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Production Lead Time Reduction in a Hydraulic Machine Manufacturing Industry by Applying Lean Techniques

Saravana kumar.M[1], Allen Jeffrey.J[2], Mohan Raj.S[3]
[1,2](Assistant Professor,Department,of Mechanical Engineering, Loyola Institute of Technology, India)
[3](Project Engineer, Chainsys India Pvt limited, India)

ABSTRACT: *Production lead time reduction is an important means to improve productivity in manufacturing industries. This paper focuses on improving the productivity through lead time reduction in a hydraulic excavator manufacturing facility. Time study has been carried out to estimate the time taken by each and every process in the product fabrication line. Pareto charts are used to analyze the process and bottleneck operations are identified. Process improvement activities are carried out by developing new methods through process and design modifications. Implementation of the proposed process improvements in the fabrication line leads to improved productivity and reduced lead time.*

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

I. INTRODUCTION

1.1 Lean manufacturing

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 utilisation 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. The productivity is also improved with reduction in production lead time and optimal manpower which accounts for greater cost saving for the organisation.

1.2 Fabrication of Hydraulic excavator parts

This work was carried out in the fabrication plant of a hydraulic excavator manufacturing industry which manufactures three major components namely Boom, Revo frame and Track frame. The major operation performed includes Welding, Shot blasting and Painting. The Fabrication plant has a capacity of 1750 units/year to weld and 2100 units/year to paint. The Component is processed through nine workstations in the fabrication line thus converted into Revo frame from main beam. The overall process cycle time is more which needs to be completed for manufacturing a single component. Thus the process improvement activities were initiated with the Revo frame line after studying the various operations involved in each work stations and calculating total average cycle time of the process.

1.3 Problem statement

The three components Revo frame, Track frame and Boom need to be produced in equal quantities in a day to fulfill the assembly line to meet the daily production target. The forecasted demand for the Revo frame shown in fig1.1 shows that there is a gradual increase in the forecasted demand for the product in future. To meet the forecasted demand there is a necessity to reduce the production lead time in the to meet the target demand through process improvement**.**

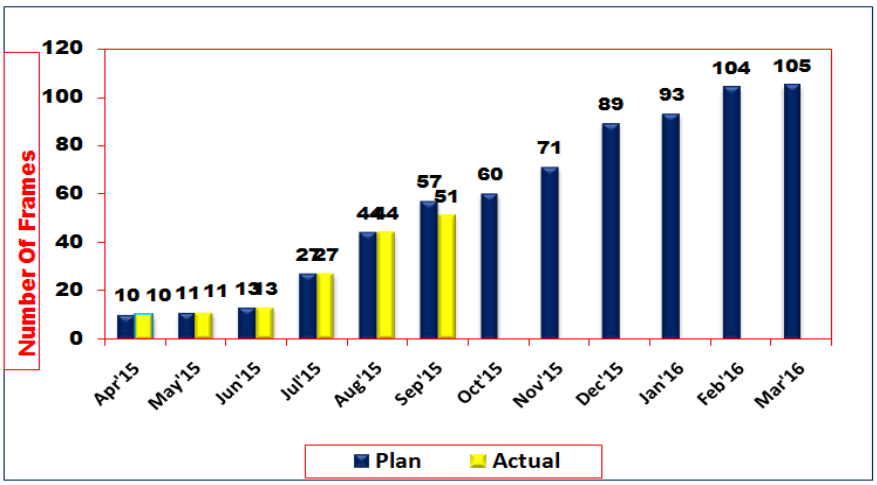

Figure (1) Forecasted demand chart for the year

The objective of the study is

1. To reduce the cycle time at each work stations to improve productivity.
2. To reduce the time taken for non value added activities such as Setup, Movement of material by using lean tools.
3. To improve operator safety and reduce fatigue.

II. MATERIALS AND METHOD

The various process involved in the production of Revo frame is studied which is shown as flow chart in figure (2).

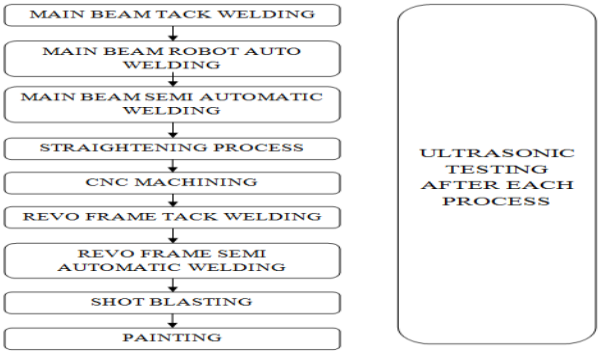

Figure (2) Revo frame process flow chart

2.1 Tack welding of Main Beam

In tack welding of Center frame the parts such as L.H and R.H side plate, bracket and plate assembly are mounted on the fixture and continuous intermittent welding is done. The welding inspection is performed to identify the penetration defects and quality of welds.

