CHAPTER 1
INTRODUCTION

1.1 MANUFACTURING SYSTEM

The system aspects of manufacturing are more important than ever today. The word “manufacturing” was originally derived from two Latin words, manus (hand) and factus (make), so that the combination means made by hand. Manufacturing can be defined as the application of physical and chemical processes to alter the geometry, properties and appearance of a given starting material to make parts or products. It also includes the joining of multiple parts to make assembled products. The process that accomplishes manufacturing involves a combination of machinery, tools, power and manual labour. Manufacturing is almost always carried out as a sequence of operations. Each successive operation brings the material closer to the desired shape.

![Manufacturing Process Diagram]

**Figure 1.1 Manufacturing**

A manufacturing system is a collection of people, equipment and procedures organized to perform the manufacturing operations of an industry. Manufacturing system can be divided into two levels as facility and manufacturing support system. The facilities of the production system consist
of the industry, the equipment in the factory and the way equipment is organized. Manufacturing support systems are the set of procedures used by the company to manage production and to solve the technical and logistic problems.

![Diagram](image)

**Figure 1.2 General definitions for any manufacturing system**

1.2 CLASSIFICATION OF MANUFACTURING SYSTEM

The manufacturing systems differ in structure or physical arrangement. Now a days, there are three types of manufacturing systems used in industries to manufacture the parts or products.

1. Job shop (or) Process based
2. Flow shop (or) Product based
3. Cellular manufacturing system

1.2.1 Job Shop Manufacturing System

In a job shop, varieties of products are manufactured in small lot sizes to a specific customer order. General purpose production equipment is required to perform broader varieties of manufacturing processes. Workers should have relatively high skills to perform the work assignments. The
unique feature of job shop is the manufacturing of products that can have different operation sequences and variation in processing times.

Job shop layout is also called as process layout. Mungawattana (2000) discussed the difference between various manufacturing systems. Based on his discussion, the lot sizes take minimum time for processing and maximum time for waiting in a queue line for other process in job shop manufacturing systems. As machines are arranged based on their function in job shop environment, most of the jobs need to flow through the entire facility during the process of some jobs. The machines are grouped according to the common type of manufacturing process as shown in Figure 1.3. The milling machines are in one department, grinding machines are in another and so on.

L-Lathe; M-Milling M/C; D-Drilling M/C; G-Grinding M/C

Figure 1.3 Job shop manufacturing system
Advantages of job shop manufacturing system

- Can handle variety of processing requirements
- High expansion flexibility
- High production volume elasticity
- Low obsolescence
- High robustness to machine failures

Disadvantages of job shop manufacturing system

- Very hard scheduling due to high product variability and twisted production flow
- Low capacity utilization
- In-process inventory cost can be high
- Material handling is slow and inefficient

1.2.2 Flow Shop Manufacturing System

Mungwattana (2000) presented the unique feature of flow shop manufacturing that maximizing the rate of production and minimizing the manufacturing cost. The plant may be arranged to produce the particular product or lot sizes, using special purpose equipment rather than the common purpose machines. Once the machines are arranged, then the flow line is entirely devoted to produce the particular part or part family. The material flow is based on the sequence of operations and material handling devices are used to transfer material from one machine to another. The machines are located in line according to the process sequence needed as shown in Figure 1.4.
Advantages of flow shop manufacturing system

- Higher rate of production
- Lower manufacturing cost
- Low material handling cost
- Utilization of labors and equipments are high
- Fixed routing and scheduling

L-Lathe; D-Drilling M/C; M-Milling M/C; G-Grinding M/C
W-Welding M/C; S-Shaping M/C

Disadvantages of flow shop manufacturing system

- Less skilled workers may not maintain the machines or product quality
- Inflexible changes in volume

Figure 1.4 Flow shop manufacturing system
1.2.3 Cellular Manufacturing System

Cellular Manufacturing System (CMS) is a hybrid system of combining the advantages of job shop manufacturing system (flexibility in producing broader varieties of products) and flow shop manufacturing system (efficient flow and high production rate). The aim of CMS is to move the raw material as quickly as possible for making the broader varieties of products and reduce the waste. Cellular manufacturing system is composed of associated cells. In cells, the dissimilar machines are arranged like a flow shop. The workstations can be modified, retooled and regrouped based on the process sequence of part family. CMS displays the improved performance in satisfying the demand for mid-volume and mid-variety of products than the job shop and flow shop manufacturing system.


Figure 1.5 Cellular manufacturing system
Part family identification and machine cell formation are two important steps in cellular manufacturing system. A group of parts can be called as a family and parts are grouped based on its geometry, shapes and process sequence. Dissimilar machines are grouped together to produce the particular part family is called machine cell. Each machine cell is responsible for producing a particular part family for simplifying the material flow and scheduling of the system. In the CMS, raw material is required to travel minimum distance, for converting that into finished products. The cellular manufacturing system layout is in Figure 1.5.

