Implementation of Lean Manufacturing to Improve Competitiveness

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ABSTRACT

In traditional manufacturing processes a lot of material is wasted in hidden ways. These can be identified through Lean Manufacturing systems. It is proven that the Lean Approach eliminates waste and improves value. This reduces excessive investment in working capital and improves Return on Invested Capital (RoIC). As a result, the shareholder's value is maximized through simultaneously reducing costs and increasing capital efficiency.

To demonstrate this we analyzed the production process of the *Upper Output Shaft,* a key component in a typical drive train assembly like a Four Wheel Drive transfer case, used in a pickup truck or SUV. Value Stream Mapping (VSM) is used to identify and reduce non value-added activities. VSM methodology for Output Shaft delivered the following benefits for DivgiWarner:

- Reduction in Inventory by 66%,
- Process cycle efficiency improved by 228%,
- Manpower cost reduced by 43%
- Material movement in the plant reduced by 68%
- Improvement in RoIC by 32%
- Cost of part reduced by 11%

This paper illustrates how to implement lean principles in the manufacturing environments of order-based medium scale production to eliminate wastes in the form of defects, unnecessary processing, and excess inventory. With the use of lean tools, we also show how to set performance baselines, track continuous improvements, and communicate progress to pursue perfection

1. INTRODUCTION

DivgiWarner is a joint venture between BorgWarner Inc, USA and Divgi Metalwares, India where Borg Warner Production System (BWPS) is being practiced. BWPS is based on the Toyota Production System. BWPS has 7 foundational pillars and 23 tactical elements. One of a foundational pillar in BWPS is Lean Manufacturing. The basic idea behind the system is eliminating waste. Waste is defined as anything that does not add value to the end product from the customer's perspective.

The primary objective of lean manufacturing is to improve company's operations and become more competitive by implementing different lean manufacturing tools and techniques. Lean manufacturing means "A systematic approach of identifying and eliminating waste through continuous improvement" The term "Lean" as Womack and Jones define it, denotes a system that utilizes less, in terms of all inputs, to create the same outputs as those created by a traditional mass production system, while contributing increased varieties for the end customer.

Lean is to manufacture only what is needed, when it is needed and in what quantity is ordered by the customer. Goods are manufactured in a way that minimizes the time taken to deliver the finished goods, amount of labor and the floor-space required, done with the highest quality at the lowest possible cost. Lean principles have proven to be universally successful at improving the results when appropriately applied.

There are five basic principles of lean manufacturing:

1. Understanding Customer Value

2. Value Stream Analysis

3. Flow

4. Pull

5. Perfection

These five lean principles work together and are fundamental in eliminating waste. Waste is commonly defined as *non-value-added activity*. Lean practitioners identify seven types of waste:

1. Excess (or early) production: Producing more than the customer demands or producing it earlier than the customer needs it. This ties up valuable labor and material resources that might otherwise be used to respond to customer demand.

2. Delays: Waiting for material, tools, information, or equipment. This may be a result of poor planning, late supplier deliveries, lack of communication, and overbooking of equipment.

3. Unnecessary Transportation: Moving material more often than necessary. Material should be delivered and stored at its point of use.

4. Inventory: More material is stored than needed. This wastes valuable space and working capital.

5. Over Processing: Doing more work on a part than is necessary, including inspection and reworking. This wastes time and money. Quality must be built into the manufacturing process so that parts are produced correctly first time.

6. Defects: Defects consume considerable resources. In addition to the original materials and labor used to manufacture the part, extra labor and machine time are required to fix the defective part. If the defective part is sold to a customer, it will increase unnecessary costs.

7. Unnecessary Movement: Excess motion of employees in getting tools, picking parts, or moving material from one point to another is non value-added activity.

A variety of techniques are available for reducing or eliminating waste. These techniques include 5S and Visual Management, Standardized Work, Value Stream Mapping, Supermarket / Pull System, Cellular manufacturing, One Piece Flow Production and Changeover Time Reduction using SMED Techniques.

2. HISTORY OF LEAN THINKING

After World War II, Japanese manufacturers had to face the dilemma of vast shortages of material, financial, and human resources. These problems differed from those of their western counterparts. These conditions resulted in the birth of the “lean” manufacturing concept.

Toyota Motor Company, led by its president Toyoda recognized that American automakers of that era were out-producing their Japanese counterparts; in the mid-1940’s American companies were outperforming their Japanese counterparts by a factor of ten. In order to make a move toward improvement early Japanese leaders such as Toyoda Kiichiro, Shigeo Shingo, and Taiichi Ohno devised a new disciplined, process-oriented system, which is known today as the “Toyota Production System,” or “Lean Manufacturing.”

Taiichi Ohno, who was given the task of developing a system that would enhance productivity at Toyota, is generally considered the primary force behind this system. Ohno drew upon some ideas from the west and particularly from Henry Ford’s book “Today and Tomorrow.” Ford’s moving assembly line of continuously flowing material formed the basis for the Toyota Production System. After some experimentation, the Toyota Production System was developed and refined between 1945 and 1970, and is still growing today all over the world. The basic underlying idea of this system is to minimize the consumption of resources that add no value to the product.