2.2 Robot automatic welding of Main beam

Robot has 2 axes (Robot and positioner).It has rotation and tilt able axis and skyhook type. Robot can access the narrow joint without interference. It has high capacity cooling torch which can achieve high current welding with 600A power source.

2.3 Semi automatic welding of Main Beam

Joints and brackets are welded at positions by using a positioner rotating clockwise, counterclockwise and tiltable axis rotation in semiautomatic welding. Positioning and welding are the major operations performed.

2.4 Straightening Process

In straightening process heating and cooling is done at LH and RH sides of the main beam. By this process the sides of the beam gets straightened after it gets distorted in the previous process of semi automatic welding. The inspection is done to check the straightness and then the component is moved to next station.

2.5 Tack welding of Revo Frame

In tack welding of Revo frame LH deck frame and RH deck frame is mounted on the fixture and fit up is done along with main beam. After proper fit up of parts continuous intermittent welding is done. Thus the main beam is converted into Revo frame after this process.

2.6 Semi automatic welding of Revo Frame

Joints and brackets are welded at positions by using a positioner rotating clockwise and counterclockwise in semiautomatic welding.After welding inspection is done to check penetration of weld and accuracy. The component is moved to the next workstation after the quality inspection

2.7 CNC machining of Revo frame

In CNC machining of track frame dual spindle with dual tool magazine is used. Dual pallet operation for loading and unloading the component during operation. The process involves rough and final machining. After machining de burring is done to remove the chips deposited.

2.8 Painting of Revo frame

In painting multiple ratio controller system is used for variable requirement of painting specification and flushing of painting guns. LPG fired drying oven is used for fast curing of the component.

2.9 Shot blasting of Revo frame

The shots sprayed with higher velocity of about 80m/s to remove the deposits on the surface. This is followed by cleaning and inspection to identify and remove the shots that is spread over the surface after the process is completion.

2.10 Detailed work description

In production of Revo frame the process needs to be improved to meet the target demand in the assembly line. To improve the process the various operations involved and the cycle time taken by the various process in the fabrication of Revo frame needs to be identified. Time study is conducted to identify the cycle time taken by each and every operation and analysis was done using a pareto chart to identify the bottleneck operation. The process improvement activity was carried out to eliminate the bottleneck operation by developing new methods through trials. After process improvement the cycle time is compared and cost saving is calculated.

2.11Time study

The cycle time taken by the various process involved in the fabrication of Revo frame is studied and the various operations involved and the time taken by them is discussed below. The cycle time taken by each operation in tack welding of main beam is shown in table (1). Totally 3 trials were conducted and average values are taken. Total average cycle time is 161mins.The various operations involved includes Loading, Unloading, Clamping, Tightening and welding.

Table (1) Tack welding of main beam

S.No	Process	Average Cycle Time in Seconds
1	Loading bottom plate and mounting on fixture	244
2	Loading and mounting front plate	428
3	Loading and mounting rh side plate	393
4	Ring clamping and adjustment	763
5	Hammering	141
6	Measuring	118
7	Welding at position1	530
8	Welding at position2	576
9	Welding at position3	559
10	Welding at position4	842
11	Welding at position5	743
12	Welding at position6	967
13	Welding at position7	761
14	Welding at position8	844
15	Grinding	466
16	Unclamping	354
17	Unloading	548
18	Punching part number	349
	Total Average Cycle time	161mins

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Similarly time study for other workstations in the Revo frame line is carried out and the total average cycle time is estimated.

2.12 Analysis of time study

The time taken by the various process in the Revo frame line was summarised in table (2). The cycle time taken by the various process is analysed using a pareto chart which was shown in figure (3).

