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NPTEL ONLINE CERTIFICATION COURSES

NPTEL

AUTOMATION IN PRODUCTION SYSTEMS AND MANAGEMENT

Flexible Manufacturing Systems-I

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Flexible Manufacturing Systems-I

- **Lecture-1:** Types and Definitions of Different Types of Flexibility in Manufacturing Systems
- **Lecture-2:** Volume-Variety Relationships in Production Systems, What is FMS?
- **Lecture-3:** Basic Features of FMS: Physical Subsystems
- **Lecture-4:** Basic Features of FMS: Control Subsystems and Manufacturing Control Activities
- **Lecture-5:** Numerical Examples

Flexible Manufacturing Systems-I

- ✓ **Types and Definitions of Different Types of Flexibility in Manufacturing Systems**

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Flexibility

- Flexibility is the cornerstone of and one of the key concepts used in the design of modern automated manufacturing systems such as flexible manufacturing system.
- Flexibility has multiple dimensions and the concept of flexibility still remains vague.
- What is flexibility? What are the different types of flexibility? What are the implications of flexibility in manufacturing systems? How are manufacturing systems distinguished on the basis of flexibility?

Flexibility

- Flexibility can be defined as a collection of properties of a manufacturing system that support changes in production activities or capabilities.

- Normally, the changes are due to both internal and external factors.

- Internal changes could be due to equipment breakdowns, software failures, worker absenteeism, variability in processing times, and so forth.

Flexibility

- Some degree of redundancy in the system is required to cope with internal changes.
- Changes in product design, demand, and product mix typically represent external changes.
- To absorb uncertainties due to product design changes, the manufacturing system must be versatile and able to produce the intended variety of part types with minimal cost and lead time.

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Flexibility

- Some degree of redundancy may, however, be required to cope with changes in the demand and product mix.

- Flexibility refers to the ability of the manufacturing system to respond effectively to both internal and external changes by having built-in redundancy of versatile equipment.

Various Types of Flexibility

❑ Machine Flexibility

- Machine flexibility refers to the capability of a machine to perform a variety of operations on a variety of part types and sizes.

- It implies ease with which the parts are changed over from one part type to another on a machine. The changeover time, which includes setup, tool changing, part-program transfer, and part move times, is an important measure of machine flexibility.

Various Types of Flexibility

- Computer numerical control (CNC) machining centers are normally equipped with automatic tool changer, part buffer storage, part programs, and fixtured parts on pallets.

- Benefits: (i) The small lot sizes are economical and lead times are lower. (ii) machine flexibility provides routing and mix flexibility.

Various Types of Flexibility

❑ **Routing Flexibility**

- Routing flexibility means that a part(s) can be manufactured or assembled along alternative routes.
- Because a wide variety of operations can be performed on flexible machines, they provide routing flexibility.
- Routing flexibility is used primarily to manage internal changes resulting from equipment breakdowns, tool breakages, controller failures, and so on.
- Routing flexibility can also help increase throughput in the presence of external changes such as product mix, engineering changes, or new product introductions.

Various Types of Flexibility

- The use of alternative routings helps provide relief, thereby resolving the bottleneck problem and permitting increased production.

- Routing flexibility is becoming a more acceptable means of improving the dependability of manufacturing systems. However, a balanced approach is required, employing a combination of small work-in-process buffers, machinery improvements, better repair and preventive maintenance practices, and routing flexibility.

Various Types of Flexibility

❑ Process Flexibility

- Process flexibility, also known as mix flexibility, refers to the ability to absorb changes in the product mix by performing similar operations or producing similar products or parts on multipurpose, adaptable, CNC machining centers.
- Mix flexibility provides protection against market variability by accommodating changes in product mix due to the use of shared resources.
- However, extreme mix variations would result in requirements for a greater number of tools, fixtures and other resources.

Various Types of Flexibility

❑ Product Flexibility

- Product flexibility, also known as mix-change flexibility, refers to the ability to change over to a new set of products economically and quickly in response to markets or engineering changes or even to operate on a make-to-order-basis.
- The product flexibility of a manufacturing system in a company is a barometer of its competitiveness.