3. INTRODUCTION TO VALUE STREAM MAPPING

Value stream mapping (VSM) is one of the powerful lean tools available to us. Value stream mapping can help you see wasteful activity in a new way.

Value stream mapping is a pencil and paper tool, which is created using a predefined set of icons (shown in Fig. 1).

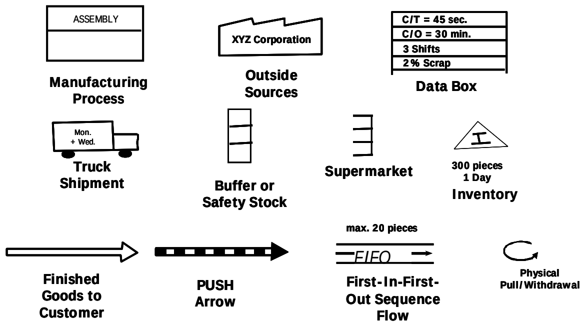

Fig. 1(a): Material Flow.

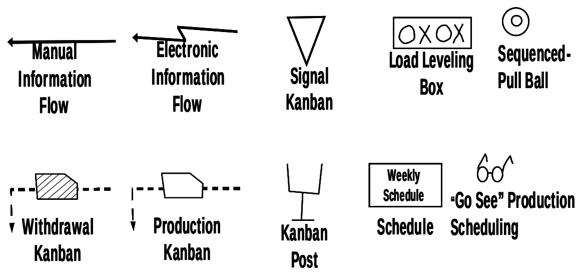

Fig. 1(b): Information Flow.

Fig. 1: Symbols Used in Value Stream Mapping.

A value stream is a set of actions, value added as well as non-value added, which are required to bring a product or a group of products that use the same resources from raw material to the arms of customers. Value stream mapping is an enterprise improvement tool to assist in visualizing the entire production process, representing both material and information flow.

3.1 Key advantages of Value stream Mapping

Operational Advantages

- Reduction in lead time (cycle time)
- Increase in productivity
- Reduction in work-in-process inventory
- Improvement in quality
- Reduction in space utilization

Administrative Advantages

- Reduction in order processing errors
- Streamlining of customer service functions so that customers are no longer placed on hold
- Reduction of paperwork in office areas.
- Reduced staffing demands, allowing the same number of office staff to handle orders in large numbers.
- Documentation and streamlining of processing steps, enabling non-critical functions to be outsourced and allowing the company to focus its efforts on customers' needs.
- Implementation of job standards and pre-employment profiling, ensuring the hiring of only above-average performers.

Strategic Improvements

- Reduced lead time, costs and improved quality provide opportunities for new marketing campaigns, allowing your company to gain market share from competitors.
- Increased RoIC and reduced working capital.

4. SELECTION OF PART FOR DEMONSTRATION

The first step recommended is to identify the product family to be mapped. The tool for this is a PQPR (Product Quantity / Product Routing) matrix. This tool can be used to garner maximum benefits from your value stream mapping efforts.

With the help of the PQPR matrix we have analyzed units shipped per month, share of business and process steps required. It was observed that the Upper Output Shaft has the significant volume (Product Quantity) and share of business. Similarly, it was observed that the Upper Output Shaft has more complex processes and may have significant opportunity to identify waste.

Fig. 2: Upper Output Shaft (UOS).

The part shown in Fig. 2 is the Upper Output Shaft, a key component in a typical drive-train assembly like a Four Wheel Drive transfer case used in a pickup truck or SUV. Input raw material for the UOS is a forging and is provided by a supplier, while all other manufacturing processes take place at DivgiWarner's two plants located at Bhosari and Sirsi. All machining processes before heat treatment are done at Sirsi, then grinding, assembly, and testing process are done at the Bhosari plant.

5. OVERVIEW OF METHODOLOGY

To demonstrate implementation of lean manufacturing tools, a systematic approach has been decided as below

- Prepare current state value stream map
- Identify wastes
- Work out solutions to reduce or eliminate wastes (Kaizen)
- Map a future state with identified solutions and prepare Kaizen implementation plan
- Implement identified solutions
- Monitor effectiveness and sustainability of implemented solutions
- Compare with the original state and note improvements

6. MAPPING CURRENT STATE OF SELECTED PART

After selecting the part for demonstration, first step is to determine the value (customer needs) of the particular product.

Following values have been identified for the improvement:

- Production lead time
- Working capital (inventory)
- Product quality

There are 9 easy steps to map the current state of value stream. We will follow these steps to map the current state value stream of the Upper Output Shaft.

Step 1: Calculate takt time.

Step 2: Have a big piece of paper ready.

Step 3: Walk the process from front to back.

Step 4: Draw in the customer box / details.

Step 5: Go to the end of the process.

Step 6: Focus on the material flow first.

Step 7: Add the Inventory/Wait Times.

Step 8: Draw in the information flow.

Step 9: Add in the timeline.

