CHAPTER 4

MANUFACTURING CELLS

4.1 MANUFACTURING SYSTEM

Today’s markets need on-time delivery, high quality, flexible, excellent value, lean and responsive suppliers. The characteristics of traditional manufacturing system uses production schedule based on forecast, build to inventory, large batch sizes, layout based on department/function, central floor room or production floor used for product staging, lot sampling used to check product quality. Some companies can use these approaches and have opportunities to make improvements. But traditional manufacturing became unfit to market need due to lack of flexibility, long cycle times, lack of responsiveness, profits may be shrinking, hard to focus on strategic issues.

Decrease their manufacturing cycle times from weeks to days (70% or more), reduce their inventory (50% or more) and while increasing the customer service level, increasing capacity to 50% or more in their current facility. Maintain or increase their output while reducing their indirect labour by 50% or more and reducing their labour by 10% or more, improve the flexibility in reacting to the changes in requirement. Allow more strategic management focus, increase shipping and billing frequencies this improves cash flow, bottom line can improve net income. All these can be achieved through proper manufacturing systems (cells).
4.1.1 Characteristics of Manufacturing Cell

a) Processing: A part moves to the production operation and is processed immediately and moves immediately to the next operation

b) With short order-to-ship cycle times, production is based on orders rather than forecast

c) Inventories (RM, WIP and FG) are minimized

d) Quick changeovers of machines and equipment allow different products to be produced in small batches with one-piece flow

e) Layouts are based on product flow

f) Quality of each item is assured during processing

g) No competition for these resources

h) Resources are focused on producing the product rather than maximizing the efficiency

i) In-process inspection

j) Team environment

k) Rapid problem solving

l) Easy to process exceptions

The goal of a manufacturing system is to create defect free products as efficiently (i.e. lowest cost) as possible. Job shop performance is often evaluated on the utilization of the machines. Each operator attempts to keep his machine running at all times. This philosophy results in creation of a large quantity of inventory, since some machines produce parts at faster rates,
and some slower. The result is that some machines will be starved (and their utilization will be less than 100%), while others will have a pile of inventory in their queue. This inventory, which Shingo refers to as the waste of stock on hand, leads to the waste of transportation, and the waste of storage. In order to maintain the profitability of a company, production managers have found CMS as a suitable configuration. Hence, many companies are shifting from job shop to flow shop through cellular manufacturing system. CMS has the advantage of both job shop and flow shop as it achieves flexibility, efficiency, improved work life and cost effective production practiced by Wafa and Yasin (1998). CMS involves grouping of parts into part families and grouping of dissimilar machines, required for the parts to be manufactured in the part family, to form cells. Ideally, processing requirements of items belong to a part family should be completed in a cell. This is rarely achieved and hence, the objective of part family/machine cell formation problem is minimization of inter-cell moves.

4.2 GROUP TECHNOLOGY

Group Technology is a management philosophy that attempts to group products with similar design manufacturing characteristics. Cellular manufacturing can be defined as an application of GT and involves grouping machines or processes on the basis of parts or part families has been given by Shishir Bhat (2008). It is a relatively recent concept and has been applied in
On the other hand, in a cellular manufacturing environment, machines are grouped into cells so that each cell is dedicated to the manufacture of a specific part family as in Figure 4.2. Typically, machines in each cell are dissimilar in their functions. Such an arrangement in which sets of machines are dedicated to specific part families allows easier control of a CMS. The main objective in the design of a CMS is to create machine cells, identify part families, and allocate part families to machine cells so that the inter-cellular movement of parts of part families is minimized. Of course, while doing so, a number of other constraints need to be considered. For example, the allocation of part families to machine cells must be such that available capacity of machines in each cell is not exceeded; safety and
technological requirements pertaining to the location of equipment and process must be met; size of a cell and number of cells must not exceed a user specified number. A majority of the papers on GT and CMS design ignore some or all the constraints listed above and focus only on the identification of machine cells and corresponding part families.

GT is a method used to create part families which has been recently expanded to include codification and classification schemes. Part families are formed based either on similar part geometries or similar process routings. If one chooses to group parts based on geometric features, then one should group parts together such that the common geometrical features will allow for common fixtures and common processing sequences. Common fixture will reduce changeover times, which will facilitate lower batch sizes, and common sequencing will allow for machine grouping which avoids under-utilization of equipment. Part families based on process routings are created by looking at the processing sequence of all parts and grouping those parts together that require the same machinery and can be processed in the same sequence.

