Grenze International Journal of Engineering and Technology, June Issue

# Minimizing in-Process Inventory and Labour Movements: A Lean Approach

Sowmya C[1], Dr. V Ramesh[2] and Dr. Savitha M[3]
[1]Research Scholar, Department of Industrial and Production Engineering, JSS science and Technology University, Mysuru-570006, Karnataka State, India
Email: sowmyac@sjce.ac.in
[2]Professor, Department of Industrial and production Engineering, Sri Jayachamarajendra College of Engineering, Mysuru-570006, Karnataka State, India
Email: vajram.ramesh1@gmail.com
[3]Associate Professor, Department of Industrial and production Engineering, Sri Jayachamarajendra College of Engineering, Mysuru-570006, Karnataka State, India

***Abstract*—This research focuses on optimizing manufacturing processes within the Tillers and Tractors manufacturing industry, specifically addressing the challenges faced in producing crankshafts. The initial assessment revealed that the company struggled to meet customer demand due to an extensive manufacturing lead time. To tackle these inefficiencies, lean manufacturing principles were applied, targeting the elimination of non value added activities such as overproduction, excessive waiting times, unnecessary material transport, defects, and underutilization of employee creativity. The implementation of a lean manufacturing system, including the redesign of the plant layout and value stream mapping, aimed to streamline the production process. The proposed changes significantly reduced material movement and optimized workflow within the manufacturing cell. The primary outcome of this research is the development of an efficient plan to achieve line balance and reduce process cycle times, ensuring the company can meet customer demand in a timely manner. By minimizing machine and labour movements and promoting multitasking on the shop floor, the proposed solutions contribute to enhanced productivity and a decrease in in-process inventory, ultimately improving the operational flexibility and responsiveness of the manufacturing system.**

***Keywords*— Lead time, non-value-added activities, Plant Layout, Value Stream Mapping.**

## I. INTRODUCTION

Lean manufacturing or lean entrepreneurship is the method used in value stream mapping to record, examine, and enhance the flow of materials or information needed to create a good or service for a consumer. In today's competitive market, businesses need to provide excellent customer service, low costs, and short lead times. Companies thus pay more attention to shorten lead time. Almost every company makes use of Value Stream Mapping (VSM) methods. Among lean manufacturing techniques is Value Stream Mapping (VSM). Value Stream mapping seeks for waste in terms of non-value added activities. Designed to provide specifics on the current situation and point up several areas of concern, the Current State Map The implementation action plan is presented on Future State Map. Industries constantly strive to increase the output of their operations and production.

*Grenze ID: 01.GIJET.11.2.732*

Lean has originally been developed and defined as the process of removing waste along with the support system to minimize or eliminate waste and non-value added activities from the many processes. Value stream mapping is all the steps, both value added and non-value added necessary taking a good or service from raw material to the customer. VSM finds, displays, and cuts process waste. Waste is any activity devoid of value for the final outcome. VMS provides a blue print for Lean Manufacturing. Mariusz Salwin et al.[1] The paper addresses Value Stream Mapping (VSM) application to the steel pipe manufacturing process. Appropriate data from this process was compiled and investigated at the start of the project. After mapping an initial process and identifying related waste, subsequent processes were mapped. The financial outcomes were estimated. As a result, savings were made and the process was enhanced. For a selected company, the article will be the basis for the subsequent development of an improvement project that aims to enhance the areas mentioned in the article. Tomas Rohac et al.[2] The purpose of this article is to present a practical example of the Value Stream Mapping (VSM) technique for process visualization and rationalization in a real business Environment. The method's own philosophy is based on a view of the value chain from each step, embracing all major transport and transformation processes which occur within a business from when suppliers deliver raw materials and semi-finished goods to the firm and finished good are received by customers. Value-Adding Processes (VA) and Non-Value-Adding Processes (NVA) are the two categories into which VSM processes are strictly divided. A value flow diagram for a company is the output of the VSM approach. VSM can be used to calculate lead times and locate piling inventory locations. Setiawan, Indra & Tumanggor, Ojakma Sihar Panaili & Purba, Humiras. (2021) [3]. Value Stream Mapping (VSM) is a lean methodology tool that facilitates analysis of the flow of information and material flow needed to deliver a good or service to the customer. Within industrial sector, VSM has drawn a lot of attention from both the manufacturing and service sectors. VSM tooling development has spread rapidly. Universities and industry do a gr of the research involving VSM tools.

