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Implementation Analysis of Cellular Manufacturing System to Improve Cell Performance

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ABSTRACT

This present paper explores the way in which the cellular manufacturing can help a selected manufacturing company for a selected Machining Center, a highly flexible shop with many different customers choice and products, achieve improved performance and customer satisfaction. The environment in which the product of selected company operates today is very different from the one in which it has historically succeeded. The decline in heavy commercial vehicle spending has increased the importance of cost or affordability in a decision process which previously emphasized the incorporation of state-of-the-art technology into new products in the heavy auto industry. In addition, the heavy vehicle industry consolidation is producing fewer companies competing fiercely for a piece of a decreasing pie. Therefore, Product of demand from master companies' success depends on its ability to exceed customers' expectations through superior performance, by delivering high quality products in a timely manner, with shorter lead-times and lower costs.

Introduction

Cellular Manufacturing

A cell is a combination of people, equipment and workstations organized in the order of process to flow, to manufacture all or part of a production unit Wilson, L. (2009). He has discussed various characteristics of effective cellular manufacturing practice. He is of the opinion that they should have one-piece or very small lot of flow. The equipment should be right-sized and very specific for the cell operations. It should have C or U shape arrangement or layout so that the incoming raw materials and outgoing finished goods are easily monitored. It should have cross-trained people within the cell for flexibility of operation. There are lots of benefits of cellular manufacturing over long assembly lines. Heizer, J., and Render, B. (2000) have in their paper discussed that the cellular manufacturing concept can lead to reduced work in process inventory, as the work cell is set up to provide a balanced flow from machine to machine.

It can lead to reduced direct labor cost due to the improved communication between employees, better material flow, and improved scheduling. It prompts for the high employee participation due to the added responsibility of product quality monitored by themselves rather than separate quality persons. Olorunniwo F. (1996), states that, there is a need for a new generation of factory layouts that are more flexible, modular, and more easily reconfigurable. Flexibility, modularity, and re-configurability could save factories from the need to redesign their layouts each time their production requirements change. Several layout design strategies have recently been proposed by researchers in order to improve the performance of job shops which are working under volatile manufacturing environments. Irani S. A (1999), divided these layout strategies into modular layouts, reconfigurable layouts, agile layouts and distributed layouts.

Wemmerlov U., Hyer N.L. (1987) has opined that the modular layout concept uses the idea of grouping and arranging the machines required for subset of operations in different routings into a specific (classical) layout configuration that minimizes distances or cost. In reconfigurable layout approach it is assumed that resources can be easily moved around so that relocation of departments is feasible. Once this assumption is made then the layout problem becomes a multi-period facility layout problem. In agile layout approach the design objectives of the layouts are different than the classical design objectives. In this approach performance measures, such as production throughput, cycle time, work in progress inventory etc. are used as the design objectives. Any type of layout like cellular, functional etc. can be developed by using performance measures. The difficulty with this approach is lengthy simulations. Generally simulation optimization approaches are more employed for designing such layouts. Wemmerlov U., Hyer N.L. (1989) developed a multiple objective parametric simulation optimization system for designing such layouts.

Cellular manufacturing (CM) is an application of group technology, a manufacturing philosophy in which parts are grouped into part families, and machines are allocated into machine cells to take advantage of the similarities among parts in manufacturing. The significant benefits of cellular manufacturing are a reduced setup time, reduced work-in process inventory, reduced throughput time, reduced material handling costs, improved product quality and simplified scheduling, etc. Nicoletti, S. Nicosi (1998) has opined that the cell formation (CF) problem is the first step of the design of cellular manufacturing systems. The main objective of CF is to construct machine cells and part families, and then dispatch part families to machine cells to optimize the chosen performance measures such as inter-cell and intra-cell transportation cost, grouping efficiency, exceptional

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elements, etc. Numerous methodologies have been reported to identify machine cells and their associated part families. Some of the widely used methods are the similarity coefficient methods (SCM). A manufacturing cell consists of several functionally dissimilar machines which are placed in close proximity to one another and dedicated to the manufacture of a part family. In Cellular manufacturing, part families are formed based on the similarities of design and manufacturing attributes of the parts to be produced. Then a group of machines along with the part families to be produced are formed as cells (Chalapathi, 2012).