**Machine Cycle Time**- The length of time required for a machine to process one part, not including loading and unloading time. It can be measured as the length of time beginning when the start button is pressed and ending when the part can be removed.

**Manufacturing Lead Time**- The length of time from the first operation for a given order until the entire order has been transported to the shipping area.

**Order (or Production) Lead Time**- The length of time beginning with receipt of an order from a customer and ending when product for that order has been manufactured and transported to the shipping area. It includes the Manufacturing Lead Time plus the time required to process the order and begin production.
**Takt Time**- A production rate determined by customer orders (or sales) which specifies the interval of time between production of successive parts. Is determined from the following equation

\[
\text{Takt Time} = \frac{\text{total time available for production per shift (in sec)}}{\text{required number of parts per shift}}
\]

**Time Division Analysis**- A technique similar to process mapping where a process is analyzed by tracking a part as it flows from raw materials to the finish crib and constantly specifying whether a part is being processed, transported, stored or inspected. Storage is further broken down into Lot delay, Transportation delay, and Processing delay.

**Value Added vs. Non Value Added Processing**- Value added processing refers to processing steps that will add value to a part, viewed from the eyes of the customer. Non value added processing includes all processing that does not add value. Thus a cutting operation on a machine is value added processing only if it creates a feature in the part that is of value to the customer.

The Takt time provides a marker or goal for the cell operators. The cell’s goal is to produce parts at a rate equal to the Takt time. If cells are linked, then they should all produce to the same Takt time. If a cell is producing parts faster than the Takt time, there will be a buildup of excess inventory. Thus a factory must strive to balance the entire factory to the production rate of final assembly, which should match customer demand rate. The most effective control mechanism to limit the flow of production to that of final assembly (or the furthest downstream operation in the factory) is the “pull system”. In the pull system, the signal to begin production is given by the downstream machine rather than by a production planner. The shipping area pulls product from the final assembler who in turn pulls parts from the
subassemblies who pull parts from the machining area who pull parts from casting, and so on.

### 4.2.1 Creating Part Families

In order to begin the transformation from a job shop to cellular manufacturing (or in startup situations) one must decide which parts will be processed in which cells. Groups of parts which will be assigned to a given cell, or linkage of cells are termed "part families". The aim is to assign a certain family of parts to a cell such that each cell will be able to take advantage of reduced changeover times, while having sufficient volume to make good usage of the machines and avoid capacity limitations in other cells. Part families are generally based on Group Technology, or formed around a product line.

### 4.3 CELLULAR MANUFACTURING

The concept of a manufacturing cell has been around for at least 50 years, from early work by Mitrafanov, Black et al and Burbidge on GT. This section present a top down look at the system, and show how a broad system approach, when designing the individual cells and individual machines for these cells, can avoid many of the pitfalls that have been encountered by industry in their attempts to replicate the Toyota Production System. Much work has been done which addresses individual issues in cellular manufacturing (such as scheduling, grouping of parts into “families”, automation, set up reduction, etc.), but often these papers (or texts) approach the problem from a descriptive level. Cellular Manufacturing is an application of GT philosophy. It recognizes the fact that small to medium sized batches of large variety of part types can be produced in a flow line manner in different manufacturing cells has been pointed from strategosinc.com. This requires identification of groups of machines, which can produce parts with similar
processing requirements. Cellular manufacturing systems result in reduced setup times, work-in-process inventories, throughput times, improvement in scheduling, tooling and flexibility. Hence, application of cellular manufacturing technology has profound implication on the profitability and operational efficiency of a manufacturing organization. The development of a system for the formation of machine and component groupings for cellular manufacturing system design is focused. Some attempts to bring out man, machine and component grouping solution with the aim of minimizing intercellular moves.

