Implementation of Lean in Excavator Bucket Manufacturing Industry

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Abstract

The aim of this paper is to reduce the cycle time for the manufacturing of Excavator buckets, reduce the rejection rate and to increase the throughput by applying the lean principles and lean, tools time study is carried out for all the process in manufacturing of excavator bucket. The process improvement is done for the process which has the high cycle time. Along with savings in time the research also helped in saving in labors. Pareto analysis is carried out in a paper to identify graphically which station is taking high amount of time. The lean principles are followed in this paper to eliminate the waste in an industry. The implementation procedure is discussed for this Realtime project. The feasibility and the significance of lean production are discussed and the results are also shown.

Keywords.
Lead time, process improvement, production rate, productivity improvement, Time study, Process study.

1. Introduction

Lean manufacturing is a manufacturing paradigm to remain competitive in the world market through production of quality products with improved productivity at reduced cost. In lean manufacturing through optimal utilization of resources major costs incurred in manufacturing the product is reduced. By implementing lean techniques in the manufacturing industry various process improvements can be achieved with reduced cycle time. ABC is an Excavator Bucket manufacturing industry in India, which supplies the buckets for Tata Hitachi and Caterpillar. EX 70, EX 110, EX 200, EX 210, ZAXIS 80, ZAXIS 120 H are the models of Tata Hitachi for which buckets are manufactured. The cost of each EX 70 bucket is $1100. The company works 8 hours per day.

1.1 Problem Statement

The Bucket for model EX 70 should be produced continuously to meet the daily production target, the forecasted demand for EX 70 buckets shown in table 1.0. The demand is increasing gradually so the industry with present capacity cannot satisfy the demand in future. Therefore, some lean tools have to applied to increase the efficiency of an industry.

Table 1 shows the demand of buckets. It can be observed that there is continuous increase in demand for this product in future. To meet the demand, it necessary to decrease the lead time.

Table 1. Forecasting the demand

2017	April 15	May 15	June 15	July 15	Aug 15	Sep 15	Oct 15	Nov 15	Dec 15	Jan 15	Feb 15	Mar 15
Units Required	78	82	95	102	110	119	128	135	141	147	150	156
Units Produced	76	81	90									

1.2 Objective

The objective of the study is to improve the productivity by reducing the cycle time at each station also to reduce the time taken for non-value-added activities such as setup, movement of material by using lean tools and to improve operator safety.

2. Literature Review

Lean means manufacturing without waste. Waste (Muda) has seven types: waste from, waste of waiting time, transportation waste, overproduction, , processing waste, waste of motion, inventory waste and waste from product defects. Even though the companies have wide knowledge and enough resources, many companies are struggling to stay. The aim of lean manufacturing is to reduce waste in inventory and human effort, reaching the market on time, and managing manufacturing stocks that are highly responsive to customer demand while producing quality products in the most efficient and economical manner. The concept of Lean Thinking originated from Toyota Production System (TPS) that determined the value of any process by distinguishing value-added activities or steps from non-value-added activities or steps; and eliminating waste so that every step adds value to the process. Lean manufacturing focuses on efficiency, aiming to produce products and services at the lowest cost and as fast as possible. For lean manufacturing, Kanban serves as a tool to control the levels of buffer inventories in the production; in simpler terms to regulate production quantities. When a buffer reaches its preset maximum level, the upstream machine is directed to stop producing that part type. Hence, in the manufacturing environment, Kanban are signals used to replenish the inventory of items used repetitively within a facility.

3. Materials and Methodology

Table 2 shows the various parts required to manufacture Excavator bucket. There are about 18 parts produced in an industry and assembled and 3 items are bought from outside.

Table 2. Part Description

PART NO.	DESCRIPTION
TB00595/0	BELLY
TB00595/13	SIDE COVER
TB00595/04	MIDDLE COVER
TB00595/02	HALF ROUND
TB00595/05	LUG
TB00595/01	SIDE PLATE
TB00595/19	BACK UO BAR
TB00595/16	FISH PLATE
TB00595/09	BACK RIB
TB00595/08	8mm WASHER
TB00595/14	6mm WASHER
TB00595/07	L PLATE
TB00595/15	GASET PLATE
X4278137	14mm BOSS
X4197029	STOPPER
X4218627	3 HOLE BOSS
X4278138	4mm 3 HOLE WASHER
TE02918	LIP PLATE
TE01741	PIN
X4278139	SHIM
T3053596	SIDE CUTTER

3.1 The process involved in manufacturing of EX 70 Excavator bucket

Table 3 shows the manufacturing process of the excavator bucket. Totally there are about 21 processes to get the bucket out of the industry.

