

Manufacturing Enhancement through Reduction of Cycle Time using Different Lean Techniques

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Abstract: In recent manufacturing system the most important parameters in production line are work in process, TAKT time and line balancing. In this article lean tools and techniques were implemented to reduce the cycle time. The aim is to enhance the productivity of the water pump pipe by identifying the bottleneck stations and non-value added activities. From the initial time study the bottleneck processes were identified and then necessary expanding processes were also identified for the bottleneck process. Subsequently the improvement actions have been established and implemented using different lean tools like value stream mapping, 5S and line balancing. The current state value stream mapping was developed to describe the existing status and to identify various problem areas. 5S was used to implement the steps to reduce the process cycle time and unnecessary movements of man and material. The improvement activities were implemented with required suggested and the future state value stream mapping was developed. From the results it was concluded that the total cycle time was reduced about 290.41 seconds and the customer demand has been increased about 760 units.

Keywords: Cycle Time, VSM, TAKT Time, Kaizen, Line Balancing

1. INTRODUCTION

Nowadays, manufacturing industries utilize more resources to improve their productivity. It is very important to stabilize their resources allocation and work environment. They want to use tools to optimize its processes to attain good results to meet the demand. They focused only on production with higher efficiency in less cycle time but they must focus mainly on customer satisfaction. In order to compensate increase in competitive environment, many manufacturing industries are looking for a winning in their competition. Manufacturers have to understand the conventional production system and it has to connect with the lean tools and techniques. Value Stream Mapping (VSM) lean tool is a technique that brings all processing steps at one place and is used to draw attention of different wastes and eliminates them in future state map. TAKT time is the rate with which products flow through the line of production, it can be achieved by synchronizing the production rate to the rate of product demand. As soon as manufacturers focused on processes, they found waste associated with changeovers, process



control factory layout, and so they tried to find ways to reduce or eliminate waste. The idea of lean concept is to maximize the customer value and minimize the wastes to increase the cost of products. A case study was carried out in a water pump pipe manufacturing industry located at Chennai, a producer of various models of water pipes. This study focused on the manufacturing area, where the chamber produces suction and delivery pipes for the water pump. This study was carried out on VSM, 5S, Kaizen and line balancing in the manufacturing area. The manufacturing chamber requires a standard work procedure to be displayed in the machining area which decreases cycle time. Line balancing was done for balancing the workload between the workers which could reduce the idle time.

2. LITERATURE REVIEW

Lean manufacturing is a performance based process used in manufacturing industries to increase profit and competitiveness through eliminating waste, reducing the cycle time and decreasing the component cost [1], [2]. The basics of lean manufacturing and VSM employ continuous improvement processes to focus on the elimination of the seven wastes or non value added activities within the industries. It is basically a workplace management methodology, which helps to improve the working environment, human capabilities and thereby increasing the productivity [3]-[5]. Nallusamy et al. discussed about the development of activities that maximize the overall effectiveness of equipment, processes and plants through uncompromising elimination of losses [6]. Teams were made from every level of organization, managers, engineers, staff, technicians, lineworkers. The principal behind is that a large number of small improvements are important than a few improvement of large value. VSM is often used in process cycle time improvement projects since it demonstrates exactly how a process operates with detailed timing of step-by-step activities [7]. It is used as a main tool to identify and implement the opportunities for various lean techniques. Various research articles have discussed the different applications of VSM method in different production areas [8]-[10]. VSM is used to define and analyze the current state for a product value stream and design a future state focused on reducing waste, improving lead time and improving workflow. A value stream map provides a blueprint for implementing lean manufacturing concepts by illustrating how the flow of information and materials should operate. VSM is divided into two components as big picture mapping and detailed mapping [11]. Cycle time or lead time is nothing but the time between the release of an order from the customer and the time taken for receiving the finished product by the customer. A study was carried out for each machine operation by using the techniques of method study and time study which are related to the subject of industrial engineering where each part involved in machining process like job setting time, tool setting time, CNC program loading time, program running time, speeds, feeds, depth of cuts used for the every operation, tool life, tool changing time, job unloading time etc [12]. Work standardization in various production industries leads to reduction in their lead time, cycle time and setup time and also increase the rate of quality of the product [13], [14]. Through a case study the various defects in a cast iron manufacturing industry were inspected and the required suggestions were given to remove the defects. [15], [16].

