Implementation of Lean Manufacturing through Value Stream Mapping

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Abstract— This research has been carried out to implement the Lean manufacturing in manufacturing unit through value stream mapping i.e. tool of Lean Manufacturing. Value Stream mapping being an effective Lean tool has emerged as the preferred way to identify and eliminate waste, through continuous improvement in almost every type of production business. This research aims at studying on how value stream mapping can be applied to a manufacturing business, in specification to the company manufacturing electric Monoblock Pumps. This research starts with the concept of integration of lean techniques with manufacturing and results in positive response with significant reduction in lead times. The process is first drawn to reflect current state of the electric monoblock pump line then analyzed for opportunities. This also includes identification of various bottlenecks, value added and non value added work content in all activities, so as to minimize the waste. The operation analysis recovered problems that exist in the process and various opportunities for improvement are highlighted with suitable suggestions. Thereby the value stream is rearranged to obtain an optimized process flow i.e. future state. The research concludes with a result that the implementation of future state value stream map can give a significant reduction in the current lead time up to 51% for highly inefficient work station and an average reduction of about 25% for complete shop floor. Various recommendations are also given to improve the current operations within the company limitations.

Key words: Lean Manufacturing, Value Stream Mapping

I. INTRODUCTION

This research study has been conducted on one of the emerging issues of every industry in present scenario i.e. 'Lean philosophy'. The case company in this study is "Mangala Engineering Pvt. Ltd" with a plant at Dewas, M.P., that manufactures electric monoblock pump sets primarily for water application, ranging from 0.12 H.P. to 3.0 H.P. The Target Product is a 'Electric monoblock pump of 1.0 H.P.' and the research is completed with the help of one of the Lean tools i.e. Value Stream Mapping (VSM).

A. History

Eiji Toyota and Taiichi Ohono at Toyota Motor Company in Japan pioneered the concept of the 'Toyota Production System', or what is known today in US as "Lean Manufacturing." Lean is a continuous improvement process designed for long term maximization of company resources.[ohno 1998][1]

Lean Manufacturing is the relentless elimination of waste. Waste is using resource without adding value. Lean manufacturing aims to achieve the same output with less input; such as less time, less space, less human effort, less machinery, less material and less cost [Wolfgang Apel,Jia Yong Li,Vanessa Walton,2007][2].Essentially, lean manufacturing seeks to produce a product that is exactly what the customer wants, when the customer wants it, while minimizing all non-value added activities in production [Womack & Jones, 1996][3].

B. Lean Manufacturing

Lean Manufacturing can be defined as "A systematic approach to identifying and eliminating waste through continuous improvement by flowing the product at the demand of the customer. Lean Manufacturing is all about looking at the time line from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that time line by removing the non – value added wastes" [Ohno, 1998][1].

In today's manufacturing environment, assembly work is routinely characterized by short production cycles and constantly diminishing batch sizes, while the variety of product types and models continues to increase. Constant pressure to shorten lead times adds to these demands and makes the mix truly challenging, even for the most innovative manufacturers. The ability to respond quickly to rapidly changing customer demands requires the use of manufacturing systems that can be re-configured and expanded on the fly, and which can accommodate advances in assembly techniques without making any initial manufacturing investments obsolete.

C. Value Stream Mapping

Value stream mapping, a lean manufacturing tool, which originated from the TPS, is known as "material and information flow mapping." This mapping tool uses the techniques of lean manufacturing to analyze and evaluate certain work processes in a manufacturing operation. This tool is used primarily to identify, demonstrate and decrease waste, as well as create flow in the manufacturing process. VSMs can be created merely using paper and pencil; however more advanced maps are created using Microsoft Visio as well as Microsoft Excel. Value stream mapping, a lean manufacturing tool, used to visualize where the waste is present in the whole stream from the supplier's raw material delivery until it sees its way through till delivering to the end customer. It is a collection of all activities both value added and non value added that are performed to produce a product. It is also a tool used to identify which lean technique has to be used to cut down the waste and be more productive [Seth and Gupta, 2005][4].VSM ties together the all lean concepts and techniques thereby more useful then quantitative tools. Also, it gives coordination between the material and information related to the entire process thereby also known as 'Material and information Flow Map'.

