Flexible manufacturing system analysis

Historyof Flexible Manufacturing Systems

Introduction

AFlexible Manufacturing System(FMS) is a manufacturing system in which there is a certain degree offlexibilitythat allows the system to react in the case of changes, whether predicted or unpredicted. According toMaleki[1], flexibility is the speed at which a system can react to and accommodate change. To be considered flexible, the flexibility must exist during the entire life cycle of a product, from design to manufacturing to distribution. Flexible Manufacturing System is a computer-controlled system that can produce a variety of parts or products in any order, without the time-consuming task of changing machine setups.

The flexibility being talked about is generally considered to fall into two categories, which both contain numerous subcategories[2].

The first category, Machine Flexibility, covers the system's ability to be changed to produce new product types, and ability to change the order of operations executed on a part. The second category is called Routing Flexibility, which consists of the ability to use multiple machinesto perform the same operation on a part, as well as the system's ability to absorb large-scale changes, such as in volume, capacity, or capability.

The main advantage of an FMS is its high flexibility in managing manufacturing resources like time and effort in order to manufacture a new product. The best application of an FMS is found in the production of small sets of products like those from amass production.

FM systems are supposed to provide the manufacturer with efficient flexible machines that increase productivity and produce quality parts. However, FM systems are not the answer to all manufacturers’ problems. The level of flexibility is limited to the technological abilities of the FM systems. FM systems are being used all over the manufacturing world and though out industries. A basic knowledge of this kind of technology is very important because FM systems are involved in almost everything that you come in contact with in today’s world. From the coffee maker to your remote control FM systems are used all over.

History of Flexible Manufacturing Systems

At the turn of the twentieth century, FMS did not exist. There was no pressing need for efficiency because the markets were national and there was no foreign competition. Manufacturers could tell the consumers what to buy. During that period, Henry Ford had been quoted as saying “ People can order any colour of car as long as it is black.” All the power remained in the hands of the manufacturer and the consumers hardly had any choices.

However, after the Second World War a new era in manufacturing was to come. The discovery of new materials and production techniques increased quality and productivity. The war led to the emergence of open foreign markets and new competition. The focus of the market shifted from manufacturer to consumer. According to Maleki, the first FM system was patented in 1965 by Theo Williamson who made numerically controlled equipment. Examples of numerically controlled equipment are like CNC lathes or mills whichKusiaksays are varying types of FM systems.

During the 1970s, with the ever-growing developments in the field of technology, manufacturers started facing difficulties and hence, FM systems became main-stream in manufacturing to accommodate new changes whenever required. During the 1980s for the first time manufacturers had to take in consideration efficiency, quality, and flexibility to stay in business.

According to Hoeffer, the change in manufacturing over time was due to several factors. (Hoeffer, 1986)

- Increased international competition,
- The need to reduce manufacturing cycle time, and
- Pressure to cut the production cost.

Everyday new technologies are being developed and even FM systems are evolving. However, overtime FM systems have worked for many manufacturers and hence will be around for the time to come.

The Process of Flexible Manufacturing Systems

As has been discussed above the flexible manufacturing system can be broadly classified into two types, depending on the nature of flexibility present in the process, Machine Flexibility and Routing Flexibility

FMS systems essentially comprise of three main systems.[3]

1. The processing stations: These are essentially automated CNC machines.
2. The automated material handling and storage system: These connect the work machines to optimize the flow of parts.
3. Central control computer: This controls the movement of materials and machine flow.

The FMS as a system stands out because it does not follow a fixed set of process steps. The process sequence changes according to requirement to allow maximum efficiency. Sequence of material flow from one tool to another is not fixed nor is the sequence of operations at each tool fixed.

Key Features of the Process[4]

Some characteristics that differentiate FMS from conventional manufacturing systems are their technical flexibility, i. e., the ability to quickly change mix, routing, and sequence of operations within the parts envelope and also complexity resulting from the integration, mechanization, and reprogrammable control of operations i. e., parts machining, material handling, and tool change. Some key features of the process are discussed below.