Cellular manufacturing allows companies to provide their customers with the right product at the right time. It does this by grouping similar products into families that can be processed on the same equipment in the same sequence. To successfully maintain one piece flow in their manufacturing cells, companies employ quick changeover techniques. A cell is a group of workstations, machines or equipment arranged, such that a product can be processed progressively from one workstation to another without having to wait for a batch to be completed and without additional handling between operations. Cells may be dedicated to a process, a sub-component, or an entire product. Integral to the manufacturing operations of a lean producer, cells are conducive to single-piece and one-touch manufacturing methods. Cells may be designed for administrative as well as manufacturing operations.

Cellular manufacturing is an approach that helps build a variety of products with as little waste as possible. Equipment and workstations are arranged in a sequence that supports a smooth flow of materials and components through the process, with minimal transport or delay. Cellular manufacturing can help make the company more competitive in cutting out costly transport and delay, shortening the production lead time, saving factory
space that can be used for other value-adding purposes, and promoting continuous improvement by forcing the company to address problems that block just-in-time production has been pointed from strategosinc.com. A work cell is a work unit larger than an individual machine or workstation, but smaller than the usual department. Typically, it has 3-12 people and 5-15 workstations in a compact arrangement. An ideal cell manufactures a narrow range of highly similar products. Such an ideal cell is self-contained with all necessary equipment and resources. Cellular layouts organize departments around a product or a narrow range of similar products. Materials sit in an initial queue when they enter the department.

Products that have a high unit price are seen to have the highest lead times in both dimensions, which is the primary reason for high WIP costs. However, it must be recognized that the typical manufacturer operates in a make to order business environment. So the job shop-type manufacturers do not have an extensive suite of well-documented, easy-to-use and thoroughly validated methods and tools to support the implementation of CM. Clearly, there is a need for new concepts and analysis tools specifically suited to implement CM in a manner that suits their business model and manufacturing environments. Naturally, the first question that will be asked is, “How do we implement the proposed Job shop cellular manufacturing strategy? The answer is: Through the integration of GT to decompose a product mix into part families and CM to design a flexible facility layout. GT seeks to identify and group together similar parts to take advantage of their similarities in manufacturing and design. CM is an application of the GT concept specifically for factory reconfiguration and layout design. Job shops are complex high-variety low-volume manufacturing facilities where the changes in product mix, volume, customer base, workforce skills, process technology, etc are significant. A complete reorganization of a typical job shop into a Cellular Layout may be ill-advised due to the inherent inflexibility
of manufacturing cells to adapt to changes in their product mix, demand volumes and capacity requirements (machine and labour) to meet.

4.3.1 Cellular Manufacturing vs. Job Shops

Cellular manufacturing as a system for production refers not only to the layout of the machines or stations, but also to the flow of product. To transform a factory which produces with a traditional (or job shop) layout as in Figure 4.3 and push a cellular manufacturing system with pull flow in Figure 4.4 requires a completely new philosophy of production. It will be informative in understanding cellular manufacturing to frequently compare CM to a job shop manufacturing system. A job shop uses a functional layout or departmentalized layout of machine tools where all machines of the same type are placed in the same location. This layout results in routing complexity, transportation wastes, and increased manufacturing lead time.

![Figure 4.3 Job Shop layout](image1)

![Figure 4.4 Cellular Manufacturing](image2)
In cellular manufacturing groups of parts, called part families are processed completely in clusters of machines called cells. The flow of the product through a cell is unidirectional. A part being processed in a cell can skip a machine but cannot backtrack. In addition, each part belongs to exactly one cell and it is easy to determine which machines it will be processed on. In contrast, in a job shop environment a part passes from one process area to the next, being processed on whichever machine is available. A cellular manufacturing system can be viewed as a chain of machines or assembly stations. A cell is a logical unit within this system which can be viewed as a single link as in Figure 4.5. A generally process-based layout was retained for repeaters and strangers, the emphasis being placed on the development of separate cell teams. However, within the constraints of the process layout, opportunities to set up dedicated machine groups such as the Nagare cell were sought for higher volume products.

![Figure 4.5 Production system with two links](image)

### 4.3.2 CM Taxonomy

A CM production system is network of logically linked cells. Hence throughput of cells can be dependent on (a) a single machine’s cycle time (the bottleneck), or (b) the speed of the material handler or operator. For this system some parameters must be studied before implementation they are,

1. **Changeover Time** is the length of time a machine or processing area is down (not producing parts) in order to change over from one part type to another. It begins when the machine finishes producing the last part of type A and ends at the beginning of the production of the first good unit of type B.
2. **Cost of Order Preparation** the costs incur by a factory in the process of receiving an order, releasing it to the floor and closing the order upon receipt by the customer.