CMS Analysis

In the very first and feasible analysis stage, the primary objectives is to gather accurate data on lead-times, costs, quality, and other important measurement to obtain a true picture of the way in which the production environment functions. Then using analysis of this data is converted into information which in turn is used to support the decision of moving on to the cell design step. The analysis 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 present research work will limit its scope to developing an approach to cellular manufacturing in already existing production environments.

Current Status

To understand the present situation at the selected shop, a sample of commercial parts was studied and shop wide metrics and measurement tools were examined. The commercial parts sample consisted of more than 160 parts, which were the ones used in the simulation mentioned above, and represent approximately one fourth of the total number of commercial parts manufactured in the Center. Tables 1 present these results, and establish the baseline for improvements.

Table 1. Current Situation at Shop using a Sample of Commercial Parts.

Average Part Travel	1730 feet within the Machining Center, from first machining step to step prior to Chemical Process.
Average Flow-time	67 days total (5% touch/95% queue), and 27 days, from first machining step to step prior to Chemical Process.
Scrap, Rework and Repair (SRR) Costs	The sample accounts for 30% of total SRR cost at the Machining Center for the first three quarters of 2015.
Average Set-up to Run Time Ratio per Part	1.4 (on average 1.4 hours of set-up was spent per 1 hour of run time when building in lot size of 1 part).

Important Parts Manufacturing in the Selected Shop

Although not easy to capture in the metrics and measurement of product performance, there was a certain case of urgency in the shop calling for immediate action. In particular the delivery performance was getting a lot of attention from upper management because of customer complaints. In addition, much work had to be off-loaded, i.e. work intended for the Center was sent to suppliers, because the shop could not handle the work. While the off-loading solution alleviates the capacity problems short term, customers do not “appreciate” having their work sent to another supplier. The important parts which the company takes the order to manufacture is shown in table 2.

Table 2. Important Parts manufactured in company.

Flywheel	2	Spline Shaft	2
Cylinder Head	1	Sliding Block	3
Spline Gear Wheel	2	Align Bush	3
Forklift Assembly	2	Jig Trolley	3
Cross-slide M. Machine	2	Turbine Shaft	3
Impeller	2	Plates	3
Bushing	1	Pipe Clamp	3
Sprocket	2	Bracket M. Support	3
Pump Shaft	2	Shims	2
Value Slide Gate	3	Discharge Head	3

Need of cell Formation

The analysis findings were presented to the selected Machining Center manager and a group of production and functional managers, who agreed that “something had to be done.” The author urged this group of managers to support the possibility of introducing cellular manufacturing as a way to increase throughput while reducing total costs and satisfying the customer quality and schedule requirements. The presentation also restated the advantages of cellular manufacturing, which were explained in greater detail and in the context of the Machining Center. For instance, by reducing set-up times and utilizing smaller lot sizes, cell capacity would increase and the Center would have the ability to “do more work,” and eliminate any off-loading of cell parts. The scheduling complexity would also be considerably reduced by dedicating machines to parts with a stable and known demand, which facilitates the Center’s ability to forecast, capacity plan and respond to schedule changes or emergencies. The collocation of the manufacturing process steps would result in reduction of part travel distance and queuing time, which in turn would decrease costs because of less WIP and shorter flow-times. In addition, by having cell operators working in close proximity quality problems would be identified and corrected much faster than before. By being responsible for several operations in the production of a part, cell operators not only are more aware of the root causes of defects, they also develop a sense of ownership facilitating quality improvements, self-discipline and trust in the process.

Process of Designing the Cell

Cellular manufacturing is often used to build a complete product or product family from cradle to grave. However, when designing a cell in an already existing production environment this cradle to grave philosophy may not be feasible. Also, some product may be too complex or require processes that are very difficult to integrate in the cell. Therefore when designing the cell process two questions need to be answered:

- What numbers of piece of the value added chain will be included in the cell formation.
- Kind of resources (primarily capital equipment) need to be included in the cell to produce the final product in the cell?