Cell: It consists of several groupings of two or more automated machines within a company. Each grouping is called a cell. All the machines present are controlled by a computer. They are programmed to change quickly from one production run to another.

A key feature is the automated flow of materials to the cell and the automated removal of the finish item. Several cells are linked together by means of an automated materials-handling system, and the flow of goods is controlled by a computer. In this manner a computer-integrated manufacturing process is initiated.

Random bypass capability: The material handling system has a random bypass capability, i. e. a part can be moved from any tool in the interconnected system to another because the transport system can bypass any tool along the path, on demand. This implies:

- Each part can traverse a variable route through the system.
- Again, this flexibility in material handling, in combination with multipurpose tools, makes it possible for a flexible manufacturing system to process a great diversity of parts.

Automation: Computers are the heart of automation. They provide the framework for the information systems which direct action and monitor feedback from machine activities.

As FMS involve a wide variety of components, each with their own type of computer control, many of these computer components are installed as islands of automation, each with a computer control capable of monitoring and directing the action. Each of the computer controls has its own communication protocol based on the amount of data needed to control the component. Thus, the task of computer integration is to establish interfaces and information flow between a wide range of computer types and models.

Computer software provides the ability to transmit timely and accurate status information and to utilize information which has been communicated from other computers in FMS.

Component redundancy: In FMS as the equipment is highly integrated, the interruptions of one component affect other components. This results in a greater time to trace the problem when compared with isolated components. In some cases, the interruption might be due to some other integration effect, and greater downtime may result before the actual cause of the problem is found.

In this situation, component redundancy provides flexibility with the opportunity for choice, which exists when there are at least two available options. Flexible manufacturing contains functionally equivalent machinery. So in case of failure of one machine the process flow is directed towards a functionally equivalent machine.

Multiple Paths: A path in flexible manufacturing represents a part sequence and requisite fixtures to complete its required operations. In a conventional machine environment, only one path exists for a part because a single fixture remains at a single machine. However, this is not the case within flexible manufacturing systems, where there are multiple paths. The number of paths which are present within flexible manufacturing is a measure of the degree of flexibility. Obviously, the higher the number of paths, higher is the degree of flexibility.

Flexibility ranks high in Japan′s manufacturing strategy but not in America′s. A true flexible factory will not only build different versions of the same car, like a coupé or a station wagon, on the same production line, but also a completely different car. This is what the Japanese factories are setting out to do. The cost of one factory can be spread across five or ten cars. Apart from lower fixed cost, it is also less painful to stop making one of those cars if it fails to sell.

FMS as a system of manufacturing process can be compared to other processes in terms of the product volume it generates and its capacity for creating part variations.

The above depicts the position of FMS vis-à-vis that of stand-alone machine and transfer lines. The horizontal axis represents production volume level and the vertical axis shows the variability of parts. Transfer lines are very efficient when producing parts at a large volume at high output rate, whereas stand-alone machines are ideally suited for variation in workplace configuration and low production rate. In terms of manufacturing efficiency and productivity, a gap exists between the high production rate transfer machines and the highly flexible machines. FMS, has been regarded as a viable solution to bridge the gap and as a gateway to the automated factory of the future.

The Process: With Reference to particular companies[5]

Though the features of this manufacturing innovation process are similar across all types of firms, the manner in which they are adopted and implemented depends on product type, manufacturing, maintenance, process planning and quality control processes. It is also contingent upon the people carrying out these processes; the productive resources being used and the organizational arrangements used to divide and coordinate the processes distinguished.

The description of the layout of a company that has adopted the flexible manufacturing system gives a clear idea of how the system works in practical life. It has all the features as mentioned before of a typical FMS.

Flexible Manufacturing System at The Hattersley Newman Hender (H. N. H.)

This company, located in U. K. manufactures high and low pressure bodies and caps for water, gas and oil valves. These components require a total of

2750 parts for their manufacture. That is why they decided to go for the system of F. M. S. to fulfill their machining requirements in a single system. The process described below shows how FMS is used for efficient production for this company.