3. **Customer Lead Time** the length of time beginning when a customer places an order and ending when the customer receives goods to fill that order. It encompasses the Production Lead Time plus the time required to transmit the order to the factory and the time to ship the product to the customer.

4. **Defects vs. Errors** defect is a product or service’s non-fulfillment of an intended requirement or reasonable expectation for use. An error is the result of improper processing of the part, which leads to a defect only when the part is inspected and fails. Thus, errors can be fixed before they become defects.

5. **External Setup Operations** changeover from one part type to the next which are done while the machine is still producing parts.

6. **Final vs. Absolute Defect Rate** the final defect rate reflects only the number of parts that fail the final inspection. However, the absolute defect rate is a measure of the number of defects for the entire process from start to finish.

### 4.3.2.1 Benefits of CM

The benefits of cellular manufacturing include,

a) **WIP reduction**

b) **Space utilization**

c) **Lead time reduction**

d) **Productivity improvement**
e) Quality improvement
f) Enhanced teamwork and communication
g) Enhanced flexibility and visibility
h) Faster throughput times and
i) Reduced set-up times

These gains are achieved because of reduction in the batch sizes. In view with benefits CM also have some limitations,

a) For a cellular layout as in the product-flow layout machine break down may still cause a work stoppage in the cell.
b) To ensure cell profitability and low unit costs, a large enough volume of products must be processed within the cell.
c) The capital expense of buying the dedicated equipment to each product is low.

4.3.3 CMS Planning

The successful implementation of cellular manufacturing in an already established production shop depends on thorough planning, involvement of employees and management, and their staunch commitment to the change. The first three steps of the design and implementation process are important i.e., assessment, design and performance analysis. By following these steps, accurate data on the current situation is gathered and used to establish a baseline, to identify the benefits from cellular manufacturing, and to obtain the support of management and employees. Key personnel are involved in the cell design to determine the scope, process, expectations, i.e. main manufacturing process of the cell, part families to be processed inside the cell, allocation of human and capital resources, and performance goals. The performance analysis is closely linked to the design in that it is used to refine the design and clarify its scope and expectations. There is an implied
iterative process during the performance analysis, necessary to ensure that the desired outcome is feasible. The main goal of this phase is to understand reality and to create a plan, which will support transitioning and sustaining the cell.

### 4.3.4 CMS Design

The design of CMS involves three major phases has been proposed by Offodile (1999) and Lari et al (2000).

(i) The formation of part families and machine cells.

(ii) The arrangement of cells on the facility floor (inter-cell layout).

(iii) The arrangement of the machines within each cell (intra-cell or machine layout).

Harnessing the benefits of CMS depends on how effectively the above three phases are implemented. All these three phases contribute to the performance of the CMS. The effectiveness of arrangements of cells on the factory floor and arrangements of machines within a cell are measured in material handling cost. This cost is a major factor, which contributes 20-50% of the manufacturing cost in a manufacturing firm. The movement of parts of a part family in a CMS is mainly within a cell, as the inter-cell movement of the parts is very minimum or made zero during the first two design phases of CMS. Hence, the major material handling cost in a CMS is due to the flow of the parts between the machines within a cell. Several researchers Chan (2004), Chan and Ip (2002), Wang (1998), Wu et al (2006) and Yaman (1993) were contributed to machine arrangements within a cell.
4.3.4.1 Design assignment

In the assessment stage, the primary goal is to gather accurate data on lead-times, costs, quality, and other important metrics to obtain a true picture of the way in which the production environment functions. Then using analysis this data is converted into information, which in turn is used to support the decision of moving on to the cell design step. The assessment stage is the foundation of the whole process. This stage has a different focus if the cell is introduced in a new facility where the main manufacturing process/layout is not yet defined. In this case, the main objective of this stage is to determine whether or not the purpose of the facility and the expected product stream match the conditions which make cellular manufacturing a beneficial production method. However, this thesis will limit its scope to developing an approach to cellular manufacturing in already existing production environments. When introducing cellular manufacturing in a shop like the Machining Centre, which has been operating as a job shop for many years, the assessment stage not only must answer the matching question. It must also explain why cellular manufacturing has the potential to yield improvements over the existing manufacturing process, and create support from management to proceed with the design stage.

