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Resilient Manufacturing Systems: Embracing Modern Manufacturing Technology.

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Abstract: *Flexibility in manufacturing systems is a key issue in today's industry, driven by the need to meet customer demands while ensuring low costs and high product quality. This has led many contemporary manufacturing firms to implement Flexible Manufacturing Systems (FMS). The essence of FMS is to optimize and enhance the efficiency of the manufacturing process, resulting in greater productivity and superior product quality. An FMS typically includes an integrated network of computerized numerical control (CNC) machine tools, automated material handling systems, and other elements, all managed by a central computer. This paper discusses the advantages and disadvantages of FMS, explores its various applications, and provides an overview of its different facets.*
Keywords: *Computer Numerical Control, FMS Layout, Flexibility, Flexible Manufacturing System.*

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I. INTRODUCTION

The rising global competition has compelled many manufacturing enterprises to adopt Flexible Manufacturing Systems (FMS) to enhance productivity and product quality. FMS encompasses an integrated network of Computerized Numerically Controlled (CNC) machine tools and automated Material Handling Systems (MHS), all governed by computer control. Additional components, such as load/unload stations, washing stations, storage, de-burring stations, and tools and fixtures setting stations, can be incorporated into an FMS (Aly and Subramaniam, 1993; Bayazit, 2005). The core of an FMS is data communication, as the flexibility of the system largely depends on the integration of various elements like machining cells, robots, and Automated Guided Vehicles (AGVs) through computer systems (Venkatesh and Ilyas, 1993; Ficko et al., 2010). FMS consists of both hardware and software components. The hardware includes tangible elements like CNC machine tools, while the software involves intangible elements such as NC programs. Flexible manufacturing enables systems to be designed to meet highly customized production needs. Challenges such as reducing inventory levels, improving market response time, adapting to market changes, and cutting product and service costs have made it essential for many companies to transition to flexible manufacturing systems to achieve these goals while maintaining high-quality and cost-effective production. FMS is essentially an automated network of numerically controlled machines and material handling systems, capable of performing a diverse range of manufacturing tasks with rapid changes in tooling and instructions. In examining FMS, it is important to remember Peter Drucker's insight: "We must become managers of technology, not merely users of technology." Since FMS is a technology well-suited to meet environmental demands, effective management is crucial.

II. LEVELS OF MANUFACTURING FLEXIBILTY

Flexibility is a characteristic that enables a hybrid manufacturing system to handle variations in part or product cycles without disrupting production during model changeovers. FMS is termed "flexible" because it can process various part styles concurrently at the workstation, and production quantities can be adjusted to match shifting demand trends. The types of flexibility demonstrated by manufacturing systems are outlined below

2.1 Machine Flexibility

Machine flexibility refers to a machine's ability to perform a wide array of production tasks and handle different part styles. The broader the range of operations and part types a machine can manage, the higher its flexibility. Several factors influence machine flexibility:

- Setup or changeover duration- Ease of downloading part programs to machines
- Tool storage capacity of the machine
- Skills and adaptability of the operators

2.2 Production Flexibility

Production flexibility denotes the variety of part styles that a system can manufacture. The extent of part styles producible at a reasonable cost and within acceptable time frames is determined by the system's process capabilities. This flexibility is influenced by:

- The flexibility of individual machines
- The collective flexibility of all machines within the system

2.3 Mix Flexibility

Mix flexibility is the capability to adjust the product mix while keeping the total production quantity constant, meaning it allows the production of the same parts in different proportions. Also known as process flexibility, it helps mitigate market variability by allowing changes in the product mix through shared resources. However, significant mix variations may demand more tools, fixtures, and resources. Key factors affecting mix flexibility include:

- Similarity of parts within the mix
- Machine flexibility
- Work content times for different parts

2.4 Product Flexibility

Product flexibility involves the ability to swiftly and economically shift to new product lines in response to evolving market demands. This includes the time required for designing, planning, tooling, and setting up new products. Product flexibility depends on:

- The relationship between new designs and existing part families
- Preparation of part programs offline
- Machine flexibility

