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A Case Study of Lead Time Reduction by Transformation to Cellular Production

Derek Wright[1], Charles R. Standridge[2]
[1](*Flexco Inc.,*)
[2](*Grand Valley State University, Seymour and Esther Padnos College of Engineering and Computing*)

Abstract:- A case study of the transformation of a job shop production orientation to a cellular production orientation for a family of pole-mounted conveyor belt cleaning products is described. Quick response manufacturing ideas drive the transformation primarily by minimizing customer lead time as opposed to efficiency and high utilization of equipment. The case study shows that the corporate target lead time of one day can be met by the cellular approach. In addition to the elimination of finished goods inventory, several benefits of the cellular approach were identified including minimizing the use of material handling equipment, record keeping, and worker retraining as well as increasing production agility in response to large orders.

Keywords: -*Quick Response Manufacturing, Cellular Manufacturing, Job Shop Conversion*

I. INTRODUCTION

Flexcois a 108 year-old company that designs, manufactures, and sells products to improve belt conveyor productivity. Flexco offers a wide variety of products from small metal hooks that splice thin belts together to large steel assemblies that can clean belts used in underground mines. These "heavy-duty" Belt Conveyor Products (BCP) fall into the "high-mix low-volume" (HMLV) classification: many products each with low annual demand.Quick Response Manufacturing (QRM) principles[1] align well with the production of such a product mix. One of the most popular BCP's is the family of EZP-1 Rockline® pole pre-cleaners, which are installed on the head pulleys of large conveyor-belt systems to scrape off material that sticks to the belt surface.

A study of the transformation of the production of the EZP-1 family from a job shop orientation with metrics emphasizing efficiency and high utilization of equipment to a cellular orientation with metrics emphasizing minimal lead time is described. QRM principles are the foundation for the transformation. A critical component of planning such a transformation is identifying a "focus target market segment" (FTMS). A Target Market Segment can be any set of customers, internal or external, where there is a clear opportunity for benefit through lead time reduction. Once identified, this large-scope opportunity needs to be refined and focused to a specific group of customers and products with shared characteristics, processes, and other production properties to arrive at an FTMS.

The EZP-1 product line is comprised of ten cleaners that share common materials and manufacturing process steps.They differ from each other only by length. Currently, the manufacturing of the components for the EZP-1 cleaner is performed at various work centers of the machine shop department at Flexco in Grand Rapids using a job shop approach and mingled with the production of other products. This combination of same materials, solid sales volumes, and un-complicated construction conform the EZP-1 product line to the definition of an FTMS.

Flexcotargets a 1-day lead time on standard size EZP-1 pole cleaners which is a competitive advantage over other manufacturers. However, this perceived 1-day lead time is accomplished by holding large inventories and building to forecast due to the current job shop production environment. The Flexco assembly department fills each day's orders by picking components from inventory, assembling them, and boxing them for shipment as finished products. This system works satisfactorily as long as the number of orders each day does not exceed the existing inventory of any single component. The lack of reliable sales forecasting tools and huge variability in customer order quantities further complicates the process of maintaining appropriate component inventory levels. Variability in the products ordered by customers also causes constant shuffling of manufacturing priorities which in-turn compounds the problem by delaying the production of planned items. It is easy to see this vicious cycle has no end and will continue for as long as the job shop approachis used to produce HMLV products

A successful transformation to cellular production based on QRM principles could result in inventory reduction or elimination, reduction in floor space required for inventory, and production flexibility including expanded product offerings in special sizes with the same MCT among other possible benefits. These improvements in turn would improve profits on the EZP-1 product as well as an increase in sales from shorter lead times on custom versions.

Much of the work done to manufacture Flexco's other heavy duty BCPs are done using similar processes.Thus,the transformation form job shop production to cellular production serves as a demonstration and test case of how this approach canhave a larger scale impact throughout Flexco.

II. BACKGROUND

Cellular manufacturing is an alternative production organization to a job shop which provides the operational benefits of a serial line [2, 3]. Each cell performs all of the processing needed on one, or at most a few, similar items in this case the EZP-1 poles. Each pole is processed through the same sequence of machines and manual operations. The cellular manufacturing approach eliminates, or at least reduces, the need for setups, since only one part or a small number of similar parts are processed in a particular cell.

