

Improvement of Productivity by New Approach-Lean Enterprise by MOST Way

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ABSTRACT: Aim of every manufacturing organisation is reduction manufacturing lead time and productivity improvement. The paper introduced methodical approach connects Lean Manufacturing (VSM) and Methods-Time Measurement (MTM) and offers new distinct advantages to reduce lead time and increase productivity based on lean principles and standardised processes. This paper reviles the conceptual framework of Work Measurement using Basic MOST and its application in for the first time in Pump manufacturing industry located in Maharashtra. A practical example highlights the redesign of manufacturing workplaces and the redesign of production processes to reduce lead time using combine approach of Lean and MTM manufacturing process elements. There is also significant scope for improvements in the facility layout, material handling system and shop floor processes described in this paper. Significant portion of the current work content and cycle time is spent in performing non-value adding activities, which can be further reduced to eliminate waste from the system.

KEYWORDS— Lean Manufacturing, Basic MOST, Lead Time reduction, Method Time Measurement, Process Activity Mapping, Productivity improvement, Value Stream Mapping.

I. INTRODUCTION

Productivity improvement and lead time reduction can be a daunting task due to the many factors that influence it and their complex interactions. Increasing productivity in a defined time frame such as one day or one shift, among other things, causes the increase in overall added value within this defined time frame. A short lead time through a process chain results in a higher output therefore in higher productivity and increases the overall added value within this given period of time. On the other hand the same overall added value can be achieved in a shorter period of time [2]. Lead time reduction in a value chain arises from reducing lead times such as operating times, idle times and transportation times. A Process is defined as one or more tasks that transform a set of inputs into a specified set of outputs for another person i.e. customer or process via a combination of people procedures and tools. Process mapping is the detailed analysis of the real process. Process maps useful for bring clarity to complex processes, highlight non-value adding activities and Start the process of thinking about improvements [1].

There are five important stages to new approach of Lean and Method Time Measurement (P. Kuhlang et al, 2011).

- (1) The study of the flow of processes;
- (2) The identification of waste;
- (3) A consideration of whether the process can be rearranged in a more efficient sequence;
- (4) Work measurement using Basic MOST
- (5) Measure of Performance.

The case study has carried out at pumps manufacturing industry in Maharashtra. The company manufactured variety of Split Case Pump, categorized as; UP Metric, DSM and SCT. The line is semi-automated and the raw casting goes through various processes; upper half and bottom casing machining.

A case study performed for waste reduction with combine approach of Lean manufacturing and MTM; process activity mapping used to identify non value adding activities while method time measurement used to evaluation and

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

productivity improvement. This study is focus only on Split Case Division Line 2 namely medium production lines, which contribute to 64 % to the total dispatch of small medium pumps. The VSM tool is used to analyse both the flow of materials and the flow of information in transformation of input to desired output. MTM contributes in evaluation and productivity improvement [4].

II. CASE STUDY

The analysis study applied for selected division of manufacturing plant, which is flow shop with semiautomatic production line. The new emerging combined approach of Lean and MTM applied to manufacturing plant to improve productivity, effectiveness of process and evaluation of performance. This tool is selected by project team and management of company. The Central planning, PPC department and industrial engineering has helped us to give past record values of selected manufacturing line, e.g. Central planning department has given monthly customer orders, production planning department has given the total existing capacity, machine shop has given classification of simple and complicated jobs depending upon their work experience and Industrial engineering department has given vital information like various standard, norms, layout of the company.

A. *Problem background:*

The lean manufacturing is becoming a popular technique for productivity improvement. To promote the use of lean manufacturing within the company was the challenge. Its focuses on the addressing identified manufacturing problems through the application of selected lean tools VSM along with BASIC MOST technique.

The problem approach is that the lean tools which are applied are drawn exclusively from those which have been found to be successful in Pump manufacturing company. The entire process from raw material entry to customer is studied. While studying the entire process from different manufacturing lines, it is clear that 'Medium Split Case' line consists of a problem for bottleneck product 'UP Metric' pumps.