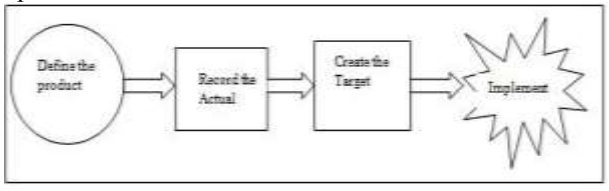

Fig. 1: Line diagram of VSM

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D. Types Of Wastes

According to the Toyota Production System (TPS) ,there are seven original wastes known as "muda" which means "waste" in Japanese. In order to create a lean working environment, these wastes need to be identified and depleted [Womack et al. 1990][5].

The Seven Wastes of Lean Manufacturing are;

- Transportation
- Inventory
- Motion
- Waiting Over-Processing
- Overproduction
- Defects

These wastes can be eliminated by Lean tools

- JIT
- VSM
- TPM
- TQM
- KANBAN
- KAIZEN
- POKA YOKE
- 5S

Type of waste	Tools for elimination
Waiting	Value Stream Mapping
	Total Productive Maintenance (TPM)
	Improved Supplier customer Relationship
	Work according to Takt time
	Just In Time
Transportation	Value Stream Mapping
	Green Technology
	One Piece Flow (Work Stream)
Unnecessary Movement	Value Stream Mapping
	5S
	One Piece Flow (Work Stream)
Inadequate Processes	Value Stream Mapping
	5S
Inventory	Value Stream Mapping
	One Piece Flow (Work Stream)
Overproduction	Value Stream Mapping
	5S
	One Piece Flow (Work Stream)
Defects	Value Stream Mapping
	Tools for Quality Control
	POKA YOKE

Table 1: Types of waste and methods for their relationship

II. OBJECTIVE OF RESEARCH

The objective of this research is to reduce production lead time by optimizing the process flow for a dedicated production line at 'Mangala Engineering Pvt. Ltd ',Dewas , M.P. The main objectives of this research is to study various lean manufacturing techniques and to achieve process optimization through-

- Identification of bottleneck operations and actions to remove bottleneck.
- Identification and elimination all forms of waste.
- Standardization of Inventory for the process.
- Standardization of Lead time.

Based on these goals, The Objectives are:

- To model the material and information flow of assembly line using VSM Approach.
- Analysis of each process activities and identifying the possible remedies for elimination of bottlenecks and optimization of processes.
- To model future state of assembly line using VSM tool and other various techniques of lean thereby reducing the production lead time.

III. RESEARCH METHODOLOGY

This research focuses on increment of productivity and optimizing the process flow by identifying various waste involved and then eliminating them with the implementation of lean principles in the 'Pump Assembly Line'.

"Value stream mapping can serve as a good starting point for any company that wants to be lean"-Nash and poling (2006)[6].

The main Goal is to identify all type of waste and taking the steps to eliminate them.

VSM has four major step explained by Rother and Shook (1996)[7]:

1) Product Selection
2) Drawing current state
3) Drawing future State
4) Develop work plan for implementation of future state