Similarly the applications of VSM and line balancing in an automobile component manufacturing industry reduces the setup time and cycle time and the case study was helped to balance the work load between the workers by eliminating idle time [17], [18]. A lean tool of

Kaizen was implemented in a daily process to reduce the movement distance and time of the workers, who was moving every time for searching tools and materials. This was implemented for the purpose of productivity improvement to meet the customer demand in time [19]. Pandit et al found that with the help of line balancing it was possible to improve productivity and achieve better utilization of resources [20]. The less attention on accuracy of standard time and poor work arrangement were identified as the root cause for low efficiency and increase in layout utilization by changing the position of equipment or by introducing the new machine into the layout. Line balancing is the appropriate method to overcome the above root cause and to enhance the productivity [21]. The cycle time of each process of existing system was calculated and proposed a new line balancing method to reduce non-value added (NVA) activities, eliminate waste and re-allocate work [22]. Reduction of cycle time using lean tools in an automobile manufacturing industry through the existing processes study found out NVA activities and reduced the same using lean tools which resulted in shortening of cycle time to avoid delay between workstations [23]. In this, the standard process chart and spaghetti diagram were used to analyze the operator movement. A case study was reported on application of VSM in an automobile industry where they improved their productivity by reduction of cycle time through improvement in value adding activities [24]. Based on the above literature an analysis was carried out in a pipe manufacturing industry to improve their productivity using different lean tools.

3. METHODOLOGY

The existing manufacturing process of selected water pump pipe was studied to identify the bottle necks. After the processes were studied, the existing cycle time and the value and NVA time for each process in the manufacturing line time were calculated using time study method. Lean tools such as VSM, 5S and line balancing were used to identify the value and NVA activities. Improvement activities were planned and implemented to reduce the total cycle time and process time. The proposed layout was developed after the line balancing was established and the future state VSM was also developed. Finally the observed results were compared with the existing values. The methodology flow chart for this study is shown in the following Fig. 1.

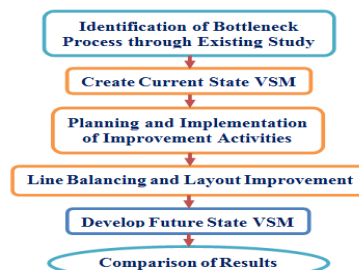


Fig. 1 Methodology Flow Chart

4. DATA COLLECTION AND ANALYSIS

4.1 Process Flow for Water Pump Pipe

The rolled sheet material of stainless steel 304 with 342 mm height was initially cut by the sheet cutting machine and the sheet was subjected to bending process slightly to initiate for rolling process. The sheet was rolled in the sheet rolling machine and sent for spot and run welding followed by tinkering process. After expanding process was carried out the water pump pipe was edge grinded using grinding machine followed by facing operation. Later the slotting was performed with slot on four sides of the water pipe and the outer ring was spot welded followed by outer ring facing. Then the total length of the water pump pipe was corrected followed by inner ring tack welding. The inner ring spot welding and facing operations were carried out. Finally the inner ring was fully welded and the inner and outer ring welding area was grinded followed by the inner and outer ring expanding operations. After the machining operations were done in the previous stations, the water pump pipe was checked for the diameter with the gauges. Later the required size was attained, the pipe was moved to burr cleaning followed by emery and buffing. Finally the water pipe was inspected and packaged. The process flow is shown in the Fig. 2.

