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ORIGINAL ARTICLE

# Optimization of flexible manufacturing systems using IoT

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A flexible manufacturing system (FMS) is an automated material handling and integrated workstation that is computer-controlled and used for the automatic random processing of palletized parts. To assess the effectiveness of the FMS design before deployments, computer simulation is a cost-effective method. It is crucial to test this simulation software before usage since they have such a clear influence on the FMS decision-making process. A FMS is a complicated, integrated system that includes a central computer numerical control machining center and an automated material management system. The sole drawback of FMS is its greater initial cost and replacement cost if it does not function properly. Therefore, it is important to analyze FMS before installing it. The use of Industry 4.0 technologies has expanded the flexibility of the entire manufacturing system. The development of these technologies, which include the Internet of Things (IoT), big data, artificial intelligence (AI), additive manufacturing (AM), sophisticated robotics, virtual reality, cloud computing, simulation, and others, has increased the industrial system's adaptability.

**Keywords:** flexible transfer lines, flexible manufacturing cells (FMC), internet of Things (IoT), flexible manufacturing system

## 1. Introduction

The availability of several workstations at which generic processes are carried out defines flexible manufacturing systems (FMS). This system's flexibility is realized through a network of programmable transportation that connects the workstations and an advanced control system that coordinates the operations of the workstations and transport systems while keeping track of the status of the ongoing jobs. In general, innovations fascinate people, especially if the results can benefit them. The global marketplace is impatient and price-sensitive.

Due to daily fluctuations in client demand for a wide range of goods with eight pre-specified quality at lower prices, Indian business requires flexible production facilities to compete in today's global market incorporating innovative production technologies like FMS, JIT, CAD, and CAM, which have enormous potential. The many independent manufacturing systems that were discussed throughout this article may be combined in India to create a single, large-scale system in which the production of parts is managed with the assistance of a central computer to satisfy the daily changes in consumer expectations. Such a production system has the benefit of being very flexible in terms of the little effort and rapid turnaround time needed to make a new product; for this reason, it is referred to as a FMS.

## 2. The FMS concept

The FMS offers batch production with the efficiency of mass manufacturing. When components are produced in lots of few to more than 50, with a total yearly demand of less than, say, 100,000 units, it is referred to as batch production. When greater yearly production rates are needed, mass manufacturing is used, and thus, the usage of specialized machinery might be justified. It may cost 100 times as much to create a single unit using general-purpose machine tools as it does to produce the identical item using the most effective mass production techniques. It should be able to lower the cost of creating components in small and medium quantities by utilizing FMS technology. Advanced

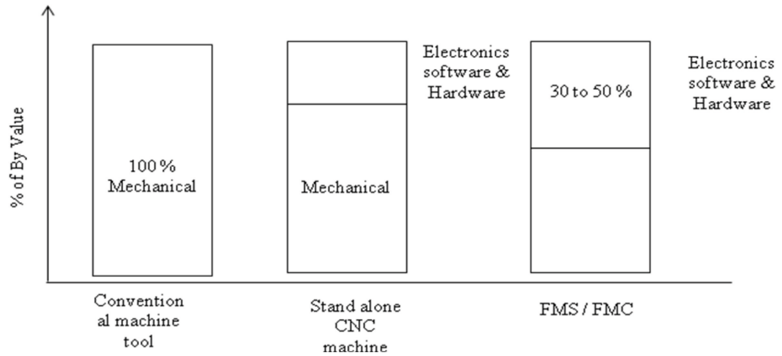


**FIGURE 1 |** Value-wise contents of mechanical and electronic software and hardware in different manufacturing facilities.

FMS will contain a high-power laser station incorporated into the production line; the laser will be used mainly for heat treatment, sheet metal cutting, drilling, and welding. At present, laser treatment of materials with a $CO_2$ laser in the 5–15 kW range is becoming more popular in the industry. The central computer of an advanced FMS will contain machining data to provide the recommended cutting parameters to the machine tools in the plant, based on a selected tool, workpiece material, and upon maximization of the production rate in the entire plant.

