Manufacturing Lead Time Reduction of Gear Box Side Frame Using Lean Principles

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Abstract

In today's high pressure market slashing lead time is the fastest and most powerful approach to profitability improvement, especially for companies who have already realized most of their core manufacturing efficiency improvement opportunities. Lead time reductions will directly impact almost every contributor to costs within the company's operations. With its strategic importance Lead time reduction has become an important element of campaign to increase the competitiveness of manufacturing industry

The objective of the study is to reduce the lead time of the side cover. The initial phase of study included the construction of a macro process map. Macro time study revealed process that has higher cycle time than Takt time. Micro process mapping and micro time study was conducted to look up on wastages in processes. Root cause analysis was carried out to find out the causes of the excess waste. Solutions to the problem were found by implementing a dedicated fixture, tool trolley, SOP, and 5S

The result showed a significant reduction in lead time of the component with an average reduction of 15% of the lead time. The use of the fixture along with tool trolley significantly reduced the process time of the concerned process by about 38%. The implementation of fixture brought in this significant improvement in lead time without the addition of an extra machine or a negative impact on quality. Future recommendation was also provided that would further reduce the total lead time of the process.

Keywords: Lead Time, Gear Box, Lean Principle,

Nomenclature

T	Takt Time
Ta	Net available time
Td	Customer Demand

Abbreviations

MLT	Manufacturing lead time
NVA	Non value adding
QC	Quality control
QFD	Quality Function deployment
SMED	Single minute exchange of dies
SOP	Standard operating procedure
WBS	Work breakdown structure
WIP	Work in progress

1. INTRODUCTION

As organizations come under increasing pressure to compete in today's fast changing business environment, the companies look for the one issue to gives the competitive advantage. This issue is often to seek a way to reduce Lead time in such a way as it decreases cost and/or increases customer service lead time reduction is one of the most important elements of successful manufacturing today. More and more customers are demanding that manufacturers quickly respond to their wants and needs, deliver perfect quality products on time. This trend, which will continue, has led companies to focus more attention on lead time.

1.1 Manufacturing Lead Time

Manufacturing Lead Time refers to the total time it takes to complete the manufacturing process of a product. It is the time from when an order is ready to start on the production line to when it becomes a finished good

1.2 Lead time reduction

Slashing lead time is the fastest and most powerful approach to profitability improvement, especially for companies who have already realized most of their core manufacturing efficiency improvement opportunities. Lead time reductions will directly impact almost every contributor to costs within the company's operations. Benefits of reduced lead time include

1. Investment in finished goods, WIP inventory and financing of receivables decreases.
2. New market opportunities based upon order fulfilment speed and flexibility are enabled, pricing can be strengthened, and customer loyalty enhanced in existing segments through improved service capabilities
3. Fewer changes to orders and production schedules mean achieving higher manufacturing efficiency levels
4. Operating costs decrease, and expediting, overtime, and other costs aassociated with "rush" orders are eliminated
5. Write-offs on raw materials, WIP or finished goods inventories are reduced, as there is less damage during storage, and less risk of obsolescence.
6. Quality problems are detected and resolved earlier, as inventory turns are increased

1.3 Place of Work

Searock is a precision machining company which is located in the Kumbalgodu Industrial Estate about 20 km from Bangalore, just off the Bangalore – Mysore

highway. Searock is a supplier to some of the most discerning OEM and Tier I companies like

1. M/s. Mico-bosch Industry Bangalore
2. M/s. Titan Industries – Precision Machine Division Bangalore
3. M/s. Component Speciality India Private Limited Bangalore
4. M/s. Makino Machine Tools Private Limited, Bangalore
5. M/s. Kinematic Transmissions Private Limited, Bangalore

2. PROBLEM DEFINITION

The problem of high cycle time can be addressed only by examining the current process and the time taken for each process, Takt time, and deviation of process time from takt time etc.

2.1 Problem Statement

To reduce the manufacturing cycle time of a side frame from 5 hours to 4 hours per component by applying lean principles.

2.2 Objectives

➢ To conduct literature review to understand factors affecting cycle time of the side frame and application of lean principles.
➢ To collect data of present situation for the selected product.
➢ To analyze factors for long cycle time and identify root cause.
➢ To propose appropriate solution based on Lean principles.
➢ To implement, validate and quantify the cost benefits

2.3 Methodology

1. Literature review on productivity enhancement and Lean principles has been carried out by referring books, journals, quality system manuals and related documents.

2. The present data of the selected product is collected and studied and the performance of machines had been identified.

3. The present process and production specifications on existing practice have been analyzed by using QC tools like why-why analysis, current state mapping, cause and effect diagram etc.