The company manufactures the products based on anticipated demand. For example, product "Split Case Pump" is manufactured according to 'Made to Stock' strategy. The current manufacturing scenario is not meeting customer delivery expectations, with available resources. According to current production data, existing practice produces a quantity of pumps 290 to 330 pumps per month, with lead time of 80 days. On the other hand target in the monthly production plan based on annual operating plan is about 370 to 390 pumps per month. It is also observed that, the current worker engagement is about 180 to 200 min. Thus, there was a need to increase the productivity of Split Case division. This includes increasing Effective Working Time (EWT) with available man power and eliminating waste within value stream. Thus it is derived to solve the problem of productivity improvement using proposed value stream mapping and method time measurement methodology. Thus it is desired to solve problem of productivity improvement using the proposed VSM and MTM. The analysis study applied for selected division of manufacturing plant, which is flow shop with conventional production line.

B. *Objectives:*

- i. To study current manufacturing process for a selected division in the case study organization and to identify non value added activity occurring at the identified production area.
- ii. To perform work study using BASICMOST at selected manufacturing processes.
- iii. Implementation of modified process derived from Lean Manufacturing and BASIC MOST application.
- iv. To carry out MOP measurement (Measure of Performance) and evaluate the improvement.

III. METHODOLOGY

The methodology for proposed case study is based on D-M-A-I-C approach adapted for six sigma. The important steps in the methodology are as follows;

Step 1 Define Phase

Identification of problem in Split Case Division

It is initial step of DMAIC methodology. Primarily, this phase is about study and understanding the current workplace environment and process which are carried out at case study area. The main objective of this phase is to define critical product family from variety of Pumps type. The company manufactures variety of pumps within manufacturing plant.

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Understanding the importance of products selections the project team had gone through the order dispatch record, customer demand rates, production schedule records, average cycle time and average TAKT time for every commodity of pumps. Based on the observations, it had been identified that the UP metric pump model have more lead time with respect to Takt time when compared to other models. So project team identify critical product family as UP metric pump division i.e. Split Case line 2. This phase also define material flow through production line, current state of value stream map. Split Case line 2 runs for 2.8 shifts with 420 minutes are available time for 25 days. The fig.1 shows Takt time analysis for variety of Split Case pumps in Split Case line 2;

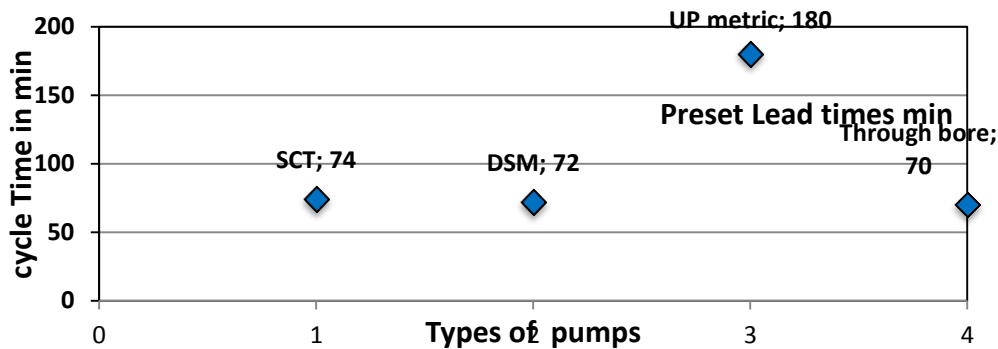


Fig. 1 Control chart of lead time product wise

Step2 Measure Phase

In this phase, the specific criterions were determined to measure the project. In this phase project team measure all the relevant data which is important for productivity improvement programs. The project team decided to validate all the current manufacturing data, so context of study the entire process sheets, manufacturing flow studied. According to that various cycle time, process time examined and Takt time calculated at each work centres. The project team defines value stream map for bottleneck operation for UP metric pumps components in split case line 2. Then team further break main activity into sub activity by applying BASIC MOST for work measurement. In this phase, team examines Content of work (CW), required number of work force currently allocated to perform main activity in machine shop. Throughout the second phase, the feedback data was collected. The data collection tools including the field observation, time study work study and focus group discussion. In this phase project team performed following tasks;

Process activity mapping involving the preliminary analysis of the process followed by the detailed study of all the activity required in each process has done for bottleneck product UP Metric Pump series to eliminate major waste in manufacturing process of identified bottleneck. TAKT time is benchmark for process pace. Takt demonstrates the rate at which the customer buys the product. TAKT reflects the frequency at which the product has to release by the manufacturer to meet customer demands. TAKT time is calculated by dividing available working time per shift with the customer demand per shift.

$$\text{TAKT time} = \frac{\text{Available time}}{\text{Customer demand rate}}$$

Available working time per shift = Operating time – Breaks = (8×60)-60=420 minutes, whereas average demand= 380 pumps per month, so demand per shift= (380/25×2.8) pumps per shift = 5 pumps per shift. Therefore TAKT time = 420 min per 5 pumps= 77.36 minutes. TAKT of 77.36 represents that; every pump has to be completed in every 77.36 min. The current state map sights out that the operation like bottom casing milling, four sides milling and drilling consumes 180 min, which is more than Takt time. So these operations considered as bottleneck operation which is need to be improved by VSM and MTM.