## II. Objective

The main objective of the project is to reduce the manufacturing lead time using Value Stream Mapping (VSM) tool.

- To study the current production system of crankshaft division
- To enhance the line balancing up to its maximum level by studying and diagnosing the process
- To achieve customer satisfaction by implementing VSM tool. Customer demand can be achieved by reducing manufacturing lead time.

## III. Methodology

VSM is a tool to visualize and simplify work processes by the methods of Lean Manufacturing. VSM assist to identify, demonstrate and reduce waste in the procedures. In generally, VSM has four main steps as described by Rother and Shook (1996):

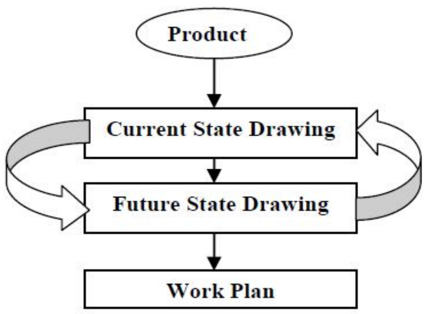


Fig 1. VSM Methodology

## IV. Results and Discussion

The stepwise work has been carried out. Initially, the identification of the product family was one of the major steps. This was selected based on the longest processing time and needed segregation of value added processes to reap the benefits.
Steps involved in value stream mapping
There are several important steps involved in getting started in value stream mapping. They are:

*A. Identify the Product Family*

The manufactures of critical engine components such as connecting rod, camshaft, crankshaft, engine cases, transmission cases, etc. Among these families the company look into the problems of crankshaft which was failing to meet the customer demands effectively.

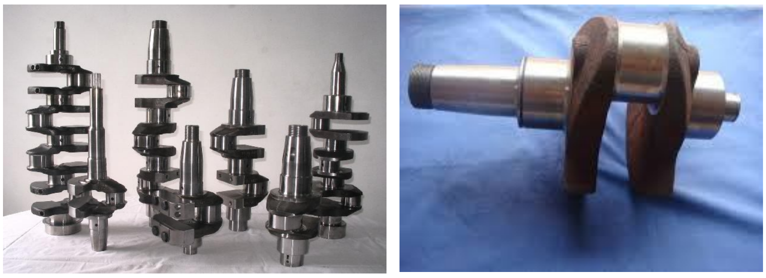

Fig 2: Crankshaft

*B. Map the floor or stream*

The process flow regarding the crankshaft in the production line is studied in detail. With the help of process flow the designed routing (movement of component from one process to next process)

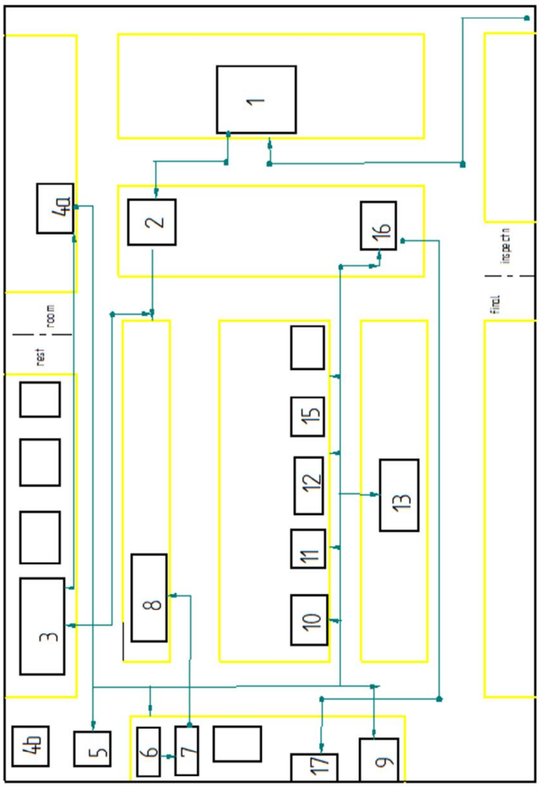


Fig 3: present layout

Each numbers in the present layout represent the specific processes are mentioned below:

- Oil hole drilling of 30 and 35 deg for crankshaft.
- Chamfering process of crankshaft.
- Induction hardening process of crankshaft.
- Tempering process of crankshaft.
- Natural air cooling of tempered parts.
- Pulley end grinding process of crankshaft.
- Flywheel end grinding process of crankshaft.
- Crack detection process of crankshaft.