Different manufacturing equipment with sensing, identification, processing, communication, actuation, and networking capabilities can be connected through the Internet of Things (IoT). The IoT can be utilized for industrial applications and smart manufacturing through network control and management of manufacturing equipment, asset and situation management, or manufacturing process control. Intelligent IoT solutions allow for quick product development, product optimization, and quick reaction to market demands.

The IoT includes digital control systems that automate process controls, operator tools, and service information systems that improve plant safety and security. Utilizing measurements, statistical analysis, and predictive maintenance, IoT can also be used in asset management to increase reliability. Energy optimization is made possible through the integration of industrial management systems with smart grids. Networked sensors are used for measurements, automated controls, plant optimization, health and safety management, and other purposes. IoT is employed for procedures in the industrialization of buildings in addition to normal manufacturing.

## 2.1. Advanced manufacturing systems

While the various evolutionary stages in the development of computer numerical control (CNC) machines provided a means for effective part production, over time and with rapid developments in electronics, machine tool technology has graduated from the concept of standalone machine tools to system-oriented manufacturing. This resulted in the introduction of flexible manufacturing cell (FMC), FMS, and computer-integrated manufacturing.

Thus, the emphasis has shifted from mechanical hardware in the case of conventional manufacturing to a combination of mechanical and electronic software and hardware, which now accounts for 30–50% of the value of modern manufacturing systems.

An FMC/FMS is typically a manufacturing cell or system made up of one or more CNC machines connected by an automated material handling system, all of which are controlled by a central computer. There may also be additional auxiliary subsystems, like component loading and unloading stations, automatic tool handling systems, wash stations, component measuring apparatuses, and tool pre-setters. Figure 2 shows the major constituents of an FMS, and Figure 3 gives the integration of various constituents of an FMS.

Factory managers may automatically gather and evaluate data using smart manufacturing to make better decisions and maximize production. IoT connectivity solutions installed at the factory level transmit data from sensors and machines to the cloud. These data are examined, merged with relevant information, and then disseminated to relevant parties with authorization.

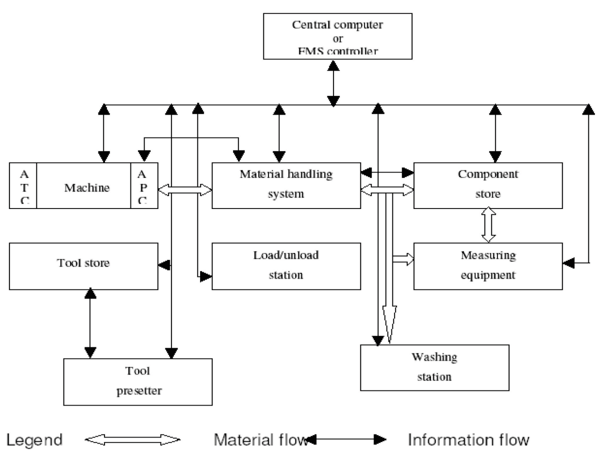


**FIGURE 2 |** Major constituents of an FMS.

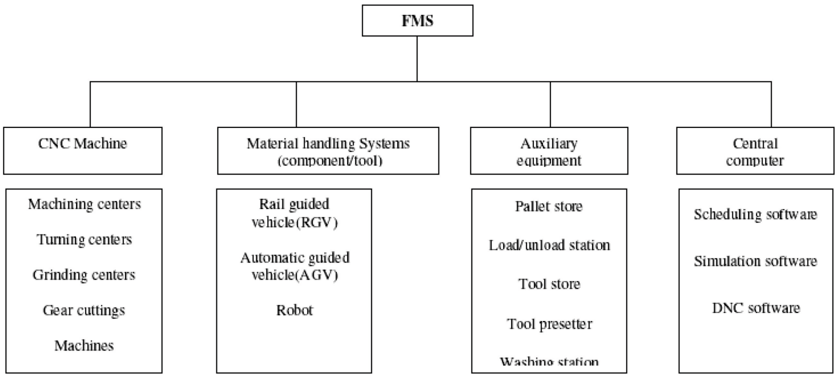


**FIGURE 3 |** Integration of various constituents of an FMS.

## 2.2. Benefits of an FMS

- Balanced output
- Better control over production
- Easier to expand
- Fewer rejections
- Flexibility to change part variety
- High product quality
- Higher machine utilization
- Higher productivity
- Just-in-time manufacturing
- Minimally manned operation
- Reduced cycle time
- Reduced work in process and inventory.

