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Application of Value Stream Mapping (VSM) in Gear Manufacturing Process: A Case Study

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Abstract: Since the end of 20th century, Lean Manufacturing has been recognized as an important approach in competitive industrial environments to improving productivity by reducing process cycle time. To remain competitive in the market, organizations are compelled to find new domains for improvements in order to reduce production lead time and to smooth the flow of processes. The current research aims at designing efficient future VSM to improve productivity by reducing process cycle time and waste in a gear manufacturing process in an automotive industry. The approach was based on mapping the current state of the process to identify the non-value-added activities and also for opportunities for improvement in value added activities. Kaizen events are the main metrics for improvement in the current process by integrating it with the future value stream map. This study concluded that the designed future value stream map helps effectively in identifying the wasteful activities i.e. distance travelled and inventory at different workstations. VSM integrated with Kaizen proves itself a useful approach in achieving continuous process improvement.

Keywords: Value Stream Mapping, Kaizen, Lean Manufacturing, Lead Time

1. Introduction

Manufacturing organizations are forced to adopt new approaches for the improvement of production processes in order to produce better quality and cost effective products. Lean manufacturing has been considered a good start for manufacturing organizations as it focuses on improving production processes and boosts employees’ job satisfaction [1]. The Lean Manufacturing concept was practiced by Toyota for the first time in the 20th century through the development of a Lean Production System. Several approaches such as Total Quality Management (TQM), Total Productive Maintenance (TPM) and Just-in-Time (JIT) were initially introduced within the lean production domain. Later, it was discovered that Value Stream Mapping (VSM), when integrated with other TQM

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tools (5S, Kaizen etc.), can develop a sustainable production environment for almost every type of organizations [2].

Value Stream Mapping is a beneficial tool for observing value added and non-value added activities which leads to the management of waste reduction, lead time and hence productivity. VSM shows the orders, forecasts, schedules and Kanbans in the current state and helps to develop the future state of a production setup. It also improves the process flow by reducing the cycle time and inventory problems. Literature can be found which enlightens the usefulness of VSM in several industrial sectors [3].

Kumar et al presented a case study of an aircraft maintenance system, and applied Sustainable Domain Value Stream Mapping which is the integration of lean manufacturing and sustainable manufacturing theories [4]. Amir et al used VSM to analyze the hidden production waste in a PCB production line. Kaizen along with Single Minute Exchange of Die (SMED) techniques were used to improve the process by reducing the lead time through eliminating waste [5]. Yang tried to minimize the lead time in food traceability systems by drawing the current stage using VSM. After identifying gaps, the research introduced an intelligent predictive algorithm based on a lean production system to improve the lead time [6]. Tobias et al used a VSM 4.0 holistic approach to improve efficiency of the production line and also used information logistics which facilitates cost benefits analysis [7]. Dorota et al discussed a case study of an automotive (door seals manufacturing) sector. The process was improved by identifying inventory changes using VSM integrated with Kaizen techniques [8]. Romero tried to explain the worth and importance of VSM as a systematic approach by presenting research, case studies etc. and emphasized that there were still many gaps in research into VSM related to the manufacturing sector [9].

Therefore, the case study in this paper concerns the comprehensive implementation of Value Stream Mapping integrated with Kaizen and JIT in a large gear manufacturer located in Lahore, Pakistan, which manufactures gears for agriculture machinery and power generators.

2. Methodology and Approach

The present research was carried out by preparation of the future state map from current state map (which consists of process and work place information). Through the future state map the areas were identified which required improvement. Modifications in the process flow were made using Kaizen as a Lean Production System tool. Many Kaizen improvements were made to reduce cycle time and waste (inventory, distance travelled, etc.) which were supported by results after processing the collected data. Some of the important Kaizen events are discussed in the paper.

3. Value Stream Mapping

Value stream mapping is a lean technique which gives a visual representation of a workplace to show the flow of inventory and information required to produce a specific product or service, from supplier to the customer. It gives visuals about information flow, product flow and product timeline. Through symbols a process flow is shown on the chart. To draw a value stream map, the workplace is examined several times to get the data. The collected data consists of:

- Process cycle time (time to perform a complete process)
- Value added time (time to add feature or value to the product)
- Non value added time (time which makes no contribution to final product)
- Changeover time (time to change tool or machine time, etc.)

When the data collection stage is completed, the data is analyzed by applying the basic principles of lean and areas are identified that need improvement. Then a future state map is prepared, which consists of the suggestions and modifications made in the current state map. To achieve the future state practically, plans being are made by following lean approaches, which are then implemented in the execution phase. Different terminologies are used such as “Takt Time” is the time a product takes to get completed. The “Value Added Time” is the actual time to produce a product or feature and customer is ready to pay for it. “Total Lead Time” is the time taken by a unit of product from start to finish as it passes through all stations at the work place. It is the sum of value added time and non-value added time.