- Face drilling and chamfering process of crankshaft.
- Tapping process of crankshaft.
- Threading process of crankshaft.
- Reaming process of crankshaft.
- Keyway process of crankshaft.
- Lapping process of crankshaft.
- Counter weight assembly and balancing process of crankshaft.
- Deburring, oil hole polishing process of crankshaft.

*C. Observe and confirm processes*

The study regarding each process in process flow is done. The time study and the distance between the processes calculated helped us to determine the non-value added activities carried out in the production line.
Process 1: Receipt of forging and inward inspection of crankshaft
Raw material in the form of forged components of the crankshaft are received, these forgings under goes initial inspection as per the inspection checklist before being sent to workshop floor.
Critical characteristics: dimensions of the part as per forging, hardness, metallurgical aspects, visual mismatch, flash, pit marks, surface defects.
Machine and tools: Brinell hardness tester.
Gauges and instruments: linear height gauge, Vernier caliper.
Process 2: 30 and 35 Degree cross oil drilling process of crankshaft
Critical characteristics: Hole of 60mm and 110 mm, check for hole clearance.
Machine and Tools: Drill bits.
Gauges and Instruments: Double ended plug gauge and drill bits.
Machine Name: Deep hole drilling machine (SPM).
30deg oil hole drilling process of crankshaft

TABLE 1: TIME STUDY OF 30 DEGREE OIL HOLE

| Loading time(sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 13 | 345 | 37 | 5 | 1 | 33.1 |

Cycle time=395seconds
35deg oil hole drilling process of crankshaft

TABLE II: TIME STUDY OF 35 DEGREE OIL HOLE

| Loading time(sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 12 | 240 | 12 | 5 | 1 | - |

Cycle time=264seconds
Process 3: Chamfering process of crankshaft
Critical characteristics: Chamfer of 2mm radius
Machine and Tools: Drill bits.
Machine Name: HMT drilling machine.

TABLE III: TIME STUDY OF CHAMFERING

| Loading time (sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 10 | 10 | 10 | 5 | 1 | 7.4 |

Cycle time=30 seconds
Process 4: Induction hardening process of crankshaft
Critical characteristics: Case depth of 1.5mm, surface hardness (53-63 HRC), specified voltage.
Machine and Tools: Induction coil, water –oil ratio act as a coolant.
Gauges and Instruments: Metallurgy lab. (For every 5000 component) Destructive form of test.
Machine Name: EMA CNC.
Pin grinding process of crankshaft

TABLE IV. TIME STUDY OF PIN GRINDING

| Loading time (sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 29 | 93 | 21 | - | 1 | 20.5 |

Cycle time=149 seconds
Journal grinding process of crankshaft

TABLE V: TIME STUDY OF JOURNAL GRINDING

| Loading time (sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 26 | 87 | 12 | - | 1 | - |

Cycle time=125 seconds
Process 5: Tempering process of crankshaft
Critical characteristics: Temperature inside the oven and duration of time for which the component has to keep in the oven, hardness.
Machine and Tools: Tempering oven.
Gauges and Instruments: Rockwell Hardness machine.
Machine Name: Oven.

- Distance moved = 20.5meters
- After tempering, components are naturally cooled, a distance of 24meters moved from tempering machine to cooling area.

Process 6: Pulley end grinding process of crankshaft
Critical characteristics: Diameter of the pulley, distance, surface finish, concentricity.
Machine and Tools: Grinding wheel.
Gauges and Instruments: Snap gauge (GO NO-GO), between centres.
Machine Name: AWH grinding machine.

TABLE VI: TIME STUDY OF A SIDE GRINDING

| Loading time (sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 15 | 145 | 10 | 36 | 1 | 5 |

Cycle time=170 seconds
Process 7: Flywheel end grinding process of crankshaft
Critical characteristics: Diameter of the flywheel, distance, surface finish, concentricity.
Machine and Tools: Grinding wheel.
Gauges and Instruments: Snap gauge (GO NO-GO).
Machine Name: AGH 150 CNC.

TABLE VII: TIME STUDY OF B SIDE GRINDING

| Loading time (sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 21 | 288 | 21 | 35 | 1 | 1 |

Cycle time=330 seconds
Process 8: Pin grinding process of crankshaft
Critical characteristics: Diameter of the pin, distance, surface finish, concentricity
Machine and Tools: Grinding wheel.
Gauges and Instruments: Snap gauge (GO NO-GO).
Machine Name: NIPPI CNC.