# 3. Trends in the adoption of FMS

FMS was adopted in the USA way back in 1967, but its widespread application has been rather slow. In 1981, the world population of FMS was estimated to be only 115, with 25 FMS installations each in the USA, Western Europe, and 40 in Japan. But by 1986, the population had grown to over 200; an industry-wise application of FMS is given in **Figure 4**.

Thus, with development over time, the manufacturing industry now has a spectrum of production alternatives to choose from depending on part variety and production volume. The production of a limited variety of parts in high volume, which is typical of automobile industries, is served by transfer lines. When the volume is large, but a variety of parts are inserted, the transfer line is designed with some built-in flexibility to handle the production requirement. FMS are ideal for the production of large part tools, industrial machinery, and general engineering.

Industries manufacturing items such as tractors, earthmoving equipment, agriculture machinery, and defense-related components have production requirements of a fairly large volume and a wider variety of parts. This need is being met by what may be termed as designed FMS/FMC, where the basic production equipment is flexible, but the volume is high enough to dedicate individual machines to specific parts.

Industries see an increase in productivity during product production when this technology is used properly. Manufacturing is done more cheaply and with fewer mistakes. To fully benefit humanity, there is still much work to be done. It has numerous uses for monitoring production systems in the manufacturing and service industries. By enabling increased performance, this technology expands manufacturing's potential for innovation and new possibilities. The main elements of this technology are software, hardware, and network connectivity for data collection and alteration. IoT fosters innovative disruption in the manufacturing sector.

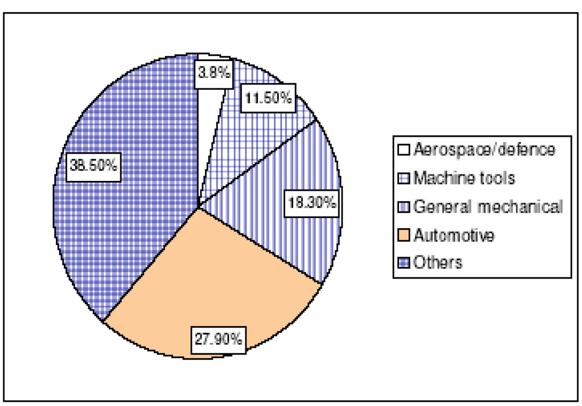


**FIGURE 4 |** Industry-wise application of FMS.

## 3.1. Stepwise approach to FMS

A leading machine tool manufacturer abroad has outlined a stepwise adoption of an FMS for prismatic production, as detailed below.

**Step 1:** The user can gain expertise in palletizing work and processing a mixed batch of components on a standalone machine with nameless operation capabilities.

**Step 2:** Performance in 2 days is improved by the addition of a rail-guided vehicle and up to 15 pallet stands. The variety of components that can be handled without operator assistance expands, and the duration of unnamed operation can be increased.

**Step 3:** It is possible to add machines with up to 15 pallet stands apiece. Pallets are dedicated to certain machines at this level. Each machine has a designated load/unload station where these operations are performed. In response to commands from the various machine control systems, the rail-guided vehicle moves.

**Step 4:** The same system hardware specifications as in step 3 plus control over separate transports. Now, any machine may be loaded with any pallet. Rather than responding to machine requests in a queue for the next component, the transporter operates following the priorities set by the operator.

**Step 5**: The cell may be extended to accommodate more machines and support operations like inspection and washing with the installation of a host computer. To fully utilize automated manufacturing technologies, encompassing all business and engineering operations leading to computer-integrated production, a host computer upgrades the system.

**Step 6:** The IoT is to collect and share data via Internet-connected machines and gadgets. It is connected to particular identification numbers or codes that can be managed by everyday gadgets like cell phones, which is very much useful for the beneficiaries of the human concern working in that industrial environment.