Table 3. Sequence of operations

SEQUENCE OF OPERATION	EQUIPMENT / MACHINE
Oxy cut individual component steel plate as per drawing dimensions as item number TB00595/00,01,02,03,05,07,08,09,12,13, 14,15,16,17,18	CNC profile cutting machine And Pug cutting machine
Completely remove mill scales, Burr flakes, Notch marks, Gauge marks	Shot blasting, Chisel or Grinding machine
Inspection	CNC profile cutting machine by terracing, by measuring tape and by 1:1 profile template
Component Rolling Part NO. TB00595/00 plate thickness 6mm IS2062	Hydraulic Rolling machine
Inspection	Bending Gauge and Measuring Tape
Component bending Part No. TB00595/13, TB00595/04	Hydraulic Bending Machine, Die Punch, Bending templet
Machining operation Component TB00595 set in Base fixture, clamped by bolt and Drill through the fixture hole. TB00595/01	Radial drilling machine
Inspection	Vernier Caliper and Go No- Go gauges;
Component Part No- TB00595/01, Left and Right Drilling by jig fixture and chamfering both end	Radial drilling machine and Fixture with PUG cutting machine
Inspection	Vernier Caliper and chamfer gauge
Assembly of bucket at a time by part TE02918/03, TB00595/00, Tb00595/02, Tb00595/01 and TB00595/09, With tag weld as per Tag welding sequence.	Assembly fixture AE/QP/01
Assembly of lug TB00595/05, Left and Right with assembly fixture.	Lug assembly, Fixture, Assembly pin and Measuring tape
Assembly bucket rib TB00595/9 by rib assembly fixture.	Rib assembly fixture measuring tape
Sub assembly Lift up bucket and assemble the Adopter TC00594 x 4 as per the distance in drawing.	Measuring tape and Adaptor assembly fixture
Welding Bucket sub weld of inside body, and other parts – TB00959	MIC – MAC Co_2 welding machine. Inspection by weld measuring tape
Assembly Assemble cover plate on middle lug and side lug support with back up bar part TB00595/4, TB00595/17, TB00595/18, TB00595/19 root gap max. 2mm	Measuring by Right angle scale
Assemble Stopper X4197029 with support of hole dia 17 mm fixture.	MIG – MAG Co_2 welding machine. Welding machine dia 17mm through mandrel fixture.
Welding Weld all the parts of the buckets as per the drawing, using the support of distortion control clamp.	MIG – MAG Co_2 welding machine. Welding measuring gauge.
Machining Set the bucket TB00595 on the boring machine with the support of bore fixture.	Toss Horizontal boring machine dia 80mm spindle Go NO-Go gauge. Dial bore gauge, height gauge, magnetic dial stand, Vernier caliper
Surface Preparation Bucket shot blasting for removal of scale and to get surface finish	Shot blasting plant
Quick dry black Painting by spray gun in paint booth	Spray gun
Inspection	Visual

3.2 Time Study

The cycle time taken by all the processes involved in manufacturing of bucket is studied and the time taken by them is discussed below. Time study for all the workstations is carried out and the total average cycle time is estimated. The cycle time includes the loading, clamping or fitting and unloading.

Table 4 shows the time study of each process involved in the manufacturing of excavator bucket. There are totally 21 processes involved. The highest cycle time is 90 min for welding operation.

Table 4: Time study of each process

SL.NO.	PROCESS	CYCLE TIME IN MIN
1.	Oxy cutting	62
2.	Removal of burr	24
3.	Inspection	5
4.	Rolling of Belly	31
5.	Inspection	7
6.	Side and Middle Cover Bending	8
7.	Machining operation Component TB00595 set in Base fixture, clamped by bolt and Drill through the fixture hole. TB00595/01	28
8.	Inspection	2
9.	Right and Left plate drilling and Chamfering	20
10.	Inspection	4
11.	Assembly Belly, half round, side plate, back rib and Tag welding	70
12.	Lug assembly	20
13.	Rib assembly	15
14.	Adapter assembly	23
15.	Welding complete inside joints and out side	90
16.	Cover plate and back up bar assembly	23
17.	Stopper assembly	14
18.	Boring	18
19.	Shot blasting	19
20.	Painting	45
21.	Inspection	10

The analysis shows that welding takes maximum time over other work stations. Improvement activities were initiated for the Process with that workstation after analyzing the time taken by each operation using pareto chart as shown in figure 1.