Their FMS consists of primary and secondary facilities. The primary facilities include 5 universal machining centres and 2 special machining centres. The secondary facilities consist of tool settings and manual workstations.

System layout and facilities:

Flexible Manufacturing Systems [F. M. S]

Primary facilities:

Machining centres: The FMS contains two 5-axis horizontal ‘ out-facing’ machines and five 4-axis machining centres under the host control. All the machines have a rotating pallet changer each with two pallet buffer stations.

These stations transfer pallets to and from the transport system which consist of 8 automated guided vehicles. The 5 universal machining centres have 2 magazines with capacity of 40 tools in each magazine. The special purpose out-facing machines (OFM) each have one magazine having a capacity of 40 tools. The tool magazines can be loaded by sending instructions to the tool setting room either from the host computer or the machine’s numerical controller.

Processing centres: The system contains two processing centres – a wash machine and two manual workstations.

Ø Wash machines: It contains two conveyor belts where one is for input and one for output of pallets, each with a capacity of three pallets to transfer the pallets. The wash booth has a capacity of three pallets. The pallets are washed in the booth and turned upside-down to drain out the water. Then they are dried with blown air.

Ø Manual workstations (ring fitting area): The operator fits metal sealing rings into the valve bodies at the manual workstations. He receives work instructions via computer interface with the host.

Secondary facilities:

Auxiliary stations:

Ø Load/unload stations: The FMS has four-piece-part load and unload stations. Loading and unloading is performed at these stations with the instructions again received via computer interface with the host.

Ø Fixture-setting station: At these stations the fixtures are readjusted to accommodate different piece parts.

Ø Administration of tools: Tools are assembled manually. The tool-setting machine checks the dimensional offsets of the tools and generates a bar code for further identification of the tool that has been set.

Auxiliary facilities:

Ø Transport system: The transport system consists of a controller and 8 automated guided vehicles (AGV). The system also contains an A. G. V. battery charging area.

Ø Buffer stores: The FMS has 20 buffer stores in order to store the empty and loaded pallets while they are waiting to be taken to another transfer station (i. e. a load/unload station or a machine tool etc.).

Ø Maintenance Area: This facility caters to pallets that may be damaged or need servicing or for storing scrapped piece-parts.

Ø Raw Material Stores: These stores are located in front of the load / unload stations and are used to store the raw materials (like forged valve bodies etc). The store is served by two fork-lift-stacker cranes and motor roller conveyors. It has a capacity of 80 containers.

Ø Fixture store: The fixtures that are not stored in FMS are stored here. It has a capacity of storing 120 fixtures. The store is served by a stacker crane and motor roller conveyors.

Flexible Manufacturing System at TAMCAM Computer Aided Manufacturing (TAMCAM) Lab.

This is an example of flexible manufacturing system that is used to describe the TAMCAM Simulation-Based Control System (TSCS)[6]. This system is located within the TAMCAM Computer Aided Manufacturing (TAMCAM) lab.

The system consists of three CNC milling machines, one CNC turning centre, two industrial robots, and an automated cart based conveyor system.

In addition to the automated equipment, human operators are used to load and unload some machines and perform assembly and inspection tasks.

Advantages of Flexible Manufacturing System

Why would firms embrace flexible manufacturing systems? What benefits does FMS provide? Answers to these two questions are important to the success of flexible manufacturing systems. It is important to understand the impacts on product life cycle, direct labour input and market characteristics.

Various advantages arise from using flexible manufacturing systems.[7] Users of these systems enlist many benefits:

* Less scrap

* Fewer workstations

* Quicker changes of tools, dies, and stamping machinery

* Reduced downtime

* Improved quality through better control over it

* Reduced labour costs due to increase in labour productivity

* Increase in machine efficiency

* Reduced work-in-process inventories

* Increased capacity

* Increased production flexibility

* Faster production

* Lower- cost/unit

* Increased system reliability

* Adaptability to CAD/CAM operations

Since savings from these benefits are sizeable, a plethora of examples from the manufacturing industry are available to illustrate these benefits.