The existing layout of the ring gear manufacturing shop is shown in Figure 1**.** Batch production is used and each part passes through eight different sections. A batch consists of eight parts (except for palletizing where the batch size is 24). The product first enters the shaping section where eight shaping machines make the internal teeth of the gear. The product remains for about 70 minutes in the machining section, and then in the marking section a locating hole is drilled on the outer surface of gear. In the washing section, excessive machining oil is removed from the surface of the gear so that localized hardening of teeth can be done by an induction hardening machine. In the tempering section a batch of eight gears is processed by heat treatment. The surface of gear is turned for later assembly purposes. Finally in the drilling section, four holes are drilled at a time by a gang drilling tool. The finished product is then sent for palletizing. The total distance travelled by a single piece of product from initial to final stage is 558 feet.

Monthly customer demand is around 3500 parts, so the “Takt Time” can be calculated by dividing the available hours (i.e. eight hours shift) with the demand. Inventory is converted in terms of lead time. The process ratio of 0.36 for the current system can be calculated by dividing the value added activities by the total lead time.

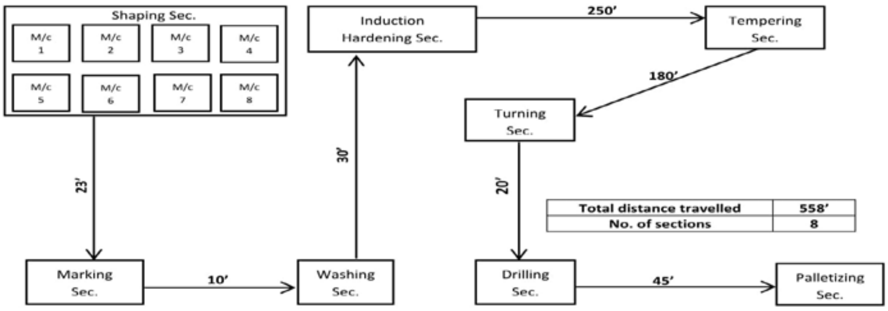

Figure 1. Actual workplace layout with distance travelled by product

The following problems were identified after drawing the current state of the ring gear manufacturing process as shown in Figure 2.

- Excessive inventory

- Large processing times
- Mismanagement of resources
- Flaws in system layout

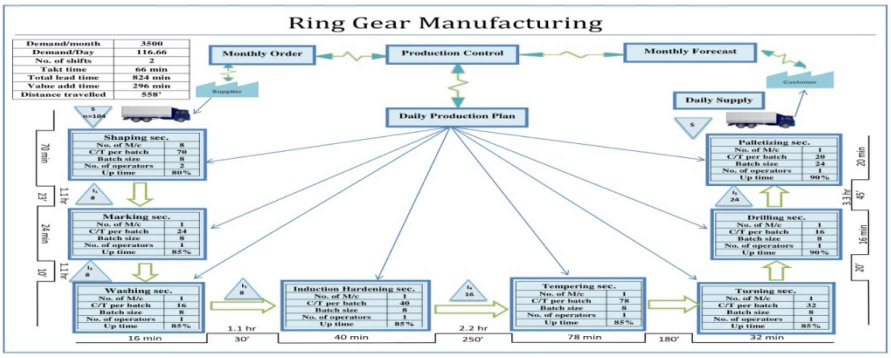

Figure 2. Current state map

Non-value added activities such as the excessive inventory adds more to increased production lead time than any other waste. Figure 3 shows inventory time at different sections of ring gear manufacturing. The process cycle time in each section is shown in Figure 4. To meet customer demand process cycle time should be less than the "takt time". In the existing process, two sections (shaping and tempering) have cycle times that exceed "takt time" and need improvement.

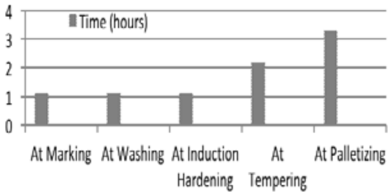

Figure 3. Inventory time at each section

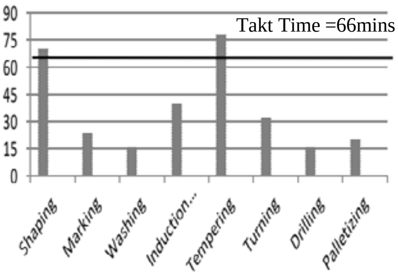

Figure 4. Operations time at each section

After identification of these two sections, different opportunities for improvements were proposed as shown in Figure 5.