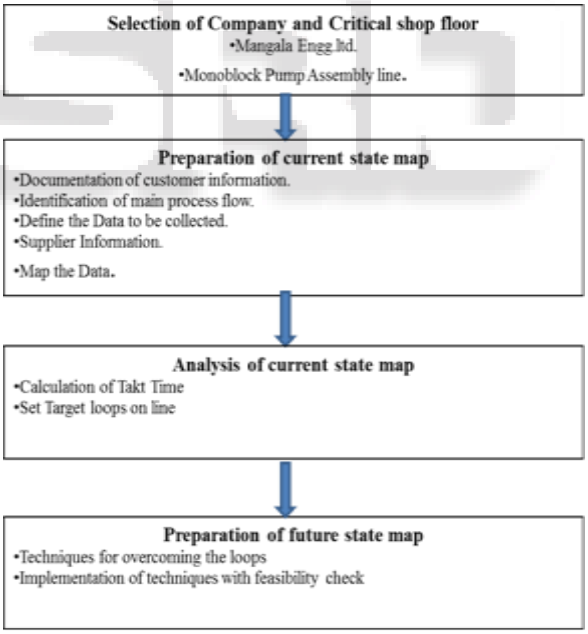

Fig. 2: VSM Implementation Flow Chart

In this way It is possible to find rough value of total production lead time (TPLT). So we can calculate the efficiency of process as the ratio of total value-added time (TVAT) with respect to TPLT.

$$\eta = TVAT/TPLT$$

IV. DATA COLLECTION & ANALYSIS

A. Company Overview

Mangla Engineering Limited is a company incorporated in the year 1996 under companies' act 1956. It is an ISO

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9001:2008 BVQI certified company manufacturing electric monoblock pumps sets primarily for water application, ranging from 0.12 H.P. to 3.0 H.P.

B. Product Details

A Electric Monoblock Pump is the most revenue giving project [*OE Mangala Engg.,2014]* to optimize any process it is necessary to analyze then operation thoroughly.

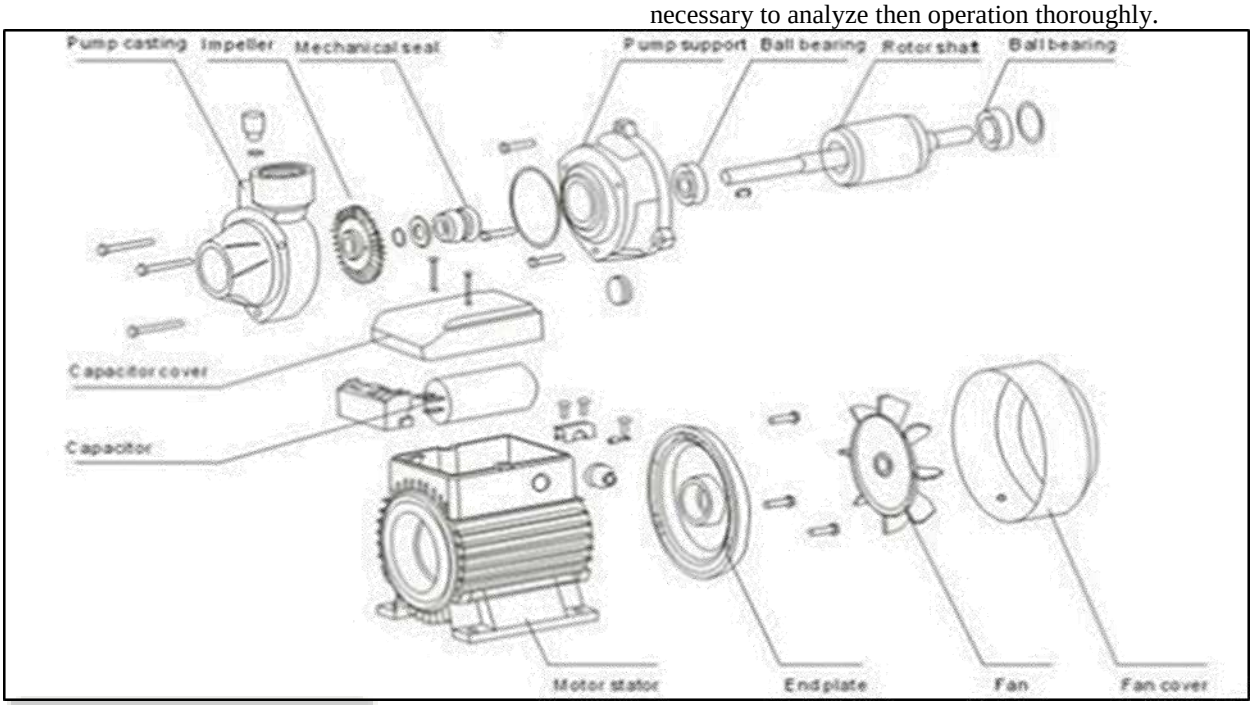

Fig. 3: Various component of Electric Monoblock Pump[Source: Company Website][8]