Step 1: Calculate takt time:

Current average demand of upper output shaft is 280 pieces / day with the following working hours

- Hours per shift: First shift: 8.5 hours, Second Shift: 8.5 hours and Third shift: 7 hours.
- Break per shift: 30 minutes.
- Shifts per day: 3.
- Working days per week: 6

$$\text{Takt Time} = \frac{\text{Available Time}}{\text{Customer Demand}}$$

$$\text{Takt Time} = \frac{22.5\,\text{Hrs} \times 60\,Min}{280}$$

$$\text{Takt Time} = 4.82\,\text{Min}$$

$$\text{Target Takt Time} = \text{Takt Time} \times \text{Plant efficiency}$$

$$\text{Target Takt Time} = 4.82\,\text{Min} \times 85\,\%$$

$$\text{Target Takt Time} = 4.10\,\text{Min}$$

In other words, we need to produce a fully finished Upper Output Shaft every 4.10 minutes in order to satisfy customer demand.

Step 2: Have a big piece of paper ready:

For the Upper Output Shaft we have used paper of size 11”x17”. It is tough but can be carried around. We always prefer to draw the map on paper first and then convert into Microsoft excel templates.

Step 3: Walk the process from front to back:

Quickly walk the process with your team in order to understand the general flow. It is also important to define the start and stop point of the process. Do not attempt to take on too much in this step. The Upper Output Shaft is processed at two locations namely Bhosari and Sirsi; Table 1 explains the master route sheet for Upper Output Shaft with locations.

Table 1: Master Route Sheet

MASTER ROUTE SHEET				
PART NAME: Upper Output Shaft				
PART No. :				
OPN NO.	OPERATION DESCRIPTION	REMARKS	MACHINE	LOCATION
10	Inward inspection	---	---	Bhosari
20	Facing & Centering	---	SPM	DIPL Suris (Vendor)
30	Pre turn short side	---	Lathe	
40	Pre turn Long side	---	Lathe	
60	Finish turn Long side	---	CNC Turning Center	
65	Finish turn Short side	---	CNC Turning Center	
70	Deep hole drilling	---	Gun Drilling	
80	Chamfering (Dia. 18)	---	Radial Drilling	
81	Finish turn rolling Dia	---	Cylindrical Grinding	Surisi
90	Hobbing (29T)	---	Hobbing M/c	
110	Spline Rolling (26T)	---	Spline rolling	
130	Spline Rolling (32T)	---	Spline rolling	
150	Thread rolling	---	Thread Rolling	
185	Drilling & chamfering	---	VMC	
190	Deburring & burr removal	---	---	
200	Heat Treatment	---		Vendor
210	Bend removal	---	Press	Bhosari
220	Grinding	---	CNC Grinding	

Step 4: Draw in the customer box / details:

In the top right hand side of the paper, draw the little saw-topped box representing the customer. Refer to Appendix 1 for current state VSM.

Step 5: Go to the end of the process:

After understanding the process, mapping of the value stream should be started. Start mapping from the customer end, followed by last process and so on.

Step 6: Focus on the material flow:

In this step we will walk through the process, collecting current process information. We have designed a data block of the characters based on values (customer needs) as previously decided. In the case of Upper Output Shaft value stream mapping, the following characteristics have been decided to measure current state process information.

Table 2: Data Table

OP.# "Operation Description	
C/T	
TAKT	
C/O T	
EPE	
FTP	
UP TIME	
SHIFTS	

Details of abbreviations used in the data block representing the process and other fields are explained as follows.

- C/T: Floor to floor cycle time (To evaluate process lead time)
- TAKT: Target Takt Time (To evaluate inventory)
- C/O T: Changeover time (To evaluate process lead time)
- EPE: Every part Every Interval (To evaluate process lead time)
- FTP: First time pass rate (To evaluate quality)
- Up Time: Equipment up time (To evaluate process lead time)
- Shifts: No of shifts for the production (To evaluate process lead time)

Using the above data table actual information of each process is collected and noted down in the value stream map. Refer to Appendix 1 for current state value stream map. While collecting the above data, a current plant layout block diagram is plotted as shown in Fig. 3

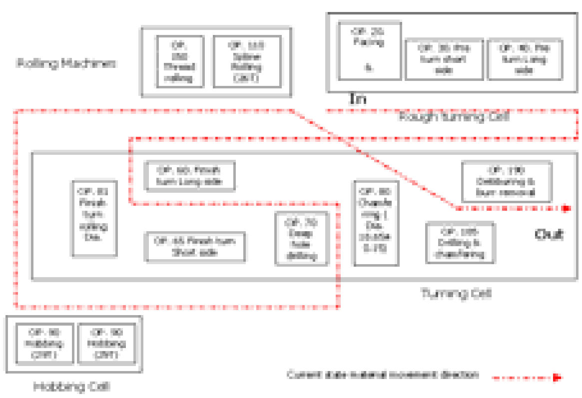

Fig. 3: Current Plant Layout.

Step 7: Add the inventory/wait times:

The symbol used for noting inventory is the little triangle with an "I" in the middle. This parameter evaluates working capital blocked in the form of inventory.

For inventory value, simply count the number of pieces at each process and note them under the triangle. Based on customer demand, calculate the days required to consume subject inventory. This shows the amount of waste at each process as a WIP stock.

Step 8: Draw in the information flow

In addition to mapping material flow, it is also important to understand information flow. If information flows electronically, a lightning bolt arrowed line shows it (refer Fig. 1). If information is communicated manually then a straight arrowed line is used (refer Fig. 1).

