FLEXIBLE MANUFACTURING SYSTEM SCHEDULING

3.1 INTRODUCTION

The term flexibility suggests the ease and ability to bring about changes in a manufacturing environment. Business entities usually compete with one another in areas of strength. These areas of strength are usually defined in terms of distinctive competencies, core competencies or competitive priorities. The competition is usually handled through factors like price (cost), quality, delivery, service and flexibility. In tune with globalization and varying consumer demands many companies are trying to compete in the area of flexibility. A manufacturing system is said to be flexible, if it is able to adapt variations in part or product style up to certain level. This adaptation should be possible without any interruption in production, due to the changes in part of the product style. In other words, a flexible system should be capable of adapting to a wide range of possible environments. An FMS has the capability to process multiple products styles.

Flexible Manufacturing System (FMS) provides the manufacturing industries to the necessary flexibility and ability to cope up with the current demands defined by the market needs. An FMS usually comprises of four or more work stations which are mechanically interconnected by a unique part handling system and electronically controlled by a distributed controlled system. Schematic representation of FMS is shown in figure 3.1. One distinct advantage of FMS is its ability to handle risk associated with an uncertain future induced by market volatility. This risk alleviation is usually brought about by process planning which maintains the flexibility of manufacturing environment. This attribute that accounts for uncertainties of future can be defined in terms of how successful or otherwise an industry can be.

Competence in flexibility is the given strength [11] to a company in two major aspects; one is the flexibility of product and the other is the flexibility of volume. Flexibility is also defined and incorporated to accommodate various other aspects as described below and illustrated in the figure 3.2.
3.1.1 **Machine flexibility.** It is an ability of a given machine in the system to adapt to wide range of production operations and manufacturing different parts.

3.1.2 **Production flexibility.** It defines the ability of the system which helps in manufacturing a range of parts.
3.1.3 **Process flexibility**: It explains the ability to have different product mix while maintaining throughput.

3.1.4 **Routing flexibility**: It defines how well a system copes up with equipment breakdown, tool failure and other interruptions at a particular work station, while maintaining its capacity to produce parts on alternate work stations under search scenario.

3.1.5 **Expansion flexibility**: It is defined as the easiness to enhance the total production volume of a system.

3.1.6 **Product flexibility**: It is defined as the ability to make changes easily in the product.

3.1.7 **Volume flexibility**: It is defined as the ability to easily absorb large shifts in demand.

3.1.8 **Tooling flexibility**: It is defined as the ability to easily change the necessary tool, depending upon the operation performed on the job.

3.2 **CLASSIFICATION OF FMS**

There are a number of ways through which a FMS can be classified. Typical measures of classification are based on kinds of operation, number of machines, level of flexibility etc.[29], each of which is described briefly below:

3.2.1 **Classification based on kinds of operation**
3.2.1.1 **Processing operation**.

Processing operations result in the transformation of work material to the final designed product or part through series of transformations of work material from one state to another state. Value addition in terms of change in the geometrical shape, properties and change in the appearance of work material will be done in this FMS.

3.2.1.2 **Assembly operation**.

This involves the creation of a new setup referred to as assembly or sub-assembly by joining two or more components and permanent joining process comprising of
rivets, press fitting, adhesive bonding, soldering, brazing and welding. These operations can also be implemented by temporary joining process which uses various types of fasteners.

3.2.2 Classification based on number of machines

A typical way of classification of FMS based on the number of machines in the system can be envisaged as Single Machine Cell (SMC), Flexible Machine Cell (FMC) and Flexible Manufacturing System (FMS), as shown in figure 3.3

3.2.2.1. Single Machine Cell.

These are fully automated machines, capable of operating without the intervention of human operator for a period of time which is usually longer than one machine cycle. These types of single machine cells are usually suitable for sequential operations, capable of processing different part mix, adaptable to changes in production schedules and accept any introduction of new parts.

