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IMPROVE PROFITS AND REDUCE CYCLE TIME WITH MANUFACTURING CELLS

Shishir Bhat .B.N
Dept. of Mechanical Engineering, Dr. M.G.R University, Bangalore, India
#219,6th main, 2nd block, KalyanNagar, Bangalore, Karnataka, India-560043
E-mail: shishir.bhatt@altair.com; shishirbn@rediffmail.com

Abstract
Cellular Manufacturing [6] is an application of Group Technology 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. 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.

This paper focuses on the development of a system for the formation of machine and component groupings for cellular manufacturing system design. This paper attempts to bring out man, machine and component grouping solution with the aim of minimizing intercellular moves and maximizing the clustering efficiency.

The paper proposes a method for introducing cellular manufacturing in an operating job shop. By applying cellular manufacturing to produce part families with similar manufacturing processes and stable demand, industry expects to reduce costs and lead-times and improve profits, quality and delivery performance. The paper outlines a method for assessing, designing, and implementing cellular manufacturing, the conclusions of the paper highlights the key benefits and lessons learned from this process.

Key Words: Cellular manufacturing, Assessments, Implementation, Case study

1. CELLULAR MANUFACTURING OVERVIEW

Customers demand variety and customization as well as specific quantities delivered at specific times; a lean producer must remain flexible enough to serve its customers' needs. 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 your company more competitive by 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 (JIT) production [5].

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. 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 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

2. A CASE STUDY OF CELLULAR MANUFACTURING ADOPTED IN FORGING SHOPS

2.1 Assessment of Forge Shops

Understanding the nature of the product life cycle is very useful in determining the appropriate production strategy [2]. Several forge shops visits by the author showed that the typical forging facility is characterized by batch-oriented processes, large monument-like equipment that cannot be relocated into cells, a large variety of forgings being produced at any time in the facility and manual shop floor communications between machine operators, forklift drivers and plant managers/supervisors. This dispersion of the manufacturing assets(,) and the functional layout of the facility at each location, results in a Value Added Ratio (Actual Man Hours/Total Lead Time) of about 10%.

Forgings 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. These job shop-type manufacturers do not have an extensive suite of well-documented, easy-to-use and thoroughly validated methods and tools to support their implementation of cellular Manufacturing. Clearly, there is a need for new concepts and analysis tools specifically suited for forge shops to implement cellular Manufacturing in a manner that suits their business model and manufacturing environments.

2.2 Implementing Cellular Manufacturing in Forge Shops

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 Group Technology (GT) to decompose a product mix into part families and Cellular Manufacturing (CM) to design a flexible facility layout.

Group Technology (GT) seeks to identify and group together similar parts to take advantage of their similarities in manufacturing and design. Cellular Manufacturing (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 production schedules. Hybrid Cellular Layouts, unlike the traditional network of manufacturing cells in a Cellular Layout, provide an effective foundation for job shops to configure their shop floors differently from the typical assembly facility. These layouts integrate the flexibility of a Process Layout with the order flow tracking and control of a Cellular Layout. They are designed based on the principles of Design for Flow to achieve waste-free, and therefore high-velocity, flows of orders in a Make-To-Order realm without necessitating repeated shop floor reconfiguration.

Here is a sample of challenging ideas that needs to be implemented in the Job shop arena for effective cellular manufacturing:

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 given by the author. The details of how the process in planned, analyzed and implemented in job shop industry is described in the following sections.

3. CELL PLANNING PHASE

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. ASSESSMENT

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. The following list presents a short summary of the main activities to be accomplished during the assessment step:

a) Answer the match question. Is the nature of the product stream (demand and process) suited for cellular manufacturing?

b) Gather accurate data on present situation. Data in every aspect of production is useful to understand the reality of the shop and how cellular manufacturing may impact it. Data on costs, production rates, scrap rates, lead-times, metrics, level of customer satisfaction, and culture of the organization should be included, but by no means this is a complete list.

c) Make the case for cellular manufacturing. Building on the two previous points, the advocate for cellular manufacturing must put together a strong and honest case to justify and build enthusiasm in the management for cellular manufacturing. The honesty and strength of the case for cellular manufacturing must be emphasized; introducing a new method of "doing things" is risky and involves costs. Management must have solid reasons to justify taking the risk and making the investment to support the new approach.