2.5 Routing Flexibility

Routing flexibility is the system's capacity to produce parts at alternative workstations in the event of equipment breakdowns, tool failures, or other disruptions at a specific station. This flexibility helps maintain throughput amidst external changes such as product mix alterations, engineering modifications, or new product introductions. Factors affecting routing flexibility include:

- Similarity among parts in the mix
- Similarity of workstations
- Commonality of tooling

2.6 Volume Flexibility

Volume flexibility refers to the system's ability to adjust production volumes for various products to meet changing demand while remaining profitable. Also known as capacity flexibility, it is influenced by:

- The percentage of manual labor involved in production
- Investment in capital equipment

2.7 Expansion Flexibility

Expansion flexibility is the ease with which a system can be scaled up to increase overall production capacity. This flexibility is determined by:

- Costs associated with adding new workstations and training workers
- Simplicity of expanding the layout

- - Type of part handling system utilized.

III. FLEXIBLE MANUFACTURING SYSTEMS (FMS) COMPONENTS

Components of Flexible Manufacturing Systems (FMS) are:

3.1 Workstations
3.2 Automated Material Handling and Storage System
3.3 Computer Control System
3.4 Inspection Equipments
3.5 Other Component

3.1 Workstations

Modern flexible manufacturing systems (FMS) commonly use workstations equipped with computer numerical control (CNC) machines that perform various machining operations on families of parts. The different types of workstations within an FMS include:

- Machining centers

- Loading and unloading stations

- Assembly workstations

- Inspection stations

- Forging stations

- Sheet metal processing units, among others.

3.2 Automated Material Handling and Storage System

Automated material handling systems in FMS transport workpieces and subassemblies between different processing stations. These systems often include storage capabilities as part of their function. Key functions of automated material handling and storage systems are:

- Allowing random and independent movement of workpieces between stations

- Managing various configurations of workpieces

- Providing temporary storage solutions- Ensuring easy access for loading and unloading workpieces

- Being compatible with computer control systems

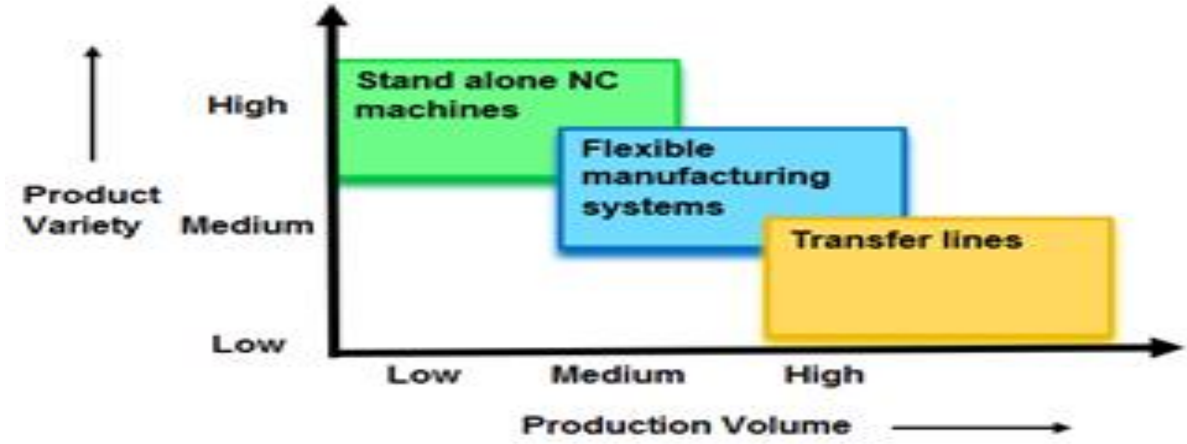


Fig. 2.1 Application Characteristics of FMS [15]

3.3 Inspection Equipment

This category includes coordinate measuring machines (CMMs), which are used for offline inspection. These machines are programmed to assess dimensions, concentricity, perpendicularity, and surface flatness. A key characteristic of these inspection tools is their seamless integration with the machining centers.

3.4 Other Components

Other essential components include a central coolant system and an efficient chip separation mechanism. Key features of these systems are:

- The ability to recover and recycle coolant effectively.