TABLE VIII: TIME STUDY OF PIN GRINDING

| Loading time (sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 15 | 436 | 45 | 21 | 1 | 5 |

Cycle time=496 seconds
Process 9: Crack detection process of crankshaft
Critical characteristics: Cracks, special care must be taken to check for cracks.
Machine and Tools: Magnetic particle inspection machine.
Gauges and Instruments: visual inspection with the help of ultraviolet light torch.
Machine Name: Magnaflux.

TABLE IX: TIME STUDY OF CRACK DETECTION

| Loading time (sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 6 | 33 | 6 | 6 | 1 | 15 |

Cycle time=45 seconds
Process 10: Face drilling and chamfering process of crankshaft
Critical characteristics: Depth of hole, position of holes.
Machine and Tools: Drill bits.
Gauges and Instruments: Double ended plug gauge.
Machine Name: HMT Radial drilling machine.

TABLE X: TIME STUDY OF FACE DRILL AND CHAMFERING

| Loading time (sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 41 | 218 | 30 | 15 | 1 | 6.4 |

Cycle time=289 seconds
Process 11: Tapping process of crankshaft
Critical characteristics: Thread profile.
Machine and Tools: Tap.
Gauges and Instruments: Plug gauge.
Machine Name: HMT Radial drilling machine.

TABLE XI: TIME STUDY OF TAPPING

| Loading time (sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 33 | 108 | 18 | 35 | 1 | 2.8 |

Cycle time=159 seconds
Process 12: Key way milling process of crankshaft
Critical Characteristics: Width and depth of the flat keyway, length and position of the flat keyway, cutter diameter.
Machines and Tools: End mill cutters.
Gauges and Instruments: Ring gauge, Slip gauge/Keyway width gauge (pin gauge).
Machine Name: AMS-vertical milling machine.

TABLE XII: TIME STUDY OF KEYWAY MILLING

| Loading time (sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 40 | 750 | 30 | 88 | 1 | 78 |

Cycle time=820 seconds
Process 13: Threading process of crankshaft
Critical Characteristics: Thread profile.
Machines and Tools: Threading tool inserts.
Gauges and Instruments: Ring gauge.
Machine Name: LT 20 (CNC)

TABLE XIII: TIME STUDY OF THREADING

| Loading time (sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 10 | 75 | 5 | 25 | 1 | 74.3 |

Cycle time=90 seconds
Process 14: Reaming process of crankshaft
Critical Characteristics: Specified dimension of the hole.
Machines and Tools: Drill bit, reamer.
Gauges and Instruments: Double ended plug gauge.
Machine Name: VMC 40

TABLE XIV: TIME STUDY OF REAMING

| Loading time (sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 15 | 185 | 10 | 10 | 1 | 2 |

Cycle time=210 seconds
Process 15: Lapping process of crankshaft
Critical Characteristics: Surface finish.
Machines and Tools: Abrasive belt.
Machine Name: Lapping lathe machine.

TABLE XV: TIME STUDY OF LAPPING

| Loading time (sec) | Operation time (sec) | Unloading time (sec) | Inspection (sec) | No. of workers involved | Distance moved (m) |
|---|---|---|---|---|---|
| 40 | 46 | 5 | - | 1 | 3.7 |

Cycle time=91 seconds
Process 16: Counter weight assembly and balancing process of crankshaft
Critical Characteristics: Balanced weight throughout the component, proper assembly of counter weights.
Machines and Tools: Drill bit.
Gauges and Instruments: Balancing table.
Machine Name: TATA column drill.

- Time required to achieve balancing of a component ranges from 6-10 minutes. Depending on the amount of unbalanced weight in the component.

Process 17: Deburring, oil hole polishing process of crankshaft
Time required for this process depends on quantity of stock from the previous operation. For a component it takes about 6 min to deburr as well as polishing manually.
Process 18: Final inspection process of crankshaft
Critical Characteristics: Diameter of the journal, pin, flywheel. Dimensions of keyway, dimensions of all hole, distance between web, drilled holes. Concentricity, parallelism, straightness, oil hole link, crack damage, thread profile, rust.
Gauges and Instruments: snap gauge, woodruff keyway gauge, flat keyway gauge, Vernier caliper, internal width gauge, double ended go no-go gauge, thread ring gauge.
Process 19: Cleaning, packing and storage process of crankshaft
All the accepted components undergo cleaning operation and rust preventing oil is sprayed on the component to preserve it for longer duration. Then the components are packed, labelled and stored at designated place.