Given the culture of an organization, the ability to move on to the next step of the planning phase will depend at least to some extent on the credibility and motives driving the party advocating cellular manufacturing. If cellular manufacturing is mandated by top management, production and functional personnel may comply, but not commit to the change. If the idea is originated at the grassroots, i.e. from the bottom up by either production of functional workers, the advocates may not have enough access to data or credibility to make an informed recommendation to get the attention of management. If the idea comes from functions supporting production, production personnel may be suspicious of the motives of the function advocating the change. Obviously, the nature of the relationship between the function(s) and production is important in this case. Finally, if the idea originates in the production area, it may or may not be acted upon depending on the amount or resources needed to study its validity. The assessment step requires that the advocate have an overall, non partisan approach, access to data, credibility and commitment. Regardless of who comes up with the idea for introducing cellular manufacturing, it is wise for that person to decide whether or not he is the best advocate, and identify an advocate in the case that the originator is not the best choice. Otherwise, the idea may not even make it to the assessment stage.

5. CELL IMPLEMENTATION PHASE

The cell implementation phase executes the cell design. Then, through on-going performance measurements it identifies areas of success and further challenges in the cell. A strategy is only as good as its implementation, therefore having a well-prepared execution plan is very important. 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. In an existing production environment, there may be already establish teams or process improvement activities that can be used as vehicles for implementation. However, it may be harder to establish cell metrics in an existing environment, as incentives are generally aligned with shop-wide metrics. This chapter discusses these topics further and presents the outcome of these steps at the Machining Centre in more detail.

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. This involvement and input often release stifled talents and skills, including leadership, innovation and forward planning; and without it is very difficult to change working practices [8]. The implementation step offers the opportunity to involve in a larger scale all those who “work with and in it.” This is an important point, because when introducing a cell in a producing 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. The author proposes the following implementation checklist.

a) Identify implementation mechanism. Regardless of what vehicle is used to implement the cell (shop floor teams, quality circles, kaizen events); there are two key elements that must be present in the implementation activity: leadership/facilitation and schedule allowing time for training and doing. It is important that the leaders/facilitators have a good understanding of cellular manufacturing concepts and are involved as early as possible in the cell planning phase. They are responsible for teaching these concepts to the participants, and for balancing the schedule of the implementation activity such that there is time to establish the goals, provide the necessary training, and allow time for the participants to brainstorm and implement their ideas. If there are no existing implementation vehicles within the company that incorporate these elements, the cell vision team needs to plan and provide one.

b) Inform all employees of cell implementation. Prior to the implementation activity, employees in the shop should be informed of the upcoming plans to introduce a cell. This can be easily accomplished at daily or weekly crew meetings. Although some employees may not embrace the planned change, it is important that all are informed one to two weeks ahead of time. By doing so, the next step of identifying the participants list may be facilitated through the interaction between operators and supervisors, i.e. operators can express their desire to participate to their supervisors and bring to their attention potential implementation concerns.

c) Identification of cell implementation participants. Shop floor and support personnel must be identified and notified prior to implementation. As stated earlier, in as much as possible, all those who work with or in the cell should participate.

d) Provide data and resources during implementation activity. Since the implementation activity takes place during “production time” data and resources needed in this period should be obtained ahead of time so that the time can be used more efficiently in “brainstorming” and doing rather than “hunting” for information. If the design steps have been carefully performed, the data is generally available and packaged in a useful form. It is helpful however to establish a list of contacts with expertise in functional areas to be “on-call” during the implementation activity. In this way, any questions that arise can be directed to the right person and answered quickly.

e) Do as much as possible and schedule remaining action items. Sufficient time should be allowed for “doing” during the implementation activity. By doing as many of the necessary tasks as possible during this time, the cell gains tremendous momentum. Realistically, some activities, like equipment relocation, may be difficult to complete during the implementation activity. In this case, a schedule of remaining action items needs to be established. The author suggests that aggressive deadlines be imposed or remaining action items to maintain a sense of momentum.

f) Inculcate importance of metrics. Throughout the implementation activity, participants must remain aware of the need to “keep track” of improvements through metrics. Therefore, participants must not only be encouraged to be creative about improvement, but also about how to measure its impact through already existing or newly created metrics.