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Vol. 3, Issue 6, June 2014

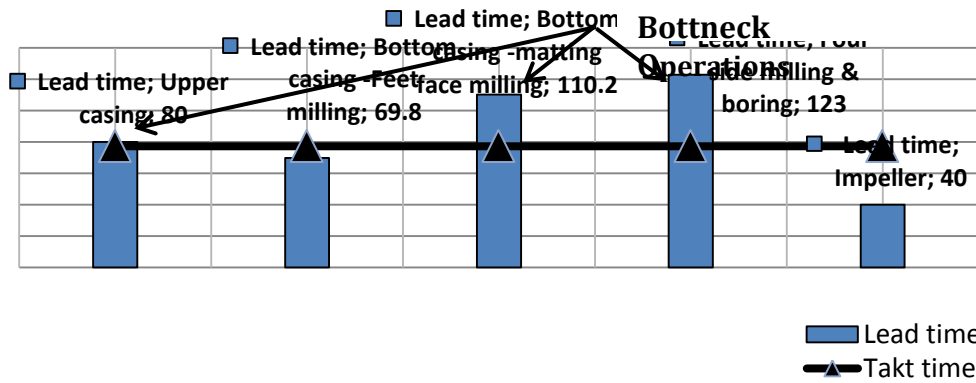


Fig.2 Bottleneck operations for UP metric pump

Element breaking by BASIC MOST for selected manufacturing process i.e. UP Metric Pump lower casing. Table I shows key elements involve in machining of lower half casing of UP Metric pump.

TABLE I
UP METRIC PUMPS LOWER CASING OPERATIONS ELEMENT BREAKING

Operation MOST Elements					
Title:	UPM Lower Casing				
SR. NO.	Operation / sub operation / element description	FREQ.	DIVIDE FREQ	MEN	OFF LINE
1	Collection of crane	1	1	1	0
2	Longitudinal travel of crane (for 5 meter)	5	1	1	0
3	Lowering of crane (for 1 meter)	1	1	1	0
4	Hold the lower casing on belt	1	1	1	0
5	Lifting lower casing (for 1 meter)	1	1	1	0
6	Cleaning with cloth (first 1 sq.ft.)	1	1	1	0
7	Cleaning for 7 places (subsequent)	7	1	1	0
8	Longitudinal travel of crane (for 3 meter)	3	1	1	0
9	Loading of job on m/c with crane (adjustment)	1	1	1	0
10	Removal of belt from component	1	1	1	0
11	Lay aside the crane (1-2 steps)	1	1	1	0
12	Place 4 fixture clamps	4	1	1	0
13	Initial tightening of bolts of clamps[4 bolts]	4	1	1	0
14	Grasp nut runner	1	1	1	0
15	Socket change on nut runner	1	1	1	0
16	Fastening of nut on clamps	1	1	1	0
18	Move while fastening nuts	1	1	1	0
19	Move 5-7 steps out	1	1	1	0
20	Close the safety door	4	1	1	0
21	Push button to send loaded part inside	1	1	1	0
22	Move towards control box	1	1	1	0
23	Operate button for in section	1	1	1	0
24	Position of tool	1	1	1	0
25	Auto cycle time for matting face milling=..... Min	18.57	1	1	1
26	Crane collection	1	1	1	0
27	Longitudinal travel of crane	4	1	1	0
28	Open door	1	1	1	0
29	Air cleaning	1	1	1	0