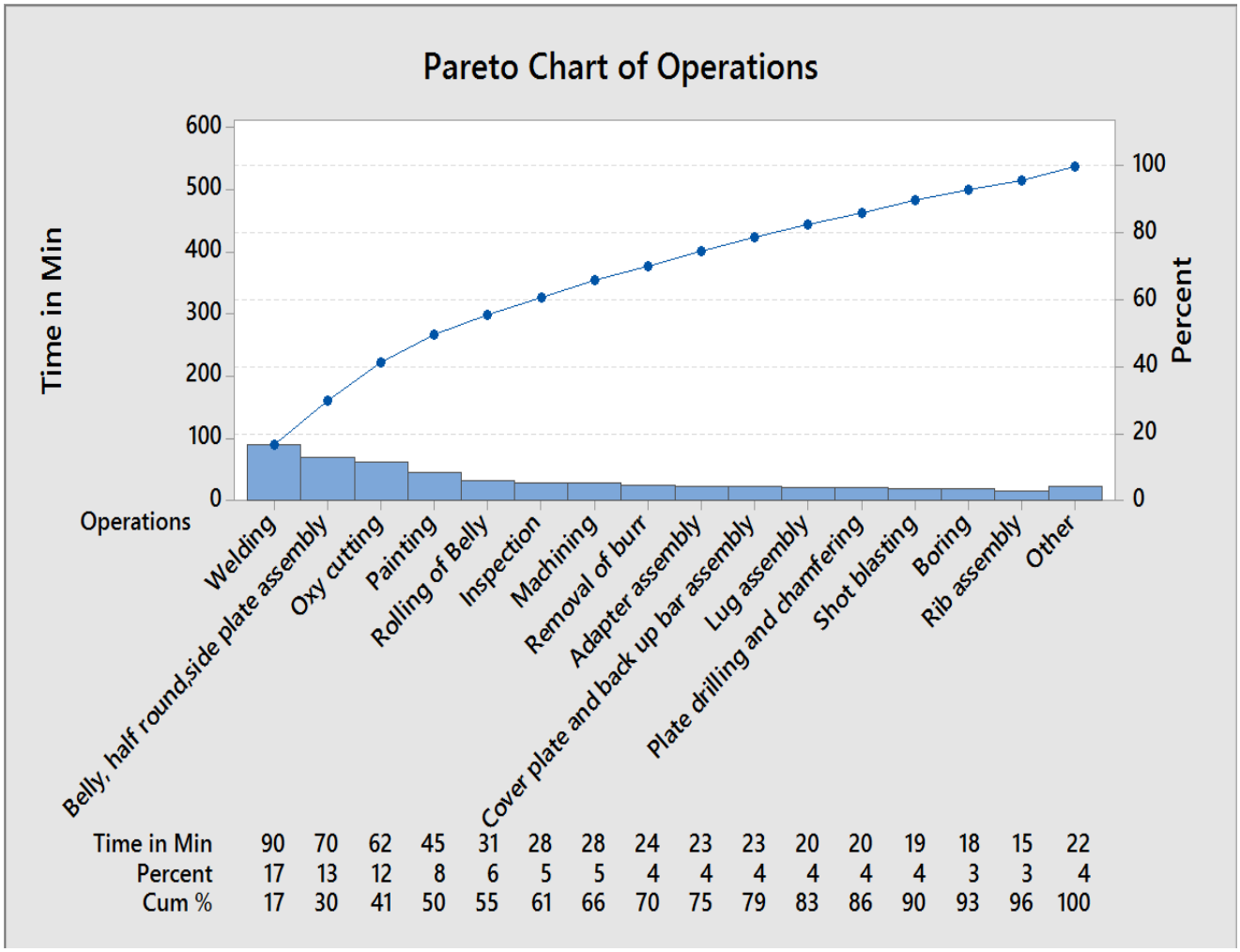

Figure 1. Pareto Analysis Chart

3.3 Welding Station

The cycle time taken by each operation in welding of bucket is shown in table 5 Totally four trials were conducted and average values are taken. Total average cycle time of the overall process is 90 minutes. The different operations involved includes Loading, Positioning, Clamping, Unclamping and Unloading. Welding grinding is the value-added operations performed in the process.

3.4 Welding operation details

Table 5 shows the number of operations involved in welding workstation, the table also shows the time taken by each operation. The highest cycle time is taken in 11th operation that is welding in posture 4. The second highest time is taken in fit up and hammering process. Therefore, Lean tools and process improvement study is carried out to reduce the time of these operations.