C. Data collection

To start with pump line , it is essential to know the basic process of the product viz; Machining and assembly. A month long time study was conducted at every work station to document the list of operations for each process. The start and end times of each operation were also recorded dutifully with digital watch. Layout of the line is observed and various activities at each work station are broken into sub activities. Interviews were also conducted with the workers to understand the importance of each task they carried out and difficulties they faced. A framework is decided to note down the details at each work station. As targeted shop floor is 'Assembly line', most of work is operated oriented therefore loading and unloading are important. *'Cycle Time'* gives the average total time a product is taking on respective station. The average cycle time tell us how well the current operation doing in relation to Takt time. Further, *Total Lead Time* or *Production Lead Time* is the total time in which particular product is taking out of entire line. This gives the very important information like the 'waiting time' and unnecessary inventory on shop floor.

D. Calculations

1) Takt Time=Net available time/Demand from Customer [9]

Available work time was determined using following assumption;

Total available time per shift (8 hr.)=480 min
Lunch time decided by management=30 min
Breaks in a shift(2 Breaks @10 min)=20min
Time Decided for morning team meeting=15 min
Thereby, available work time can be calculated as

480min (8 hr. shift)
- 30min (lunch)
- 20min (tea breaks)
- 15min (daily meeting)

= 415 min

Daily demand from customer=500pc/day
[source :OE Mangala Engg.]
Takt time:- 415/500=.85min=49.8sec = =50 sec
For convenience Takt time is taken as 50 sec.

Ideally Takt Time gives the rate of production meaning that one product must be delivered o come out of the line at every 50 sec. For a balanced line product could be completed at each workstation with a regular time interval of 50 sec. But in real total production time is longer than that. Therefore cycle time should be in coordination with takt time. For ideally balanced line cycle time should be equal to takt time and waiting time between the work stations should be zero.

Table for time study of each process.

Summary of time study-by each process and TAKT time			
S. No	Work Station Activity	C/T in sec	Takt Time
1	Machining of Motor Body	48	50
2	Drilling of Hole in Motor Body	45	50
3	Threading of Hole	52	50
4	Rotor fitted shaft for machining	21	50
5	Machining of Rotor fitted shaft	52	50
6	Winding Pressing	38	50
7	Motor Body bending	65	50
8	Cleaning of chips and Provide earthing nut	20	50

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9	Bearing Fitting	10	50
10	Stud, Rotor and Nut Fitting	43	50
11	High Voltage Testing	42	50
12	Fan, Mechanical seal Impeller Fitting	28	50
13	Delivery Casing, Flange, Rubber Gasket Fitting	78	50
14	NRV(Non Return Valve) and Suction Flange Fitting	32	50
15	RPM testing	90	50
16	Capacitor Box Fitting	67	50
17	Capacitor Fitting	27	50
18	Packing of Box and Checking	22	50
19	Fan Packing	33	50
20	Cutting Oil and final Packing	47	50
21	Tagging	51	50
22	In Box Packing	48	50

Table 2: Cycle time of each activity compared with Takt time.

From the above table (as observed from current state map), When the cycle time is compared with Takt time, it is found that 'Motor Body bending', 'Delivery Casing, Flange, Rubber Gasket Fitting', 'RPM testing', 'Capacitor Box Fitting' are processes that time is more than Takt time .