Sr. No.	Process Description	Waste Elimination		Layout modification	Method Improvements		Capital Investment	
		Standardize Operations	Motion Economy		Introduction of modern tooling	Optimize the machine parameters	Investing for machines	Investment for staff training
1	Shaping	◯	◯		◯	◯	◯	◯
2	Tempering	◯		◯		◯		◯

Figure 5. Opportunities for improvement

The future state map is prepared after identifying the sections in the current state map with solutions for improvement and a visual road map is predicted as shown in Figure 6. Based on the future state map, the following Kaizen steps were implemented on the existing process for improvements.

The existing layout was not efficient as compared to the proposed layout. The tempering section was 250ft from induction hardening which is far away from the remaining setup. In the new layout, the tempering machine is shifted close to the induction hardening setup forming a continuous work flow resulting and a drastic reduction in total distance travelled by the product i.e. from 558ft to 120ft and also reducing the cycle time.

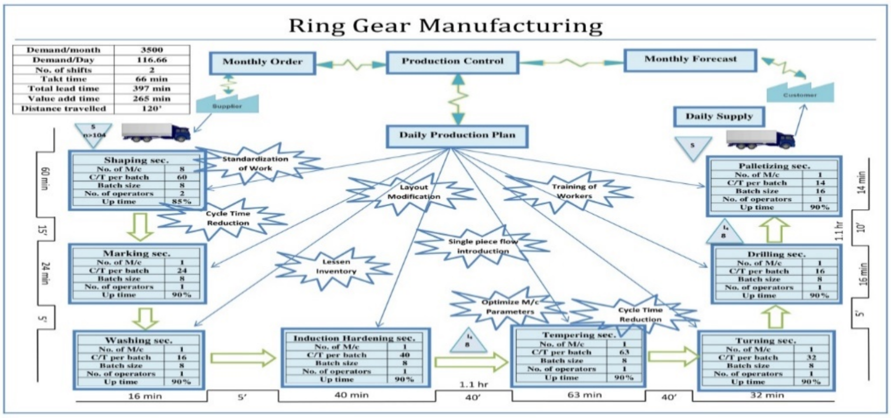

Figure 6. Future state map

From the current state map the shaping and tempering sections were identified as being beyond the takt time limit. Initially these processes were not standardized. During the shaping process, the loading, unloading, clamping, unnecessary movements and idle machine time were analyzed and improved which resulted in a reduction of 10 minutes of cycle time for a batch of eight parts. In the tempering section, the loading mechanism of batch was improved and the coils of the oven were changed which resulted in a 15 minute reduction in cycle time.

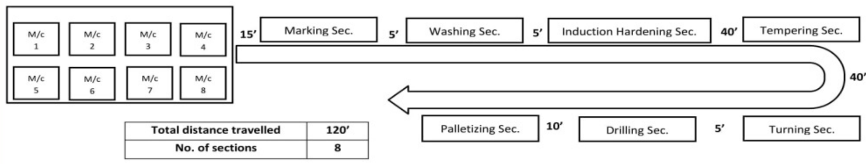

Figure 7. Modified layout of workplace

Just in time (JIT) was introduced to minimize the inventory as it focuses on elimination of non-value added activities. The system is directed towards a demand oriented pull system to reduce the material handling time as well as space utilization. To achieve the desired results, gravity assisted guiding rails were installed to reduce the excessive inventory. Before the implementation, inventory was equal to 528 minutes of production lead time which was then reduced to 132 minutes as shown in Figure 8.

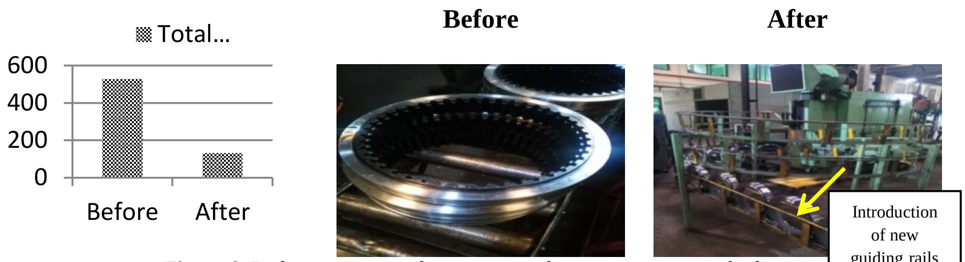

Figure 8. Reduction in waste by improving the transportation method

After implementation of VSM integrated with Kaizen, Continuous process flow, reduction in process cycle time, reduction inventory and reduction total time for travel has been achieved. The process ratio was significantly increased (by reduction in production lead time) to 0.67, which was initially 0.36.

4. Conclusions

Following conclusions were drawn from the present case study:

- VSM integrated with Kaizen proves strong tool to improve lead time of the product and hence productivity.
- VSM a tool of “Lean Manufacturing” can be used for continuous process improvement.

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