The central control of information is shown as a box. This box includes the letters "MRP" in it as current production control mechanism used is traditional material resource planning. The information received from customers is in the form of a Customer Requirement Schedule (CRS) as well as schedules given to suppliers and each process is shown in VSM. (Refer current state VSM for information flow Appendix 1)

Step 9: Add in the timeline:

As shown at the bottom of the value stream map, a saw tooth like structure has been mapped. It separates the value added and non-value added time.

The last step in value stream mapping is to sum up all the "value-added" (cycle times) and note them at the end of the timeline. Likewise, also sum up the "inventory" times and note that on the timeline scale.

Value stream mapping of current state is shown in Appendix 1.

7. IDENTIFICATION OF WASTES

All activities that do not add any value are called waste and need to be removed or reduced from the system. As discussed before, wastes are of seven types.

After studying the current state VSM, the following wastes are identified:

- The traditional batch production plant layout is compelling higher material movement within the plant.
- Every production process is scheduled separately for its output, hence inventory levels and WIP levels are observed to be very high.
- Higher inventory of forgings is observed. It is also noticed that there is no standard material ordering quantity decided for forgings procurement.
- Set up time of some operations is very high; especially spline rolling operation.
- Unnecessary inventory piled up at some processes and no control of over production
- It is observed while routing through the manufacturing shop that no standardization of manufacturing processes is noticeable.
- Also, workplace organization and standardization is poor which results in many hidden wastes. Improvement required in 5S and workplace organization.
- 14 operators are working in the plant exclusively for the Upper Output Shaft. Refer to operator allocation graph.

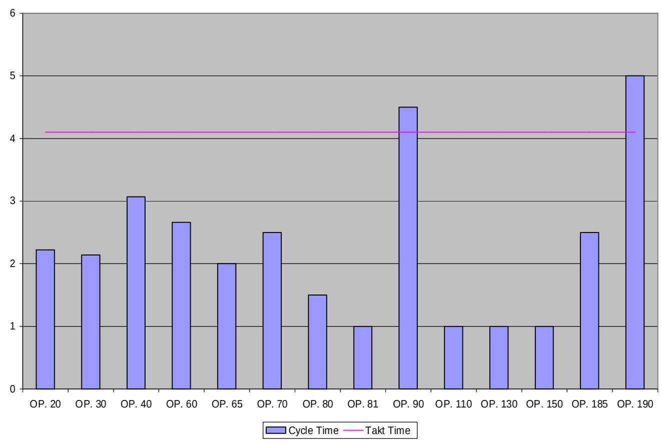

Fig. 4: Graph of Cycle Time vs. takt Time.

- Cycle time of OP#90 and OP#190 are more than takt time, one needs to improve and reduce overtime costs.
- Currently, all the operators work in isolation. In lean terms, they are working to their own drumbeat. Whenever possible, it is desired that all operators work to the same beat – namely takt time.
- So far, we have identified all the wastes along the material flow. There is opportunity observed in the area of information flow. Rather than scheduling each process "on an island", the lean approach is to schedule one process. It is called the pace maker process since it sets the pace for the entire system.

8.SOLUTIONS TO ELIMINATE IDENTIFIED WASTES and PLOTTING OF FUTURE STATE MAP

The following actions have been identified to eliminate wastes from the system.

- Change the equipment layout to a cell layout
- Select optimum crew size
- Operator line balancing to optimize manpower utilization
- Set a target to reduce WIP inventory at each operation and implement single piece flow wherever possible.
- Introduce use of Kanban for pull system between two plant location as well as use of Kanban for internal material movement.
- Introduce super market concept for finished goods and maintain min max levels to optimize finish goods inventory.
- Improve communication and schedule a pacemaker
- Finalize the inventory model and determine EBQ for forging to optimize transportation and inventory cost between two plants located at Bhosari and Sirsi.
- Prepare visual standard operation sheet for each operation and train the operators
- Reduce set up time for spline rolling machine
- Implement 5S and standardize workplace organization

From the above information and discussed improvement, the future state map is generated as shown in Appendix 2. Every identified opportunity (Kaizen) is listed along with responsibility and target date of completion. Weekly review meetings are conducted to track activities with respect to target dates.

8.1 Change equipment layout to a cell layout

To optimize manpower cost it has been recommended to have workers able to work on multiple stations simultaneously and move from one station to another. For the subject reason, a layout has been prepared in the typical "U" shape format as shown in the block diagram below. To have single piece flow and enable workers to move from one station to another, a typical U shape cell layout was developed as shown in the block diagram, Fig. 5(a), for all green operation.

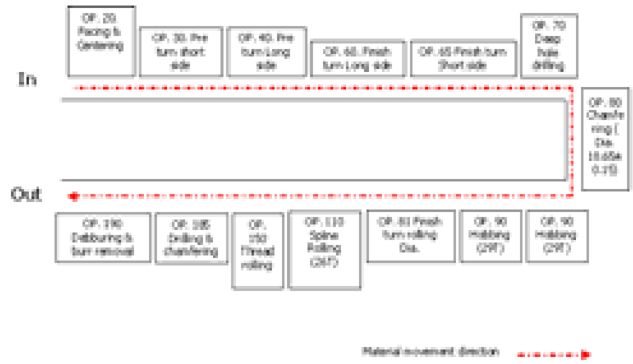

Fig. 5(a): Modified Plant Layout Block Diagram.