3.2.2.2. Flexible Machine Cell (FMC).

They usually consist of two to three processing workstations and a part handling system. The part handling system is usually connected by a loading or unloading station. These systems are capable of manufacturing different parts simultaneously.

3.2.2.3. Flexible Manufacturing System (FMS).

This system usually consists of four or more processing stations like turning center, milling center, horizontal machine center, vertical machine center etc., which are interlinked by a common part handling system (AGVs, Robots) as well as tool handling systems (Tool magazine, Automatic tool changer) and automatically controlled by a distributed computer system. It also includes automatic pallet changes, coordinate measuring machine and automatic scrap removal. These features make the FMS stand apart from the FMC.
3.2.3 Classification based on level of flexibility

Depending upon the level of flexibility associated with a given FMS system, they can be classified into two distinct categories: one is a dedicated FMS and the other one is a random order FMS. Differences between the dedicated and the random-order FMS types are as shown in figure 3.4.

3.2.3.1 Dedicated FMS.

A dedicated FMS is usually designed for producing a particular variety of part styles. Since the product design is considered to fix, these systems can be designed with a particular amount of process specialization, making their process and operation much more efficient.

3.2.3.2 Random order FMS.

These systems are capable of handling multiple parts styles and in order to accommodate for variation in part styles and these systems should be more flexible than the dedicated FMS. Parts having a higher degree of complexity can be handled by the random order FMS. To deal with these complexities, highly sophisticated computer control systems are used for controlling the random order FMS.
Fig. 3.4: Differences between dedicated and random order FMS types.

3.3 SCHEDULING OF FMS

An FMS system offers the combined advantage of traditional flow line and job shop systems to accommodate for the changes in demand. The operation and control of FMS having many challenges associated with them, which can be categorized into four stages such as designed stage, system setup, scheduling and control stage. Because of inherent flexibility of FMS, there are number of alternates available to the choice of machine to perform a particular operation. The flexibility of FMS system gives many alternative routings. In order to maintain the throughput and efficiency, it is very important to choose the best available route from the multiple routing options. Thus, even at two machines scheduling problem becomes a Non polynomial (NP)-hard problem.

Flexible manufacturing system scheduling could be considered as a static scheduling problem, where a fixed set of orders are to be scheduled either using optimization or priority scheduling heuristics. Alternatively, this could also be viewed as a dynamic scheduling problem, where orders arrive periodically for scheduling as daily orders are released from a material requirement planning system or as individual customer’s order [61]. The prime importance of FMS scheduling is to enhance the
utilization of resources, thereby reducing the idle time and in process inventory by having efficient and effective utilization of resources. Scheduling helps to achieve its strategic objectives. In practical enumeration procedures coupled with high cost have made it extremely difficult to generate consistently good schedules in medium to large shops [2].

Scheduling in production domain has many variations, like single machine scheduling, parallel machine scheduling and job shop scheduling. Each of these scheduling approaches has their unique constraints and objectives. An FMS can be considered as a complex discrete event dynamic system [17] making it extremely important to utilize the available resources completely to optimize the productivity. Some of the objectives of the FMS scheduling are reduction in the idle time, reduction in the in-process inventory, reduction in tardiness, reduction in the make span etc., In several of the industrial operation environments, a specific manufacturing task for a particular product has a manufacturing dead line in the form of due date, a penalty is incurred if the due date is not met and the task is not completed in time.

One can employ multiple approaches to schedule the manufacture of parts to a system. These approaches may vary from system to system and are different for different situations. Some of these approaches include the following:

- To determine the optimal sequence at which the parts of a selected part types are to be given as input into the system. At times these part types must be produced in certain relative ratios. For certain types of FMS systems, it will be appropriate to maintain the periodic input sequence. Sometimes, maintaining a fixed production ratio of part types on the systems may also be considered. Some of the operations can be scheduled by having a fixed predetermined input sequence. While for other operations, a flexible real time decision categorizes for which part has to be given as input for the next sequence should be incorporated [12].