Rubich and Watson [4] give some advantages of cellular manufacturing approach versus the job shop approach:

- Improved communication and teamwork – operators are close enough to talk and help each other if necessary.
- An understanding of the entire manufacturing process from raw material to finished product
- An opportunity to meet and discuss issues with customers if any customer concerns develop
- An environment where cell operators have a greater sense of control in how their cell is run
- Responsibility and ownership for producing high quality products on time
- Higher job satisfaction through increased job responsibility and variety

Another goal of cellular manufacturing is to minimize the work-in-process inventory. This is accomplished using the principle of one piece flow [5] that seeks to move individual parts through a work cell as quickly as possible. A worker seeks to keep one piece or part moving through the entire cell. This is demonstrated in the prototype cell described in this study. This is the opposite approach to processing multiple parts (a batch) at one workstation and then moving the entire batch to the next workstation for processing as is currently done. In other words, one piece flow uses a batch size of one.

III. METHODS

The goal of this study is to demonstrate the increased effectiveness of producing the EZP-1 in a work cell designed using QRM principals versus the current job shop approach. The first step requires identifying the manufacturing critical path and computing the time required by one unit of product to traverse this path that is the manufacturing critical path time (MCT). Suri [1] defines manufacturing critical-path time as "the typical amount of calendar time from when a customer creates an order, through the critical path, until the first piece of that order is delivered to the customer".

The second step is identifying the equipment needed to perform the manufacturing processing steps necessary to construct an EZP-1 pole cleaner. Finally, the effectiveness of the cellular production strategy is demonstrated by constructing demonstration units of the EZP-1 pole cleaner.

In addition to the MCT, utilization of equipment in the cell is of interest. The utilization is computed using equation 1.

$$Utilization = \frac{Time\ \ to\ Fill\ Orders + Changeover\ \ Time + Maintenance\ \ Time}{Operator\ \ Working\ \ Time} \quad (1)$$

IV. RESULTS

Fig. 1 lays out the process from order placement to delivery for an EZP-1 pole cleaner which is needed to determine the MCT. Table 1summarizes the MCT for the EZP-1 pole cleaner from order to delivery. The MCT of 36 days includes significant delays in processing, waits in inventory, and standard lead times from suppliers.

The basic steps to manufacture an EZP-1 assembly are:

1. Cut Pole to length from full bar
2. Deburr cut ends of pole
3. Punch holes at both ends of pole (4 total)
4. Shear pole plate to length from full bar
5. Punch hole set on both ends of plate
6. Weld Pole Plate onto pole
7. Powder coat weldment