1.2.3.1 Advantages of cellular manufacturing system

The advantages derived from CMS is, in comparison with traditional manufacturing systems in terms of system performance have been discussed by Farrington & Nazemetz (1998); Kannan & Palocsay (1999); Suresh & Gaalman (2000); Hug et al. (2001); Assad et al. (2003). These benefits have been established through simulation studies, analytical studies, surveys and actual implementations.

Reduced setup time: A machine cell is designed to process the parts having similar shapes and relatively similar sizes. So that, many of the parts can be used the same or similar work holding devices. General work holding device can be developed for a part family so that, time required for changing fixtures and tools can be reduced.

Throughput times are reduced: Parts are transferred between workstations in batches. But, in cellular manufacturing system each part is immediately sent to the next machine after it has been processed. Thus, the waiting time of parts are reduced significantly.
Lot sizes are reduced: Once setup time is minimized in cellular manufacturing system, the small lot sizes are possible and economical. Small lot sizes also provide smooth production flow.

Product quality is improved: Since parts travel from one workstation to another as a single unit and it has completely processed in a small area. The feedback is immediate and the process can be stopped when things go wrong.

Inventories are reduced: With smaller sizes and minimized setup time, the amount of work in process can be minimized. The reduced setup time and work in process inventory are reduced the finished goods inventory.

Material handling time and cost are reduced: In cellular manufacturing system, most of the parts are manufactured within a single cell. So that, the part traveling time and distance between the cells is minimized.

Reduction in flow time is obtained: Reduced material handling time and setup time are minimized the material flow time.

Tool requirements are reduced: Part family is processed in a machine cell because of parts are having similar shape and size. Thus, they often have similar tooling requirements.

A reduction in space required: Reduction of work in process, finished goods inventory and lot sizes lead to less space required.

Better overall control operations: Parts may be traveled through the entire shop in job shop manufacturing system. So that, the scheduling and material control is complicated. The manufacturing facilities are broken into manufacturing cells and each part family travels within a single cell, resulting in easier scheduling and control.
The basic difference between functional layout and cellular layout is discussed in Table 1.1

Table 1.1 Differences between functional layout and cellular layout

<table>
<thead>
<tr>
<th>Function</th>
<th>Functional Layout</th>
<th>Cellular Layout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of moves between the departments</td>
<td>Many</td>
<td>Few</td>
</tr>
<tr>
<td>Traveling distance</td>
<td>Longer</td>
<td>Shorter</td>
</tr>
<tr>
<td>Traveling paths</td>
<td>Variable</td>
<td>fixed</td>
</tr>
<tr>
<td>Throughput time</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Job waiting time</td>
<td>Greater</td>
<td>Shorter</td>
</tr>
<tr>
<td>Equipment utilization</td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td>Scheduling complexity</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Supervision difficulty</td>
<td>Higher</td>
<td>Lower</td>
</tr>
</tbody>
</table>

1.3 BASICS OF CELLULAR MANUFACTURING SYSTEM

As this research is concerned about cellular manufacturing system, the basic aspects of cellular manufacturing system are discussed below:

1.3.1 Group Technology

Group Technology (GT) is a manufacturing technique in which parts having similarities in shape, size and operation sequence are manufactured in one place using dissimilar machines or processes. GT is one of the most effective manufacturing techniques for producing a high variety and low demand products. GT seeks to improve productivity by grouping parts, tasks and equipment into larger groups having similarity in geometry and manufacturing process that are grouped together. An application of GT in
manufacturing is called cellular manufacturing system. The aim of CMS is to reduce the production cost and improve product quality by reducing the setup time and throughput time. The group of similar parts is known as part family and the group of workstations used to manufacture the part family is known as manufacturing cell (Selim et al. 1998).

When the philosophy of group technology is implemented into manufacturing, then at the starting stage of design, the parts of a product which are similar to each other are processed on similar processing arrangement (Irani 1999). GT is a source of improving productivity by bringing together the similar recurrent activities and organizing common tasks alongside each other. The associated improvements with the implementation of GT are summarized by Pullen (1976); Houtzeel & Brown (1984); Wemmerlov & Hyer (1989) as follows:

i) Throughput time is reduced from 5% to 9%

ii) Setup time requirements are reduced between 2% to 95%

iii) Quality of products is improved from 5% to 90%

iv) Work in process inventory is reduced from 80% to 10%

v) Material handling costs are reduced from 10% to 80%

vi) Fixture requirements is reduced from 10% to 75%

vii) The reduction in space requirement stays between 1% to 85%

1.3.2 Part Family

A part family is a collection of parts which has similarity in design attributes (Geometrical shape and size) and manufacturing attributes (process sequence of parts). The parts within a part family are different, but their
similarities are close enough to merit their identification as a member of part family.