4. Alternate solutions for reducing the cycle time is identified with the help of analysed data.

5. The solution is implemented and validated by providing SOP and Training

3. DATA COLLECTION AND ANALYSYS

3.1 Introduction

The first step in analysing any process for scope of improvement is to understand the current status of the process "where are we now". Only by understanding the current status of the process we can plan for improvements. Data collection is the first step for this.

3.2 Manufacturing Process of the Side Frame

The side frame goes through different manufacturing processes before it gets converted into the finished product. The various stages through which the side frame goes through during the manufacturing processes are discussed below.

3.2.1 Material Arrive

Material arrives every 15 days in the form of metal sheets as per requirement and are stored in the store

3.2.2 Incoming Inspection

In this station the raw material is tested for chemical as well as mechanical properties as per SIP-01, CCM-01. The tests are carried out at the material testing lab. The material testing lab runs for two shifts with one employee per shift. After the test the accepted materials are forwarded to the next station and the rejected materials are sent back to the supplier and replaced.

3.2.3 Rib Welding

Ribs are welded on to the surface of the plate. The station consists of a welding machine and an operator to work on it. The welding is done manually using the welding machine and the station runs a shift per day..

3.2.4 Milling

The thickness of the side frame (19+0.3mm) is maintained in this station. The station has a conventional milling machine. The station has a single operator and station runs a shift per day. All the setting required for the machining operation is carried out manually by the operator..

3.2.5 Finish Boring and Drilling

In this station the final drilling and boring is carried out. The machine used is the batliboi 3 axis machining center. The machine has 24- tool holders. The settings required for this machining operation is carried out manually.

3.2.6 Tapping

After the finish boring and drilling the parts are forwarded for tapping. The tapping station has one employee and runs for a shift per day. Tapping is done manually using tapping tool.

3.2.7 Deburring

After Tapping, the component is forwarded to the deburring station. This station has a single operator and deburring is done manually using deburring tool. All holes are deburred and cleaned.

3.2.8 Final Inspection

In this stage the visual inspection is done to check the parts conformance with drawing

3.2.9 Assembly

At this station the side cover is assembled with the rest of the gear box. The assembly is done manually. The station has an employee and it runs a single shift per day.

3.2.10 Packing

Finished parts are forwarded to the packing section for oiling and packing. The section consists of an operator and the station runs only a shift per day.

3.2.11 Dispatch

This station prepares gate pass and logistic instruction for the dispatch of the finished parts to the customer. The station has a single employee and runs a single shift per day.

3.3 Study of the Process

To understand the entire manufacturing process of the Side frame a Macro process mapping was carryout. A macro process map is a tool used to map the board organizational processes. It provides a graphical representation of the process.
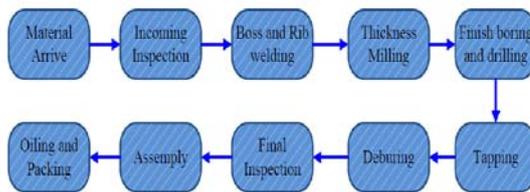

Fig. 1 Macro process map for the manufacturing process of side frame

3.3.1 Macro Time Study

A time study was carried out to examine and analyze the time required to complete individual operations. Time study is a tried and tested method of work measurement for setting basic times and hence standard times for carrying out specified work. This is achieved by observing the work, recording what is done and then timing and simultaneously assessing the pace of working.

3.3.2 Takt Time Calculation

Takt Time is defined as the time interval between consecutive items in a production system that must be achieved to meet customer demand. The available production time divided by customer demand gives Takt time.

T = Takt Time
Ta = Net available time
Td= Customer Demand

Takt Time Calculation	
Customer Demand/Month	60 nos
Number of working days allotted for this product per month	14 days
Number of shift per day	1
Hours per shift	9 hrs
Available time per shift (mins)	540 mins
Lunch Break (mins)	30 mins
Tea Break (2 nos of 10minutes each)	20 mins
Planned Down Time/Shift	0
Net Working Time/Shift	490 mins
Net Working Time/Month	6860 mins

Table 1. Takt time calculation

$$\text{Takt time} = \frac{\text{Total Available Time/ Month}}{\text{Customer Demand/ month}}$$

$$\text{Takt time} = \frac{6860 \text{ min}}{60 \text{ nos}}$$

$$\text{Takt time} = 114.33 \approx 114 \text{ min}$$

3.3.3 Takt Time Study

A graph was plotted with Takt time against cycle time, to understand the deviation of individual process from the Takt time. The graph thus got is plotted below. From the graph it is clear that the cycle time of finish boring and drilling is higher than the calculated Takt time. The figure 2 shows the graph plotted with takt time on x- axis and process on y- axis
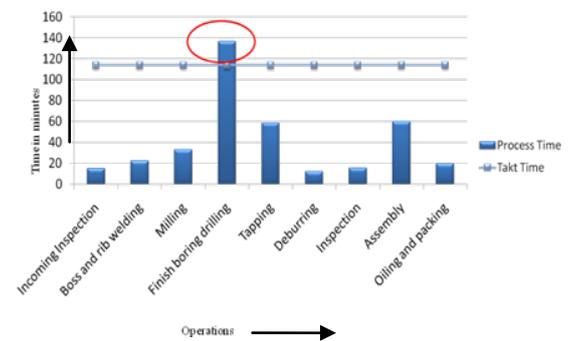

