Chapter-3

FLEXIBLE MANUFACTURING SYSTEM LAYOUT AND SCHEDULING
# CHAPTER - 3

**FLEXIBLE MANUFACTURING SYSTEM LAYOUT AND SCHEDULING**

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FLEXIBLE MANUFACTURING SYSTEM LAYOUT AND SCHEDULING

3.1 INTRODUCTION

In this work, we focused on how layouts are modeled under various setups (or work-flow structures). Our eminence is on computable techniques, further we illustrate with examples of how qualitative factors are vital in the design of the layout.

In Flexible Manufacturing System, unlimited progress has been made in the layout design with integrated scheduling. Till now a vast literature found using different methodological approaches. Imminent work desires to be done in exploring the use of the methodologies in the practical field, in order to make convenient control system to the worker, and to evolve more user ample control system. Investigation should be done on integrated scheduling and computer control of FMS where there is human participation in the industrial environment [15].

“Most of the works are committed to FMS planning problems. Resource allocation problems are the scheduling problems with a smaller time horizon along with a layout arrangement. Rather than using the heuristic approaches a few authors did some work in this area [15]. In this chapter a brief review of flexible manufacturing system layout and flexible manufacturing system scheduling is discussed.
3.2 INTRODUCTION TO FLEXIBLE MANUFACTURING SYSTEM

Manufacturing Industries are facing vigorous threats by inflation in market needs, corporate lifestyle and globalization. Hence, in current situation, Industries which are responding rapidly to market fluctuations with more competitiveness will have great capabilities in producing products with high quality and low cost. In the view of manufacturers, production cost is not at all a significant factor which affects them. But, some of the factors which are important to the manufacturer are flexibility, quality, efficient delivery and customer satisfaction.

Hence, with the help of automation, robotics and other innovative concepts such as just-in-time (JIT), Production planning and control (PPC), enterprise resource planning (ERP) etc., manufacturers are very keen to attain these factors.

Flexible manufacturing is a theory which permits production systems to perform under high modified production needs. The problems such as minimum inventories and market-response time to bump into customer needs, response to adjust as per the deviations in the market. In order to sweep market by reducing the cost of products and services will be mandatory to various companies to shift over to flexible manufacturing systems. FMSs as a possible way to overcome the said issues while making reliable and good quality and cost effective yields. Flexible manufacturing system has advanced as a tool to bridge the gap
between high mechanized line and CNC Machines with efficient mid-volume production of a various part mix with low setup time, low work-in-process, low inventory, short manufacturing lead time, high machine utilization and high quality [74]. FMS is especially attractive for medium and low-capacity industries such as automotive, aeronautical, steel and electronics.

Flexible manufacturing system incorporates the following concepts and skills in an automated production system [75].

1. Flexible automation
2. Group technology
3. Computer numerical control machine tools
4. Automated material handling between machines

3.2.1 TYPES OF FMS

Flexible manufacturing systems can be separated into various types subject to their natures:

1. **DEPENDING UPON KINDS OF OPERATION**

   Flexible manufacturing system can be illustrious subject to the kinds of operation performed:

   a. **Processing operation.** It performs some activities on a given job. Such activities convert the job from one shape to another continuous up to the final product. It enhances significance by
altering the geometry, features or appearance of the initial materials.

b. **Assembly operation.** It comprises an assembly of two or more parts to make a new component which is called an assembly/subassembly. The subassemblies which are joined permanently use processes like welding, brazing, soldering, adhesive bonding, rivets, press fitting.

2. **BASED ON NUMBER OF MACHINES**

“There are typical varieties of FMS based on the number of machines in the system:”

a. **Single machine cell (SMC).** It consists of completely automated machines which are capable of performing unattended operations within a time period lengthier than one complete machine cycle. It is skilful of dispensing various part mix, reacting to fluctuations in manufacture plan, and inviting introduction of a part as a new entry. It is a sequence dependent production system.

b. **Flexible manufacturing cell (FMC).** It entails two or three dispensing workstations and a material handling system. The material handling system is linked to a load/unload station. It is a simultaneous production system.

c. **An Flexible Manufacturing System (FMS).** It has four or more processing work stations (typically CNC machining centers or turning centers) connected mechanically by a common part
handling system and automatically by a distributed computer system. It also includes non-processing work stations that support production but do not directly participate in it e.g., part / pallet washing stations, co-ordinate measuring machines. These features significantly differentiate it from Flexible manufacturing cell (FMC).

