and scanners are self-explanatory, so it doesn't take new employees long to become efficient at the checkout counter. And, barcodes greatly reduce the need for memorization and institutional knowledge. At a grocery store, for example, the worker doesn't have to know the codes for popular items to be productive.

- Inventory control:
  Barcodes improve inventory management and reduce excessive spending on products. Employees can always find the most current information when reviewing inventory positions or trends in demand, which facilitates better decisions around purchasing and discounting. This cuts down on both inventory carrying costs and obsolete inventory, which boosts long-term profitability.

- Low cost:
  Barcodes offer tremendous value, as the upfront investment is not large compared to systems that provide comparable benefits. Companies can create a limited number of barcodes for internal use for a low price, and as their needs grow, the cost of supporting technology remains reasonable.

Types of Barcodes

As noted earlier, there are two basic types of barcodes. Here are the basics on each and key differences:

- ## Linear/1D

Most stores put linear barcodes on their products.

Linear, or 1D, barcodes are what most people visualize when they picture a barcode—black vertical bars with numbers below them. This is what most stores put on their products. Linear barcodes contain numbers, letters and symbols, which tie the code to a set of information in a database with details like product name, type, size and color. A 1D barcode must be linked to a database to function properly. Linear barcodes are often used on consumer goods, loyalty cards, shipping labels and books.

- ## Matrix/2D

QR codes, such as this one, are one type of 2D barcode.

Matrix or 2D barcodes can store additional information, including quantity, images and website URLs. A 2D barcode can render this information boarding passes. They have also become increasingly common in high-value manufacturing environments that require detailed tracking of parts and products, like medical equipment and pharmaceuticals.

AUTOMATIC DATA CAPTURE TECHNOLOGIES.

AIDC is a process that is used to both identify and collect data. Once the collection is complete, the data is automatically stored in a computer system, where it is then categorized and, depending on the software, is aggregated. The process of AIDC is performed without the use of a keyboard and is generally integrated in order to track items, inventory, tools, assets, and even workers.

How Automatic Identification and Data Capture Works

AIDC refers to a relatively broad **spectrum of specific technologies** that employ it as an attribute. The list includes:

- Bar codes
- RFID (Radio Frequency Identification)
- Iris and facial recognition systems (biometrics)
- Optical character recognition (OCR)

- Magnetic strips
- Smart cards
- Voice recognition

  All of these technologies use AIDC in unique ways but are synthesized differently depending on the ins-and-outs of the processes.

  Typically, though, the device takes images, sounds, or videos of the target and captures the data with the help of a transducer. Transducers differ depending on the application of the technology, whether it be a bar code, smart card, RFID, or something else, but the main objective is the same – to convert the sound, image, or video into a digital file.

From there, the captured data is then held in a database or automatically transferred to a cloud-based system. It is then that the data can be analyzed and/or categorized; this step is something that is determined by the software and how it works to integrate with the capturing device, whatever it may be.

Although AIDC covers a wide scope, the technology is mostly used for one of three things:

1) Identification and validation,
2) Asset tracking, and
3) Interfaces to other systems.

The Benefits of Using Automatic Identification and Data Capture

When considering the benefits of employing AIDC, one must first take a closer look at the technologies that are enhanced by it.

- **Barcode readers –** AIDC has existed for years in the form of barcode labels and barcode reader technologies. Barcodes can be used for tracking, identification, and counts in a variety of industries, including retail, healthcare, education, warehouse settings, manufacturing, entertainment, and much more.
- **RFID – RFID tags** transmit in-depth information from a scanner and is captured using a special reader through AIDC. Typically, RFID tags are placed on items that require advanced tracking and/or real-time reporting and data collection.
- **Biometrics –** Biometrics identify individuals by using a specialized AIDC scanning process that compares biological features, like irises or fingerprints. It was once a technology that only existed in science fiction films, but now this advanced data capture technology is used in office settings and even personal mobile devices.
- **OCR (Optical Character Recognition) –** OCR employs AIDC in order to scan written or typed text. This is the technology that is used in digitization processes.
- **Magnetic strips –** Magnetic strips use AIDC so that important information can be "swiped" for near-immediate verification. Nearly everyone has this AIDC technology on their person at any given moment; these magnetic strips are the ones used on credit/debit cards, building entry cards, library cards, public transportation passes, etc.
- **Smart cards –** Smart cards are, essentially, more advanced forms of magnetic strips. Typically, they are used in similar ways, and on cards that are for personal uses only. It is also the AIDC technology that is used in passports.
- **Voice recognition –** Similar to biometrics, voice recognition uses a device to capture data which is then automatically analyzed using the AIDC technology to compare a voice against a catalog of others.

QUALITY MANAGEMENT (SPC) AND AUTOMATED INSPECTION

SPC is method of measuring and controlling quality by monitoring the manufacturing process. Quality data is collected in the form of product or process measurements or readings from various machines or instrumentation. The data is collected and used to evaluate, monitor and control a process. SPC is an effective method to drive continuous improvement. By monitoring and controlling a process, we can assure that it operates at its fullest potential. One of the most comprehensive and valuable resources of information regarding SPC is the manual published by the Automotive Industry Action Group (AIAG).