4.3.4.2 CMS implementation

The cell implementation phase executes the cell design through on-going performance measurements it identifies areas of success and further challenges in the cell. The success of the implementation can be monitored in time through performance measurements to ensure that continuous improvement is achieved. Thus the two main steps in this phase are implementation and performance measurement. To ensure that the cell runs smoothly, the commitment of those who work in it and with it is essential. Any staff involved in the operation of the cell should be part of the decision making process at the design stage and be invited to share their views, skills
and experience. When introducing a cell in a production shop there is a tendency to minimize disturbances to production by limiting the number of participants in the cell implementation activity. However, employees that do not participate may not feel compelled to buy-in to the cell, and the effectiveness of the cell can be greatly diminished. During implementation the following checklist can be verified.

The check list for continuous flow cells are,

a) Decide which products or product families will go into your cells, and determine the type of cell

b) Calculate Takt Time.

c) Determine the work elements and time required for making one piece.

d) Determine the cell equipment can meet Tact time.

e) Create a lean layout.

f) Balance the cell.

g) Determine how the work will be divided among the operators.

After checking the above elements, one can gather much of the necessary data required to correct the drawing and layout of their manufacturing cell before starting.

4.4 FLEXIBLE MANUFACTURING

Flexible Manufacturing System is an automated manufacturing system which consists of group of automated machine tools, interconnected with an automated material handling and storage system and controlled by computer to produce products according to the right schedule. Parts are generally processed in parallel rather than serially as in a CMS. Operational flexibility is enhanced by the ability to execute all manufacturing tasks on
numerous product designs in small quantities. However, there are often limitations in flexibility due to the hard tooling that is required for material transport and featuring in each machining cell. Capital investment is very high as compared to a manned cell.

The inherent efficiency of a FMS combined with additional capabilities, can be harnessed by developing a suitable production plan. Machine scheduling problems arises in diverse areas such as flexible manufacturing system, production planning, computer design, logistics, communication etc. Each job consists of chain of operation, each of which needs to be processed during an uninterrupted time period of a given length on a given machine. Each machine can process at most one operation at a time. A schedule is an allocation of operations to time intervals of the machines. The problem is to find the minimum schedule length. The quality of schedules has extreme importance in FMS utilization. Because this system creation is concerned with high capital investments the intensive utilization of resources has basic role in gaining high profit. For the solution of FMS scheduling problems similar approaches as for usual problems of manufacturing scheduling can be used. For quality solution of FMS scheduling one issue should be very seriously taken into account. This is the fact that for these systems the times necessary for setups are much less than the processing (manufacturing) times. This is a trivial fact because in other cases the systems would hardly be named flexible.

4.4.1 Product-Process Matrix

A product-process matrix links the product and process life-cycles with the intent of providing a means to assess whether or not a firm has properly matched its production process to the product structure. It suggests that as the sales volume of the product increases, the process flow should become more continuous. This is what one would expect, as when volumes
grow, automation may be introduced and lines may be dedicated to the product. Since traditionally the small-scale industry has considered itself a low-volume producer, until recently the majority of its operations had opted for a flexible process layout, to permit them to handle small quantities of a large variety of products. As a result, machines are grouped by function to minimize machine idle time and maximize machine utilization as part of FMS has been pointed out by Shishir Bhat(2008).

4.4.2 Product Line Cells

Another way to determine the family of parts to be processed in individual cells is to select a product line and manufacture all the parts in that product line in one cell or one group of cells linked to final assembly. This family grouping allows for the array of cells producing a line of products as a factory within a factory, having its own cost accounting structure, maintenance staff, and other support labor. A key benefit of product line grouping is that one can create a manufacturing system which produces one "set" of parts in each cycle that can be assembled to form one final product.