3.5 Computer Control System

The computer control system in an FMS is crucial for coordinating the operations of processing stations and the material handling system. Its functions include:

- Controlling each workstation individually

- Distributing control instructions to workstations

- Overseeing production processes

- Managing traffic and shuttle movements

- Handling workpieces and monitoring the system

- Monitoring and reporting system performance

FMS is particularly well-suited for production scenarios that involve a moderate variety of parts and medium production volumes.

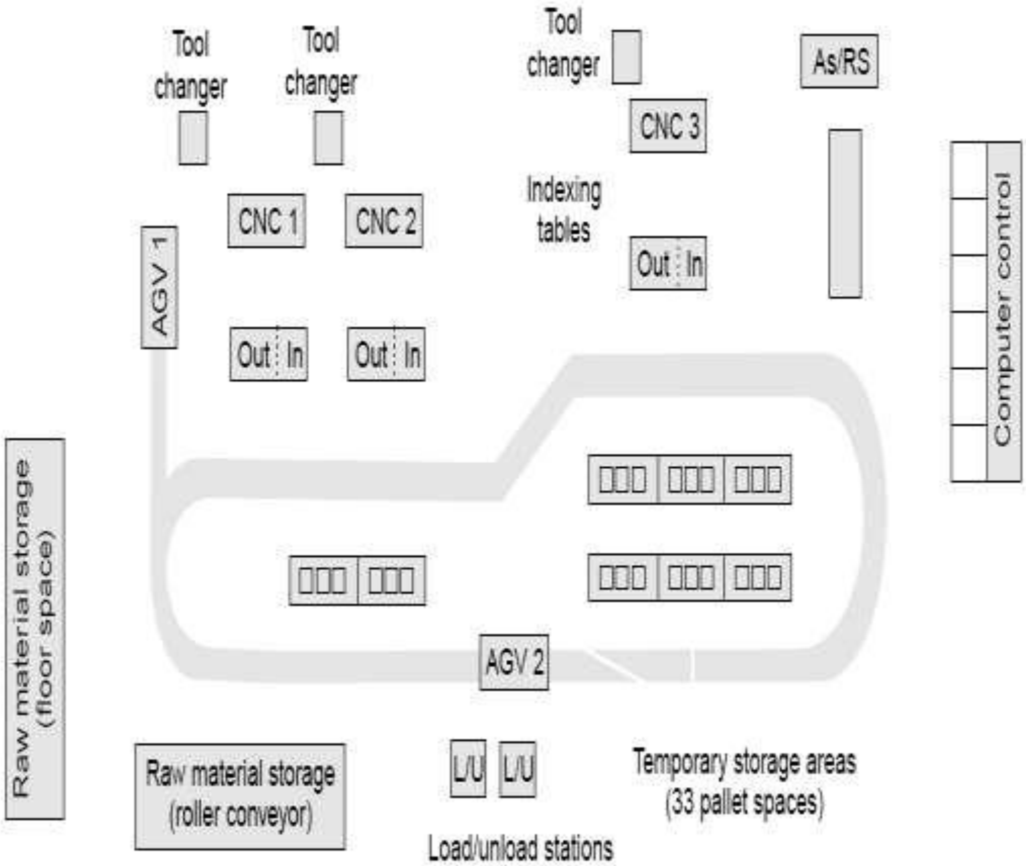


Fig.2.2 Flexible Manufacturing System [15]

IV. TYPES OF FMS LAYOUT

The different type of layout is:

- Progressive layout
- Loop type
- Ladder type
- Open field type
- Robot centered type

4.1 Progressive Type or Line Type

In this configuration, machines and the handling system are set up in a straight line, as illustrated in Fig. 3.1(a). This setup is ideal for systems where parts move from one workstation to the next in a specific sequence without any backtracking. The operation of this system is similar to a transfer line, where the workflow always follows a unidirectional path.

4.2 Loop Type

As depicted in Figure 3, the loop configuration allows parts to circulate in one direction around the loop. The parts can stop and be transferred to any station along the loop. The loading and unloading station is generally positioned at one end of the loop.

4.3 Ladder Type

In the ladder configuration, as shown in Figure 3.1, the loading and unloading stations are usually placed at the same end. The parts move from one machine tool to another in a sequence resembling a ladder, facilitating the operation and transfer process.