Why Use Statistical Process Control

Manufacturing companies today are facing ever increasing competition. At the same time raw material costs continue to increase. These are factors that companies, for the most part, cannot control. Therefore companies must concentrate on what they can control: their processes. Companies must strive for continuous improvement in quality, efficiency and cost reduction. Many companies still rely only on inspection after production to detect quality issues. The SPC process is implemented to move a company from detection based to prevention based quality controls. By monitoring the performance of a process in real time the operator can detect trends or changes in the process before they result in non-conforming product and scrap.

How to Use Statistical Control (SPC)Process

Before implementing SPC or any new quality system, the manufacturing process should be evaluated to determine the main areas of waste. Some examples of manufacturing process waste are rework, scrap and excessive inspection time. It would be most beneficial to apply the SPC tools to these areas first. During SPC, not all dimensions are monitored due to the expense, time and production delays that would incur. Prior to SPC implementation the key or critical characteristics of the design or process should be identified by a Cross Functional Team (CFT) during a print review or **Design Failure Mode and Effects Analysis (DFMEA)** exercise. Data would then be collected and monitored on these key or critical characteristics.

Collecting and Recording Data

SPC data is collected in the form of measurements of a product dimension / feature or process instrumentation readings. The data is then recorded and tracked on various types of control charts, based on the type of data being collected. It is important that the correct type of chart is used gain value and obtain useful information. The data can be in the form of continuous variable data or attribute data. The data can also be collected and recorded as individual values or an average of a group of readings. Some general guidelines and examples are listed below. This list is not all inclusive and supplied only as a reference.

ariable data

- Individual – Moving Range chart: to be used if your data is individual values
- Xbar – R chart: to be used if you are recording data in sub-groups of 8 or less
- Xbar – S chart: to be used if your sub-group size is greater than 8

Attribute data

- P chart – For recording the number of defective parts in a group of parts
- U chart – For recording the number of defects in each part

Control Charts

One of the most widely used control charts for variable data is the X-bar and R chart. X-bar represents the average or "mean" value of the variable x. The X-bar chart displays the variation in the sample means or averages. The Range chart shows the variation within the subgroup. The range is simply the difference between the highest and lowest value. The following steps are required to build an X-bar and R chart:

- Designate the sample size "n". Usually 4 or 5 are common sample sizes used in many industries. Remember the sample size should be 8 or less. Also determine the frequency that the sample measurements will be collected.
- Start collecting your initial set of samples. A general rule is to collect 100 measurements in groups of 4 which would result in 25 data points.
- Calculate the average value for each of the 25 groups of 4 samples.
- Calculate the range of each of the 25 samples of 4 measurements. The range is the difference between the highest and lowest value in each set of 4 sample measurements.
- Calculate X-dbar (the average of the averages), which is represented on the X- bar chart by a solid centerline.
- Calculate the average of the sample ranges or "R" values. This will be the centerline of the Range chart.
- Calculate the Upper and Lower Control Limits (UCL, LCL) for each chart. To be clear, the control limits are not the spec limits set by the engineer on the drawing. The control limits are derived from the data. Most engineers utilize statistical software that will perform the calculations automatically.

Once the chart is setup, the operator or technician will measure multiple samples, add the values together then calculate the average. This value is then recorded on a control chart or X-bar chart. The range of the subgroups is also recorded. The sample measurements should be taken and recorded in regular intervals, including date and time to track the stability of the process. Watch for any special or assignable causes and adjust the process as necessary to maintain a stable and in control process.

The X-bar and R chart is merely one example of the different control charts available for process monitoring and improvement. For assistance in determining the best practices to improve your processes, contact one of the many professionals at Quality-One.

Analyzing the Data

The data points recorded on a control chart should fall between the control limits, provided that only common causes and no special causes have been identified. Common causes will fall between the control limits whereas special causes are generally outliers or are outside of the control limits. For a process to be deemed in statistical control there should be no special causes in any of the charts. A process in control will have no special causes identified in it and the data should fall between the control limits. Some examples of common cause variation are as follows:

- Variation in material properties within specification
- Seasonal changes in ambient temperature or humidity
- Normal machine or tooling wear
- Variability in operator controlled settings
- Normal measurement variation

Adversely, special causes generally fall outside of the control limits or indicate a drastic change or shift in the process. Some examples of special cause variation are below:

- Failed controllers
- Improper equipment adjustments
- A change in the measurement system
- A process shift
- Machine malfunction
- Raw material properties out of design specifications
- Broken tool, punch, bit, etc.
- Inexperienced operator not familiar with process

When monitoring a process through SPC charts the inspector will verify that all data points are within control limits and watch for trends or sudden changes in the process. If any special causes of variation are identified, appropriate action should be taken to determine the cause and implement corrective actions to return the process to a state of statistical control.

There are other variations or patterns of data points within the control limits that should also be tracked and investigated. These include but are not limited to:

- Runs where 7 or more data points are in a row on one side of the process centerline
- Changes in the normal spread of data, where multiple data points fall either farther apart or closer together
- Trends which are represented by 7 or more data points consistently raising or declining
- Shifts in the data spread above or below the normal mean

By addressing any special causes, trends or shifts in the process we can assure we are producing parts that meet the customer's requirements. Remember the control limits should always fall between the spec limits determined by the engineer and / or the customer. For more information regarding the SPC process and available tools, mentoring, training or assistance in implementation of SPC, contact one of the Subject Matter Experts (SME) at Quality-One. We are always ready to provide any assistance or information you made need.