Table 5. Time study in welding work station

SL.NO	Action	Avg cycle time in seconds
1.	Loading Belly and mounting on fixture	222
2.	Loading bottom plate and mounting on fixture	244
3.	Loading front plate and mounting	201
4.	Loading Right and Left cover plate and mounting	282
5.	Loading Lip plate, back up bar and mounting	240
6.	Fit up and Hammering	390
7.	Measuring	170
8.	Welding at posture 1	330
9.	Welding at posture 2	380
10.	Welding at posture 3	350
11.	Welding at posture 4	430
12.	Welding at posture 5	267
13.	Welding at posture 6	376
14.	Welding at posture 7	378
15.	Grinding	250
16.	Unclamping	260
17.	Unloading	350
18.	Punching Part number	280
	Total Average Cycle Time	5400 sec = 90 mins

3.5 Pareto analysis of Welding process

The various operation involved in the welding is analyzed using pareto chart which is shown in figure 2. In the pareto chart fit up and hammering process takes maximum time next to welding at posture 4, which needs to be concentrated for process improvement. The other process improvement activities are also carried to improve the productivity in EX 70 bucket manufacturing which needs to be discussed in improvement phase.

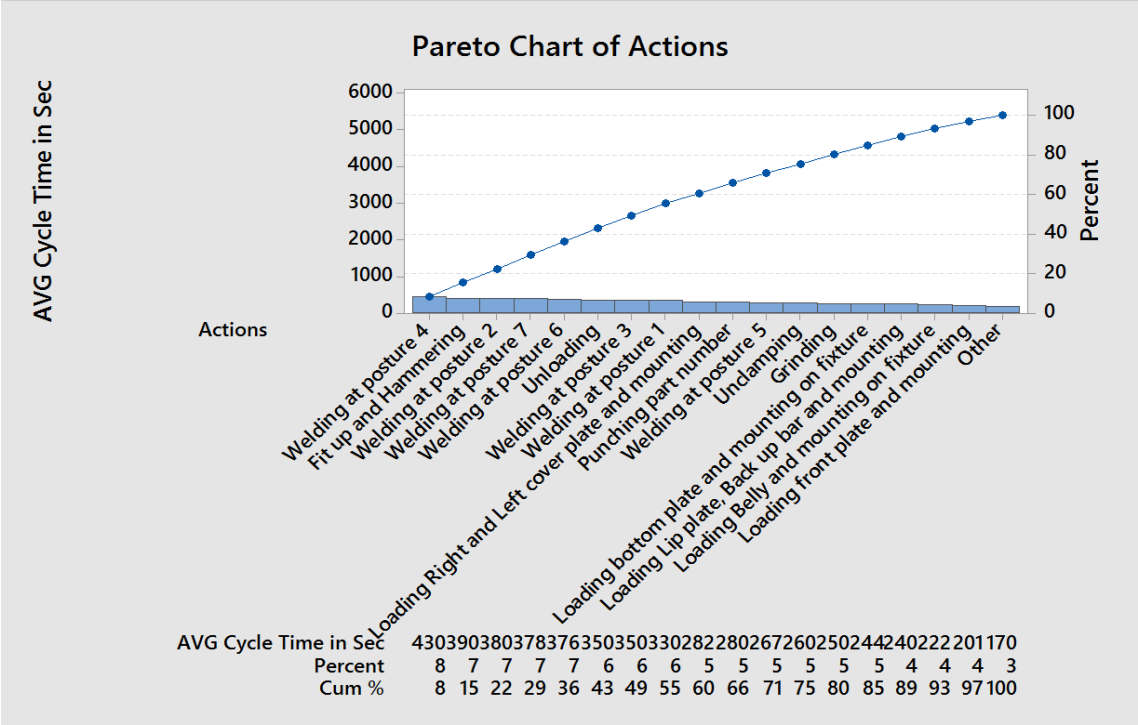

Figure 2. Pareto analysis of welding process

3.6 Process improvement in side cover plate fit up in bucket manufacturing

For the fit up of side plates up to two operators are required for dimensional checking and holding plates in fixture. The dimensional clearance of about 100 mm is required during the fitment. The operator fatigue is more as the clearance is small and possibility of hand injury during welding. By providing the small block which can hold the plate, fit up was made easy and dimensions can also be measured easily. Lead time saved is around 10 minutes per bucket. Moreover, there is also a saving of 1 operator, as the simplified operation can be done by a single operator.

The figure 3 below shows the fit up of side plate by two operators. This fit up process is taking a lot of time and there is also some concern with safety.