Various Types of Flexibility

❑ Production flexibility

- Production flexibility refers to the ability to produce a range of products without adding major capital equipment, even though new tooling or other resources may be required.

- The product envelope, that is, the range of products that can be produced by a manufacturing system at moderate cost and time, is determined by the process envelope.

Various Types of Flexibility

- Process envelope in turn is determined by the hardware and software capabilities of a manufacturing system, such as variety of machines, their flexibility, the material-handling system, and the factory information and control system.

- The greater the production flexibility, the higher will be the investment in flexible capital equipment and software.

Various Types of Flexibility

❑ Expansion flexibility

- Expansion flexibility refers to the ability to change a manufacturing system with a view to accommodating a changed product envelope.
- In the case of expansion flexibility there are additions as well as replacements of equipment, but these changes are easy to make because such provisions are made in the original manufacturing system design.
- For example, automated guided vehicles can be more easily rerouted than conveyors; modular design of system software makes it possible to change a module rather than the whole system.

Flexible Manufacturing Systems-I

- ✓ **Volume-Variety Relationships in Production Systems,**
- ✓ **What is FMS?**

Volume-Variety Relationships For Understanding Production Systems

- A highly flexible system permits manufacture of a high variety of parts.
- Two extreme production situations are high-volume, low-variety (H-L) and low volume, high-variety (L-H).
- Between these two extremes there is an important mid-volume, mid-variety (M-M) production situation.

Volume-Variety Relationships For Understanding Production Systems

Five types of manufacturing systems:

1. Transfer line
2. Stand-alone numerical control (NC) machine
3. Manufacturing cell
4. Special manufacturing system
5. Flexible manufacturing system