Fig. 2 Graph with cycle time plotted against processes

3.4 Analysis of High Cycle Time in Finish Boring & Drilling

To analyse the causes of high cycle time in finish boring and drilling a micro process mapping was conducted. This helped to find out processes/activities involved in concerned process. The figure 3 shows the micro process map for finish drilling and boring.
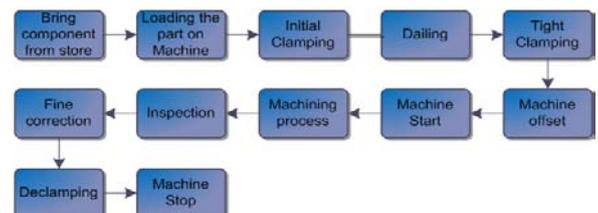

Fig. 3 Micro process map

3.4.1 Micro Time Study

A time study was conducted on the micro processes of finish boring and drilling operation to find out the time distribution for individual operation. When time distribution for individual processes was analyzed in detail it was found that 45% of the total cycle time of finish boring and drilling was for non value adding processes.
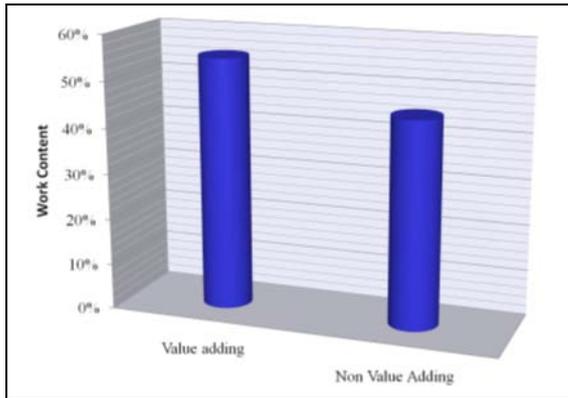
Fig. 4 Percentage value adding and non value adding activities

3.4.2 Cause and Effect Analysis

To analyze various factors that might be contributing to a high non value adding time in finish boring and drilling brain storming session was carried out and the most probable causes are shown with the help of a Cause and Effect diagram. A Cause and Effect Diagram is a tool that helps identify, sort, and display possible causes of a specific problem. It graphically illustrates the relationship between a given outcome and all the factors that influence the outcome. This type of diagram is sometimes called an "Ishikawa diagram" or a "fishbone diagram".

Many contributing causes for high non value adding time in finish boring and drilling is listed down using a cause and effect diagram. From that some of the major causes were short listed for corrective action. They are Manual setting, No proper location of parts, No SOPs, Time wasted on searching for tools.

3.4.3 Why-Why Analysis

It is a tool to identify root causes of a problem so that countermeasures can be applied to prevent reoccurrence. It is a method of asking "Why" till the root cause is reached

A why – why analysis was carried out to find out the reasons for high cycle time in Finish drilling and boring, The result obtained from Why- why Analysis showed that three causes contributed to high cycle time in finish boring and drilling. Which are manual setting, no 5S, and Lack of SOPs.

4. PROBLEM SOLVING

The why-why analysis pointed out the causes of high cycle time in drilling and boring. This chapter discusses about the solutions for the problems pointed out by why- why analysis.

4.1 Fixture

From the detail study of the process it was found that the manual setting of the component on to the machine contributed much to the non value added time. For every component loaded the operator had to manually dial the component which took a lot of time. Any improvement in this should contribute in reducing the lead time of the component.

4.1.1 Observation

Every time a component is loaded on to the machine The operator does the setting manually. This includes Initial clamping, dialing the component, final clamping, zero offset etc.

4.1.2 Solution

To design and manufacture a fixture that can reduce the time required for the initial setting.

4.1.3 QFD

Weightages	Customer Requirements
5.0	Should be able to use the existing CNC PRGM
4.0	Should be able to manufacture inside
4.0	Should be able to use the same reference
5.0	Should prevent operator Error
3.0	Easy to operate
3.0	Ease of loading and unloading component
2.0	Less maintenance
1.0	Should not damage the component
3.0	Reduce cycle time
3.0	Low cost

Table 2. Customer requirements and weightages

To translate the customer requirements of the fixture to design characteristics Quality function deployment was used. Quality Function Deployment is a systematic approach to design based on a close awareness of customer desires. Ultimately the goal of QFD is to translate often subjective quality criteria into objective ones that can be quantified and measured and which can then be used to design and manufacture the product. The customer specifications for the fixture are given above.