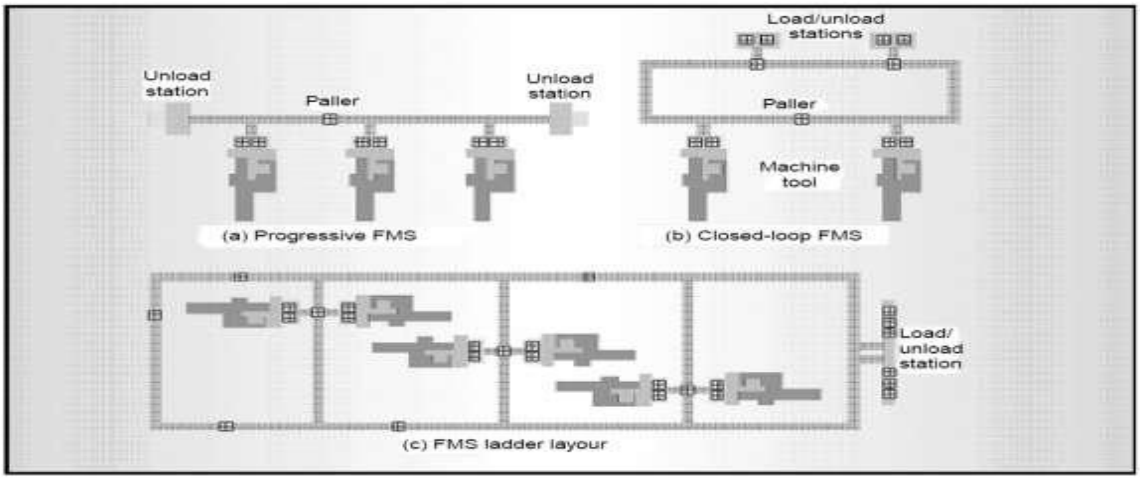


Fig. 3 Layout [15]