### *D. Map the floor or stream and creating implementation plan*

To reduce non-value added activities we decided to introduce value stream mapping technique. To achieve this we are currently working on current value stream mapping which will help us to predict the future value stream mapping.

## V. METHODOLOGY USE TO CREATE VALUE STREAM MAPPING

The process followed for developing current state VSM for crankshaft is done through following steps,

- Choosing the product to be mapped.

- VSM symbols.
- Establishing product boundaries.
- Steps in the process.
- Information flows.
- Process data.
- Determining the time line.
- Customers and Suppliers
- Understanding the data.
- Next steps (ideal and future state maps)

While value stream mapping is a handy tool for visually representing the entire process, creating these maps by hand can be quite challenging. However, with the "EDRAW MAX" software, you can effortlessly create value stream maps using its user-friendly value stream mapping maker.

*A. Current Value Stream Mapping*

Current state value stream mapping helps organizations pinpoint waste and its origins. By understanding the current state, teams can establish a waste line that serves as a foundation for developing a future state VSM.

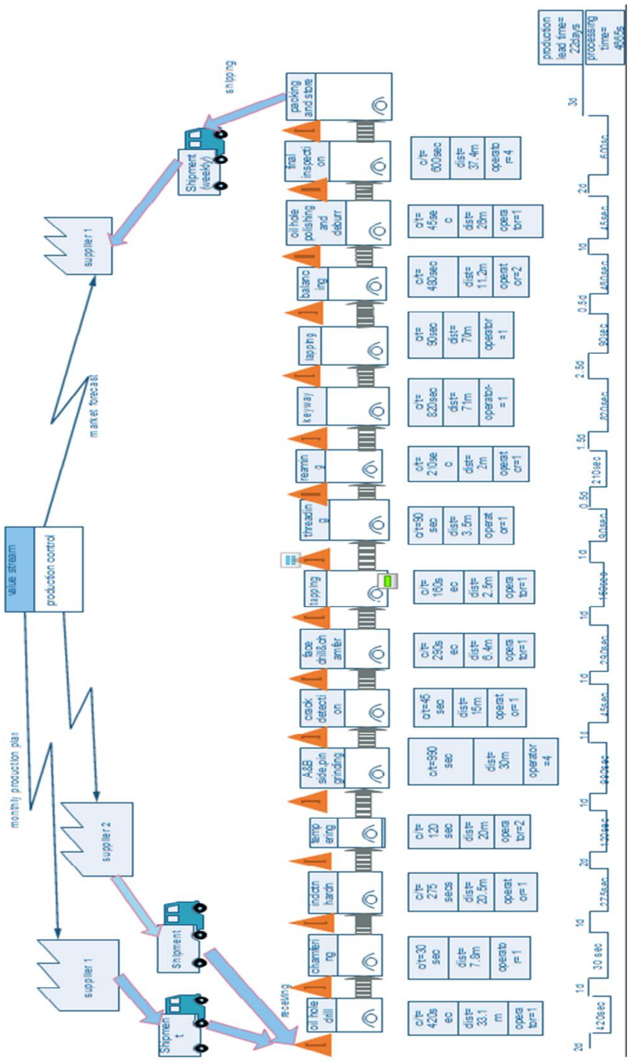

Fig 4: current value stream map

Process time= 4665 seconds
Production lead time= 22days
Factors to be considered to reduce the lead time

*Inventory*
Inventory, whether it's raw materials, work-in-progress (WIP), or finished products, represents money that's been spent but hasn't yet generated any income for either the producer or the consumer. If any of these items aren't actively being processed to add value, they're essentially just waste.

*Transportation*
Every time a product is moved, there's a chance it could get damaged, lost, or delayed, which adds costs without providing any real value. Transportation doesn't change the product in a way that consumers are willing to pay for.

*Motion*
Unlike transportation, which deals with the risks of moving products, motion refers to the wear and tear that the production process inflicts on the equipment and the people involved. This can happen over time through regular use or during specific incidents, leading to injuries or equipment breakdowns.