To answer the very first question, it is expedient to use the routing sequences of the parts being considered as a potential family from the previous step. By doing so, the order and direction of the flow can be established very quickly, and the decision of what processes can/should be included in the cell can be made based on constraints. For instance, if one of the manufacturing steps can only be performed at a supplier, it may be more reasonable to exclude that process from the cell and work in conjunction with the supplier to ensure that WIP and flow-times are minimized while meeting customer demand requirements.

Once the cell final product has been determined, then the question of what resources to include in the cell must be addressed. Since the routings have already been established, then it is easy to summarize the type of equipment needed according to its capabilities. The cell equipment can be determined based on the necessary capabilities (if new equipment is acquired), or by dedicating the machines where the parts are already running to the cell. In the latter case, the cell designers must be sensitive to the impact of dedicating specific equipment that may serve a large number of parts within the job shop to the cell. Before assigning a piece of machinery to the cell, the designers must understand how many other parts are affected by dedicating this piece to the cell, and explore alternate ways for the cell and non-cell parts to get processed. The cell performance analysis step follows the determination of the cell process and equipment capabilities.

Performance Analysis for Selected Machining Center Cell

To obtain accurate set-up and runtimes for all potential parts, the standard set-up and run times were multiplied by their corresponding machine variances to standard. Then, using these "realistic" set-up and run times and the monthly part demand, the required production hours per month was calculated. The available machine time was calculated assuming that there are 20 manufacturing days in a month, each containing 21 hours of production time. Using historical data, down time (due to machine break down, not to set-up time) for each Factory Work Code was obtained, and the total machine available time was reduced by this percentage. Table 3 summarizes these results.

According to these calculations, it was apparent that if all 134 parts were to be included in the cell, three of the four NC Factory Work Codes could be potential bottlenecks.

The cell designers proceeded to reduce the number of parts considered, particularly in NC Factory Work Codes No. 5 and No.9 to match as closely as possible the available machine hours.

In the case of NC Factory Work Code No. 7, a 5 Axis, 3 spindle vertical mill, this alternative was not pursued because the 48 parts that visit this Factory Work Code are closely related in geometry and tooling. It was expected that by dedicating the machine to these parts, machine time would be freed up, as the set-up times would be significantly reduced since the tools for these parts can stay on a permanent basis in the bed of the mill. The end result was to include 123 parts in the cell. Table 4 summarizes the required hours per month and the resources allocated to the cell to produce these parts.

Note that the available machine hours of the NC Factory work Code No. 7 is smaller than the monthly required production hours. No parts were eliminated from this NC Factory Work Code because the cell designers expected to offset the differences between allocated and required hours through a significant reduction in set-up times achieved by dedicating the machine to the cell.

Performance Measurement of the Machining Center Cell

The cell team proposed that the following metrics be tracked to monitor cell performance and accomplishments:

Metrics Units

Weekly throughput Number of orders completed per week On time delivery performance No. of counters Flow days through cell No. of manufacturing days an order spends in the cell Scrap, repair and rework (SRR) costs Rs (INR)

In addition, operators proposed to keep daily logs on machine availability to quantify more accurately time spent on set-ups and down time due to breakdowns or other reasons. The remaining action items of the improvement in the workshop sub-teams were placed in a schedule, and progress on these items would be reported on a quarterly basis to the Cell Sponsor, a member of the manufacturing management team identified at the end of the accelerated

Table 3. Initial Required Capacity and Machine Availability Calculations.

Factory Work Code (FWC)	FWC Variance to Standard	Machine Downtime	Hours per Month Required to Produce 134 Parts	Available Hours per Machine per Month	Available Number of Machines
Conventional Saws	1.8	5%	94	399	1
Conventional Drills	1.8	5%	241	399	1
Conventional Mills	1.0	5%	424	399	1
NC FWC 1	1.5	15%	287	357	1
NC FWC 5	2	15%	1260	357	2
NC FWC 7	2	20%	441	336	1
NC FWC 9	2	25%	454	315	1
Deburr	2	5%	1646	399	N/A

Table 4. Final Cell Capacity Calculations and Allocated Resources.