Fig. 5(b): Modified Plant Layout Photograph.

8.2 Select optimum crew size

To optimize manpower requirement and to avoid over burden on a particular operator, "optimal crew size" is determined as follows.

Total cycle time of operations carried out in Sirsi plant is 32.09 min. Calculated target takt time is 4.1 min.

$$\text{Optimum Crew Size} = \frac{\text{Total Time}}{\text{Takt time}}$$

$$\text{Optimum Crew Size} = \frac{32.09\ \text{Min}}{4.1\ \text{Min}}$$

$$\text{Optimum Crew Size} = 7.82\ \text{Nos}$$

$$\text{Optimum Crew Size} \approx 8\ \text{Men (Rounded off)}$$

The team worked with their lean sense and specially designed u-shaped cell where all 8 operators would work simultaneously in a one-piece flow manner. Once the work is redistributed, the team is able to produce one Upper Output Shaft approximately every 4.10 min. The total time is now 26.45 minutes with balanced operations.

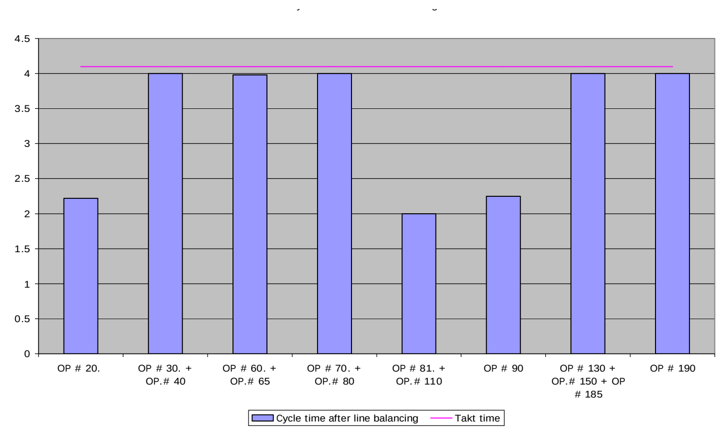

Fig. 6: Allocation of Operators.

The graph above explains which operation should be assigned to which operator. Line balancing is done in such a way that none of the workers are overloaded or underutilized. Because of some practical constraints OP# 20 cannot be combined with the other operation but we have defined a supermarket between OP#20 and OP# 30 to avoid over production. A similar supermarket is introduced before OP# 130.

8.3 Set a target to reduce WIP inventory and Single Piece Flow wherever possible

With the help of the new cell layout for the Upper Output Shaft, it is possible to have single piece flow. Although some constraints do exist, such as only one spline-rolling machine is available where two set-ups are mandatory. Apart from that, all other processes have dedicated equipment and WIP level is defined for each process. Refer future state VSM Appendix 2 for WIP levels.

8.4 Introduce use of Kanban for Pull System

The cellular layout has taken care of WIP inventories. Wherever a single piece flow is not possible, the pull system is to be used. Pull System stocks relatively small amounts and is frequently replenished with the use of visual signal called a Kanban. Normally, the Kanban card is used for signaling between the customer and the supplier.

It is observed from the process flow of the Upper Output Shaft that to implement a Kanban system at several stages such as –

A) Machine shop to forger when forging stock goes below the reorder level.

B) To eliminate in-house WIP inventory where single piece is not possible

C) To schedule production process between the two plants.

Fig. 7: Typical Kanban Card and Notification Board.

The location of flashing Kanban card is selected in such a way that it is easily visible and quickly noticed. Photograph in Fig. 7 shows an example of the Kanban board. It has been placed right near by the supervisor's workplace, where it is not possible to miss the Kanban requirement.

8.5 Introduce the super market concept and visual control

The super market concept is a method of visual control used to notify the reorder level. An indicator with red and green paint is placed nearby the stock store. When the stock is consumed so that red paint on indicator is visible, it triggers a signal of reorder. Kanban has been raised to pull the parts from the earlier process to replenish the stock up to the maximum level. The maximum inventory level is also marked on the indicator to avoid over production.