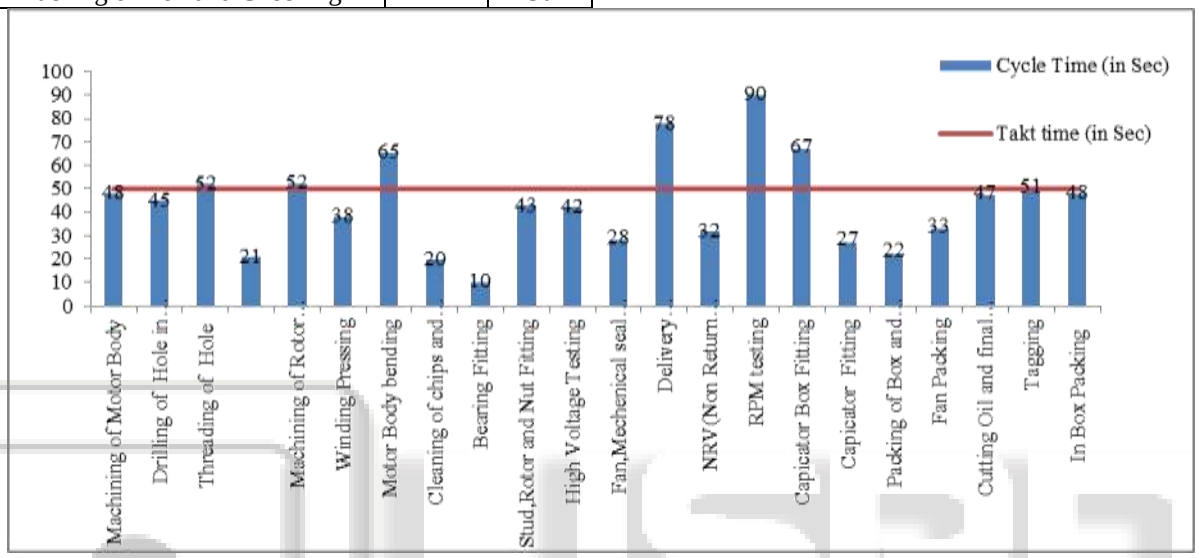

Fig. 4: Comparison of cycle time with Takt time for every component and operation

So, there is a need to great extent of improving the process capabilities of following operations;

- Motor Body bending
- Delivery Casing, Flange, Rubber Gasket Fitting
- RPM testing
- Capacitor Box Fitting

The table below summarizes the efficiency/process ratio for each operation Motor Body bending, Delivery Casing, Flange, Rubber Gasket Fitting, RPM testing, Capacitor Box Fitting.

Processes	Production lead time(sec.)	Value added time/work content(Sec)	Non-Value added time(Sec)	Process Ratio (% Value Added time)
Motor Body bending	90	65	25	72.22222222
Delivery Casing, Flange, Rubber Gasket Fitting	83	78	5	93.97590361
RPM testing	95	90	5	94.73684211
Capacitor Box Fitting	127	67	60	52.75590551
Rotor fitted shaft for machining	325	25	300	7.692307692
Winding Pressing	338	38	300	11.24260355

Table 3: Calculation of process ratio for each process

E. Current State Map

Due to company copyright act Current State Map cannot publish.

F. Recommendations:-

1) Motor Body bending:

As seen in current state map that Motor Body bending operation has high production lead time (cycle time i.e. value added time and Movement of inventory i.e. Non value added time).Cycle time is higher then takt time due to improper racks at improper place for loading and unloading and Movement of inventory due to use of trolley rather than conveyer so that inventory also reduced. So for improvement in cycle time it is recommended that Design modifications in racks can reduce loading, Unloading & storage time at work station. As the rack allotted to keep inventory (WIP & finished from one station) contains very narrow and less spacious shelves thereby it takes time to load and unload. As in current rack is placed behind the operator, so operator has to turn back and down for loading and storage. That's why it is recommended that racks should be modified in to two parts and one placed at the right side of operator for loading and one at left side of operator so that he can easily put WIP Inventory.

(Expected Saving: Approx 18 sec)

(Approved by Production, Mangala Engg.)

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Ideally the inventory between any two work stations can be calculated as the difference of their cycle time. The excess inventory as observed in current state map is due to following reasons:

– Lack of material handling management.