Table (2) Summary of cycle time in Revo frame line

S.NO	PROCESS	CYCLE TIME IN MINS
1	TACK WELDING OF MAIN BEAM	161
2	SEMI AUTOMATIC WELDING OF MAIN BEAM	164
3	STRAIGHTENING PROCESS	57
4	CNC MACHINING OF REVO FRAME	119
5	TACK WELDING OF REVO FRAME	163
6	SEMI AUTOMATIC WELDING OF REVO FRAME	88
7	SHOT BLASTING OF REVO FRAME	59
8	PAINTING OF REVO FRAME	142

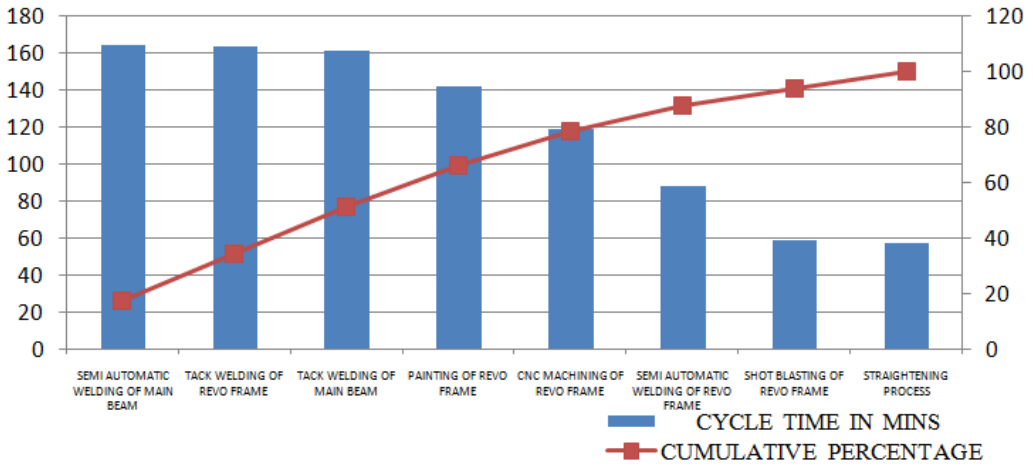

Figure (3) Pareto analysis chart of Revo frame line

The analysis shows that Semi automatic welding of main beam takes maximum time over the other workstations. The Process improvement activities were initiated with that particular workstation after analysing the time taken by each and every operation using pareto chart.

2.13 Station3 semi automatic welding of main beam

The cycle time taken by each operation in Semi automatic welding of main beam is shown in table 1.3.Totally 3 trials conducted and average values are taken. Total average cycle time of the overall process is 164mins.The various operations involved includes Loading, Unloading, Positioning, Clamping, Unclamping and Unloading. Welding grinding are the value added operations performed in the process.

Table (3) Semi automatic welding of Main beam

S.NO	PROCESS	AVERAGE CYCLE TIME IN SECS
1	Loading main beam and mounting on fixture	419
2	Clamping on fixture and fit up	187
3	Fit Up and Hammering	691
4	Welding at position 1	430
5	Positioning for welding	277
6	Welding at position 2	671
7	Positioning for welding	155

8	Welding at position 3	770
9	Positioning for welding	149
10	Welding at position 4	658
11	Positioning for welding	173
12	Welding at position 5	645
13	Positioning for welding	136
14	Welding at position 6	602
15	Positioning for grinding	157
16	Grinding at position 1	336
17	Positioning for grinding	129
18	Grinding at position 2	367
19	Positioning for grinding	162
20	Grinding at position 3	466
21	Unclamping	537
22	Unloading	566
	TOTAL	164mins

2.14 Pareto analysis of Semi automatic welding of Main beam

The various operations involved in the semi automatic welding of main beam is analyzed using Pareto chart which is shown in Figure (4). In the Pareto chart fit up and hammering process takes maximum time next to welding which needs to be concentrated for process improvement. The other process improvement activities are also carried out to improve productivity in fabrication of Revo frame which needs to be discussed in improvement phase.