Fig. 3.1: Comparison for three categories of FMS

In this research, authors focused on Flexible manufacturing system

3. **BASED ON LEVEL OF FLEXIBILITY**

FMS is further classified based on the level of flexibility related to the manufacturing system. Two categories are depicted here:

a. **Dedicated FMS.** It is made to produce a certain variety of part styles. The product design is considered fixed. So, the system can be designed with a certain amount of process specialization to make the operation more efficient.
b. Random order FMS. It is able to handle the substantial variations in part configurations. To accommodate these variations, a random order FMS must be more flexible than the dedicated FMS. A random order FMS is capable of processing parts that have a higher degree of complexity. Thus, to deal with these kinds of complexity, sophisticated computer control system is used for this FMS type.

In this research, authors consider Random order FMS

Fig. 3.2: differences between dedicated and random-order FMS types

3.2.2 ELEMENTS OF FLEXIBLE MANUFACTURING SYSTEM

A flexible manufacturing system consists of two subsystems:

- Physical subsystem
- Control subsystem

Physical subsystem includes the following elements:
1. **Workstations.** It consists of NC machines, machine-tools, inspection equipments, loading and unloading operation, and machining area. More recent Flexible manufacturing system, however, include other types of processing equipment also.

2. **Storage-retrieval systems.** It acts as a buffer during WIP (work-in-processes) and holds devices such as carousels used to store parts temporarily between work stations or operations.

3. **Material handling systems.** It consists of power vehicles, various types of automated material handling equipment such as conveyors [76], automated guided vehicles, in floor carts and robots are used to transport the work parts and sub-assemblies to the processing or workstation.

### 3.2.3 HARDWARE COMPONENTS OF FLEXIBLE MANUFACTURING SYSTEM

1. Pallets and fixtures
2. Machining centers
3. Robots
4. Inspection equipment
5. Chip removal system
6. In process storage facility
7. Material handling systems
3.3 LAYOUT CONFIGURATIONS OF FLEXIBLE MANUFACTURING SYSTEM

Flexible manufacturing system brings rewards in actual manufacture of products as the process is designed for several products to be run on different machines within a manufacturing facility which allows for greater growth and stability with more diversity in the output. A Flexible manufacturing system is designed to provide an effective operation sequence to fulfill the production requirements and reasonably allocate the resources [19]. The objectives of the system are to shorten the throughput time and reduce the resource requirements which include avoiding deadlock in material flow, decreasing in-process inventory, balancing the workload of all machines and make good use of the bottleneck devices [77].

3.3.1 Line layout

An Automated guided vehicle is most efficient when the movement is in straight-lines along the AGV path in a single-row machine layout. Machines are arranged only on one side of AGV path [78], and in double row machine layout, machines are arranged on both sides. A possible arrangement of this layout is shown in fig-3.3 [79].
3.3.2 Loop layout

The loop layout uses conveyor systems that allow unidirectional flow of parts around the loop. A secondary material handling system is provided at a workstation which permits the flow of parts without any obstruction. A possible arrangement of this layout is shown in fig-3.4 [80].

Fig. 3.3: Line layout

Fig. 3.4: Loop layout
### 3.3.3 Ladder type layout

Ladder type layout consists of rungs on which workstations are located. This reduces the average travel distance thereby reducing the transfer time between workstations.

A possible arrangement of this layout is shown in fig-3.5[81].

![Ladder layout](image)

**Fig. 3.5: Ladder layout**

### 3.3.4 Carousel layout

In the Carousel layout configuration, parts flow in one direction around the loop. The load, unload stations are placed at one end of loop. A possible arrangement of this layout is shown in fig 3.6 [82].

![Carousel layout](image)

**Fig. 3.6: Carousel layout**
3.3.5 Robot centered cell

If a handling robot is used in a Flexible manufacturing system cell, the machines are laid out in a circle, such a layout is called circular layout. A possible arrangement of this layout is shown in fig-3.7[1].

![Diagram of Robot centered cell]

Fig. 3.7: Robot centered cell

3.3.6 The open field layout

The open field layout is also an adoption of the loop configuration. The open field layout consists of loops and ladders organized to achieve the desired processing requirements. This is used for the processing of a large family of parts. The number of different machines may be limited,
and the parts are routed to different workstations depending on availability of machines. A possible arrangement of this layout is shown in fig-3.8[11].

![Diagram of Open Field Layout](image)

**Fig. 3.8: Open Field Layout**

### 3.4 SCHEDULING OF FLEXIBLE MANUFACTURING SYSTEM

#### 3.4.1 Introduction to FMS scheduling

Scheduling is a method of totaling start and finish time data to the job sequencing dictated in the sequencing process. Sequencing process in turn, is defined as getting the order in which jobs are processed on a machine. The sequence thus obtained determines the schedule, since authors assume each job is started on the machine as soon as the job has finished all predecessor operations and the machine has completed all earlier jobs in the sequences. This is referred to as a
semi-active schedule and acts as an optimal policy for minimizing the completion time, flow time, lateness, tardiness, and other measures of performance. Scheduling problems are often denoted by N/ M/ F/ P, where N is the number of jobs to be scheduled; M is the number of machines; F refers to the job flow pattern and P is performance measures that are to be appropriately minimized or maximized. The solution of scheduling problems is generally presented in the form of gantt-chart which is plotted between different work centers and total processing time on that work center.