Figure 3. Before process improvement two operators involved

The figure 4 below shows the less clearance and poor visibility to during the fit up of side plate. The poor visibility leads to take more time.

Figure 4. Dimensional checking before process improvement

The figure 5 is the dimensional block, which is suggested to place under the plate so holding of plates will be easy and it will be easy to measure also.

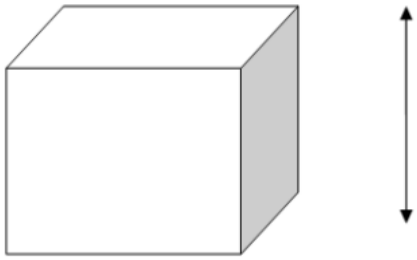

Figure 5. Suggested dimensional block for holding plate.

The figure 6 shows the ease of working after placing the dimensional block under the plate, now only one operator is enough to work and visibility has also increased thus reducing the fatigue to work.

Figure 6. Dimensional block inserted inside plate after process improvement

3.7 Side plate fitment lead time reduction calculation

The lead time reduction calculation of side plate fitment process is shown in Table 6. Due to improvement activity 40-man mins can be saved per day and in addition to this one-man power is also saved.

Table 6. Lead time comparison in side plate fitment process

Process	Time taken for operations (mins)	Operators required	Total Time saved/day (min)
Present process	24	2	40
Improved process	14	1	

3.8 Process improvement in inline checking of Lugs

Inline checking of Lugs in the inspection process which is to check the dimensional accuracy of the bore machined using CNC machine. During inline checking process the pin is inserted to see the alignment where the boom is mounted during assembly. The weight of the pin is approximately 40 kg's and two operators are required to hold the pin. More operator fatigue and possibility of foot injury due to slippage when handled by single operator. By providing a light weight pin, inline inspection is possible by single operator. The safety is improved and operator fatigue is very much reduced. Lead time saved is around 20 mins per day and moreover 1 manpower is reduced.

The Figure 7 shows the inline checking of lug by two operators as the pin weight is about 40 kg's. It is bit risky as the pin may slip from hand fall on foot. we can also see that the grip of the pin also not good.

In line checking requires two operators

Figure 7. Inline checking before improvement process

The Figure 8 shows the inline inspection using hallow light pin. Only one operator can perform this operation. There is no risk of injury as well. Lead time of about 20 mins is saved by this improved technique.

Hollow inline checking pin with less weight

Figure 8. Inline checking after improvement process

3.9 Inline checking of Lugs lead time reduction calculation

The lead time reduction calculation of the inspection process is shown in table 7. Due to improvement activity 20 mins is saved per day and one manpower is also saved.

Table 7. Lead time comparison in inline checking of Lugs.

Process	Time taken for operations (mins)	Operators required	Total Time saved/day (min)
Present process	18	2	20
Improved process	13	1	

3.10 Process Improvement in Painting Process

The painting process for one bucket take about 45 min and involves 9 processes in painting. There are few non-value-added processes which is reduced using Value Stream Mapping as shown below. The total process time is reduced from 45 min to 40 min. The standard procedures like Annexure A and Annexure B are built and followed as shown in Table 8 and Table 9. Figure 8 shows the VSM of the current process and Figure 9 shows the Future VSM.