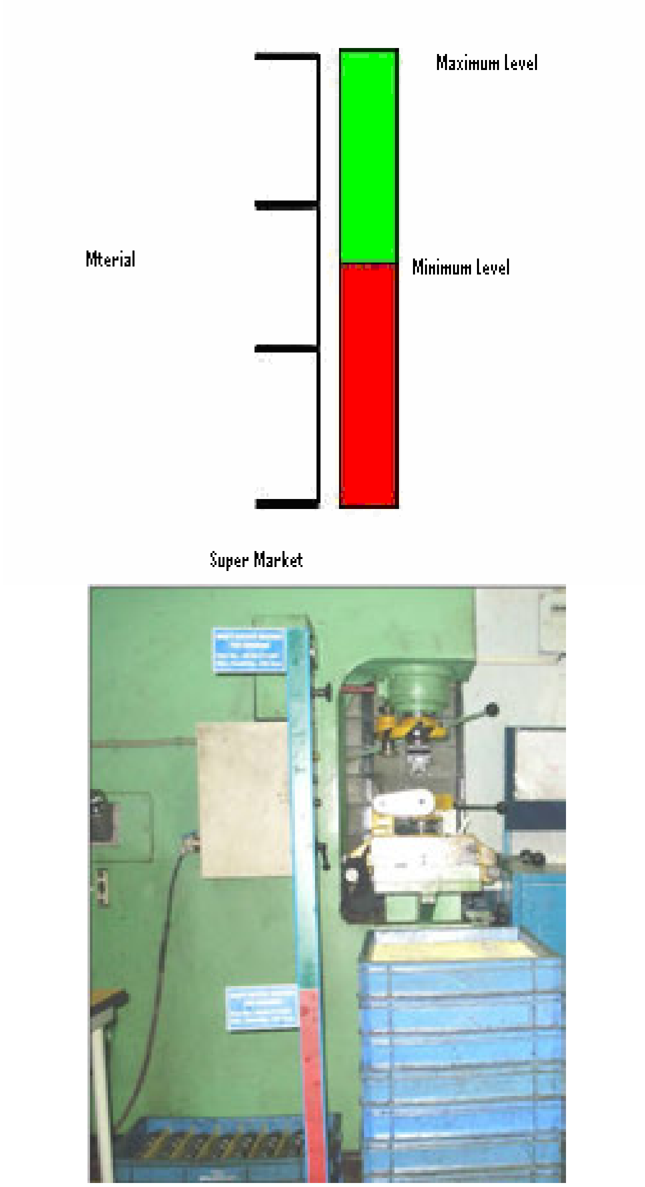

Fig. 8: Visual Control – Super Market.

For the Upper Output Shaft the super market concept is used to control finished goods inventory level. To decide the maximum and minimum inventory stock, the average daily consumption of product is considered. After reorder one batch can be made available within one day. The pace maker process is heat treatment.

$$\text{Daily average demand} = 280 \text{ Nos}$$
$$\text{Daily avg.demand with } 85\% \text{ plant efficiency} = 280 \div 85\%$$
$$\text{Daily average demand} = 329 \text{ Nos}$$

We need to maintain minimum buffer stock of 329 quantities. Considering pace maker process we have decided to have minimum stock of 332 and marked reorder level at 332 quantities. Heat treatment batch size is 166 parts per furnace lot. Considering the requirement of each day, we need two heat treatment batches daily so every top up will be in a multiple of 332. Based on this, maximum inventory could go up to 332 + 332 = 664 Numbers. A Green indicator is marked and fixed up near the store area as shown in the Fig. 8.

8.6 Improve communication and schedule a pacemaker

Similar to material and manpower, waste in the information side has to be reduced. Rather than scheduling each process as seen in current state VSM, the lean approach is selected to schedule one process. That process is called as "pacemaker process" since it sets the pace for the entire system. By definition, the pacemaker is typically defined as the process step closest to the customer whereby everything after it flows.

In case of the Upper Output Shaft, this would be the heat treatment process since the supermarket after the cell technically impedes flow. So the aim is to schedule production for heat treatment.

Additionally, it is mandatory to have communication with customers and suppliers. This two-way communication will enable all parties to prepare for demand fluctuations.

8.7 Finalize inventory model and determine EBQ for forging

While deciding the inventory model the following points are considered:

1) Daily production demand = 332 Numbers

2) Time required to flow information from machining plant to forging plant = 4-6 hours

3) Transit time from forging plant to machining plant = 16-18 hours

Based on total lead time of information flow and material flow it requires 2 days hence we have kept reorder level as 2 days average demand + safety stock of one day.

Reorder level = safety stock + (lead time for information flow + material flow)

= 1 day + (1day + 1 day)

= 332 + 332+ 332

= 996 Numbers

The minimum ordering quantity for forging, as decided by the supplier depending on their setup time and cycle time. In UOP case mutually agreed forging batch size is 996 nos, which is 3 days average demand. The forging supplier has asked to maintain supermarket as per the average requirement i.e. two batches of 996 parts.

Max level: Reorder level + standard batch size

: 996 Numbers + 996 Numbers

: 1992 Numbers

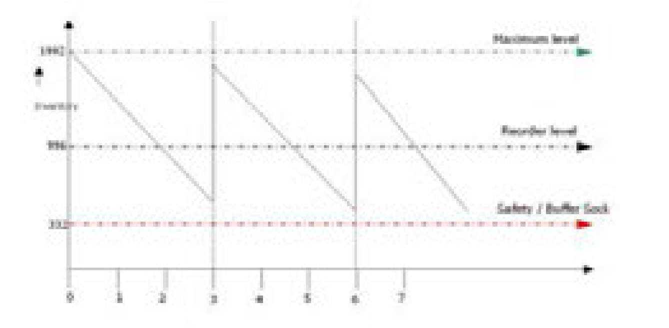

Fig. 9: Inventory Model

8.8 Prepare a standardized work sheet for each process and train the operators

Standardized work improves productivity and consistent quality. To analyze each operation, elemental tasks and its sequence video recording for each process is collected. Each job element is divided into 3 distinct categories namely - handwork, machine work and walking. After that, the non-value added job elements are identified. Some of the non-value added elements are eliminated. The elemental operation sequence is reordered to reduce total operation cycle time. Modified work sequence is documented in the typical format called Standard Operation Sheet (SOS) refer sample Appendix 4. It describes Job elements, element time, handwork time, walking time, job safety requirement, incidental work and work flow diagram for an individual operation. Critical steps of the Standard operation sheet are visually described in the Job element sheet (JES) to explain what is to be done, how it is done and importance of a particular step. Refer to Appendix 5.