- It is very important to develop appropriate scheduling methods and algorithms. Tools to aid scheduling can range from simple dispatching rules to complex algorithms or procedures incorporated for the future.
In some cases, when different parts are waiting to be processed by the same machine tool, it is important to identify the priority among these parts. In most of the situations, it will be appropriate to determine an optimal sequence at each machine tool. Many of the usual performance measures such as maximizing the productivity, optimizing a machine utilization time, minimizing the inventory, reaching the due date in the system are relevant [24].

3.3.1 Solution methods for solving FMS scheduling:

FMS operations can be categorized into the following ways on the basis of the methodologies employed [6]:

1. Mathematical programming approach
2. Multi criteria decision making approach
3. Heuristic approach
4. Control theoretical approach
5. Simulation based approach
6. Artificial intelligent based approach
7. Metaheuristic approach

3.3.1.1. Mathematical programming approach: In Mathematical programming approach, many researchers have cast the problem into an optimization model. The typical optimization approach includes, linear programming and branch and bound algorithm. Most of the mathematical models available in the literature are very specifically suitable for very small size problems and are not efficient, if the problem size increases. Most of the simplifying assumptions made in the mathematical models are not always verified in practice.

3.3.1.2. Multi criteria decision making approach (MCDMNA): The operation of an FMS is inherently loaded with multiple criteria. MCDMNA tends to model these criteria in the form of goals that can be used for effective scheduling. Goal programming and Integer programming formulations are widely used. The typical goals that are usually considered include satisfying the production requirements, reducing the throughput time of parts and balancing the machine utilization.
3.3.1.3. **Heuristic approach**: To account for the difficulties encountered with the mathematical optimization methods, the uses of heuristics are well investigated in the literature. The heuristics formulated, can either be in the form of usual dispatching rules, a combination of them or more complex than them. Usually, the combinations of these rules are used specifically considering the availability of alternate routes. Most of the heuristic procedures are iterative with different possible rates being evaluated to see which route can result in the best possible improvement of the objective.

3.3.1.4. **Control theoretical approach**: The idea behind the control theoretical scheduling approach is to maintain and safety buffer of parts produced in FMS, as long as it is feasible to do so. The typical characteristic of such a framework is its ability to find the solution within the production capacity of the FMS. For each machine state, a capacity state is defined along with a safety buffer level for each part type.

3.3.1.5. **Simulation based approach (SBA)**: In case of simulation based approaches, discrete event simulation tools such as Promodel, Quest, Flexsim etc., are used to define an effective schedule. In this approach, simulation is proposed as a tool to evaluate different dispatching rules. Usually, a real production system is used to build a simulation model and the model is initialized to represent the manufacturing setup followed by testing of different dispatching rules on the model. This type of approach is capable of yielding a feasible solution and provides quality decision support and the time that is necessary to test all the different dispatching rules.

3.3.1.6. **Artificial intelligent based approach**: Artificial intelligence based approaches have been used typically to solve complex real world optimization problems, which have a large search space. Expert systems have been used in an attempt to emulate the performance of a human expert. Specific systems are usually built for defined manufacturing setups. Artificial intelligent techniques have shown good results for domain specific problems.

3.3.1.7. **Metaheuristic approach**: A heuristic method can be defined as a procedure i.e., more likely to provide a very good feasible solution, but the solution need not be necessarily an optimal solution. Most of the heuristic approaches are custom made to
fit a specific problem of interest and hence cannot be used for a wide variety of applications, because of the complex nature of the FMS scheduling problems. Approaches that are assured to provide an optimal solution are feasible only for small size problems. Finding these solutions also consumed a lot of computation effort and time. Under such circumstances, researchers have moved towards Metaheuristics. A Metaheuristic is a general solution method that provides a general structure and strategy guidelines for developing heuristic method to fit a particular kind of problem [20].

Metaheuristic algorithms combine heuristics in a more general frame work to guide the search process in efficiently exploring the search space to find a near optimal solution. So, most of the Metaheuristic approaches are suitable for addressing even large size problems with smaller computational time and effort.