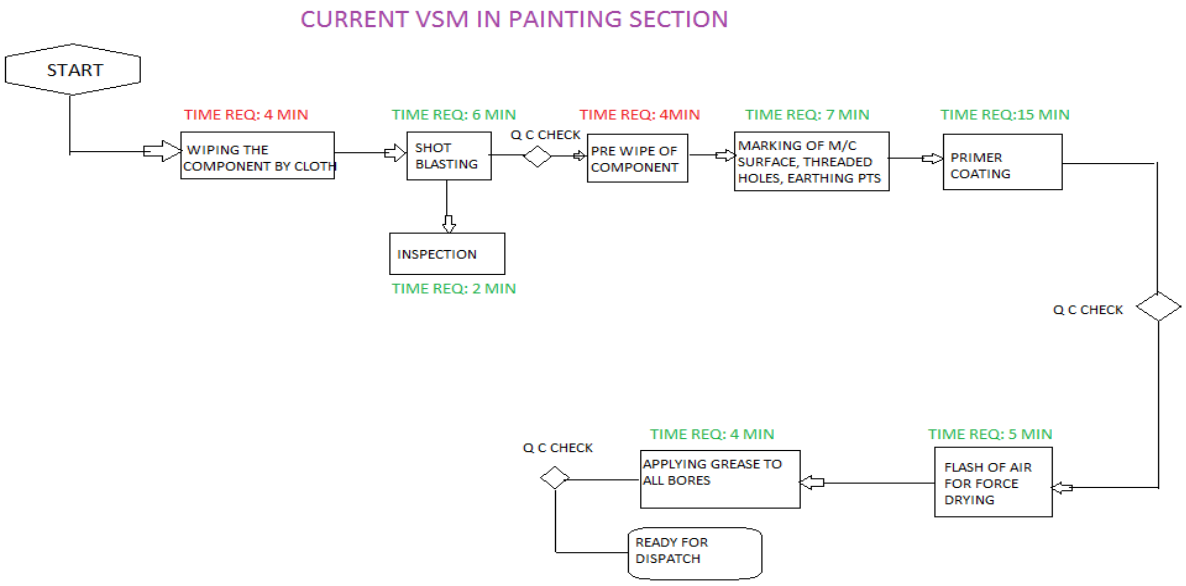

Figure 8. Current state value stream mapping of painting process

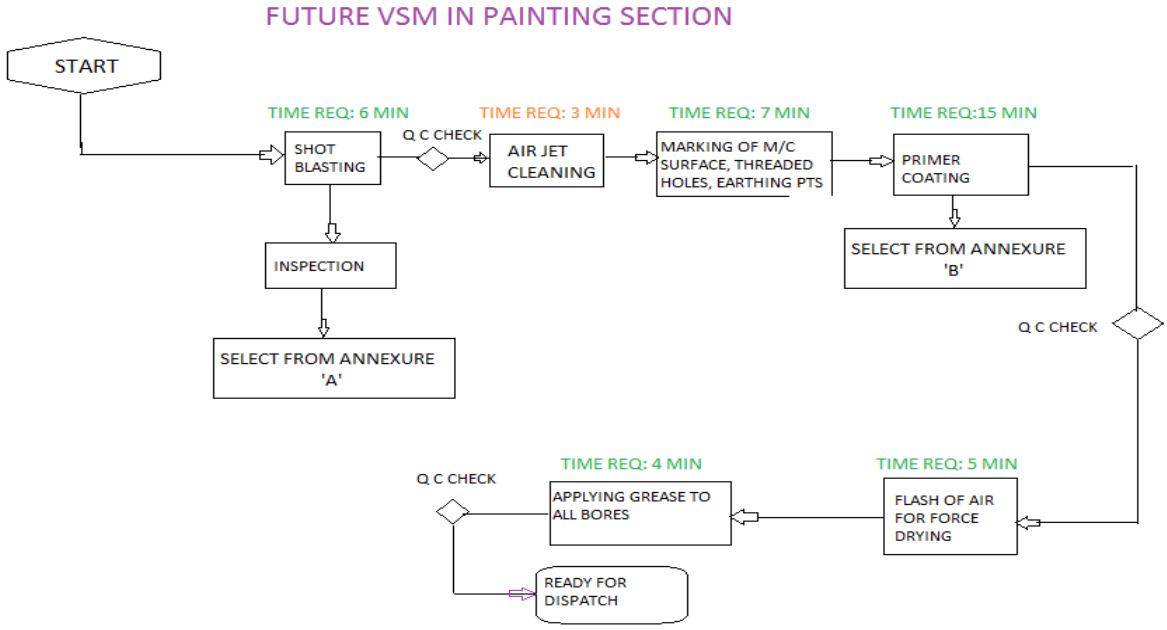

Figure 9. Future state value stream mapping of painting process

ANNEXURE 'A'
PROCEDURE FOR BUCKET PAINTING

Table 8. Annexure A

Surface preparation	Objective	Process	Make	Application Method
Step 1: Degrees	Completely remove oil, Grease, root, welding sheet, dirt or any other foreign material.	Degrease iron phosphate using 3 in 1 chemical.	Dg 28 OF Chemical Rai Pune or Duridene 7760 of Henkel chemical bond.	By spray using high pressure spraying machine.
Step 2: De rusting	To remove mill scales, loose flakes			
Step 3: Under coat	To prevent rusting of components			
Step 4: Dry off				