A typical format of SOS and JES filled for one of the processes named grinding is shown in Appendix 4 and Appendix 5 respectively. Such SOS and JES are generated for all the processes of the Upper Output Shaft.

After standardizing the work sequence, we have defined the procedure, (Refer to Appendix 6) to train the operators as per the standardized operation sheet and job element sheet. Every operator is trained using standardized procedure and issued the operator license. Refer to Appendix 6 for operator licensing procedure.

8.9 Reduce set up time for the spline rolling machine

To identify the opportunity for improvement in reducing set-up time while changing over from 26T rolling to 32T rolling on the spline rolling machine, we need to understand the complete activity chart and time required for each activity.

Single Minute Exchange of Die (SMED) is one of the powerful lean tools available to reduce changeover time systematically.

Steps followed for SMED:

1. Detailed time study of the current state

2. Sorting of Internal and External Activities wherever possible

3. Reduce internal activity time by performing parallel operations

4. Preparation and Implementation of Target concepts

5. Standardization

Refer to Appendix 3 Table: 1 to view Detailed Activity Chart of spline rolling setup

It can be noticed from Appendix 3 (Table: 1) that setup change over time is around 3 hours, which is too high. It increases WIP and jobs wait for more time, which increases waste. It has been decided to implement SMED techniques to reduce setup time at the spline rolling operation. Same activity chart is further used to subdivide tasks for operator and setter (parallel operations) in Appendix 3 Table: 2.

It can be noticed from Appendix 3 (Table: 2):

- Changeover time taken by operator = 1.46 Hrs (Excluding External Activities)
- Change over time taken by setter = 0.61 Hrs (Excluding External Activities).
- Changeover time taken simultaneously by operator and setter = 0.16
- Total changeover time = 1.46 + 0.16 = 1.62 Hrs.

Setup time is reduced from 3.062 to 1.62 Hrs by using SMED techniques. It means the spline roll changeover time is reduced by around 47% with the help of SMED techniques.

9.MONITORING FOR IMPROVEMENT AFTER IMPLEMENTATION OF LEAN TOOLS

After implementing lean manufacturing tools, benefits have been foreseen from the future state value stream mapping. It was also observed that inventory level has significantly reduced and previously blocked working capital has been released. For quick comparison of a few benefits, some data has been monitored as we had done before implementing lean tools.

9.1 Data collection for inventory and WIP

Inventory data has been monitored to provide a quick reflection of the benefits of lean manufacturing system. Reference data has been collected to compare with current state data. Additionally daily monitoring of inventory has been done for six months.

The following table states standard inventory level to be maintained at each operation.

Table 3: Inventory level

Op No	Process	WIP
00	Forging	1000
10	Inward inspection	0
20	Facing & Centering	1000
30	Pre turn short side	332
40	Pre turn Long side	332
60	Finish turn Long side	166
65	Finish turn Short side	8
70	Deep hole drilling	8
80	Chamfering (Dia. 18)	0
81	Finish turn rolling Dia.	166
90	Hobbing (29T)	16
110	Spline Rolling (26T)	8
130	Spline Rolling (32T)	332
150	Thread rolling	8
185	Drilling & chamfering	8
190	Deburring & burr removal	8
200	Heat Treatment	830
210	Bend removal	664
220	Grinding	8
	Finish Parts	8
	Total	**4902**

Inventory level monitored for six months and observed that we can sustain at lower inventory level without any concern for more than six months. Fig. 10 shows inventory monitoring results.

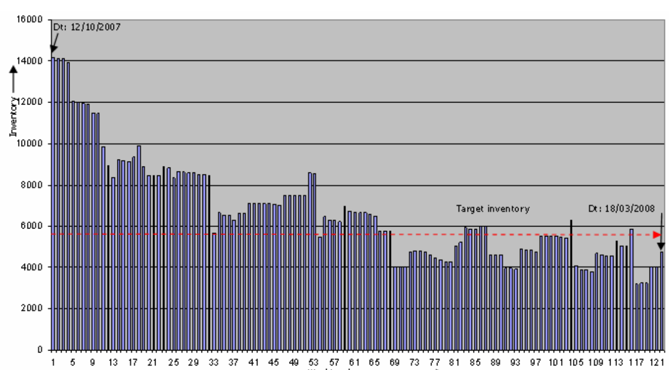

Fig. 10: Inventory monitoring results.

9.2 Time study

As studied at the beginning of the lean implementation, time study was carried out to understand differences in cycle time. After line balancing and introduction of SOS/JES, cycle times of many of the processes have been reduced.