– Lack of process capabilities

– Lack of coordination between the work stations

2) Delivery Casing, Flange, Rubber Gasket Fitting:

As seen in current state map for this operation two operators are deployed and before this operation Fan, Mechanical seal Impeller Fitting station has two operators and cycle time is 28 sec so this work can be done by single operator and remaining one operator can be deployed for Delivery Casing, Flange, Rubber Gasket Fitting station. So that time saving for this operation is 20 sec. So for this operation new cycle time is 58 sec which is nearby takt time and for fan, impeller and mechanical seal fitting station new cycle time is 48 sec which is less than takt time.

G. RPM testing:

It is recommended that use proper arrangement (robotic Arm) for loading components on the RPM Machine. (Expected Saving: Approx 10 sec)
Requirement of one more RPM testing Machine.

H. Capacitor Box Fitting:

As seen in current state map this operation has more cycle time than takt time so it recommended that next two work stations have cycle time 27 and 22 sec respectively so if we make one work station instead of two and use one operator at Capacitor box fitting station. So we can save approximately 30 sec. So new cycle time for Capacitor box fitting station is 35 sec and next work station cycle time is 48 sec. So both have cycle time less than takt time.

I. Other Recommendation:

– Input output trolleys should be differentiated and proper arrangement of rack can reduce loading/unloading time to a great extent.

– Hanging tools : Need Separate air tool with attachments at each workstations for different child parts.

– Identify and develop a plan for shop cleaning and equipment inspection maintenance, for implementation of 5S actions (cleaning, periodic maintenance, sorting and tagging excess material in shop area)

Workers in all other processes do not require any specialized certification and are thus allowed to help out across different processes. This also helps to remove bottleneck at any work station and reduce ideal time for other.

V. RESULTS AND DISCUSSION

The figure below gives a comparison of cycle time before and after implementation of the improvement Techniques i.e. for the current state and for future state as well.