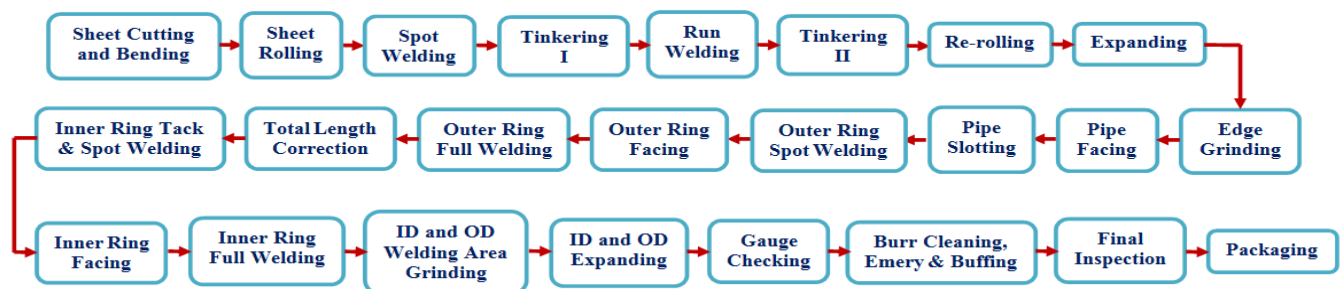


Fig. 2 Process Flow for Water Pump Pipe Manufacturing Process

4.2 TAKT Time

Duration per shift	= 480 minutes	Break and lunch duration
	= 60 minutes/shift	
Available time/day (2 shifts)	= 840 minutes	Available time/month (840x25)=2100mins
Customer demand/month	= 5000 Nos	Therefore, TAKT Time = 4.2 minutes

4.3 Current State Value Stream Mapping

Based on the existing data the current state VSM was developed to know the existing process steps and to find out the value and NVA activities is shown in Fig. 3. The total cycle time, value and NVA processes time were also calculated for developing the future state VSM.

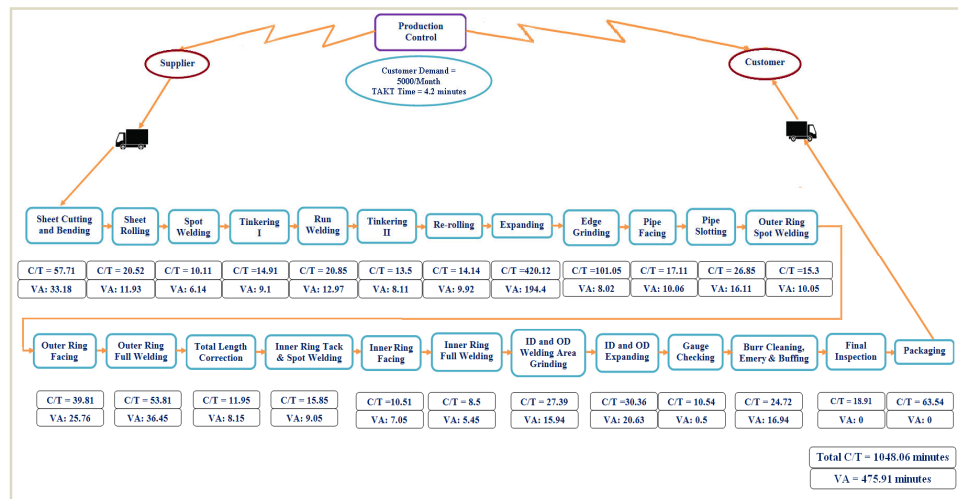


Fig. 3 Current State Value Stream Mapping

4.4 Calculation of Workers Movement

The present layout of production line is shown in Fig. 4. It indicates the movement of workers and materials from raw material inventory to the finished product. It was observed that the total movement of the workers during the manufacturing of water pump pipe is about 115 meters.

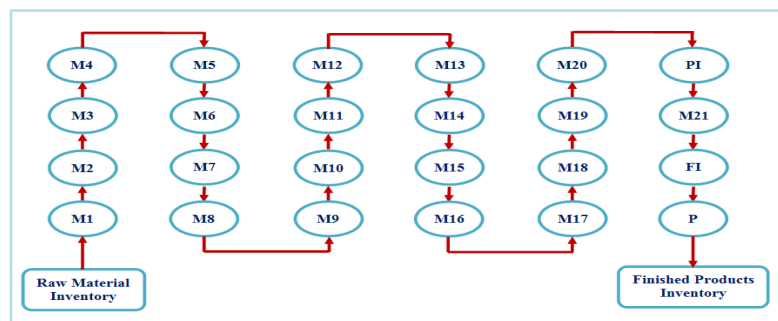


Fig. 4 Spaghetti Diagram

[M1- Sheet Cutting & Bending, M2- Sheet Rolling, M3 - Spot Welding, M4- Tinkering I, M5- Run Welding, M6- Tinkering II, M7- Re-rolling, M8- Expanding, M9- Edge Grinding, M10- Pipe Facing, M11- Pipe Slotting, M12- Outer Ring Spot Welding, M13- Outer Ring Facing, M14- Outer Ring Full Welding, M15- Total Length Correction, M16- Inner Ring Tack & Spot Welding, M17- Inner Ring Facing, M18- Inner Ring Full Welding, M19- ID & OD Welding Area Grinding, M20- ID & OD Expanding, PI- Primary Inspection, M21- Burr Cleaning, Emery & Buffing, FI- Final Inspection, P- Packaging]