*Waiting*
Whenever goods are sitting idle, whether in transit or waiting to be processed, they're just waiting. In many traditional processes, a significant portion of a product's life is spent in this waiting phase, which is far from efficient.

*Defects*
When defects happen, it leads to extra costs for reworking the product, rescheduling production, and more. This can significantly increase labor costs and extend the time a product spends in the "Work-in-progress" stage. In fact, defects can sometimes double the cost of a single product, and these losses shouldn't be passed on to consumers.

## VI. Takt Time

Takt Time is all about figuring out how quickly we need to produce goods or services to keep up with what customers want. The term comes from the German word "Taktzeit," which is often seen as the heartbeat or drumbeat of production in Lean Manufacturing. By looking at Takt Time alongside current production rates, we can spot process loads, bottlenecks, and any extra capacity we might have. This analysis helps us see which operations are ahead of the demand and which ones are lagging, highlighting areas where we can improve. Essentially, it's a straightforward formula that helps us measure how well an operation is performing—whether it's meeting or exceeding expectations, and by how much.
To calculate Takt Time, you can use this formula:

$$T = \frac{T_a}{D}$$

Where
T = Takt time, Ta = Net time available to work, D = Demand (customer demand)
Net available time refers to the actual time we have to get work done, excluding breaks and any planned downtime, like maintenance or team meetings.

| Net Available Time | | | Customer Demand | | |
|---|---|---|---|---|---|
| Working shifts / day | 3 | shifts | Customer demand / day | 120 | pieces |
| Hours / shift | 8 | hours | | | |
| Available time / shift | 480 | minutes | | | |
| Break time / shift | 30 | minutes | | | |
| Lunch time / shift | 30 | minutes | Net available time / day | 75600 | seconds / day |
| Planned downtime / shift | 0 | minutes | Customer demand / day | 120 | pieces / day |
| Net working time / shift | 420 | minutes | | | |
| Net working time / shift | 25200 | seconds | | | |
| Net available time / day | 75600 | seconds | **takt time =** | 630 | seconds / piece |

Figure 5

Takt time= 630seconds/ piece

*5S*

5S: Good House Keeping Techniques for Enhancing Productivity, Quality and Safety at the Work Place.


Figure 6

Proper arrangement of the waste is not managed. This may consume more amount of time while identifying the waste.

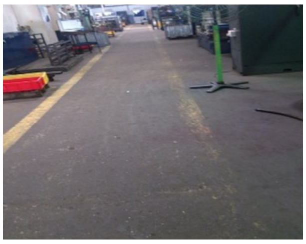

Fig 7: improper maintenance of yellow line concept

Yellow line system is not maintained properly. Since it is not visible for the workers, they may cross the line and tend to affect with accidents unknowingly.

## VII. Proposed Plant Layout

The goal of the future layout is to pinpoint areas of waste by contrasting it with the existing layout. The future layout reflects the vision for change and shows how the elimination of unnecessary movement in future will affect the process. Replacement of few machines reduces the WIP inventory and operators involved.

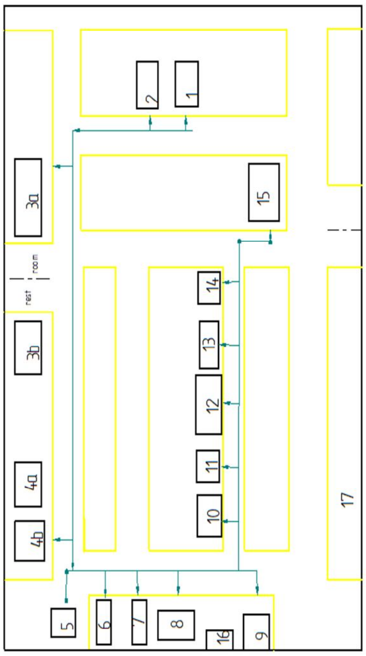


Fig 8: proposed layout

Each numbers in the present layout represent the specific processes are mentioned below:

- Oil hole drilling of 30 and 35 deg for crankshaft.
- Chamfering process of crankshaft.
- Induction hardening process of crankshaft.
- Tempering process of crankshaft.
- Natural air cooling of tempered parts.
- Pulley end grinding process of crankshaft.
- Flywheel end grinding process of crankshaft.
- Pin grinding process of crankshaft.
- Crack detection process of crankshaft.
- Face drilling and chamfering process of crankshaft.
- Tapping process of crankshaft.
- Threading process of crankshaft.
- Keyway and reaming process of crankshaft.
- Lapping process of crankshaft.
- Counter weight assembly and balancing process of crankshaft.
- Deburring, oil hole polishing process of crankshaft.
- Final inspection.

