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CELLULAR MANUFACTURING - THE HEART OF LEAN MANUFACTURING

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Abstract:
Cellular Manufacturing (CM) 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. The paper proposes a method for introducing CM in a small scale industry. By applying CM to produce part families with similar manufacturing processes and stable demand, plants expect to reduce costs and lead-times and improve quality and delivery performance. The paper outlines a method for assessing, designing, and implementing CM, and illustrates this process with an example.

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

1. INTRODUCTION

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. CM 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.

CM [1] 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. CM 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.

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 10-15 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 CM include WIP reduction, Space utilization, lead time reduction, Productivity improvement, Quality improvement, Enhanced teamwork and communication, Enhanced flexibility and visibility

Cellular manufacturing, Assessments, Implementation, Case study

2. GOAL OF THIS RESEARCH WORK

Developments in the CM over recent years have influenced focus areas related to manufacturing technologies mainly from the view point of productivity and product performance as the most important contributors. Based on requirements of productivity and product performance, various technologies were developed including processes for efficient production methods to improve WIP, Space utilization, lead time reduction, Productivity improvement, Quality improvement, Enhanced teamwork and communication, Enhanced flexibility and visibility.

After a lot of survey through journals, periodicals, technical magazines, and various publication websites, it was evident that a that volume of work was done in CM where the industry had more than 30-35 CNC's, automated material handling devices etc or in a typical job-shop production. The intension of this work/research was to implement CM in a small scale industry where there are 10-15 machining centers without any automated material handling devices etc.

This research has dual purposes: learning and improvement. The situation of the machining center in the small scale industry called for action towards improvement. Any avenue leading toward increasing throughput, lowering costs and improving delivery was welcome. CM was seen not only as a way to increase the efficiency of the shop floor, but also as a potential new way to "do business." However, before considering CM for the small scale industry, it was necessary to answer several questions: are the desired conditions for justifying CM present? What would be the performance requirements of a cell in the Center? How could CM be implemented successfully? The rest of this paper aims to answer these questions in detail.

The report on CM – The heart of Lean Manufacturing presents a review of progress in recently developed or implemented techniques/methods. Finally design for efficiency in production, quality, to improve profits and reduce cycle Time which is analyzed from different view

3. ASSESSMENT OF CELLULAR MANUFACTURING

Understanding the nature of the product life cycle is very useful in determining the appropriate production strategy [2]. This section discusses this concept in greater length by introducing the product-process matrix. Then, it discusses the benefits and limitations of the different processes structures, making it easier to appreciate the advantages of CM and the situations in which its implementation is desirable. Next, it explains the reasons that justified pursuing the design and implementation of a manufacturing cell in the Machining Center. Finally, the process used to introduce the cell is outlined.

3.1 Product -Process Matrix

The product-process matrix [3] 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.

It is useful to consider the Machining Center products in the context of the product-process matrix. The factory builds several secondary products for tier 2 companies that may be at different stages of their product life cycle. It also builds primary products for tier 1 companies, most of which are in the mature phase of their product life cycle. Yet, the production process is the same for all programs, i.e. there is no process structure differentiation depending on the process life cycle of the product or part, and its relative volume to other parts built in the factory.

3.2 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 for 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). Also, batching products before they move to the next step in the process increases WIP and hides quality problems. 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" [5] 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.

3.3 Cellular Manufacturing: Benefits and Limitations

CM offers an opportunity to combine the efficiency of product flow layouts with the flexibility of functional layouts. In CM, 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 [6]. 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, CM warrants much more flexibility than a pure product-flow layout. In terms of the Product-Process matrix, CM 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 CM 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 CM promises, may end up with fewer benefits than expected.

4. IS THERE A MATCH?

The functional layout is effective when extreme flexibility is required in a factory to manufacture one-of-a-kind or very low product volumes, and there is no certainty in the nature of the demand. However, applying this approach in low-volume, semi-repetitive environments have been the accepted way to do business, and it has burdened companies with its large inefficiencies. In today's competitive environment, using a cell manufacturing approach can help small scale factories to shed costs, reduce lead-times and increase throughput while maintaining production flexibility to satisfy different customers

The 'ideal' environment for CM as one where [8]:

1. There is a high ratio of set-up to processing time,
2. Demand is stable,
3. The work has unidirectional flow, and
4. There is significant time delay in moving parts between departments.

This criteria certainly justifies the introduction of CM at the small scale industry. First, primary and secondary products have similar characteristics in that they both exhibit a less set-up to processing time ratio. Second, given the current layout of the shop and the scheduling system, there are significant time delays in moving the parts around the shop. Third, both types of parts have, in the vast majority of cases, unidirectional work flow. The main difference between primary and secondary products is the nature of the demand.

As explained earlier, the current military programs in the Center are either at the beginning or end or their life cycles. The secondary products is at the end of the prototyping stage and start of the production ramp-up stage is still uncertain, while the primary products program, for which the factory built a large number of components, is at the end of its life. On the other hand, demand for parts from commercial customers is stable and well known ahead of time. Given these circumstances, CM can be best implemented right away in the production of primary products, where the factory faces competition from outside suppliers and it must satisfy stringent cost and delivery customer requirements.

5. CELL PLANNING PHASE

The successful implementation of CM 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 CM, 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 main goal of this phase is to understand reality and to create a plan which will support transitioning and sustaining the cell.

5.1. Assessment Phase

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 CM a beneficial production method.