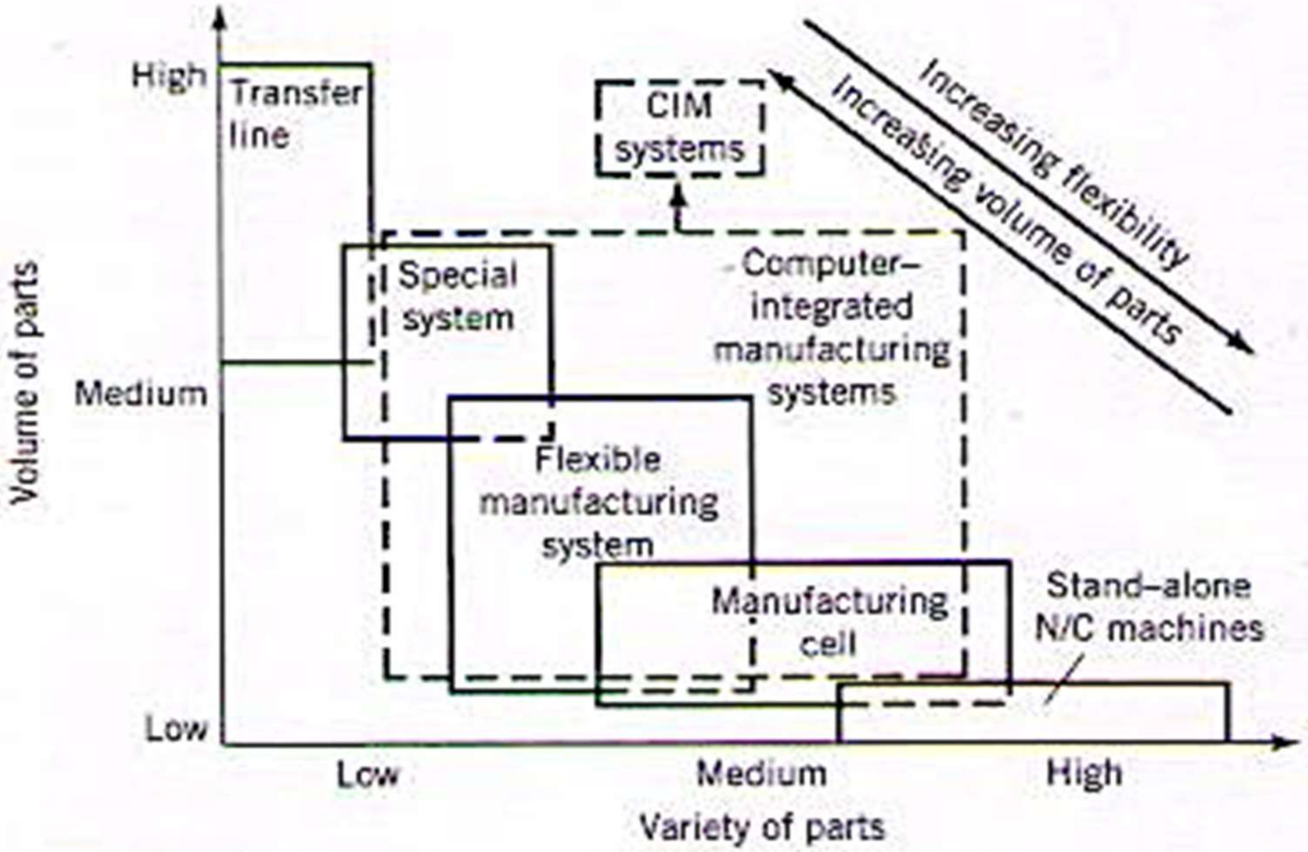

FIGURE 13.1 Volume–variety relationships categorizing production systems.

Volume-Variety Relationships For Understanding Production Systems

- ❑ High-Volume, Low-Variety (H-L) Production System
- ❑ Low-Volume, High-Variety (L-H) Production System
- ❑ Mid-Volume, Mid-Variety (M-N) Production Systems

- The simultaneous requirements of flexibility and production volume place more emphasis on system integration and automation.

Volume-Variety Relationships For Understanding Production Systems

Depending on the degree of integration and level of automation, the M-M manufacturing systems popularly known as computer-integrated manufacturing systems can be further classified as:

i. Manufacturing cell

ii. Special manufacturing system

iii. Flexible manufacturing system

Volume-Variety Relationships For Understanding Production Systems

- **Manufacturing Cell**

- The design of manufacturing cells is based on the concepts of group technology.
- The objective is to process some families of parts on a group of NC machines within a cell so that the intercellular material-handling effort is minimized.
- In a cell the NC machines are linked together by a direct numerical control (DNC) system.

Volume-Variety Relationships For Understanding Production Systems

❑ Special Manufacturing System

- In a special manufacturing system the machines are laid out to manufacture a family of parts based on the sequence of operations.

- A fixed-path material-handling system links the machines. The parts move on the material-handling system in a sequence from machine to machine.

Volume-Variety Relationships For Understanding Production Systems

❑ **Flexible Manufacturing Systems**

- A flexible manufacturing system lies between the two extremes of a manufacturing cell and a special manufacturing system.
- It is a true mid-volume, mid-variety manufacturing system, having a higher production rate than a manufacturing cell and much more flexibility than a special manufacturing system.
- An FMS is closer to a cell manufacturing system.
- An FMS is, however, characterized by a higher level of computer control and more non-machine entities such as coordinate measuring machines, and part washers.

Key Characteristics of Various Manufacturing Systems

- Transfer Line
- Flexible Manufacturing Module (Stand-Alone NC Machines)
- Manufacturing Cell
- Special Manufacturing System
- Flexible Manufacturing system

Key Characteristics of Various Manufacturing Systems

- True mid-volume, mid-variety manufacturing system consisting of a series of flexible machines, automated material-handling system, automated tool changer, other equipment such as coordinate measuring machines, part washers, and so on, all under high-level centralized computer control.

- Permits both sequential and random routing of a wide variety of parts.

- Higher production rate than a manufacturing cell and much higher flexibility than a special manufacturing system.

What is an FMS?

- An FMS is an automated, mid-volume, mid-variety, central computer-controlled manufacturing system.

- It covers a wide spectrum of manufacturing activities such as machining, sheet metal working, welding, fabricating, and assembly.

- In an FMS, families of parts with similar characteristics are processed. Therefore, group technology (GT) and consequently cellular manufacturing are significant parts of the system.