## VIII. Highlights of Proposed Layout

- Replacement of chamfering machine in the layout, beside the oil hole drilling leads to the reduction of unnecessary movements, work- in-process inventor and operators.
- Interchange of induction hardening machine and tempering oven reduces half of the movement done by operators.
- Placing pin grinding machine next to flywheel machine reduces the zig zig movement of inventory.
- New machine for both keyway and reaming is introduced at the position of 12th process there by high reduction of inventory movements and achieving all the process within the crankshaft module.

## IX. Future State Value Stream Mapping

The Future State Map paints a picture of what we want to achieve and illustrates how cutting out waste in the future will transform the process. Each step is designed to get as close as possible to delivering exactly what the customer needs, right on time. This approach helps us pinpoint what actions are necessary to drive improvements

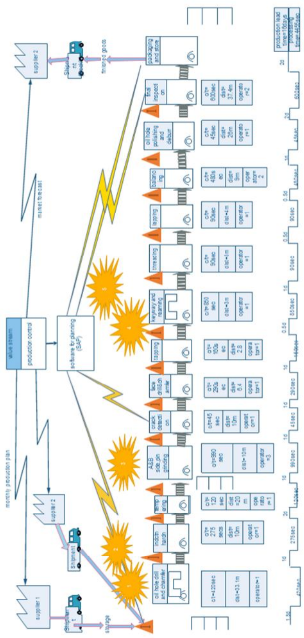

Fig 8: Future value stream mapping

Processing time=4455seconds
Production lead time=16days
Therefore production lead time can be reduced to 16days by practicing these improvements in future state value stream map of crankshaft and can meet the customer demands on time. There will be easy flow of information and materials across the processes which increase the efficiency of overall processes and there will appropriate utilization of time in the future state value stream mapping.

## X. CONCLUSION

These improvements in future will reduce cycle time of each process, manufacturing lead time of crankshaft from 22 days to 16 days and the number of workers from 18 to 15 operators.
The major outcome of this study is developing a plan/mapping to achieve line balance with short lead time to meet customer demand on time, machine and labour movements can be minimized to use multi tasking works in the shop floor which helps to attain the specified cycle time and to reduce in process inventory.

## REFERENCES


[1] Salwin, M., Jacyna-Gołda, I., Bańka, M., Varanchuk, D., & Gavina, A. (2021). Using Value Stream Mapping to Eliminate Waste: A Case Study of a Steel Pipe Manufacturer. Energies, 14(12), 3527. https://doi.org/10.3390/en14123527

[2] Tomas Rohac, Martin Januska, Value Stream Mapping Demonstration on Real Case Study, Procedia Engineering, Volume 100, 2015, Pages 520-529, ISSN 1877-7058, https://doi.org/10.1016/j.proeng.2015.01.399.

[3] Setiawan, Indra & Tumanggor, Ojakma Sihar Panaili & Purba, Humiras. (2021). Value Stream Mapping: Literature Review and Implications for Service Industry. Jurnal Sistem Teknik Industri. 23. 2021. 10.32734/jsti.v23i2.6038.

[4] Rother M., J.Shook, "Learning to see", Lean Enterprise Institute, 1999

[5] Juan C Tinoco [2004] "Implementation of Lean Manufacturing"

[6] Emil suciu, Mihal, Arvinte value stream mapping-A lean p1roduction methodology, 2011

[7] G.Saranya, Mr.S.B.Nithyananth, "Improvement of crankshaft assembly supply chain using lean techniques", IJMER, Apr-2012, pp-403-406

[8] Manjunath M., Dr. Shiva Prasad H. C., „Value Stream Mapping: A Lean Tool",(ISSN 2321 – 8916) April 2014.

[9] Praveen Tandon, Dr. Ajay Tiwari, Sunanda Das and Shashikant Tamrakar, „Complimentary the Lean Manufacturing in Foundries by Including the Value Stream Mapping to Improve The Production of Cast Steel.", November 2015.

[10] Deepak Sharma, Alok Khatri and Dr. Y B Mathur, "Application of Value Stream Mapping in Bhujia Manufacturing", November–December 2016, pp.443–448, Article ID: IJMET_07_06_043.