“ A major Japanese manufacturer, by installing a flexible manufacturing system, has reduced the number of machines in one facility from 68 to 18, the number of employees from 215 to 12, space requirements from 103000 square feet to 30000 and processing time from 35 days to a 1. 5 days”

“ Ford has poured $4, 400, 000 into overhauling its Torrence Avenue plant in Chicago, giving it flexible manufacturing capability. This will allow the factory to add new models in as little as two weeks instead of two months or longer. The flexible manufacturing systems used in five of Ford Motor Company’s plants will yield a $2. 5 billion savings. By the year 2010, Ford will have converted 80 percent of its plants to flexible manufacturing.”

The benefits enlisted above are the operational benefits.[8] Flexible Manufacturing Systems also give rise to benefits in terms of strategy for the firm.

Operational Benefits

Strategic Benefits

Lower Costs per unit

A source of competitive advantage in present and future.

Lesser workstations

Less space in plant required.

Reduced Inventories

Less of Storage Space. Plant Layout gets simplified. The space is freed up for other activities.

Increase in labour productivity

Lesser workforce required.

Operational Flexibility

Ability to meet varying customer demands in terms of numbers (seasonality) and choices.

Improved Quality

Increased customer satisfaction

Less inspection costs

Lesser lead time

Increased Machine Efficiency

Less technical workforce for handling maintenance and repair

Less Scrap and Rework

Consistent Production Process

On a macro level, these advantages reduce the risk of investing in the flexible manufacturing system as well as in ongoing projects in such a firm.

Let us look at how flexibility helps firms. To maximize production for a given amount of gross capacity, one should minimize the interruptions due to machine breakdowns and the resource should be fully utilized. FMS permits the minimization of stations′ unavailability, and shorter repair times when stations fail. Preventive maintenance is done to reduce number of breakdowns. Maintenance is done during off hours. This helps to maximize production time. Cost of maintaining spare part inventories is also reduced due to the fact that similar equipment can share components. Hence we can see that higher the degree of flexibility of the workstation, the lower the potential cost of production capacity due to station unavailability.

To make a product every day, the trade – off between inventory cost and setup cost becomes important. However, each time the workstation changes its function, it incurs a set-up delay. Through flexibility one can reduce this set-up cost. [9]

CAD/CAM aids in computerized tracking of work flow which is helpful in positioning inspection throughout the process. This helps to minimize the number of parts which require rework or which must be scrapped. FMS changes the outlook of inspection from a post-position to an in-process position. Hence, feedback is available in real time which improves quality and helps product to be within the tolerance level.[10]

Flexible manufacturing systems (FMS) are virtually always used in conjunction with just-in-time (JIT) order systems. This combination increases the throughput and reduces throughput time and the length of time required to turn materials into products.

Flexible Manufacturing Systems have a made a huge impact on activity-based costing.[11] Using these systems helps firms to switch to process costing instead of job costing. This switching is made possible because of the reduced setup delays. With set-up time only a small fraction of previous levels, companies are able to move between products and jobs with about the same speed as if they were working in continuous, process type environment.

To look at another aspect of strategic benefits, enterprise integration can be facilitated by FMS. An agile manufacturer is one who is the fastest to the market, operates with the lowest total cost and has the greatest ability to " delight" its customers. FMS is simply one way that manufacturers are able to achieve this agility.[12] This has also been reported in many studies that FMS makes the transition to agility faster and easier. Over time, FMS use creates a positive attitude towards quality. The quality management practices in organizations using FMS differs from those not using it.

The adoption of flexible manufacturing confers advantages that are primarily based upon economies of scope. As a result of aiming simultaneously at flexibility, quality and efficiency, the future manufacturing industry will strive towards: producing to order, virtually no stock, very high quality levels, and high productivity. [13]

Disadvantages of Flexible Manufacturing System[14]

Now that we have looked at the multiple advantages flexible manufacturing systems offer, the next obvious question is, if they are so good and so useful then why are they not ubiquitous by now? It is essential to look at the other side, especially the impact these systems have on costing, product mixes decided by the company and the inevitable trade- off between production rates and flexibility.