What is an FMS?

The essential physical components of an FMS are:

- Potentially independent NC machine tools capable of performing multiple functions and having automated tool interchange capabilities.
- Automated material-handling system to move parts between machine tools and fixturing stations.
- All the components (machine tools, material-handling equipment, tool changers) are hierarchically computer controlled.
- Equipment such as coordinate measuring machines and part-washing devices.

What is an FMS?

- Before machining is started on the parts, they are mounted onto fixtures.
- Both the parts and the fixtures are then mounted onto special pallets.
- The material-handling system moves the pallets to the machining centers for processing.
- If a machining center is busy, the pallets are automatically transferred to an idle machining center, thereby ensuring effective utilization of the FMS.
- A flexible manufacturing system consists of two subsystems:
  a) Physical subsystem
  b) Control subsystem

What is an FMS?

1. The physical subsystem includes the following:

a) Workstations consisting of NC machine tools, inspection equipment, part-washing devices, load and unload area, and work area.
b) Storage-retrieval systems consisting of pallet stands at each workstation and other devices such as carousels used to store parts temporarily between the workstations or operations. An automated storage and retrieval system can also be considered part of an FMS in a broader sense.
c) Material-handling systems consisting of powered vehicles, towline carts, conveyors, automated guided vehicles (AGVs), and other systems to carry parts between workstations.

What is an FMS?

2. The control subsystem required to ensure optimum performance of the FMS includes the following:

a) Control hardware, which includes mini- and microcomputers, programmable logic controllers, communication networks, sensors, switching devices and many other peripheral devices such as printers and mass storage memory equipment.
b) Control software consisting of a set of files and programs used to control physical subsystems. It is important to have hardware and software compatibility for efficient control of the FMS.

Flexible Manufacturing Systems-I

✓ **Basic Features of FMS: Physical Subsystems**

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Numerical Control Machine Tools

- The major building blocks of an FMS are machine tools.
- They determine the degree of flexibility and capabilities of the FMS. We discuss some of the characteristics of machine tools used in an FMS.

1. The majority of FMSs use horizontal and vertical spindle machines. Machining centers with vertical spindle machines offer less flexibility than horizontal machining centers.

Numerical Control Machine Tools

2. Machining centers with numerical control of movements in up to five axes (that is, spindle movements in x-, y- and z- directions, rotation of table, and tilting of table toward the column) are available.

3. The machining centers have the flexibility of performing a wide variety of operations, from simple turning to hole drilling to five-axis contouring. The shape (rotational and prismatic) of parts, accuracy requirements, weight, and so forth would determine the type of machining center suitable for an FMS.

Workholding and Tooling Considerations

- Effective utilization of a flexible manufacturing system depends on the workholding (fixtures and pallets), tooling, tool storage and tool changers, tool identification systems, coolant, and chip removal systems.

- FMS-specific fixturing considerations are:

1. Fixtures must be designed minimize part-handling time. Modular fixturing is an attractive way to fixture a variety of parts quickly.

Workholding and Tooling Considerations

2. Before machining is started on the parts, they are mounted on fixtures. Both the parts and the fixtures are then mounted on special pallets. This may lead to error buildup in the part-to-fixture, fixture-to-pallet, and pallet-to-machining center steps and render some of the parts out of tolerance. To reduce the error buildup problem, some fixtures should be pinned to the pallets.
3. Part variety considerations in FMSs lead to high usage of fixtures. Management strategies must be evolved for identification, storage, and retrieval of fixtures and their integration with the automated storage and retrieval system (AS/RS) and material-handling systems such as AGVS.

Workholding and Tooling Considerations

- All the machining centers are equipped with tool storage systems known as tool magazines. Common types of tool magazines, as shown in Figure 13.4 are:
  a) Disk type
  b) Drum type
  c) Turret type
  d) Chain type
- An optimal tool management strategy should include duplication of the most often used tools in the tool magazines, quick tool changers, tool regrinding, tool maintenance, and provision of spares.