4.4 Open Field Type

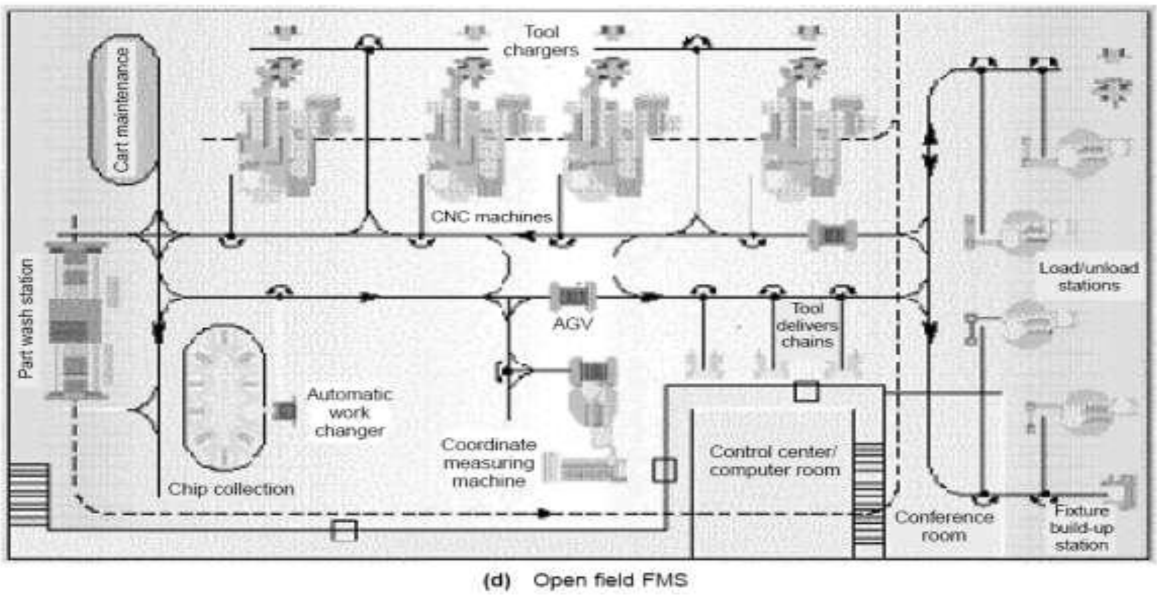
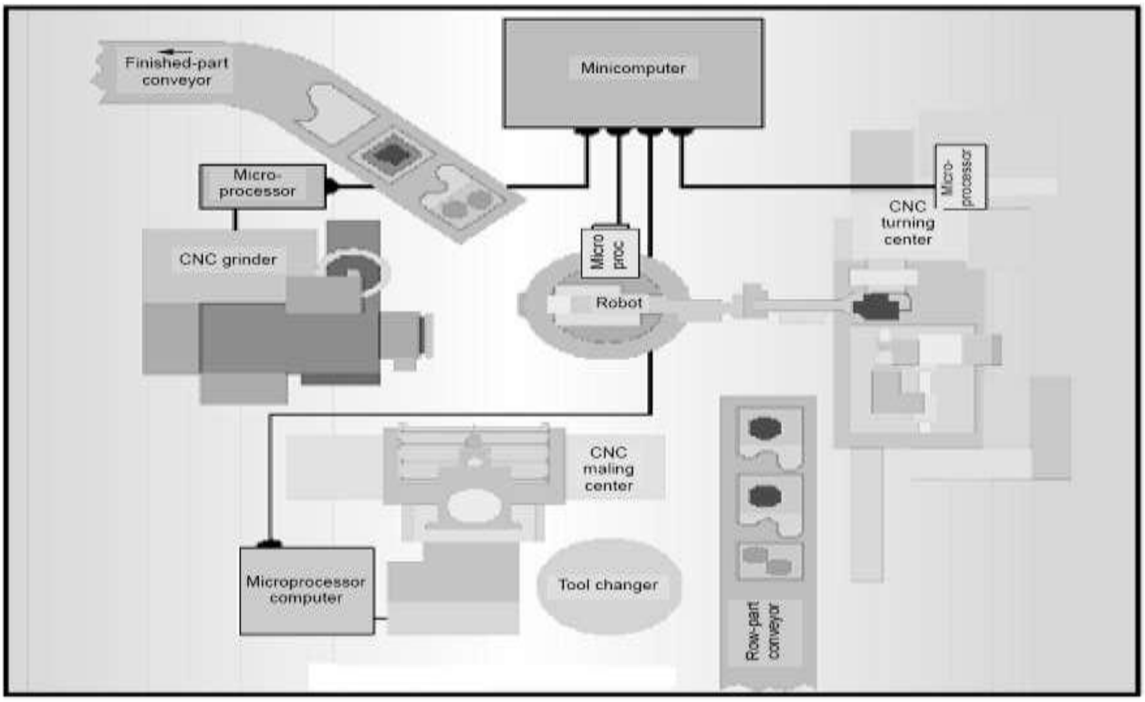


Fig.3.1 Open Field Type FMS [15]

The open field configuration, as depicted in Fig. 3.1(d), typically has the loading and unloading station positioned at the same end. In this setup, parts are transported through various substations, such as CNC machines, coordinate measuring stations, and washing stations. Automated Guided Vehicles (AGVs) are used to move the parts from one substation to the next, ensuring smooth workflow and efficient processing.

4.5 Robot-Centered Type

The robot-centered cell is a more recent type of flexible system where one or more robots serve as the material handling mechanism, as illustrated in Fig. 3.1(e). Industrial robots, often equipped with specialized grippers, are particularly effective for managing rotational parts. This configuration leverages the robots' precision and versatility to handle various tasks within the system.



(e) Robot centered FMS

Fig. 3.3 Layout [15]

V. OBJECTIVE OF FMS

- Reduced lead times
- Enhanced throughput
- Greater machine utilization
- Better adherence to due dates
- Lower inventory levels
- Reduced work in progress
- Improved quality

VI. AIMS OF FMS

- Minimize costs
- Lower inventory levels
- Decrease the unit cost per part
- Enhance technical capabilities
- Boost production output
- Handle smaller batch sizes efficiently
- Achieve quicker or zero changeover times
- Improve order processing and development
- Shorten lead times or delivery schedules
- Enhance market competitiveness

VII. MERITS OF FMS

Here are the benefits derived from implementing a Flexible Manufacturing System (FMS):

- Lower inventory levels
- Shorter lead times
- Enhanced machine utilization
- Reduced labor time requirements
- Improved management control over the entire manufacturing process
- Lower equipment costs
- Reduced floor space requirements
- High-quality products

VIII. DEMERITS OF FMS

The following are some considerations for implementing a Flexible Manufacturing System (FMS):

- FMS systems involve significant costs.
- They are more complex than transfer lines. Since each system is unique and customized, the development and commissioning process can be time-consuming.
- There is a need for highly skilled personnel to operate and manage the system effectively.