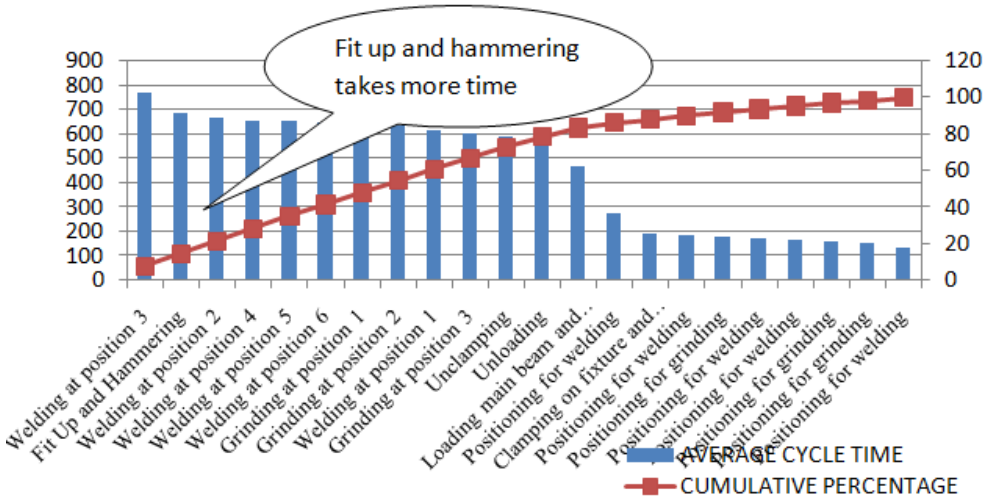

Figure (4) Pareto Analysis of Semi automatic welding of Main beam

2.15 Process improvement in side plate fitup of semi automatic welding of main beam

During side plate fit up two operators are required for dimensional checking and holding gusset plate. The dimension clearance of about 128 mm is required during the fitup.The operator fatigue is more as the clearance is small and possibility of hand injury during welding. By providing a small dimensional block which can hold the plate, fit up was made easy and dimension can also be easily measured. Lead time saved is around 10 minutes per component. Further there is also a saving of 1manpower, as the simplified operation can be performed by a single operator.

Figure (5) Before process improvement two operator involved

Figure (6) Dimensional checking before process improvement

The cubical block with a size of 128mm is used to support the plate. The trial runs were taken to check the accuracy and position so that the plate can be held rigidly on the surface for welding.

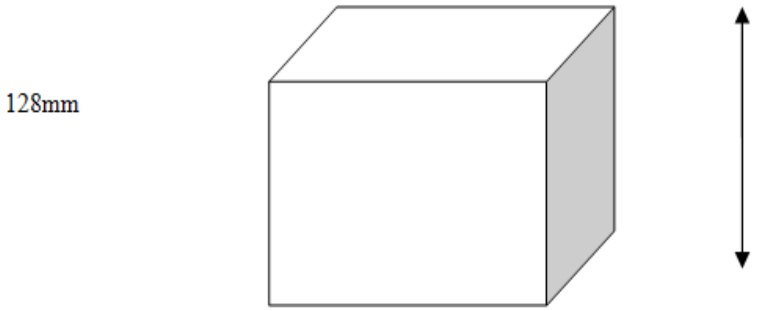

Figure (7) Dimensional block suggested for holding plate

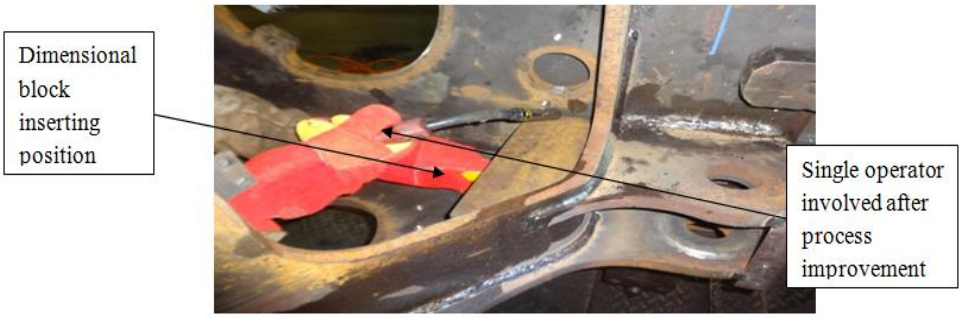

Figure (8) Dimensional block inserted inside plate after process improvement

2.16 Side plate fit up process of Revo frame lead time reduction calculation:

The lead time reduction calculation of the side plate fit up process is shown in table (4). Due to improvement activity 40 man minutes can be saved in addition to this manpower saved by the improved process.

Table (4) Lead Time Reduction in Side plate fit up process

Process	Time taken for operation (mins)	Manpower required	Total Time saved/day (mins)
Current process	24	2	40
Improved process	14	1	

2.17 Process improvement in Inline checking of Revo frame:

Inline checking of Revo frame is the inspection process which is to check the dimensional accuracy of the bore machined using CNC machine. During inline checking of Revo frame a pin is inserted to check the bore where the boom has to be mounted during assembly. To hold the inline pin two operators are required as the weight of the pin is approximately 42 kgs.More operator fatigue and possibility of foot injury due to slippage when handled by single operator. By providing a light weight pin, inline checking is possible with single operator. Safety is improved and operator fatigue is very much reduced after this process improvement. Lead time saved is around 20 mins per day in addition to the manpower reduction of 1.