4.5 5S Implementation

The different wastes were identified around the manufacturing area to be eliminated through various improvement processes. One among the processes 5S was implemented in order to reduce the waste of waiting and motion as items are easier to find in the first stage. The second stage of 5S implementation results in ensuring that components, equipment, tools, machines, workers are

located in the most ergonomic and thus efficient with safer positions. The third stage of 5S implementation ensures that the work place remains clear without any signs of malfunction. The fourth and most important step in the 5S is that of standardization, where ensure that there are standard ways of working. The fifth stage ensures that it continues on an ongoing basis and remains each person responsibility. The sample result of 5S implementation in the manufacturing area before and after is shown in Fig. 5.



Fig.5 Implementation of 5S

4.6 Reduction of Process Flow Time

In the water pump pipe manufacturing process material handling takes more time. Especially during the edge grinding, welding and tinkering process more time was taken to handle the materials and hence the process flow time increased. To reduce the process flow time a new material handling stand was designed and proposed in order to reduce the NVA time. After implementing 5S and new material handling device there was reduction in flow time and the material handling time was eliminated, which ultimately reduced each process time. It was found that the flow time of the pipe before implementation of the above was 1048.06 seconds. After implementation it was reduced to 969.12 minutes. The total cycle time was reduced nearly 78.94 seconds and there was an improvement of 9.2% reduction in total flow time. In the existing system there was a manual setup for fixing the pipe in the machine. The proximity sensor was used to control the hydraulic cylinder movement and there was no physical contact. During the process the piston was not able to return to its original position due to sensor problem and it leads to breakdown. To avoid this problem there are three best alternatives, introduction of limit switch, solenoid valve and electro mechanical actuator were reduced the process time. The method used was evaluation matrix which can be best for finding the best alternative with their corresponding parameters. Alternative-I is limit switch, alternative-II is solenoid valve and alternative-III is electro mechanical actuator. The parameters for the alternatives given with key letters like speed, maintenance, reliability and performance are A, B, C and D respectively. The quantitative method matrix is given in Table I and the decision matrix for selected alternatives is given in the Table II.

Table I. Quantitative Method Matrix

	B	C	D	Total	% of Weight
A	A/B	A/C	2A/D	4	36.63
	B	B/C	D	2	18.81
		C	D	2	18.81
			D	3	27.72

Table II. Decision Matrix

		Speed	Maintenance	Reliability	Performance	Total Points	Rank
	Weights	36.63	18.81	18.81	27.72		
Current Method		2 72.27	3 54.45	2 36.63	2 54.45	217.80	4
Alternative Method I		4 145.45	4 90.81	4 72.27	4 109.18	417.71	1
Alternative Method II		3 109.18	3 54.45	2 36.63	3 81.27	281.53	3
Alternative MethodIII		4 145.27	3 54.45	3 54.72	4 109.18	363.62	2

From the decision matrix, it has been clearly observed that alternative method I of limit switch was ranked as 1 with the total points of 417.71. Hence the design was proposed with alternative method I of limit switch. After implementing the proposed design, the cycle time of the expanding process was reduced to 211.47 seconds. The flow time of the water pump pipe before implementation of decision matrix was 969.12 seconds. After implementation of all the lean tools it was reduced to 757.65 seconds. The total cycle time was reduced about 290.41 seconds after implementation of different lean tools which is about 28% in the overall cycle time.

4.7 Line Balancing

Line balancing is the process of assigning tasks to different workstations, so that all the workstations have approximately equal time requirements. We used the method of line balancing to minimize idle time-balance bottlenecks. Based on the current line balancing layout, the new layout was proposed with some of the processes were merged into single station like M1 with M2, M3 with M4, M5 with M6, M9 with M10, M17 with M18, PI with M21 and F2 with P. The proposed line balancing layout is shown in Fig. 6. After implementing the proposed line balancing it was found that the movement distance of the workers in the manufacturing area was reduced to 104.2 meters through merging the different workstations. Ultimately, the lead time was also reduced by the proposed line balancing method.