IX. AREA OF APPLICATION OF FMS

The following charts in the Fig. 3.2 shows the various applications in an industry

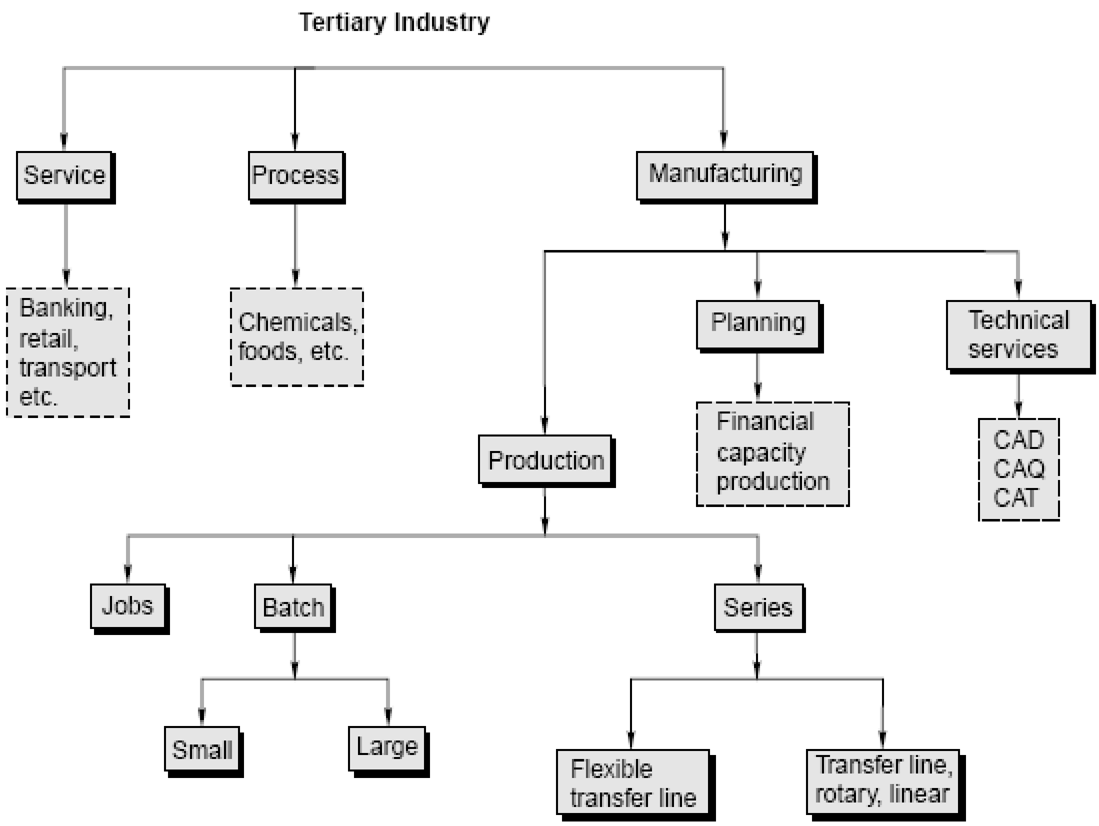


Fig.3.2 Area of Application [15]

X. CONCLUSION

In today's competitive business landscape, where manufacturing companies strive to enhance productivity and produce high-quality products at lower costs to meet market demands, Flexible Manufacturing Systems (FMS) offer an efficient and effective solution. The advantages and applications of FMS make it a valuable tool for achieving these goals. Additionally, FMS presents opportunities for innovation and the development of new manufacturing technologies, shaping the future of the industry.

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