Figure (9) Inline checking of Revo frame before process improvement

Figure (10) Inline checking of Revo frame after process improvement

2.18 Inline checking of Revo frame lead time reduction calculation:

The lead time reduction calculation of the inspection process is shown in table (5). Due to improvement activity 20 minutes can be saved in addition to this manpower saved by the improved process.

Table (5) Lead Time Reduction in Inline checking of Revo frame

Process	Time taken for operation (mins)	Manpower required	Total Time saved/day (mins)
Current process	18	2	20
Improved process	13	1	

III. RESULTS AND DISCUSSION

The process improvement activities were initiated after careful analysis of cycle time taken by each operation in semi automatic welding .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 semi automatic welding of main beam 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 (11).

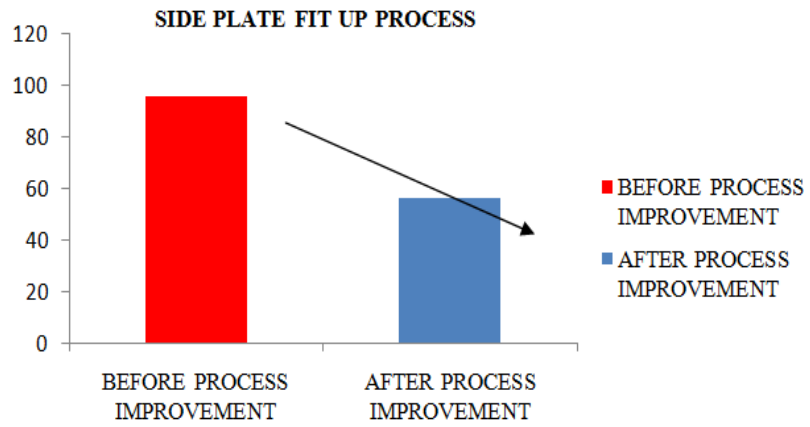

Figure (11) Comparison of cycle time in side plate fit up before and after process improvement

Inline checking of Revo frame is the final inspection of the Revo frame for the mounting of boom during assembly. The process in the inline checking of Revo frame 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.

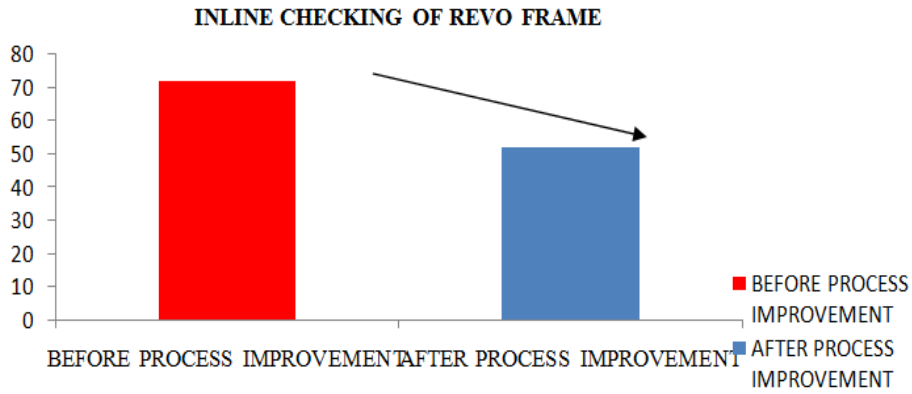

Figure (12) Comparison of cycle time in side plate fit up before and after process improvement

3.1 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 (6)

Table (6) Payback calculation

Process	Lead time reduction (m hrs)	Fabrication cost (1138/hr)	Cost saving/Year
Side plate fit up process	0.167	190.046	47511.5
Inline checking of Revo frame	0.1833	94.795	23698.75
Total	0.2503	284.841	Rs 71210/Yr

IV. CONCLUSION

The research work proves that by using the lean tools production lead time is reduced in fabrication of Revo frame. Thus the productivity in the fabrication stations have been improved.The total cycle time of 168 minutes stations is reduced to 108 minutes in production of four revo frames per day for the assembly of excavator. 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 INR Rs 71,200 in a year. This work can still be further improved through continuous improvement by improving the process.

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