### 3.2. Flexible manufacturing cells

An FMC is the most fundamental type of FMS and is therefore the most adaptable. It is made up of a few general-purpose or specialized CNC machine tools connected to automatic tool and material changes. Centers are frequently the starting point for FMS, but they can be automatically machined by FMCs. A turning center with a gantry, an unloading system, and pallets for storing workpieces and finished components is commonly known as a flexible turning cell. The productivity of the cell can be increased if the turning center contains post-process metrology tools like Renishaw probes or inductive measuring tools, automatic tool changes, tool magazines, block tooling, automatic tool offset measurement, and automatic chuck changes. One or more horizontal machining centers with modular fixtures, numerous pallets, an advanced tool management system, an automobile tool changer, an automobile head changer, an automatic magazine change, robots or other material handling systems to aid in job access to the machine, and one or more flexible machining cells make up a flexible machining cell.

### 3.3. Flexible transfer lines

High-volume productions are suited for flexible transfer lines (FTLs). In a high-volume manufacturing setting, a part could need to go through numerous operations, each of which is assigned to be completed on a single machine. As a result, each component travels along a set path through the system. Typically, the material handling system consists of a conveyor, carousel, or pallet. Along with general-purpose machines, it may also include robots, special-purpose machines, and some specialized equipment. It is simpler to plan for balancing machine loads. Unlike conventional transfer lines, the FTL allows for the fabrication of a variety of work parts. The process of resetting is mostly automatic.

Multiple universal or specialized flexible automated machine tools are combined into a flexible machining system called a flexible machining system. This allows for the simultaneous machining of multiple work components. The defining characteristic is the machine interlinkage, which is unrestricted by cycle concerns. It is possible to compensate for varied machining times at the various stations by employing centralized or decentralized workpiece buffer storage. Flexibility is applied to machines through CNC control and product flow from one machine to another, which is made possible by adaptable transport systems. Flexibility is the capacity of a system to adapt to changes in the volumes of the product mix as well as the machining procedures and sequences. As a result, an FMS will be able to react quickly to shifting consumer and market demands.

## 4. Major elements of FMS

Each major subsystem in an FMS carries out a variety of tasks, and each one depends on the others for the system to operate as a whole. The tasks vary according to the machinery and manufacturing processes that are used.

- Production equipment
- FMS for sheet metal work
- FMS for machining
- Support systems.

Automated machine tools frequently require many systems to function. At each machine or in the center tool storage, the required tools for machining centers or turning centers' numerous operations may be housed in magazines. Local publications provide quick access and backup capacity, but in a large FMS, a central tool facility might be more efficient.

### 4.1. Material handling system

To maintain an FMS, several material-handling systems are often required.

- A mechanism for moving goods in and out of the FMS, such as RVs, gantry systems, AGVs, and overhead conveyors.
- A transfer system to load and unload the machines.
- A buffer storage system for machine workpiece queues (e.g., pallets).
- These systems must be coordinated with machine operations to function properly.

## 5. Optimization of FMS

The following strategies should be taken into account to maximize the FMS's overall effectiveness and efficiency.

- Utilizing each machine to its fullest capacity, cutting down on process cycle times, and keeping work organized in automated storage systems so that machines can process it are all good practices.
- The use of identity marking methods, providing adequate sensors for defect or problem detection, having backup options, including in-process measurement and inspection processes, and having backup options.

## 6. Conclusion

An FMS is adopted not only in advanced countries but also in the Indian industry. In the past 5 years, some of the leading automobile, machine tool, and defense sectors in the country have also installed FMS. HMT has already developed an FMS on a pilot basis and has undertaken the supply of an FMS to the defense sector under a joint working agreement with an overseas manufacturer. Although the FMS requires a higher initial investment, its benefits are substantial in the long run. Hence, the adoption of FMS in the Indian industry is likely to grow in the future as the demand for flexibility and productivity increases.

With thermal and video sensors gathering comprehensive product data across various stages of a product cycle, the IoT makes this procedure proactive. At each stage of the manufacturing process, the goods can also be checked to see if their characteristics meet the requirements. Instrumentation and monitoring of production equipment also assist quality control staff in determining whether and where equipment calibration deviates from standard settings. Such inaccuracies must be stopped in advance to prevent misalignment of products.

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