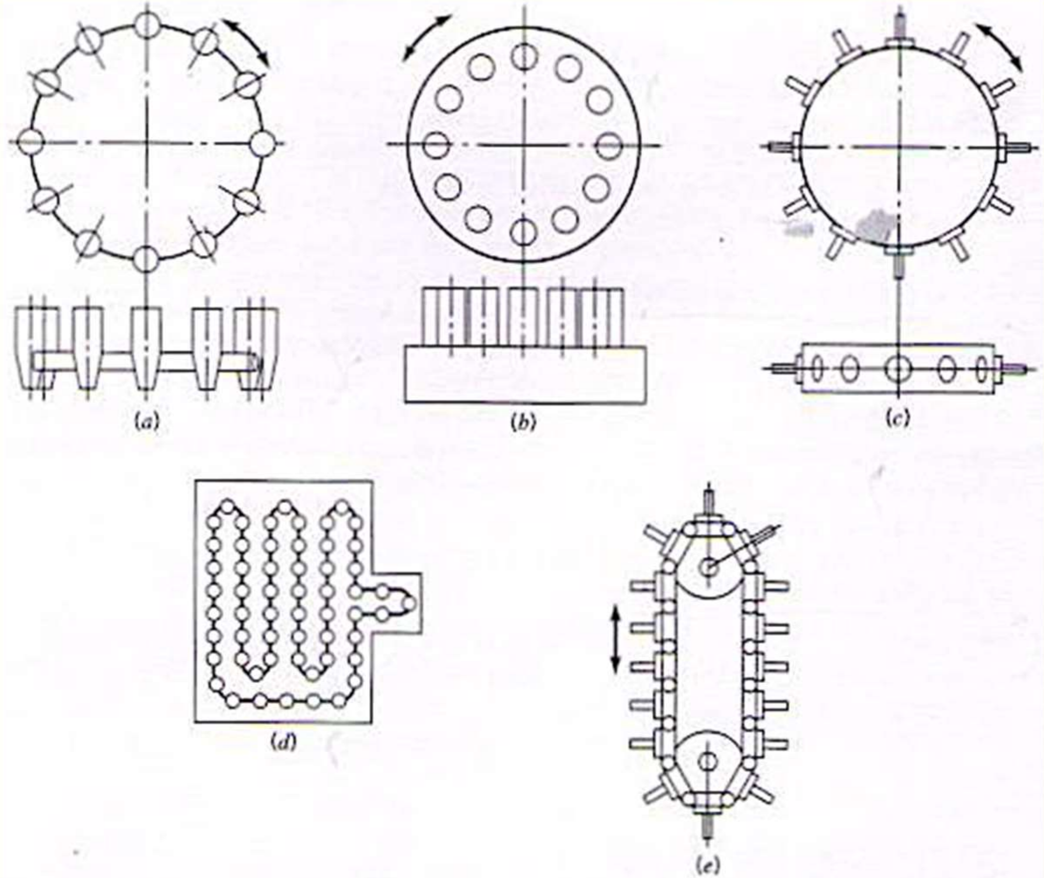

FIGURE 13.4 Various types of tool magazines: (*a*) disk type, (*b*) drum type, (*c*) turret type, (*d*) chain type, and (*e*) chain type. (Kusiak, Andrew: *Intelligent Manufacturing Systems*, ® 1990, Figure 2.23, p. 40, reprinted by permission of Prentice Hall Inc., Englewood Cliffs, NJ.)

Material-Handling Equipment

- Depending on the nature and variety of parts, the material-handling systems used in flexible manufacturing systems are robots, conveyors, automated guided vehicle systems, and many other specially designed systems for customized FMS.
- The most important consideration in selecting a material-handling system should be integration with the machining centers and the storage and retrieval systems together with an efficient identification system.
- The full potential of a material-handling system cannot be realized without having a bar-coding system to identify raw materials, work-in-process, finished parts, tools, fixtures, and pallets in different locations.

Inspection Equipment

- The distinguishing feature of FMSs is integration of the inspection equipment with the machining centers such as probing machining centers.

- Coordinate measuring machines (CMMs) are three-dimensional devices used for off-line inspection and programmed to measure concentricity, perpendicularity, and flatness of surfaces and hole dimensions.