Following are the major disadvantages that have been observed

Complexity

These sophisticated manufacturing systems are extremely complex and involve a lot of substantial pre planning activity before the jobs are actually processed. A lot of detail has to go into the processing. Often users face technological problems of exact component positioning. Moreover, precise timing is necessary to process a component.

Cost of equipment[15]

Equipment for aflexiblemanufacturingsystem will usually initially be more expensive than traditional equipment and the prices normally run into millions of dollars. This cost is popularly known as the Risk of Installation.

Maintenance costs are usually higher than traditional manufacturing systems because FMS employs intensive use of preventive maintenance, which by itself is very expensive to implement. Energy costs are likely to be higher despite more efficient use of energy.

Increased machine utilization can result in faster deterioration of equipment, providing a shorter than average economic life. Also, personnel training costs may prove to be relatively high. Moreover there is the additional problem of selecting system size, hardware and software tailor made for the FMS.

Cost of automation in the form of computer integration is the most significant cost in a flexible manufacturing system. The components require extensive computer control. Also, the costs of operation are high since a machine of this complexity requires equally skilled employees to work or run it.

Adaptation Issues

There is limited ability to adapt to changes in product or product mix. For example, machines are of limited capacity and the tooling necessary for products, even of the same family, is not always feasible in a given FMS. Moreover, one should keep in mind that these systems do not reduce variability, just enable more effective handling of the variability.

Equipment Utilization

Equipment utilization for flexible manufacturing systems is sometimes not as high as expected. Example, in USA, the average is ten types of parts per machine. Other latent problems may arise due to lack of technical literacy, management incompetence, and poor implementation of the FMS process. It is very important to differentiate between scenarios where FMS would be beneficial (ex, where fast adaptation is the key) and those where it wouldn't (ex where a firm's competency is based on minimizing cost).

Product/Job Costing[16]

Arguably the biggest disadvantage of flexible manufacturing systems is the difficulty faced by the company in allocating overhead costs to jobs. Usually, several products share the same resources with different consumption characteristics. Ideally, the overhead allocation should be directly proportional to the resource consumption. But this becomes complicated in the case of flexible manufacturing systems since it is very difficult to estimate which product used which machine for which purpose and for how long. Often this leads to under costing of some products and consequently over costing of others.

In systems that use FMS, usually the fixed costs are quite high due to the following reasons:

* The machines are costly, material handling is more expensive and the computer controls are state of the art, thereby leading to a higher depreciation than seen in traditional manufacturing systems.

* A lot of items which are otherwise usually treated as direct costs are counted under indirect costs in case of flexible manufacturing systems. For example, labour is normally attributed to the job directly done, but in FMS, the same workers work on machines that usually run two jobs simultaneously. Hence even labour costs are to be treated as overhead or indirect costs.

* In order to ensure smooth running of the flexible manufacturing systems, a lot of support activities carried out by engineers and technicians.

Keeping the above points in mind, we can infer that in order to cater to these scenarios, Activity Based Costing techniques are used with FMS to reduce distortion of product costs.

FMS Adoption in Automobile Industry

The Flexible manufacturing system has been adopted extensively in the manufacturing industry in this day and age. It addresses the issue of automation and process technology which is a key area for concern of manufacturing management along with inventory production planning and scheduling and quality.

One industry which has extensively adopted this system is the Automobile Industry. Almost all global giants now follow the Flexible Manufacturing system and many have developed their own manufacturing system keeping FMS as an integral part of it.