The following table notifies the cycle time as well as setup time for each process after implementing lean manufacturing tools

Table 4: Cycle Time Measurement

Op No	Process	Cycle Time	Setup Time	Remark
	GRR & Unloading	0.12	---	
10	Inward inspection	0.185	---	
20	Facing & Centering	2.22	---	Dedicated equipment
30	Pre turn short side	1.78	100.0	
40	Pre turn Long side	2.22	100.0	
60	Finish turn Long side	2.98	60.0	
65	Finish turn Short side	1	-	Dedicated equipment
70	Deep hole drilling	2.1	-	Dedicated equipment
80	Chamfering (Dia. 18)	1.9	-	Dedicated equipment
81	Finish turn rolling Dia.	1	60.0	
90	Hobbing (29T)	2.25	-	One more equipment added
110	Spline Rolling (26T)	1	97.0	
130	Spline Rolling (32T)	1	97.0	
150	Thread rolling	1	-	Dedicated equipment
185	Drilling & chamfering	2	-	
190	Deburring & burr removal	4	-	
	Doc Audit & Inspection	1	-	
	GRR & Unloading	0.12	-	
200	Heat Treatment	5.78	-	
	Unloading in Stores	0.72	-	
210	Bend removal	1.30	-	Dedicated equipment
220	Grinding	4.28	-	
	Total	**39.96**		

10. COMPETITIVE ADVANTAGES ACHIEVED

All the information collected before and after lean concepts implementation is compared to explain several competitive advantages

As discussed earlier, lean manufacturing tools provide several competitive advantages. From subject study with reference to upper output shaft, we had implemented some of the lean manufacturing tools and the results are monitored.

10.1 Inventory

One of the key benefits foreseen from value stream mapping is inventory reduction and WIP reduction. From Table 3 and Fig. 10 the effect of lean manufacturing can be understood. Benefits from inventory reduction can be summarized as below:

- Total inventory before lean implementation is 14091 Numbers
- Total inventory after lean implementation is 4902 Numbers
- Approximately 66% reduction in inventory has been achieved.

10.2 Process cycle efficiency

- From the "current state" process of Shaft output following observations can be noted.
- Production lead time (PLT) of 43 days
- Total value added time (Cycle time) is 45.60 minutes
- Process cycle efficiency (PCE) is 0.07%
- After implementing lean manufacturing, process efficiency is improved as below.
- Production lead time (PLT) of 13 days
- Total value added time (Cycle time) is 39.96 minutes.
- Process cycle efficiency (PCE) is 0.23%
- Process cycle efficiency has improved by 228%

10.3 Manpower cost

- Manpower in use before implementation of lean manufacturing is 14
- Manpower after line balancing and modified cell layout is 8
- Total reduction in manpower is 6; that means a reduction by 43%

10.4 Material movements within plant

- To monitor effectiveness of cell layout, we had measured distance traveled by a single part before layout change and after group layout
- Before layout modification – 161.8 meters
- After layout modification – 51.3 meters
- From above measurement results it has been seen that reduction in material movement – 68%

10.5 Other advantages

Advantages seen from lean manufacturing tools are as below

- Ease of communication throughout the organization
- Supplier scheduling and production control made easy
- Manufacturing problem such as slow production, quality defects, machine down time, maintenance issues are brought to the surface for resolution.
- Effective and controlled utilization of manpower is achieved
- Manufacturing efficiency is increased
- In addition to the above advantages, the following administrative improvements have also been achieved from lean manufacturing system:
    - Reduction in order processing errors
    - Customers are no longer put on hold
    - Reduction of paperwork in office areas
    - Reduced staffing demands, allowing the same number of office staff to handle larger numbers of orders

It is very evident that the lean manufacturing tool can bring rhythm to work and set work disciplines of thinking for continual improvement, which in terms counted as most beneficial for the organization in the long term. Summarizing all above a detailed discounted cash flow analysis is done. It is noticed from cash flow analysis that the overall improvement achieved in **RoIC is around 32%** or in other words to get same RoIC **cost of goods can be reduced by 11%** to remain competitive in the market.

11. CONCLUSION

The Lean tool can be beneficial for low/medium volume production industries when appropriately applied. It was observed that value stream mapping is an ideal tool to expose the waste in a value stream and to identify Kaizen for improvement. Lean-manufacturing tools can greatly reduce wastes identified by the current state map.

Objective benefits of lean production system can be summarized as

Reduced inventory by 66%,

Improved process cycle efficiency by 228%,

Reduced manpower cost by 43%,

Reduced material movement by 68%.

The collective impact on cash flow and return on invested capital was improved by 32 %; in other wards, cost of product reduced by 11 % to get the same return on investments.

Lean manufacturing tools also delivered reduced WIP, increased inventory turns, increased capacity, cycle-time reduction and improved customer satisfaction.

Planning and execution of operations was improved by balancing production to set line rates and pulling parts using Kanban signals. Use of different tools such as cell layout, operator licensing, work standardization, 5S, SMED techniques, visual controls etc contribute to the competitive advantage.

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

RoIC - Return on Invested Capital

Bhosari- Divgi Warner assembly plant location

Sirsi- Divgi Warner machining plant location

Takt time- Refers to how often a part to produced based on customer demand and available time

Kanban- Visual control tool used for signaling between the customer and the supplier

VSM- Value Stream Mapping

BWPS- Borg Warner Production System

UOS- Upper Output Shaft

WIP- Work In Progress

SMED- Single Minute Exchange Dies

GRR- Goods Receipt Report

EBQ- Economical Batch Quantity

APPENDIX

1. Current state value stream map

2. Future state value stream map

3. SMED techniques

4. Sample SOS

5. Sample JES

6. Standardized Operator training procedure and operator license

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