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30	Process time for air cleaning	40	1	1	0
30.1	Cleaning with cloth and inspection for casing height	1	1	1	0
31	Bring nut runner	1	1	1	0
32	Loosen nuts on clamp	1	1	1	0
33	Aside the clamps	4	1	1	0
34	Collect crane	1	1	1	0
35	Longitudinal travel of crane(for 2 meter)	1	1	1	0
36	Lowering of crane	1	1	1	0
37	Placement of belt ends on lower casing	1	1	1	0
38	Lift the casing	1	1	1	0
38.1	Chip removal from suc. and del. Side	1	1	1	0
39	Longitudinal travel of crane(for 3meter)	3	1	1	0
40	Lowering of crane	1	1	1	0
41	Lowering job on floor	1	1	1	0
42	Removal of belt from component	1	1	1	0
43	Lay aside the crane	1	1	1	0

Work measurement has done using Maynard Operation Sequence technique for all the activities in selected manufacturing division. Table II shows summary report of MOST analysis with each activity. The followings calculations considered during analysis of BASIC MOST;

Work Content = Operator time = Σ (ONLINE + OFFLINE + MOVE);

Cycle time = Operation time = Σ (ONLINE + AUTO CYCLE). ONLINE is the time of manual activities done by Operator when machine in not running (Longest Path time of the activities done in parallel), while offline time of manual activity when machine in running condition. It also represented in table II.

TABLE II
TIME DETAILS SUMMARY REPORT BY BASIC MOST

Operations group UP metric pump group		Time in min.				
UP Metric Pumps Upper & Bottom Casing Operations		Machine centres				
Sr. no	Activity	VTL	Drill M/c	VMC	CNC Drill M/c	HMC
1	Loading	14	4	38	6	23
2	Auto cycle time	24.2	13.8	95	16	82
3	Clean/ inspection	2	1	8.5	2	4
4	Unloading	8	2	24	3	18
5	Walk	6	2	9.5	2	3
6	CT=ON Line+ Auto cycle time	46.2	19.8	157	25	123
7	CW=ON line+ OFF line+ walk	30	9	80	13	48
8	Production capacity units/shift	9.09	21.21	2.68	16.80	3.41
9	Total CW	272.73	190.91	214.01	218.40	163.90

Step 3 Analysis Phase

In this phase, the quality tools control chart and water fall diagram used to analyses of the data. Water fall diagram used to calculate lead time of UP metric pump in machine shop. Bar chart used to analyses major activity which is needed to improve compare with cycle times for bottleneck product (UP metric pump). From that, the highest cycle time activity will be improved. Also wastes are ranked and improved by analyzing them through bar chart. In this phase project team analyzed manufacturing process of selected product and identifies highest waste need to be improved. The fig.3, shows highest waste occurs in Split Case division 2;

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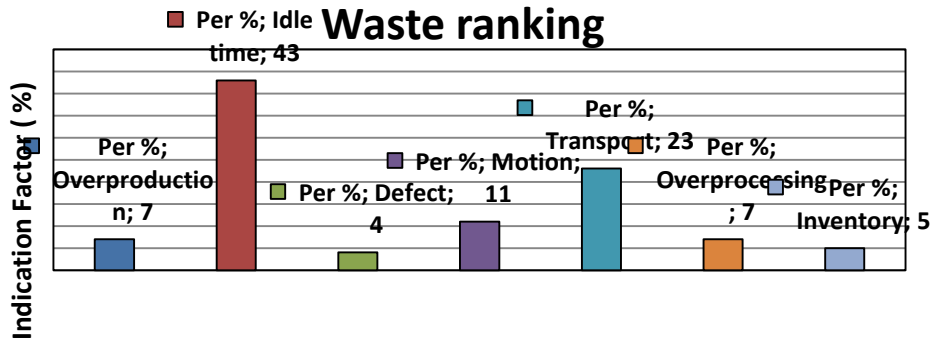


Fig. 3 Waste ranking bar chart in UP Metric pumps division 2

Step 4 Improve Phase

For the improvement phase, project team proposed the new derived manufacturing process by combine use of VSM and MTM. Project team applies lean technique to identify and eliminate waste in machine shop activity. The waste (muda) like loading and unloading time, excessive material handling eliminated and suggesting process improvement though KAIZEN. The project team derives new work force allocation by analyzing work measurement in machine shop. In this phase project team also define future state of modified process through VSM.

Implementation of modified process as result derived from combined approach of Value Stream Mapping and BASIC MOST application. For future state waste areas like setup time, over processing and bad layout are identified and eliminated. BASIC MOST applied for to improve effectiveness of process and improve Effective Working Time of worker (EWT). All these waste elimination along with BASIC MOST are described in following Table III.