Inspection Equipment

❑ Other Components

- Environmental considerations require that there is a central coolant and chip separation system with the capability of recovering the coolant.
- The FMS has deburring and cleaning stations. The combinations of parts, fixtures, and pallets must be cleaned to remove dirt and chips before operations and inspections.

Flexible Manufacturing Systems-I

- ✓ **Basic Features of FMS: Control Subsystems and Manufacturing Control Activities**

Basic Features of Control Components of an FMS

- Flexible manufacturing systems are designed and developed to meet specific customer requirements.

- These requirements dictate that the system:

➢ Is flexible enough to produce the quantities and varieties of parts desired by the customer.

➢ Has the ability to transfer parts automatically to other machining centers in case of system failures or systems being busy.

Basic Features of Control Components of an FMS

We divide the total manufacturing control activity into the following control functions:

1. Work-order processing and part control system
2. Machine-tool control system including inspection machines
3. Tool management and control system
4. Traffic management control system
5. Quality control management system
6. Maintenance control system
7. Management control system
8. Interfacing of these subsystems with central computer

Work-Order Processing and Part Control System

- The work-order processing and part control system is the system that essentially drives other control systems.
- The basic information used in the part control system is contained in a number of files.
- For example, a part identification file contains the information about the part name and the number of parts required.

Work-Order Processing and Part Control System

- For each part, the part routing file contains information such as number of operations, alternate machining centers on which these operations can be done, names of part programs files, machine identification files, tools required, operation time and operation cost, and sequence selection options.
- The manufacturing instruction file, also known as the part program file, contains ASCII (American Standard Code for Information Interchange) or EIA (Electronics Industries Association) program data in CNC format for each machining operation.
- The part setup file contains information on fixturing and palletizing of parts.

Work-Order Processing and Part Control System

- The part control system consists of a number of modules.
- For example, the part process planning module creates a process plan using information from the part identification, part routing, and program files.
- The process plan and the part routing modules are used to control the part movements in an FMS.
- The part setup module in conjunction with part identification controls the fixturing and palletization of parts.

Work-Order Processing and Part Control System

❑ **Machine-Tool Control System**

- The machine-tool control system has a number of modules such as a DNC transmitter, NC editor, and machine monitor and control modules.

Tool Management and Control System

- One of the distinguishing features of an FMS is the tool magazine, which holds a large number of tools. The tool magazine capacity is an influential factor in determining the flexibility of the system. A proper tool management and control system is needed to control the processing of parts and enhance the flexibility to manufacture variety of parts. Tool identification, tool setup, and tool routing are accomplished by the tool management and control system. Tool replacement strategies can also be part of such a control system. Details of various tool replacement strategies are given in later sections.

Tool Management and Control System

- **Traffic Management Control System**

The material handling and storage control system coordinates part routing, fixtures, pallets, and tool modules with the objective of tracking the destination of parts for successive operations on machining centers. In addition, it records and controls the storage and retrieval of parts, tools, fixtures, and pallets for quick availability.

Tool Management and Control System

- **Quality Control Management System**

The quality control management system in an important module of an FMS control system. The capabilities of the system include collection, storage, retrieval, and archiving of workpiece inspection data. The inspection programs for the workpiece are created at the coordinate measuring machines. These programs are then uploaded to the FMS computer for storage and retrieval of data.

Tool Management and Control System

- **Maintenance Control system**

The maintenance control system, also known as the service control system, is a kind of help menu. In the event of alarms due to problems in the operation of the machining centers and other equipment and systems, on-line help is available through this system.

Tool Management and Control System

❑ Management Control System

- The management control system is designed to provide the management status of output performance.

- It consists of a number of modules that coordinate with various other systems, including a provision for manual scheduling and control, scheduling of parts based on their requirements available from the material requirements planning (MRP) system, and report generation on output statistics of parts.

Tool Management and Control System

- A number of control architectures are possible, depending on the complexity of an FMS. However, the management control system provides a direct link into the corporate system database. This helps provide management information on the status of the system on a real-time basis.