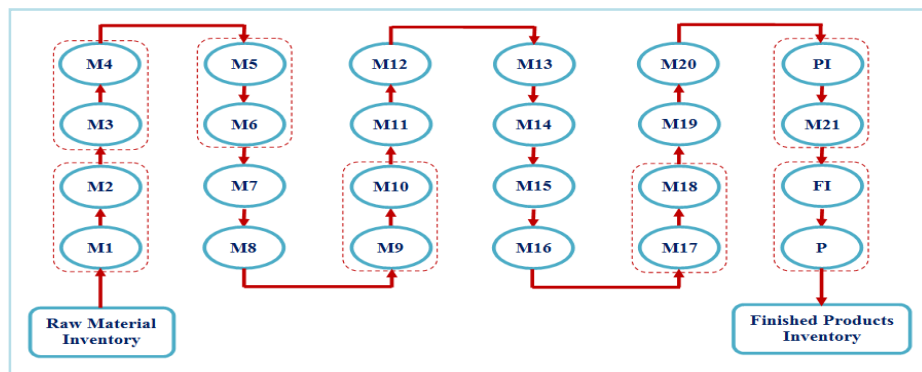


Fig.6 Proposed Line Balancing

4.8 Future State Value Stream Mapping

Based on the data collection and analysis the future state VSM was constructed by combining different processes to reduce the cycle time and is shown in Fig. 7. From the future state VSM it was found that the total cycle time was reduced by 27% and NVA time was also reduced.

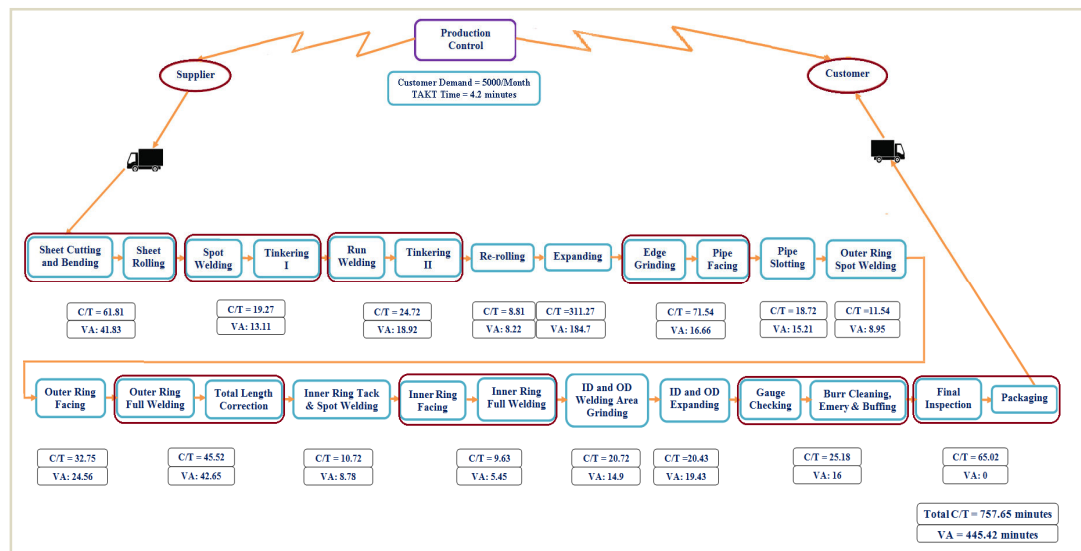


Fig.7 Future State Value Stream Mapping

5 CONCLUSION

The developments were established in the selected manufacturing line of water pump pipe through the analyses of existing scenario. Based on the calculated results the following conclusions were made.

- From the current state VSM, it was clearly identified the value added and the non-value added time for each process.
- The cycle time was reduced by identifying and eliminating wastes through 5S implementation.
- Expanding process has more non value added activity as compared to other processes after the improvement activity implementation.
- The movement distance was reduced about 10.8 meters through the implementation of proposed line balancing.
- It was clearly observed from the future state VSM that the total cycle time was reduced 290.41 seconds and monthly demand was increased as 4320 units instead of 3560 units per month which is increased by about 18%.

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