ANNEXURE 'B'
PROCEDURE FOR BUCKET PAINTING

Table 9. Annexure B

BASE COAT		TOP COAT	
Details	Primer	Details	QD Paint
Make	Burger	Make	Burger
Color	Red oxide	Color	Semi Metal Black
Paint Cat.No.	644991	Paint Cat. No.	150850
Tinner Cat. No.	807900	Tinner Cat. No.	807900
Application Method	By spray Gun	Application Method	By spray Gun
Spray pump	Trition 308 1:1	Spray pump	Trition 308 1:1
Spray Gun	Air Pro compraint	Spray Gun	Air Pro compraint
Spray Pump Pressure	6 kg/cm^2	Spray Pump Pressure	6 kg/cm^2
Spray Gun Pressure	4.5 to 5 kg/cm^2	Spray Gun Pressure	4.5 to 5 kg/cm^2
Application Viscosity	20 to 22 scs.	Application Viscosity	20 to 22 scs.
No. of Coats	2 to 3	No. of Coats	2 to 3
Dry film thickness	40 to 45 microns	Dry film thickness	40 to 45 microns
Drying Method	Air Dry	Drying Method	Air Dry
Drying Time	25 to 30 Mins	Drying Time	25 to 30 Mins

4. Payback calculation

The payback calculation is calculated by considering the fabrication cost and total lead time saved after process improvement which is shown in Table 10. Hence, from study $81,912 is saved per year.

Table 10. Payback calculation

Process	Lead time reduction man (hrs.) per day	Man-power reduction, hours saved	Fabrication cost saved per day ($ 35 per hour)	Amount saved/day due to reduction of man power	Cost saving per year
Welding process	0.666	5.3	23.31	186	$ 65,304
Inline checking of Lugs	0.333	0.86	11.65	30	$ 12,994
Painting process	0.333	0	11.65	0	$ 3626.36
Total	1.332	6.19	46.61	216	$ 81,912/Year

5. Results

The process improvement activities were initiated after careful analysis of cycle time taken by each operation in welding station. The process improvement in side plate fit up started with various suggestions which can be implemented in a simpler way without adding more cost for the design and material. The operators are trained for the appropriate standard operating procedure after process improvement. After implementation of the proposed process improvement in the welding there is a reduction in cycle time of about 40-man minutes per day with a manpower saving which can be compared by using bar chart which is shown in figure (10.0).

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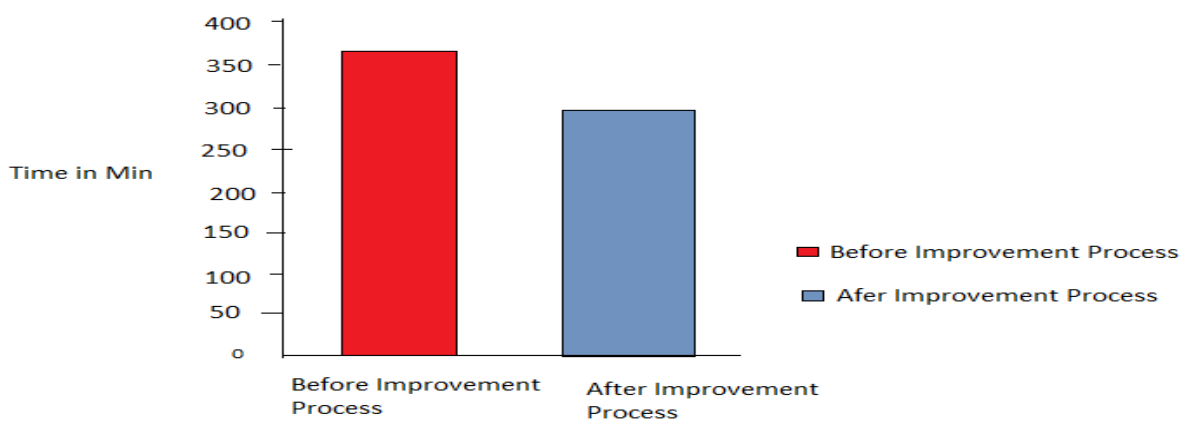

Figure 10. Comparison of cycle time in side plate fit up before and after process improvement.

Inline checking of Lugs for the mounting of boom during assembly. The process in the inline checking of Lug is improved by reducing the weight of the inline pin which initially requires two manpower for the inspection. After process improvement by reducing the weight of the inline pin one manpower and the time taken by the operator is

also saved. The proposed process improvement reduced a total cycle time of 20 minutes per day which accounts for a greater cost saving for the organization.