Factory Work Code (FWC)	Hours per Month Required to Produce 123 Parts	Corresponding Available Hours	Resources Allocated*
Conventional Saws	85	142	1 Machine, 1 Shift
Conventional Drills	236	285	1 Machine, 2 Shifts
Conventional Mills	374	399	1 Machine, 3 Shifts
NC FWC 1	287	256	1 Machine, 2 Shifts
NC FWC 5	631	714	2 Machines, 3 Shifts
NC FWC 7	441	336	1 Machine, 3 Shifts
NC FWC 9	309	315	1 Machine, 3 Shifts
Deburr	1514	1596	2 Operators, 2 Shifts

* Let 1 operator per machine per shift

improvement in workshop. These quarterly reports are expected to ensure that not only the projected benefits are realized and the action items are completed, but also that feedback from those "living and working within the cell" is sought and incorporated to perpetuate continuous improvement and learning.

After the cell was implemented, average part travel distance was reduced by 57%, from 1730 ft to 730 ft. The average flow time needed to complete all operations prior to Chemical Processing was 27 days; after cell implementation flow time was reduced to 15 days, a 44% improvement, and estimated to decrease to 10 days by the end of 2015. Furthermore, scrap, repair and rework costs of cell parts were expected to shrink 90% in the year following the inception of the cell. Finally, a "cell culture" developed. Those "living and working within the cell" began to value the discipline of working within schedules, communicating with the support functions such as NC programming, facilities and shop load as problems arose in production, and creating an environment of collaboration and accountability. Although, the "cultural" changes are intangible and their benefits are very difficult to quantify, they are necessary when enduring improvements are sought; the culture of the environment must be enabling and supportive of change and learning.

Figure 5, presents the reader with some proof that the projected benefits of the cell are being realized. It illustrates the average variance to standard for all the machines within the cell for a period of four months after the inception of the cell. According to this figure, after the introduction of the cell, the average variance to standard increased considerably. This may have been caused in part by the interruption of the end of the year (holiday) shut-down. It can also be explained because often when a change is first introduced, the expected results are not achieved for some time, as the new process gets in "control." Figure 1, shows that by the end of January 2017, the average machine variance to standard began to decrease steadily. The variance to standard is a meaningful metric within the shop and the cell because it translates directly into the price charged for the product. Since the customers are charged for direct labor hours, as the variance to standard decreases, the customer is charged a lower price. Thus as expected, cellular manufacturing is already helping the Machining Center to improve customer satisfaction.

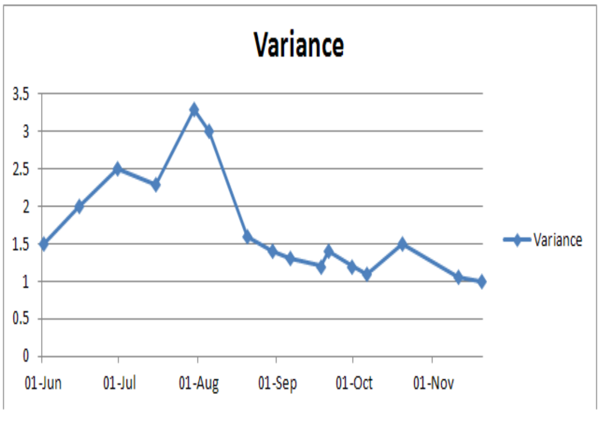

Figure 1. Average Variance to Standard for all Cell Machines for First Quarter of Operation.

Conclusions

A successful implementation requires thorough analysis of existing layout. 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. 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 from as many of those who will "work and live within the cell" is obtained prior to implementation; it will make the implementation process much smoother. Cellular manufacturing requires communication amongst and between the operators and the functional support personnel to support rapid problem solving and results. In conclusion, this paper has shown 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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