Flexible material-handling systems for manufacturing have the capability of moving articles or carrying materials between process stations in different sequences. The traditional method for controlling the routing of carriers is to determine, in advance, all of the useful paths within the system, and store the information in a central computer until needed.

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 orders [83]. For these types of scheduling,
performance criteria minimizing the make span or the mean order lateness and tardiness are usually considered.

Under both types of scheduling problems, three different scheduling and control decisions are taken while managing day-to-day operations.

i. When to load a part into FMS?

ii. Which type of part to be loaded into FMS?

iii. Dispatching of part.

For the first decision, factors such as system congestion and part fixture availability are considered. The second decision concerns choosing the type of part to enter the FMS at the loading station when it is time for a new part to enter the system, considering such factors as part characteristics and machine workload conditions. The dispatching decision is depend on routing parts through the FMS at the time of actual production, and also sequencing parts at the individual machines in an FMS.

3.4.2 Functions of scheduling

To design an effective production scheduling system, the following functions must be carried out in most systematic and efficient manner [2].

1. Assigning different jobs to different facilities after considering the feasibility of allocation (loading).
2. Establishing a set of rules of priorities to sequence the activities on the facilities. (sequencing)

3. Dispatching job orders as per the schedule to initiate loading of jobs to facilities.

Reviewing the status of jobs i.e., monitoring the achievement and the scheduling or changing the priorities of the jobs to rectify the deviation.

### 3.4.3 Objectives of scheduling

The objectives of FMS scheduling [84].

1. Achieving high efficiency of the operations by optimally utilizing machines and equipment.
3. Maintaining short flow time of products.

The objectives often become conflicting to each other and as such the scheduling process involves a trade-off conflicting objectives such that proper balance is obtained.

### 3.4.4 Elements of scheduling

Scheduling determines the timings and order of the operations to optimize the use of resources to meet production requirements. The following are the elements of scheduling [85].

a. Job arrival patterns

b. Number and variety of machines /operations
c. Ratio of workers to machines/operations

d. Flow pattern of jobs

e. Priority rules for allocating work

3.4.5. Principles of scheduling

“In view of the direct equivalence between the workflow and cash flow, scheduling should be done with utmost care. The following are the major principles of scheduling.

i. Effectiveness should be measured by speed of workflow

ii. Scheduling jobs as a string with process step back

iii. A job started should not be interrupted

iv. Speed of flow is most efficiently achieved by focusing on bottlenecks

v. Reschedule every day

vi. Obtain feedback on each job at each work center every day

vii. Match the work center input information to that the worker can actually do

viii. When seeking improvement in output, look for incompatibility between engineering design and process execution

ix. Always work to attain certainty of standards and routings
3.5 Scheduling priority rules

“A sample set of priority rules are presented below”

In this work, there are six kinds of rules for operation selecting from the given allowed set.

(1) *Short Processing Time (SPT)*,

- Process the operation with minimum processing time.

(2) *Most Work Remaining (MWR)*,

- Process the operation among the tasks with the maximum total processing time.

(3) *Random Selecting Rule*,

- Select an operation from the giving allowed set with a random way.

(4) *Long Processing Time (LPT)*,

- Process the operation with maximal processing time.

(5) *Most Operation Remaining (MOR)*,

- Process the operation among the tasks with most remaining operation.

(6) *Earliest due date Rule (EDD) rule*,

- The earliest due date rule minimises the maximum job lateness, or job tardiness, but unfortunately it tends to need more tasks and increased the mean tardiness.

The author made an attempt on a few priority rules such as *Most Work Remaining (MWR), Short Processing Time*
(SPT), Random Selecting Rule in this task of scheduling for optimum arrangement of machines in FMS layout

3.6 Benefits of FMS

Flexible manufacturing system benefits are listed as follows:

- Reduction of inventories throughout the complete chain of manufacturing including work-in-progress
- Reduction of lead time by 40%
- Improved machine utilization by 30%
- Reduction of labour times by 30%
- Reduction of direct and indirect labour costs
- Increased management control over the entire manufacturing process
- Substantially reduced scrap levels.
- The ability to adapt quickly to new work pieces.

Summary

As the work reported on flexible manufacturing system layout optimization, using scheduling as a constraint is very scanty, the researcher is motivated in selecting this problems as his research work.