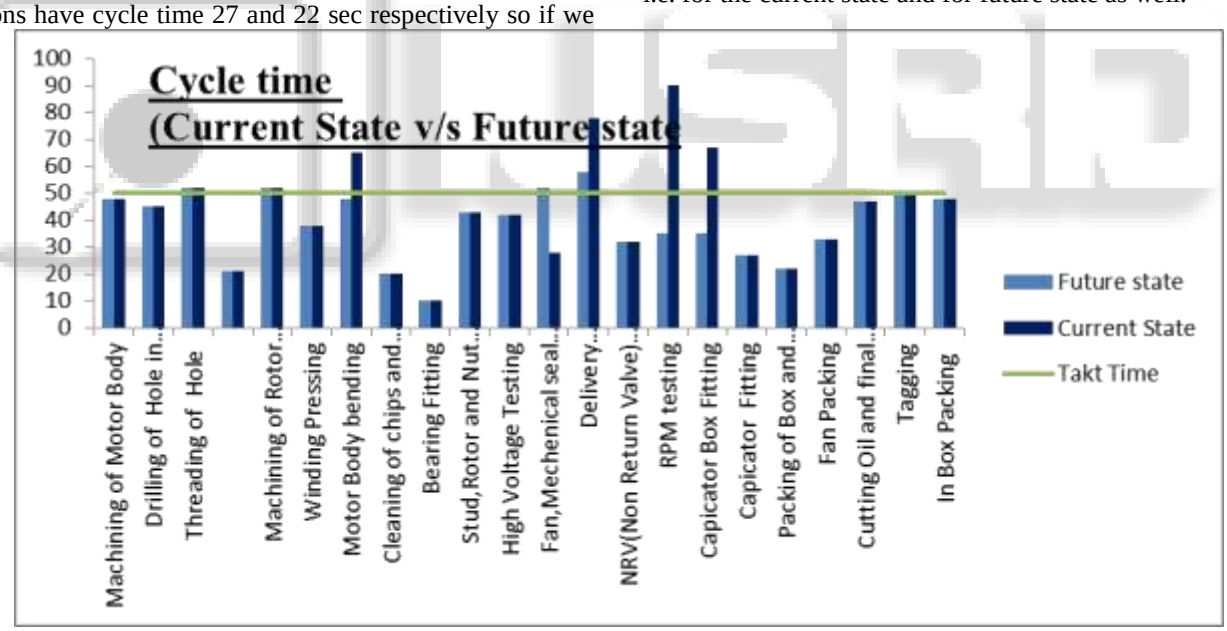

Fig. 5: Reduction Cycle time

Calculation of Total Lead Time directly depends on two parameters i.e. cycle time and inventory for each workstation. With reduced cycle times and ideal condition of inventory for each process, the reduction observed in lead times is summarized in table below:

Processes	Production Current lead time(sec.)	Production future lead time(sec.)	% Reduction
Motor Body bending	90	73	18.88888889
Delivery Casing, Flange, Rubber Gasket Fitting	83	63	24.09638554
RPM testing	95	40	57.89473684
Capacitor Box Fitting	127	65	48.81889764
Rotor fitted shaft for machining	325	205	36.92307692
Winding Pressing	338	218	35.50295858

Table 4: Percentage reduction Lead Time

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As it can be directly observed out of the above table that reduction in lead times is possible up to 57 %. and Average reduction is 37%.

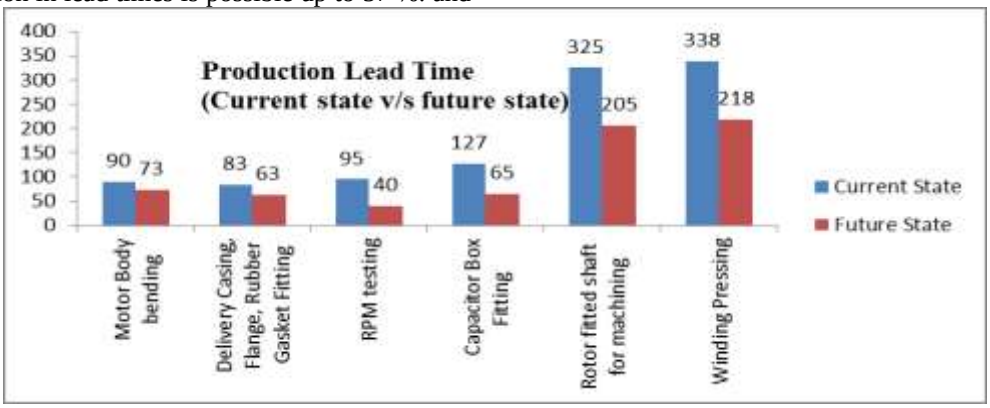

Fig. 6: Graph showing reduction in Lead Time

VI. CONCLUSION

Value stream mapping has proven to be an effective way to analyze a company's current production state and point out problem areas. The visual nature of value stream mapping, by combining information and material flow on one map, depicts how the two relate to the Lead time. Also this research made a successful attempt towards the implementation of various tools of lean in manufacturing that has given direction in the form of suggestion and feasible recommendation to solve the problem of Process Optimization and increased process ratio by reducing cycle time of line to the great extent. Standardization of inventory between work stations and Kanban opportunities that can be executed on the line, results in reduced lead times. The satisfactory results of implementation of VSM proved that it is feasible to reduce the current lead time up to 57% and an average reduction in lead time for all processes is about 37%.

Therefore organizations of similar type can use the research outcomes as a knowledge base to identify their wastes and come up with suitable remedies. Findings of this research can be valuable to other organizations of which hope to implement Lean Manufacturing in the near future.

A. Future Scope

1) An idea for further research would be to conduct similar case studies in other manufacturing companies.
2) Lean Manufacturing concept can be implemented in units other than automobile industries, electronics industries and process industries.
3) Further Implementation of mathematical modeling would be beneficial to count the work force flexibility.
4) Application if VSM simulation software can be the area of future studies so as to provide authentication to the outcomes and search out for the possibilities by altering variables.
5) Application of various line balancing techniques and other industrial techniques like job scheduling can be the future research in area of manufacturing.

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