6. CELL IMPLEMENTION FOR CONTINUOUS FLOW CELLS

After you’ve mapped your value streams, you are ready to setup continuous flow manufacturing cells. Most cells that have been set up in the past ten years do not have continuous flow; most changes to cells have been a layout change only. That is, machines were moved in a cellular arrangement and nothing more was changed. A change in layout alone does not create continuous flow. This article will discuss seven steps to creating continuous flow manufacturing cells.

a) Decide which products or product families will go into your cells, and determine the type of cell: Product-focused or Group Technology (mixed model). For product focused cells to work correctly, demand needs to be high enough for an individual product. For mixed model or group technology cells to work, changeover times must be kept short.
b) Calculate Tact Time. Tact time, often mistaken for cycle time, is not dependent on your productivity- it is a measure of customer demand expressed in units of time:

Tact Time = Available work-time per shift / Customer demand per shift (1)
Ex: Work time/Shift = 27,600 seconds
Demand/Shift = 690 units
Tact Time = 27,600/690 = 40 sec.

The customer demands one unit every 40 seconds. What if your demand is unpredictable and relatively low volume? Typically, demand is unpredictable; however, aggregate demand (that is, demand of a group of products that would run through a cell) is much more predictable. Tact time should generally not be adjusted more than monthly. Furthermore, holding finished goods inventory will help in handling fluctuating demand.
c) Determine the work elements and time required for making one piece. In much detail, document all of the actual work that goes into making one unit. Time each element separately several times and use the lowest repeatable time. Do not include wasteful elements such as walking and waiting time.
d) Determine if your equipment can meet Tact time. Using a spreadsheet determine if each piece of equipment that will be required for the cell you are setting up is capable of meeting tact time.
e) Create a lean layout. More than likely, you will have more than one person working in your cell (this depends on tact time); however, you should arrange the cell such that one person can do it. This will ensure that the least possible space is consumed. Less space translates to less walking, movement of parts, and waste. U-shaped cells are generally best; however, if this is impossible due to factory floor limitations, other shapes will do. For example S shaped cells in areas where a large U-shape is physically impossible.
f) Balance the cell. This involves determining how many operators are needed to meet tact time.

Number of Operators = Total Work content / Tact time (2)
Ex.: Total work content: 49 minutes
Tact time: 12 minutes
Number of operators: 49/12 = 4.08 (4 operators)

If there is a remainder term, it may be necessary to kaizen the process and reduce the work content. Other possibilities include moving operations to the supplying process to balance the line. For example, moving simple assembly operations from their assembly line to their injection moulding operation to reduce work content and balance the line.
g) Determine how the work will be divided among the operators. There are several approaches. Some include:
Splitting the work evenly between operators, having one operator perform all the elements to make a complete circuit of the cell in the direction of material flow, reversing and combinations the above

After you've determined the above 7 elements, you will have gathered much of the necessary data required to begin drawing and laying out your continuous flow manufacturing cell.

7. PRODUCT-PROCESS MATRIX

The product-process matrix [9] 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 [3] in what is often called a job shop layout.

7.1 What is that the Market Needs?

On-time delivery, High Quality, Responsive and Flexible, Excellent value, Lean, responsive suppliers

7.2 Results of Traditional Manufacturing

Lack of Flexibility, Long cycle times, Lack of Responsiveness, Profits may be shrinking, hard to focus on Strategic issues.

7.3 Characteristics of Traditional Manufacturing

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.

Companies, using these approaches, have opportunities to make improvements.

7.4 What if the companies knew that it is possible to…?

Decrease your manufacturing cycle times from weeks to days (70% or more), Reduce your inventory (50% or more), while increasing the customer service level, Increasing capacity 50% or more in your current facility. Maintain or increase your output while reducing your indirect labour by 50% or more and reducing your 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 improving cash flow, Bottom line is: IMPROVE NET INCOME

All these can be achieved by manufacturing cells.