TABLE III
TIME DETAILS SUMMARY OF IMPROVEMENTS

Sr.no	Activities	External activity	Internal Activity	Time in (min)	Achieved (min)	Action triggered	Action/Improvements
A	Part - Top UP 150/38+ OLD VTL						
1	Locate Top casing in yard	EXT		2	1	Muda of searching/ idle	Suggest to separate locations in yard according to model wise
2	Transport casings from yard to machine centre	EXT		6	1	Muda of transportation	Suggest to change layout for storage location of casting nearer to machine shop .i.e. palletized storing arrangement .Meanwhile constant load provided at outside of machine shop
						Process improvement (Kaizen)	Implementing rail system for transport of loaded pallets of castings.
3	Fixture arrangement (offline)	EXT		12	0	Muda of processing	Making setup offline by providing manual pallet changer arrangement for milling of top casing
						Stadardisatio n	Total 20 varieties of fixtures converted into 6 nos. by providing adjustable height pads.

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4	Loading + Clamping	EXT		3	1.5	Muda of processing	Making loading top casing offline on manual pallet changer
5	Probing (NR)	EXT		2	1	Process improvement (Kaizen)	Special program has been made for commodity wise so it minimises adjusting time of probe.
6	Milling operation (1r+1f)		INT	24.2	18	Muda of overproduction	Small pattern modification done to minimise machine allowance. Now operation can be achieved with 1r+1f cut.(one rough & one finish cut)
						Process improvement (Kaizen)	Capacity of milling cutter increased by modification done by outsource cutting tool supplier according to demand.
7	Inspection	EXT		1	1		
8	Unloading job & cleaning ,deburring of jobs			4	2	Muda of processing	Deburring process previously done manually, which was time consuming .New De-burring tool developed & de-burring operation done after milling operation on same machine.
9	Moving job from VMC to NC drilling machine	EXT		2	1	Muda of transportation	Suggest to change layout for NC drilling machine nearer to VMC.
10	Fixture arrangement (offline)	EXT		4	0	Muda of processing	Making loading top casing offline on manual pallet changer
11	Loading+ Clamping	EXT		3	3		
12	Drilling operation		INT	13.8	13.8		
13	Chamfering while drilling		INT	1.5	1.5		
14	Reaming two holes (Drill+ Reamer)		INT	2	2		
15	De-clamping & unloading (Already considered)	EXT		2	1		
16	Tool change	EXT		3	1.5		
17	Inspection			1	1		
	Total time			86.3	50.3		
B	Part - Bottom Casing VMC						
B1	Feet milling + Drilling						
1	Locate bottom casing in yard	EXT		2	1	Muda of searching/ idle	Suggest to separate locations in yard according to model wise
2	Transport casings from yard to machine centre	EXT		6	2	Muda of transportation	Suggest changing layout for storage location of casting nearer to machine shop. Meanwhile constant load provided at outside of machine shop
						Process improvement	Implementing rail system for transport of loaded pallets of

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						(Kaizen)	castings.
3	Guide plate arrangement (one time)Offline	EXT		12	0	Muda of processing	Making setup offline by providing manual pallet changer arrangement for milling of bottom casing
4	Loading + Clamping (Offline)	EXT		8	4	Muda of processing	Making loading offline by providing manual pallet changer arrangement for milling of bottom casing
5	Milling operation (only one finish cut)		INT	34.8	28	Muda of overproduction	Small pattern modification done to minimise machine allowance. Now operation can be achieved with 1r+1f cut.(one rough & one finish cut)
6	Drilling operation with chamfer		INT	2	2		
7	De-clamping & unloading (offline)	EXT		4	3		
8	Tool change (3 tools)+ Pallet in out	EXT		2.5	1.5	Process improvement (Kaizen)	Providing sister tooling concept. Which consist of trolley with the entire required tool, all these tools preloaded.
9	Inspection	EXT		2	2		
10	Cleaning & Deburing	EXT		1.5	1.5		
	Total Time			74.8	45		
B2	Mating face milling + drilling VMC						
1	Pin arrangement (one time) (Offline)	EXT		12	0	Muda of processing	Making setup offline by providing manual pallet changer arrangement for milling of bottom casing
2	Loading + Clamping (Offline)	EXT		8	4	Muda of processing	Making loading offline by providing manual pallet changer arrangement for milling of bottom casing
3	Probing		INT	2	1	Process improvement (Kaizen)	Special program has been made for commodity wise so it minimises adjusting time of probe.
4	Milling operation (1R+1F)		INT	58.2	52	Muda of overproduction	Small pattern modification done to minimise machine allowance. Now operation can be achieved with 1r+1f cut.(one rough & one finish cut)
						Process improvement	Tie up with tool manufacturing company to develop milling counter according to requirement to carry more load during operating condition.
5	Drilling operation +Chamfering		INT	8	6		
6	Tapping operation		INT	4	4		
7	Drill+ Reaming holes (2 nos)		INT	3	3		
8	De-clamping & unloading (offline)	EXT		4	3	Muda of processing	De-burring process previous done manually , which was time