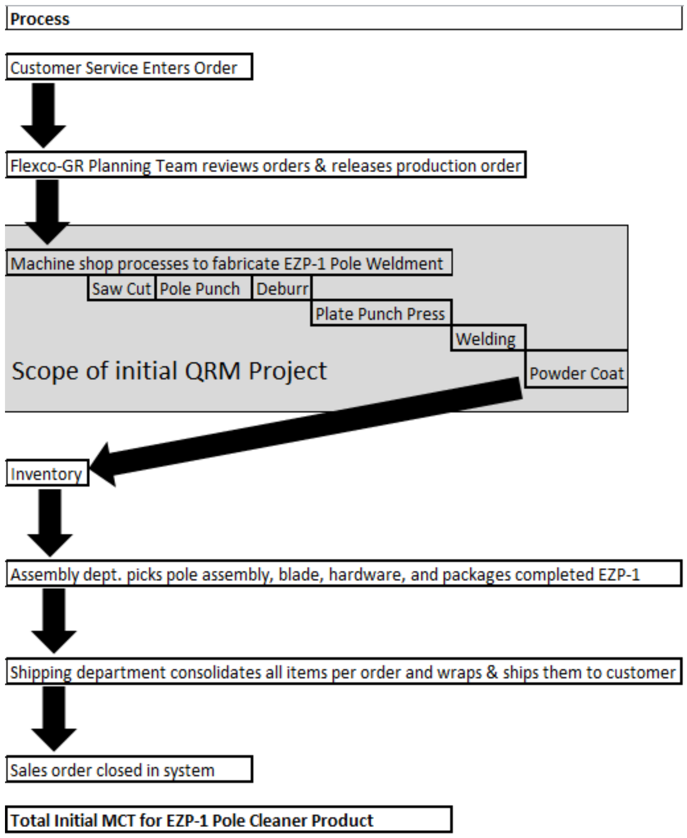

Figure 1**:** Process for filling EZP-1 customer orders

Table 1: CurrentMCT for EZP-1 customer orders

Lead-time for EZP-1 Cleaner Assembly

Time (days)	Person / Team Responsible (Location)	Process Description
0	Customer service (Flexco-DG)	Customer order is entered by CSR
0	Customer service (Flexco-DG)	CSR creates a sales order in ERP system (Baan)
1	ERP System (Flexco-DG)	ERP/MRP system regenerates nightly
0	Purchasing/Planning (Flexco-GR)	Interpret/Review ERP report, plan production order
1	Purchasing/Planning (Flexco-GR)	Release order to manufacturing dept.
3	Purchasing/Planning (Flexco-GR)	Order & receive material to fulfill above order that was released
2	Saw cut parts (Machine Shop - GR)	Both the main pole and blade plate piece are cut off from full bars of material
0	Pole Punch (Machine Shop - GR)	The main pole is punched after being cut by a portable press by the saw operator
0	Deburr (Machine Shop - GR)	The ends of the main pole are deburred after being punched by the saw operator
3	Punch Press (Machine Shop - GR)	The blade pole plate has holes punched in it by a stamping press in the press area
3	Welding (Machine Shop - GR)	The blade pole plate is welded to the main pole in the welding area
9	Powder Coat (Outside Supplier)	The welded pole assembly is shipped to an outside supplier for powder coat finishing
10	Component Inventory (Flexco - GR)	Coated parts are stored on shelves until they are pulled for an order and assembled
1	Final product Assembly (Assembly - GR)	Parts are assembled to order and shipped within 1 day of order being placed
0	Packaging and Shipment (Shipping - GR)	Assemblies are consolidated by order and shipped to customer via freight
0	Sales order closed (Shipping - GR)	Sales order is closed out in the ERP system
3	Customer Receives order	Customer receives their order within a couple days depending on shipping method
36	Approximate Manufacturing Critical Path Time (MCT) for an assembly that has a 1-day lead-time to ship to customers	

These steps can be completed in a work cell and some using the same equipment. The equipment that is needed to process these parts includes a band saw, pole de-burring machine, ironworker/pole punch, and welder. Fig.2shows the equipment and flow within the cell. Once the processing steps and equipment were identified, cycle times could be estimated based on similar equipment in use at Flexco.

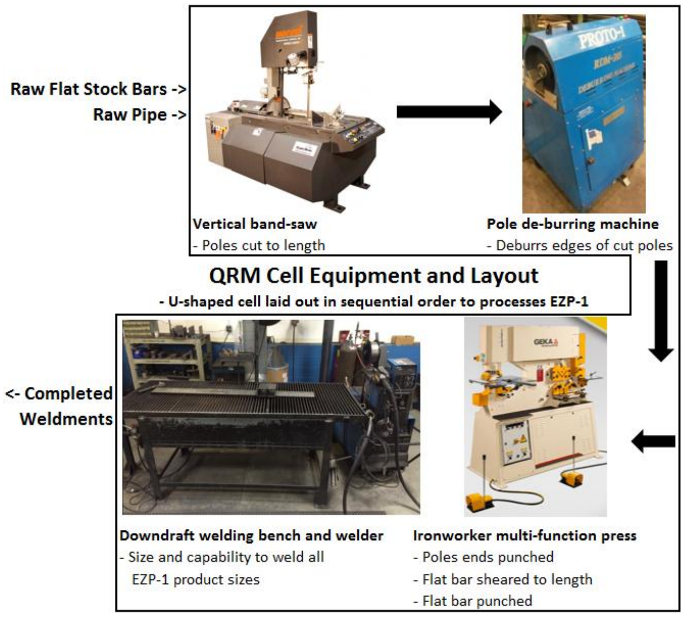

Figure 2**:**QRM cell layout for EZP-1 weldments.

The next step was to run a physical simulation of the production cellto confirm the estimated cycle times and resulting utilization. This step provides validation under production conditions as required by management before pursuing implementation. Flexco is a vertically integrated manufacturer which made the physical simulation possible. There is a vertical band saw used to cut the pipe sections. The cutting department has a pole de-burring machine with the correct tooling to deburr the EZP-1 pipe edges. The fabrication department contains an Ironworker multi-function press that is capable of a multitude of processes including shearing flat stock, punching holes in flat stock, and punching holes in pipe with additional tooling. The welding department has all the necessary fixtures, tools, and equipment to properly weld the pipe and bar together to complete the EZP-1 pole assembly.