❑ **Interfacing of These Subsystems with the Central Computer**

The complete FMS control system can be linked with the company's corporate computer. The objective is to integrate the FMS subsystem with other subsystems such as finance, marketing, and personnel.

Flexible Manufacturing Systems-I

✓ **Types of Problems in FMS**

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FMS Benefits

- FMS offers manufacturers more than just a manufacturing system that is flexible.
- It offers a concept to improve productivity in mid-variety, mid-volume production situations, an entire strategy for changing company operations ranging from internal purchasing and ordering procedures to distribution and marketing.
- Benefits resulting from implementing FMS technology cut across all the functional boundaries in any organization.
- The principal benefits of FMS are associated with the **system flexibility**, that is, responsiveness to problems on a short- and long-term basis.

Responsiveness to Short-Term Problems

- The use of NC machines permits flexibility in absorbing market fluctuations resulting in engineering and process changes.
- The control system built in the FMS permits the effective use of high capital investment equipment.
- If queuing of jobs continues because of the non-availability of machines, then the central control system may even reschedule the arrival of parts into the system.

Responsiveness to Long-Term Problems

- Reduction in direct labour by removing the operators from the machine site.
- Improved operational control through feedback control mechanisms and reduction in the number of uncontrollable variables.
- Improved machine utilization through elimination and/or reduction of machine setup time, use of automated tool changers and fixtures to change tools and workpieces, and optimal tool planning replacement using tool wear monitoring.
- Reduction in inventory through small lot sizes, improved inventory turnovers, and implementation of just-in-time principles.

FMS Planning and Implementation Issues

- **Planning and Design Issues**

- **Part family considerations:** Any flexible manufacturing system must be designed to process a limited range of part or product styles. In effect, the part family to be processed on the FMS must be defined.

- **Processing requirements:** The types of parts and their processing requirements determine the types of processing equipment that will be used in the system.

FMS Planning and Implementation Issues

- **Physical characteristics of the work parts:** The size and weight of the parts determine the sizes of the machines 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 of each type will be required.

- After the part family, production volumes, and similar part issues have been decided, the design of the system is initiated.

FMS Planning and Implementation Issues

- Important factors that must be specified in FMS design include:

- **Types of workstations:** The types of machines are determined by part processing requirements. Consideration of workstations must also include the load/unload station(s).

- **Variations in process routings and FMS layout:** If variations in process sequence are minimal, then an in-line flow is appropriate.

FMS Planning and Implementation Issues

- **Material handling system:** Selection of the material handling equipment and layout are closely related, because the type of handling system determines the layout.

- **Work-in-process and storage capacity:** The level of work-in-process (WIP) allowed in the FMS is an important variable in determining its utilization and efficiency.

- **Tooling:** Tooling decisions include types and numbers of tools at each station, and the degree of duplication of tooling at different stations.

FMS Planning and Implementation Issues

- **Pallet fixtures:** In machining systems for nonrotational parts, it is necessary to select the number of pallet fixtures used in the system. Factors influencing the decision include allowed WIP levels and differences in part style and size. Parts that differ too much in configuration and size require different fixturing.

FMS Planning and Implementation Issues

❑ Operations Management Issues

- **Scheduling and dispatching:** Scheduling of production in the FMS is dictated by the master production schedule. Dispatching is concerned with launching of parts into the system at the appropriate times.

- **Machine loading:** This problem is concerned with deciding which parts will be processed on which machines and then allocating tooling and other resources to those machines to accomplish the required production schedule.

FMS Planning and Implementation Issues

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

- **Part grouping:** Part types must be grouped for simultaneous production, given limitations on available tooling and other resources at workstations.

- **Tool management:** Managing the available tools involves making decisions on when to change tools and how to allocate tools to workstations in the system.

FMS Planning and Implementation Issues

- **Pallet and fixture allocation:** This problem is concerned with the allocation of pallets and fixtures to the parts being produced in the system. Different parts require different fixtures, and before a given part style can be launched into the system, a fixture for that part must be made available. Modular fixtures are used to increase pallet and fixture interchangeability.

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Thank You!!