Normally Part families are formed by following three methods,

- Visual inspection
- Classification and coding
- Production Flow Analysis (PFA)

1.3.2.1 **Visual inspection**

The visual inspection method is the least complicated and least expensive method. It involves the allocation of parts into part families by looking at either the physical parts or their drawings and arranging them into similar groupings. This method is generally considered to be the least accurate method.

1.3.2.2 **Classification and coding**

Classification is a process in which items are separated into groups based on the existence and absence of characteristic attributes. Coding is the establishing symbol to be used for meaningful communication. The following are the important coding systems:

- Opitz classification and system
- Multi class system
- CODE system
- DCLASS system
- KK3 system
1.3.2.3 Production flow analysis (PFA)

PFA is a method for identifying part families and linked grouping of machine tools. It was introduced by Burbidge 1975. Production flow analysis is introduced to analyze the process sequence and machine routing for the produced part in the given shop. Based on the similar routing parts are grouped into part families and these groups can be used to form the machine cells. Since PFA uses the manufacturing data rather than the design data.

1.4 DESIGN OF CELLULAR MANUFACTURING SYSTEM

In the past three decades, researchers have addressed various issues concerning cell formation problem, cell layout design, various production factors and operational control of cellular manufacturing systems. In the past decades, there had been an incredible interest in cell formation problem from practitioners. Cell Formation (CF) is to group the dissimilar machines and their related parts in the same cell. A machine – part occurrence matrix is taken as an input data for the cell formation problem. The objective of cell formation problem is to minimize the exceptional elements and voids and increase machine utilization within the cell. Let P be set of parts and M be set of machines.

Each and every part has its own process sequence. The process sequence is nothing but, an ordering of machines for successive processing of parts. All the parts processing plan is expressed in the machine part occurrence matrix of size \((m \times n)\). Let m rows represent machines and n columns represent parts. A machine-part occurrence matrix can be formed as Table 1.2. The input matrix consists of 5 parts and 7 machines.
Table 1.2 Binary machine-part occurrence matrix

<table>
<thead>
<tr>
<th>Machines</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>0</td>
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<tr>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 1.3 shows the solution of machine-part occurrence matrix with two cells. First part family p₄, p₂, p₃, p₅ are processed in the machine groups m₄, m₂, m₅. Second part family p₆, p₁, p₇ are processed in the machine groups m₃, m₁. In manufacturing process, each part has to be processed according to the sequence of operations. In practice, some parts need to be processed in more than one cell. These parts are called as exceptional elements. From the Table 1.3, the matrix elements m₃p₄, m₃p₃, m₃p₅, m₁p₅, m₄p₁ and m₅p₆ are known as exceptional elements. A void indicates that all parts assigned to the cell need not to be processing in all the machines assigned to a cell.

Table 1.3 Solution matrix after rearrangement

<table>
<thead>
<tr>
<th>Machines</th>
<th>4</th>
<th>2</th>
<th>3</th>
<th>5</th>
<th>6</th>
<th>1</th>
<th>7</th>
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</thead>
<tbody>
<tr>
<td>4</td>
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<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0</td>
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<td>1</td>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Exceptional elements Voids
When a part passes a machine without being processed on the machine, it increases the intra cell movement. Repeated movement of parts results high material handling cost and low machine utilization. But, CMS has offered high benefits such as reduction in inventory cost, material handling cost and increasing the production rate and quality.

1.5 ORGANIZATIONAL STRUCTURE OF THESIS

The research work reported in this thesis consists of nine chapters.

Chapter 1 presents the introduction of the cellular manufacturing systems and the outline of thesis.

Chapter 2 is about literature review of the work has been done in the area of CF problem and machine cell layout problem in cellular manufacturing system. This leads to the identification of nature and scope for this research. It also describes the research gap.

Chapter 3 presents the problem statement and research objectives, based on the research gaps identified. The research approach is to be followed to achieve the proposed research objectives and the proposed research methodology is also included.

Chapter 4 presents a hybrid approach to identify machine cell and part family in cellular manufacturing system by considering binary machine part occurrence matrix.

Chapter 5 presents binary machine part occurrence matrix based similarity approach for cell formation problem and this approach is applied to a case study.
**Chapter 6** proposes an operational sequence based weighted similarity modified approach for solving the cell formation problem and cell layout problem simultaneously.

**Chapter 7** reports an instant forward and backward movement of parts based weighted similarity modified approach for solving the cell formation problem and cell layout problem simultaneously.

**Chapter 8** presents the result and discussion of the research work.

**Chapter 9** reports the conclusion and future scope of research.