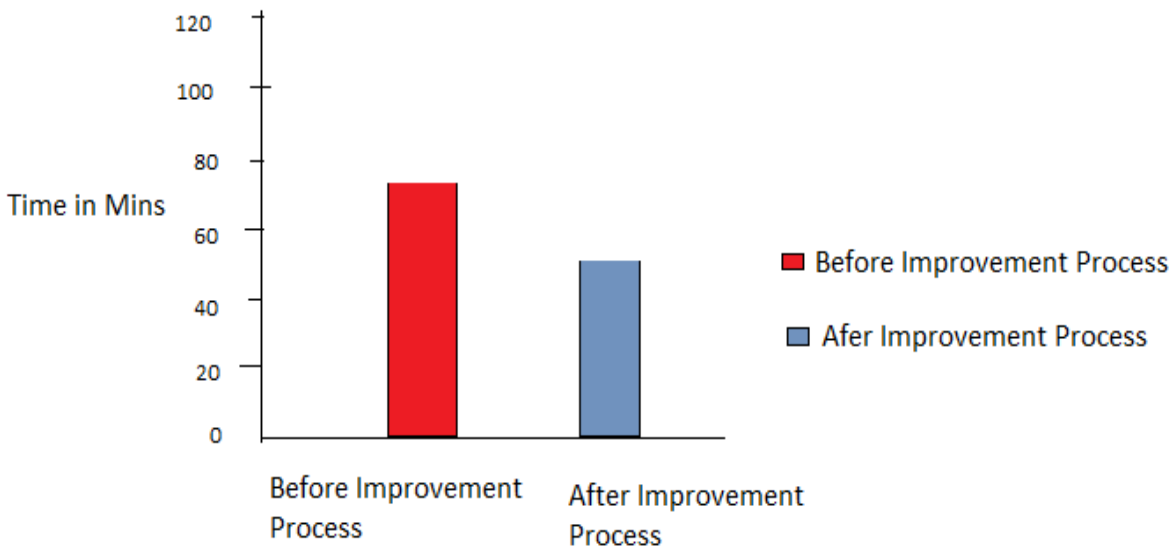

Figure 11. Comparison of cycle time in Lug alignment process

The painting process initially had 9 processes which had many non-value-added times involved. The new process has 8 procedures and the total time required to paint one bucket was reduced from 45 min to 40 mins per bucket, resulting 20 mins save per day as shown in the below.

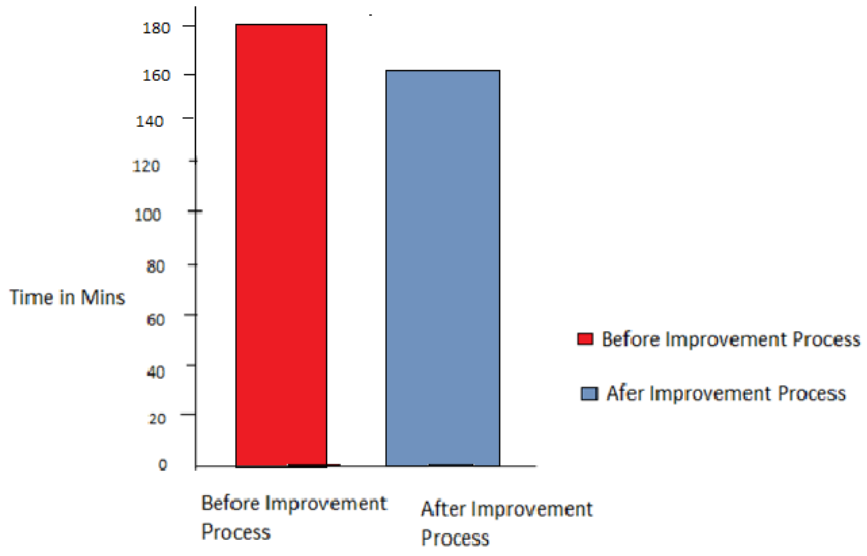

Figure 12. Comparison of cycle time in painting process before and after improvement

6. Conclusion

The research work proves that by using the lean tools production lead time is reduced in manufacturing of EX 70 excavator bucket. Thus, the productivity in the fabrication stations have been improved. Total time taken in welding station was reduced from 90 mins to 80 mins per bucket, total time taken in Lug alignment inspection was reduced from 18 mins to 13 mins per bucket and total time taken in painting station was reduced from 45 mins to 40 mins per bucket thus, total cycle time of 538 minutes to manufacture a Ex 70 excavator bucket is reduced to 518 minutes per bucket. The ergonomic condition of worker and manpower utilization is also improved after implementation of proposed process. The productivity can further be improved by continuous process improvement and according to the product requirements. The total cost savings due to productivity improvement is about $ 81,912per year. This work can still be further improved through continuous improvement by improving the process.

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Biography

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