4.4.3 Machine Flexibility and Material Handling

Parts can be produced in a multitude of different production environments, after choosing the systems one should be careful and understand the benefits and drawbacks of each system before investing valuable capital. Depending on how the work will be performed and the type of material handling, one may choose from systems that are very flexible within their part family but which have difficulty adjusting to design changes or addition of new parts. Manual work cells, manned automatic cells are very flexible to volume changes, since their production rates are generally limited by the number of operators rather than the machines’ cycle times. In addition, these two also process parts serially which is a prerequisite for tracking the
processing of parts is laid out in order of capital investment, from lowest at the top to highest at the bottom, suggesting that FMS and Transfer Lines should be reserved for high volume, long product life parts which will not undergo significant design changes that might make pallets or fixturing obsolete. In all manned cells, operators are responsible for multiple machines or assembly operations. In contrast, in a job shop there is generally a one to one correlation between operators and machines called "one man, one machine" paradigm. In addition to higher labor costs, a lack of multi-skilled workers makes production extremely sensitive to absenteeism.

4.4.4 Batch Size

The batch size refers to the number of parts that are processed on each machine before moving the "batch" to the next operation. Since one part is generally processed at a time, the other parts in the batch must wait, either before the machine, or after the machine, waiting for the rest of the batch to be processed before moving to the next operation. When changeover times are large, the job shop philosophy is to process parts in very large lots, to "spread" the changeover costs across the batch of parts. But in cellular manufacturing, changeover times are reduced by grouping families of parts to promote common fixtures and thus do not require lengthy time-consuming changes in the configuration of the machine. However, since frequent changeovers occur within a family of parts, reduction in changeover times is a prerequisite for cellular manufacturing families of parts. This active approach to reduction in changeover time eliminates the need to spread changeover costs over a large batch of parts. So the batch size will be part family.

4.4.5 Reduction in Lead Time

Large reductions in lead time can be gained from the flow philosophy of cellular manufacturing. Since there is no queue between machines in cells, there is no need to wait for the entire batch to be processed before sending a part on to the next machine. Thus, parts can flow one by one.
from one machine to the next in what is termed "single piece flow". The lead
time (LT) to produce \( X \) parts using single piece flow is given by:

\[
LT_{SPF} = \sum_{i=1}^{n} MCT_i + (X-1) \times MCT_{BN}
\]

where \( n \) is the number of machines, \( MCT \) is the machine cycle time for each
machine, and \( BN \) denotes the bottleneck machine (the machine with the
longest \( MCT \)).

As the batch size increases and the length of cycle time not
including the bottleneck machine increases, the benefits of single piece flow
increase greatly. It should be noted that in general cells are designed so that
the operator’s motions are the “bottleneck”, and machine cycle times are only
important for maximum capacity calculations. As the result, the difference in
lead times between single piece flow and batch production will be dependent
on the staffing of the cell.

4.4.6 Lead Time Unpredictability

In CM the lead time of parts are predictable because there is no
queue for parts to wait in, and the cycle times of parts belonging to a given
cell are known through standard work instructions. Thus, it is easy to
calculate the time required for a given lot to be produced in the cell which
manufactures that part type. Capacity calculations in CM are much simpler
than in job shops, due to the fact that capacity is calculated for each cell,
rather than for an amalgamation of machines, which does not take sequence
of processing into account. By knowing the capacity and lead time for each
part type the scheduler is able to release the work order for a part much closer
to the due date and still be confident that it will be completed in time. This allows for design changes or order cancellation.

4.4.7 Balancing the System

The maximum throughput of any process is limited by the machining, assembly, or inspection step with the longest cycle time which is designated as “bottleneck”. However, the chief goal of the process engineer is to balance the entire system, so that all linked cells and processes are producing parts at the same rate and that they are producing them at the same rate they will be used in the final assembly. Thus, every cell that processes a given part should be producing to the same Takt time. In optimizing a cell for maximum capacity the process engineer works with each part type to balance, or equilibrate the cycle times of all machines. This is done through optimizing the tool paths or assembly operations or by shifting workload from one machine to another. The eventual goal is to balance all the machining times so that when the cell is running at capacity, no station will be idle. When this is achieved, storage of parts and waiting by operators are completely eliminated; an operator will reach each machine just as it finishes its machining cycle.