The complete welded EZP-1 poles were loaded onto a skid and staged to be sent to Flexco's outside vendor to be powder coated. Upon return, the fit and finish of the parts was verified by completely assembling them. A total of 4 assemblies were produced to demonstrate the cellular manufacturing concept.

An important goal was to determine if a cell staffed with one-person could meet demand during high volume periods. Annual sales data was collected and analyzed to find maximum demand requirements per year over the time period of 2008-2014. The actual maximum volume shown is a standardized quantity of 1000. The actual volume is confidential.

These maximum volumes were multiplied by the estimated processing time per part to find the resulting annual production hours required. The production hours were divided by 250 working days to find the average number of processing hours required per day to meet the maximum annual demand. It is also important to account for additional planned machine occupied time on the QRM cell equipment. This time was estimated at 1.5 hours per day to account for tooling changeovers required to run different operations on the same piece of equipment as well as the daily preventative maintenance procedures often performed by machine operators at Flexco.

Table 2 shows the utilization calculation. The estimated processing times and the processing times observed during the physical simulation are compared. The changeover and maintenance time has been standardized as was the annual volume such that the utilization is correct.

Table 2: Utilization Computations

		Estimated	Physical Simulation
A	Total Processing Time (minutes)	54.67	44.44
B	Total Processing Time (hours) = A / 60	0.91	0.74
C	Standardized Maximum Volume (2008-2014)	1000	1000
D	Annual Processing Time (hours) = B * C	911	741
E	Processing Time per Day (250 days per year) (hours) = D / 250	3.64	2.96
F	Standardized Daily Changeover and Maintenance Time (hours)	1.50	1.50
G	Daily working hours	6.75	6.75
H	Utilization = (E + F) / G	76%	66%

V. CONCLUSION

The physical simulation confirmed that the cell-based production approach developed using QRM thinking was applicable to the Flexco EZP-1 product line. With a test processing time under 45 minutes as shown in Table 2, a cell operator would need approximately 4.5 hours a day to keep up with maximum annual production volumes, 2.25 hours less than the work day. A single worker was able to produce four sellable assemblies from start to finish in six steps.

Several additional benefits were observed. First, every part except for the 21' pipe bar was able to be transported and positioned without cranes, forklifts, or lift-assists. This is an improvement over the current bulk-processing method that requires the use of large, slow, lifting equipment that is shared among several departments and adds to the MCT.

Second, worker time was not diverted from productive manufacturing to record transactions or count inventory that is required when individual components are produced in bulk and stored as in the current job shop approach. With the cellular approach the only transactions that need to be made are at the beginning when raw material is pulled from inventory and at the end when weldments are finished and sent off for powder coating.

Third, MCT is reduced since there is no wait time for any other products to be manufacturedsince equipment is dedicated to the EZP-1 product line. Such ample capacity is the opposite of the batch-processing equipment that is often scheduled over-capacity and subject to constantly-changing order priorities.

Fourth, workers engaged in batch processing often require retraining when producing a particular part infrequently, such as once a month. Thus, MCT increases. However, a cell operator knows their FTMS product line well and such retraining is avoided.

Fifth, all of the parts were started and finished and shipped out the same day that is product is made to order. There was no WIP inventory to take up room on storage shelves and consequently no money is tied up in inventory. This is a drastic improvement over the current batch-processing method that totals close to $20,000-per-day of WIP and finished-goods inventory.

Sixth, a cell operator develops a sense of pride by making a product from start to finish versus producing a batch of individual components and never seeing a completed assembly.

Seventh and most importantly, the MCT it takes for the EZP-1 to go from order to delivery is reduced by 7 days, a 20% improvement in customer responsiveness just by focusing on the physical manufacturing (or "touch time") of the product. Realistically the MCT for the EZP-1 could be reduced to one day total, not including shipping, by implementing changes like: in-house powder coating, same-day order entry and communication to the production cell, more frequent raw material deliveries, and building to-order instead of to-forecast. This would allow Flexco to rapidly respond to any size customer order at any time free from the drawbacks of batch-processing and inventory.

The actual average processing time for the test parts was 44.4 minutes and results in a utilization of 66% as shown in Table 2. This utilization may be less than ideal for a dedicated cell, but Flexco has many other product offerings with similar components and features to the EZP-1. It would be very feasible to expand this cell and FTMS to other products and still comfortably meet annual production requirements with utilization less than 85%.

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