8. 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 cycles 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

9. FUNCTIONAL AND PRODUCT FLOW LAYOUTS: BENEFITS AND LIMITATIONS

The jumbled flow and disconnected line flow of the product-process matrix correspond to what is often known as a functional layout or job shop. 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. For example, as the number of products and machine type's increase, scheduling complexity increases substantially. Since the products travel a lot around the factory, lead-times are higher and it becomes difficult to track down the work-in-progress (WIP). Batching products increases WIP and hides quality problems, before they move to the next step in the process, thus defects are found late in the process and are generally costlier to correct, as there is already a large number of products in the pipeline that have to be reworked or scrapped [4]. Since maximizing machine utilization is an important metric in this environment, larger batch sizes are preferable to minimize change-over and set-up costs. This incentive of increasing machine utilization causes an increase in inventory costs, in terms of both work-in-progress and finished goods and perpetuates long lead times and decreasing throughput. Goldratt in his book "The Goal" [1] has warned managers from using machine utilization as a driving metric, but in a functional layout it is hard to resist this temptation and succumb to large inefficiencies for the sake of keeping all the machines busy.

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.

One of the main disadvantages of the product-flow layouts is lack of flexibility, as only one or a very small number of products may be manufactured in one line, and accommodating product changes or new products can be difficult and costly. Product-flow layouts also require high initial capital investment to purchase dedicated manufacturing and handling equipment, which are connected "in series." However, when one of the pieces of equipment breaks, it can cause the whole line to stop, or at least considerable disruptions in production.

10. CELLULAR MANUFACTURING: BENEFITS AND LIMITATIONS

Cellular Manufacturing offers an opportunity to combine the efficiency of product flow layouts with the flexibility of functional layouts. In cellular manufacturing, products with similar process requirements are placed into families and manufactured in a cell consisting of functionally dissimilar machines dedicated to the production of one or more part families. By grouping similar products into families, the volume increases justifying the dedication of equipment. But since this volume is justified by process and product similarity, cellular manufacturing warrants much more flexibility than a pure product-flow layout. In terms of the Product-Process matrix, cellular manufacturing allows movement down the vertical axis, i.e.

it allows increasing the continuity of the manufacturing process flow without demanding that the products be made in large volumes.

The benefits of cellular manufacturing include faster throughput times, improved product quality; lower work-in-process (WIP) levels and reduced set-up times [7]. These gains are achieved because the batch sizes can be significantly reduced. As set-up times decrease through the use common tools or the collaboration of cell workers during set-up times, batch size can be reduced. The shorter the set-up time the smaller the batch size, and as a goal a batch size of one is feasible when set-up time is zero. Within a cell, small batch sizes do not travel very far as machines are collocated, resulting in less work-in-progress, shorter lead times and much less complexity in production scheduling and shop floor control.

Unfortunately, in a cellular layout as in the product-flow layout, a machine break down may still cause a work stoppage in the cell. Another limitation of this approach is that to ensure cell profitability and low unit costs, a large enough volume of products must be processed within the cell so that capital expense of buying the dedicated equipment to each product is low. Managers who disregard this fact when pursuing the improvements that cellular manufacturing promises, may end up with less benefits than expected.

11. CONCLUSION

The goal of this work was in two folds: Primary reason was to achieve the objectives (improvement of profits and reducing the cycle time) and secondary to document the author's learning from interaction with the industry and these have been accomplished.

The cell design and implementation process proposed in this paper was used to implement the ideas at the Machining Centre, and the Machining Centre has begun to realize the benefits expected from the cell. The key findings from the author's industrial experience are listed below:

a) Do not underestimate the importance of analysis. A successful implementation requires thorough analysis. When introducing a cell in an already existing job shop, managers may decide to rely on their own knowledge and experience rather than on data and analysis to determine part families and cell capacity.

b) People make it happen. Analysis is necessary, but not sufficient. Participation from people across the organization facilitates and enhances the design; and it is people who implement the design. Ensure that input's from as many of those who will "work and live within the cell" are obtained prior to implementation. It will make the implementation process much smoother.

c) Break down the functional barriers. Cellular manufacturing requires communication amongst and between the operators, and the functional support personnel to support rapid problem solving and results. The culture of an already existing shop may not support the kinds of interactions and relationships that support cellular manufacturing. Managers should be aware that the introduction of cellular manufacturing can potentially require changes to the organizational culture.

In conclusion, this paper shows that when a job shop manufactures a group of products with similar characteristics and stable demand, cellular manufacturing can be a very effective way to obtain performance improvements. The method proposed in the paper is recommended to design and implement cellular manufacturing in existing job shop environments.

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