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							consuming .New de-burring tool developed & de-burring operation done after milling operation on same machine.
9	Pallet in out	EX T		2	2		
10	Tool change (6 tools) 2.5 min	EX T		3	1.5	Process improvement (Kaizen)	Providing sister tooling concept. Which consist of trolley with all the required tool , all these tools preloaded.
11	Inspection	EX T		3	3		
	Total time			107.2	79.5		
C	Top & Bottom casing boring (DOOSAN)						
1	Assembly of Top & Bottom casing	EX T		16	12	Process improvement	Pre preparation of activity of assembly
2	Fixture arrangement(Offline)	EX T		18	0	Muda of processing	Making setup offline by providing manual pallet changer arrangement for milling of bottom casing
3	Loading + Clamping (Offline)	EX T		8	6		
4	Probing		INT	4	4		
5	Facing operation		INT	6	4		
6	Boring operation.		INT	32	26	Muda of processing	Proposed to develop combination boring bars to perform two boring operation simultaneously.
7	Delivery flange milling		INT	18	12		
8	Suction flange milling		INT	12	8		
9	Drilling operation+ Chamfering		INT	4	4		
10	Tapping operation		INT	4	4		
11	Drill+ Reaming holes (2 nos)		INT	6	6		
12	De-clamping & unloading (offline)		INT	6	4		
13	Pallet in out	EX T		4	4		
14	Tool change (6 tools) 2.5 min	EX T		6	4		
	Total time			144	98		

IV. RESULTS AND DISCUSSION

As discussed in measure phase, it necessary to balance split case line 2 and also define measure of performance for the same line. The current, performance of line judged according to dispatch of months. To define MOP (Measure of Performance) tracking for selected division to apply incentive plans for workers. Following Table IV shows time summary reports to improvements achieved after implementation of Lean and BASIC MOST technique.

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TABLE IV
TIME SUMMARY REPORT OF IMPROVEMENTS BY LEAN AND BASIC MOST

Sr. no	MOST operation description	Work centre	All times value in min.		Man power				MOP in min.	
			CW	LCW	As per CW	As per LCW	Current	Proposed	Present	After
10	Upper casing mating face milling	1	273	223	0.649	0.532	1	1	273	416
20	Upper casing mating face drilling	1	191	192	0.455	0.458	1		191	
30	Bottom casing feet milling+ drilling	1	214	171	0.510	0.407	1	1	214	351
40	Bottom casing mating milling								218	
50	Bottom casing mating drilling	1	218	180	0.520	0.429	1	1	218	
60	Top and Bottom boring on HMC	1	164	115	0.390	0.275	1	1	164	164
	Total	5	1059.95	881.69	2.52	2.09	5.00	3.00	211.99	353.32

V. CONCLUSION

The combine approach of Lean and MTM can be used effectively in any kind of sectors as it is a world class manufacturing tool. In this study bottleneck product was identified. Further Lean manufacturing was employed for identification of wastes in a process along with Method time measurement to improve effectiveness of process. This study is carried out on Split Case production Line 2(Medium), which contributes to 64 % to the total dispatch of small medium pumps, therefore study, is focused on second production line. The study carried out to eliminate waste by Value stream mapping and implementing BASIC MOST to improve effectiveness of process. Also BASIC MOST helps to improve effective working time (EWT). Value stream mapping tool and MTM can be effectively employed to reduce wastes and to improve the process. The paper shows improvement in EWT of line 2 by synchronisation of Lean and BASIC MOST about 40 %and improvement in lead time by an amount of 15 %.The interaction of Lean and MTM also called as hybrid optimization of added value, recently this trend known as Lean Enterprise by MOST Way.

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International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

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