The Big Three of the American Automotive Industry namely General Motors, Ford Motors and Chrysler Motors enjoyed a monopolistic environment for a very long time. This in some way inhibited their innovation capabilities as there was no competition in the market which could drive them to innovate. These companies, therefore, maintained production facilities that were suitable for mass production of any single model, which ensured economies of scale and plant profitability. But gradually as Asian car makers gained prominence in the automotive market, the Big Three of the United States faced huge challenges across all product lines. The main Asian competitors that came into picture were Toyota, Honda, Nissan and Mitsubishi from Japan and Hyundai from South Korea. With these Asian countries exporting vehicles to the United States of America, competition heightened and the profitability of the Big Three decreased. To improve its profitability and maintain its market share Chrysler Corporation, General Motors and Ford Motor Company employed Flexible Manufacturing System in their production lines following what had been started in Japan.

The essential driving force for adoption of FMS in Automobile industry is

1. The emphasis on increasing product variety and individualization has created a strong need to develop a flexible manufacturing system to respond to small batches of customer demand.

2. Cost savings were required to be more competitive. Newer varieties needed to be introduced in lesser time and at lesser cost.

Given below are examples of some companies and their motive for adopting FMS as well as the benefits that they have achieved through it

Japanese Companies and Latest FMS

Toyota

Toyota has been at the forefront of adopting flexible manufacturing system which has been in place since 1985. In 2002, Toyota unveiled its Global Body Line (GBL), a radical, company-wide overhaul of its already much-envied FMS.[17] The GBL process was developed so Toyota could implement a common vehicle-assembly “ platform” at any and all of its worldwide assembly locations — regardless of volume or method of assembly. GBL helps Toyota to meet its goal “ To seamlessly manufacture our products in any country, at any volume”

The advantages that GBL delivers over the older FBL system of Toyota are

* 30% reduction of the time a vehicle spends in the body shop.

* 70% reduction in time required to complete a major model change.

* 50% cut in the cost to add or switch models.

* 50% reduction in initial investment.

* 50% reduction in assembly line footprint.

* 50% reduction in carbon dioxide emissions due to lower energy usage.

* 50% cut in maintenance costs.

More than 20 of Toyota's 24 worldwide body lines already have been converted, and the rest either are in the process of conversion or will be refitted for GBL in conjunction with upcoming model changes.

Operations in Toyota

Older Flexible Body Line (FBL) System :

Each vehicle would require three pallets — each tightly gripping either a major bodyside assembly or the roof assembly and assuring its adherence to dimensional hard points — as the body panels travelled through the various stages of welding to the floorpan and to one another. Three pallets limited the number of vehicles that could be in the build sequence at any given time – in some plants the number was 50. Also, the design of the pallets — which held the bodysides and roof panels from the outside — limited the access of welding robots and required a lot of floor space. Planners had to " guess" about how many pallets to build and work that guess into the plant's vehicle mix (FBL-equipped plants could handle as many as five different models). Bad guesses about pallet allocation were very costly. Also, quick reaction to a change of production mix was discouraged by the 3-pallet system.

Newer Global Body Line (GBL) System :

GBL design solves those problems by replacing FBL's three pallets with a single pallet, one that now holds all three major body panels from the inside. This " master pallet," layout eliminates the need for predicting initial pallet demand. Since each model or variant requires only the lone pallet, switching new models in or out of the production mix is a breeze. Thus the 70% reduction in time required to facilitate a model change[18]. GBL doubles the amount of floor space that can be occupied by robots, and, on a GBL tour here, every inch appears to be used. In the Georgetown plant of Toyota, the floor space freed by GBL allows a second GBL line — helping the plant achieve a recently announced capacity increase to 500, 000 units.

Highly advanced robots are central to leveraging the advantages of the GBL layout – the system was designed to make the most of new-generation body shop robots that are smaller, more precise and more energy efficient. The number of robots has increased from about 250 to nearly 350.

GBL system is enhanced by initial vehicle designs that ensure commonality for various hardpoints. This makes it easier to accommodate a variety of models: GBL-ready plants now can build as many as eight, rather than five with the FBL system.

However even with the ability to produce eight different models, there is a limit to GBL's flexibility. Once pressed, engineers admit that not everything Toyota makes, from Vitz to Land Cruiser, can be produced on a single GBL line. There are two siz