When introducing CM in a small scale industry, which has been operating for many years, the assessment stage not only must answer the matching question, it must also explain why CM 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:

5.1.1 Answer the match question. Is the nature of the product stream (demand and process) suited for CM?

5.1.2. Gather accurate data on present situation. Data in every aspect of production is useful to understand the reality of the shop and how CM 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.

5.1.3. Make the case for CM. Building on the two previous points, a strong and honest case to justify and build enthusiasm in the management for CM must be put together. The honesty and strength of the case for CM must be emphasized; Management must have solid reasons to justify taking the risk and making the investment to support the new approach.

The assessment step requires that the advocate has an overall, non partisan approach, access to data, credibility and commitment. Regardless of who comes up with the idea for introducing CM, 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.

5.2 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. This section discusses these topics further and presents the outcome of these steps in 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 [9]. 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 the cell idea, and the effectiveness of the cell can be greatly diminished. The implementation check lists proposed are

5.2.1. 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 CM 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.

5.2.2. 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 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.

5.2.3. Identify 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.

5.2.4. 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.

5.2.5. 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. It is suggested that aggressive deadlines be imposed or remaining action items to maintain a sense of momentum.

5.2.6. 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. A CASE STUDY OF CELLULAR MANUFACTURING ADOPTED IN GEAR MANUFACTURING MACHINE SHOPS

6.1. Assessment of Gear manufacturing machine shops

The gear manufacturing machine shop or the small scale industry which is considered for research showed that the typical machine shop facility is characterized by batch-oriented processes, large monument-like equipment, a large variety of gears 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%.

Gears 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 small scale manufacturers do not have an extensive suite of well-documented, easy-to-use and thoroughly validated methods and tools to support their implementation of CM. Clearly, there is a need for new concepts and analysis tools specifically suited for Gear manufacturing machine shops to implement CM in a manner that suits their business model and manufacturing environments.

6.2. Implementing Cellular Manufacturing in Gear manufacturing machine shops

Naturally, the first question that will be asked is, "How do we implement the proposed CM strategy? The answer is: Through the integration of Group Technology to decompose a product mix into part families and CM to design a flexible facility layout.

Group Technology seeks to identify and group together similar parts to take advantage of their similarities in manufacturing and design. CM is an application of the Group Technology concept specifically for factory reconfiguration and layout design.

Small scale production units 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 small scale industry 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 labor) 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 are some factors which need to be taken care for effective CM implementation:

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) Implement virtual (dynamic and reconfigurable) cells for a portion of its product mix
c) Develop a self-motivated workforce knowledgeable in Industrial Engineering skills who seek to eliminate muda 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) Develop a partnership with its suppliers in order to better estimate and control supplier delivery schedules

f) Define its “core manufacturing competencies” into a guidebook that its sales staff could use to accept, evaluate or reject new orders based on past cost/benefit performance measures
g) Implement Finite Capacity Scheduling without purchasing expensive software, since Theory Of Constraints and Drum-Buffer-Rope scheduling have been known to succeed in such facilities
h) To achieve flow and be flexible to changes in product mix, demand and manufacturing technology

6.3 Performance Measurement

I - Before implementing cellular Manufacturing

Monthly throughput(Average No of Orders completed per Month)

	Dec-05	Jan-06	Feb-06	Mar-06
Main Gear	60	58	59	61
Differential gear box(DGB)	40	41	38	39
Accessiories to Main Gear	30	28	31	29
Accessiories to DGB	20	19	20	21

II - After implementing cellular Manufacturing

Monthly throughput(Average No of Orders completed per Month)

	Apr-07	May-07	Jun-07	Jul-07
Main Gear	90	92	91	89
Differential gear box(DGB)	40	41	38	39
Accessiories to Main Gear	50	51	48	49
Accessiories to DGB	35	37	36	35

III - Before implementing cellular Manufacturing

Flow hours (Average No of Manf hours a product spends in shop floor)

	Dec-05	Jan-06	Feb-06	Mar-06
Main Gear	58	56	57	59
Differential gear box(DGB)	38	39	36	37
Accessiories to Main Gear	29	27	30	28
Accessiories to DGB	19	18	19	20

IV - After implementing cellular Manufacturing

Flow hours (Average No of Manf hours a product spends in shop floor)

	Apr-07	May-07	Jun-07	Jul-07
Main Gear	29	33	31	27
Differential gear box(DGB)	21	23	22	20
Accessiories to Main Gear	19	22	16	19
Accessiories to DGB	14	17	15	13

The case study mentioned above is just in a nut shell showcasing about the problem and the solution given to implement the CM. The details of how the process in planned, analyzed and implemented in a small scale industry is described in the above sections.

7. CONCLUSION

The goal of this work was in two folds: Primary reason was to achieve the objectives (to implement the CM technology in a small scale industry) and secondary to document the learning from interaction with the industry and these have been accomplished.

The approach to cell design and implementation process proposed in this paper was used to implement the ideas at a small scale industry, and it has begun to realize the benefits expected from the cell. The key findings from the industrial experience are listed below

7.1. 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.

7.2. 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 that 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.

7.3. Break down the functional barriers. CM 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 CM. Managers should be aware that the introduction of CM can potentially require changes to the organizational culture.

In conclusion, this paper has shown 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 performance improvements. The method proposed in the paper is recommended to design and implement CM in existing job shop environments.

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