However, once capacity has been established for a process, the process engineer must be concerned with setting up operator movements so that the Takt time can be met. This requires dividing manual tasks so that all operators have an equal workload. This is a challenging task, since operators often have different physical skill. The result of an imbalance due to operator differences will be a creation of idle time, Achieving true flow is by no means a simple process. It requires dividing up the processing operations among the machines, as well as deciding on a sequence for the operations for each part type. It requires visibility between linked cells so that imbalances in production rates can be discovered and eliminated.

4.4.8 Tracking Defects
It is generally difficult to determine which machine processed a given part, and operators will sometimes "pass the buck" and claim they didn’t make the defective part, in order to defer blame for the costs of repair. So quality problems are very difficult to solve. But in CMS the path of each part can be easily tracked through the plant. Thus, when a defect is found, the problem can be traced back to the individual machine which processed it, and the cause of the defect can be eliminated. This "traceability" of defects leads to greatly improved quality as well as reducing the need for inspections. Often poka-yoke devices been built into machines which prevent defective parts being made by halting the machines.

4.5 LEAN MANUFACTURING

Lean manufacturing has increasingly been applied by leading manufacturing companies throughout the world, led by the major automobile manufactures and their equipment suppliers. A core concept of LM is pull production in which the flow on the factory floor is driven by demand from downstream pulling production upstream as opposed to traditional batch-based production in which production is pushed from upstream to downstream based on a production schedule. In a recent survey, approximately 36% of US-based manufacturing companies have implemented lean or are in the process of implementing lean. LM is a series of techniques for identifying and eliminating waste by continuously improving the flow of product at the pull of the customers. Lean is a system for satisfying customers on delivery, quality and price. The basic goal is to get more work done with fewer resources. Lean results dramatic reduction in cycle times, faster customer responsiveness, increased employee productivity and higher equipment utilization. Space requirements, scrap and rework are also reduced. In addition Just in time manufacturing approach is used to achieve the excellence in a manufacturing company based on the continuous elimination
of waste and consistent improvement in productivity. It provides the cost of effective production and delivery of only the necessary quality parts, in the right quantity at the right time and at right place. The ultimate aim is to achieve zero paper, zero lead time, zero break down and zero defects. Here is a sample of challenging ideas that needs to be implemented in the flow shop arena for effective CM

a) To identify and implement not just a single “pilot” cell, but all potential cells for different families of parts that may exist in its large product mix

b) To implement virtual (dynamic and reconfigurable) cells for a portion of its product mix

c) To develop a self-motivated workforce knowledgeable in Industrial Engineering skills who seek to eliminate mud in a wide variety of administrative and production processes on a daily basis

d) To adopt the concepts and models of Lean Thinking depending on demand forecasts

e) To develop a partnership with its suppliers in order to better estimate and control supplier delivery schedules

The case study mentioned above is just in a nutshell showcasing about the problem, challenges faced and the solution observed through references.

The product-process matrix links the product and process life-cycles with the intent of providing a means to assess whether or not a firm has properly matched its production process to the product structure has been pointed out by Shishir Bhat (2008). It suggests that as the demand volume of
the product increases, the product flow should become more continuous. This is what one would expect, as when volumes grow, automation may be introduced and lines may be dedicated to the product. Since traditionally the small-scale industry has considered itself a low-volume producer, until recently the majority of its operations had opted for a flexible product layout, to permit them to handle small quantities of a large variety of products. As a result, machines are grouped by function to minimize machine idle time and maximize machine utilization. To meet the market needs on-time delivery, high quality, responsive and flexible, excellent value, lean, responsive suppliers, results of traditional manufacturing, lack of flexibility, long cycle times, lack of responsiveness, profits may be shrinking, hard to focus on strategic issues.

The facility layout used during lean implementation can be either a line layout or in the form of cells. After grouping parts into various part families, machine cells can be formed to produce those parts well inside the cells. As some of the lean manufacturing concepts are different from that of cellular manufacturing, e.g., establishment of Takt time, Takt-based resource balancing, etc., some new cell design methodology is required to be explored that is compatible with lean manufacturing. The rate at which work progresses through the factory is called flow rate or Takt. Based on Takt time for various parts, the production flow among cells was optimized thus minimizing several non-value added activities/times such as bottlenecking time, waiting time, material handling time, etc. This case study can be useful in developing a more generic approach to design cellular layouts in lean environment.

An LM facility is capable of producing product in only the sum of its value added work content time. Features of a typical LM model include: one unit at a time production; non-value added time eliminated; production in the work content time only; relocation of required resources to the point of
usage; and all processes balanced to produce at same Takt rate. The rate at which work progresses through the shop floor is called Takt. It is a time-volume relationship calculated as the rhythm, beat, or cadence for each process of a flow line and used to establish resource definition and line balance. The flow of the product is achieved by causing all of its work tasks to be grouped and balanced to a calculated Takt time.

4.6 NAGARE CELL

Nagare Cell (NC) is a Japanese concept; it is an integrated work of GT, FMS, LM and CM. In NC the machines are arranged based on product flow (“U” shaped). The manufacturer walks around the cell, the machines are loaded manually and unloaded automatically. The last operation is adjacent to the first material flows smoothly through the cell. Careful flow chart analysis is done to prevent any obstacles. Tools and support materials have a predetermined place and are maintained tidily. The cell layout, manning pattern changes with change in customer demand. The manpower is planned for maximum utilization. The manufacturing cycle time is designed to meet the customer demand. Once processing begins, they move directly from process to process (or sit in mini-queues). The result is very fast throughput. Communication is easy, since every operator is close to the others. This improves quality and coordination. Proximity and a common mission enhance teamwork. The objectives of NC are,

- The manufacturing lead time can be reduced.
- The output of the sub cell (equal to the output of the operator) can be increased.
- The material handling time and the inventory can be reduced.

4.7 CELL DESIGN AND LAYOUT
While designing cells, one must be certain that the prerequisites be followed before attempting for cells or in designing new cells. The prerequisites include reliable machines, short changeover times and an able work force. One must keep in mind both the production system as well as the machine or operation design during designing a cell or an array of cells. In addition with prerequisite at the system level one must take into account the customer demand rate, length of product life, skill level of operators, ergonomic design, easy and fast to load and unload, minimal changeover times, machine footprints the rectangular size of the machine on the floor to reduce operator walking distances if all these issues are considered in designing cells then the full benefits of cellular manufacturing be achieved.

4.7.1 Design methodology

When moving to CM design, one must remember that CM requires quick changeovers, reliable machines and able workforce. The design methodology can be done as the following steps they are,

a) Translate demand from customers into a Takt time

b) Break out parts according to size and weight.

c) Estimate the machining/assembly times for each operation

d) Survey existing equipment and assess capacity

e) If capacity is greater than demand translated into Takt time then go to step

f) If there is insufficient capacity,

i. Reduce the number or length of operations.

g) The layout of the cell is very important

h) Balancing the cell
i) Designing for multiple operators

j) Installation of quality control devices

k) Optimizing the cells

4.7.2 Layouts

The layout of the cell is very important the most successful general layouts are the U shaped cell as shown in Figure 4.6, and two parallel rows, as in Figure 4.7.

Figure 4.6 Model cell layout 1

Figure 4.7 Model cell layout 2
In a functional layout equipment with the same function is located together, providing a great deal of flexibility; therefore a wide variety of products can be manufactured at a low volume. It also allows easier training of workers as they have the opportunity to learn from each other when they are collocated. However, the functional layout has several disadvantages. As the number of products and machine type’s increase, scheduling complexity increases substantially products has to travel a lot around the factory, lead-times are higher and it becomes difficult to track down the WIP. Since maximizing machine utilization is an important metric in this environment, larger batch sizes are preferable to minimize change-over and set-up costs.

Product-flow layouts correspond to the connected line flow in the product process matrix. These layouts are used when the product volumes are large enough to justify a dedicated line to support a sequence of operations, i.e. machines located according to the line of flow of the product. The main advantages of this layout are the reduction of WIP as batching is eliminated, and no WIP is accumulated between process steps. Since waiting times are reduced considerably, cycle times decrease and throughput is higher.

4.8 SUMMARY

This chapter gave the idea about the difference between traditional manufacturing and CM. The cell design and implementation process proposed in this section was used to implement the ideas at the machining centre, and the machining centre has begun to realize the benefits expected from the cell. As conclusion it shows that when a job shop manufactures a group of products with similar characteristics and stable demand, CM can be a very effective way to obtain the performance improvements. The types and design methods proposed here is recommended to implement CM in existing job shop environments.