From the QFD it is clear that the shape must be given importance while designing the fixture. The second importance must be given to the size of the fixture during the design.

4.1.4 Designing

Three designs were proposed for the fixture. The designing were done with the help of CATIA R19 software the proposed designs are shown below.

4.1.4.1 Proposed Design -1

Design-1 uses the same reference as that of the existing CNC programme. In this design the component is placed in such a way that it is easy to make corrections in dimensions while executing the programme. It has quick changeover clamps and vice mechanism for easy clamping and unclamping.
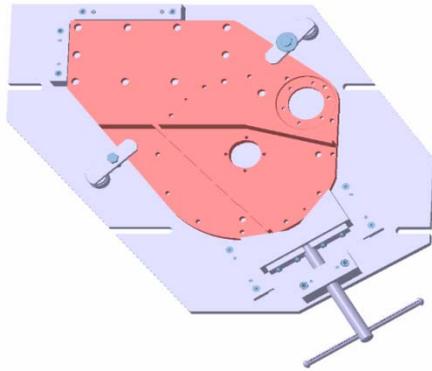
Fig. 5 Proposed design 1

4.1.4.2 Proposed Design – 2

Design – 2 follows the same mechanism as of design-1 for clamping and unclamping but the reference used is different from design-1. It also has a higher base plate area when compared to design one which makes it heavier.
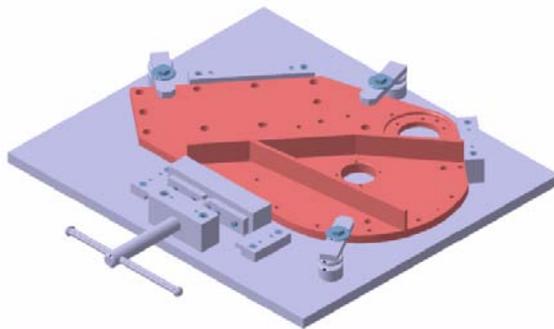

Fig.6 Proposed design 2

4.1.4.3 Proposed Design – 3

Design-3 follows the same clamping and locating mechanisms as that of design-1 and design-2. The difference is in the positioning of the component in the fixture as shown in Fig: 4.3
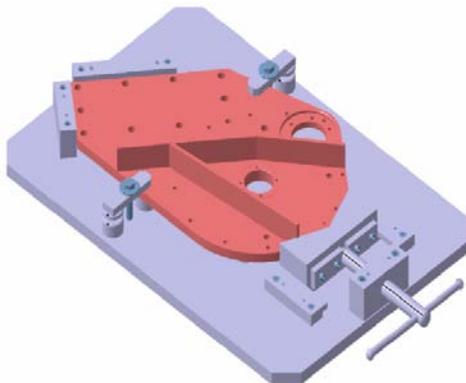

Fig. 7 Proposed design 3

4.1.5 Selection of Design

Full Analytical Criteria Method was used to select the most suitable design from the three proposed designs. The Full Analytical Criteria Method is a way of prioritizing a set of items by comparing each against each other along with the use of weighting factors

4.1.5.1 Full Analytical Criteria Method

The first step in the Full Analytical Criteria Method is to judge the relative importance of each criterion compared to every other criterion. To do that, an L-shaped matrix is made with all the criteria listed on both the horizontal and the vertical legs of the L. The numeric weightings for the first step is given below.

4.1.5.2 Numeric Weightings

1.0 = The criterion being considered is equally important or equally preferred when judged against the criterion it is compared to.

5.0 = The criterion Being considered is significantly more important or more preferred.
10.0 = The criterion is extremely more important or more preferred.
0.2 = It is significantly less important or preferred
0.1 = It is extremely less important or preferred
Add the values recorded in each column, and then add the column totals to get the grand total. Add the values recorded in each row, then add the row totals to get the grand total. Divide each row total by the grand total. This percentage is the weighting that shows the relative importance of each criterion.
The second step in making a priority matrix involve selecting a criteria and comparing each possible choice with every other possible choice by asking how well it will deliver that criterion. The numeric weightages for the second step is given below.

4.1.5.3 Numeric Weightings

1.0 = The choice being considered is equally able to deliver the desired criteria.
5.0 = The choice Being considered is significantly more important or more preferred.
10.0 = The choice is extremely more important or more preferred.
0.2 = It is significantly less important or preferred
0.1 = It is extremely less important or preferred.
After giving appropriate numeric weightings add the rows and columns and calculate the percentages. This is repeated for all the criteria. The final step in the Full Analytical Criteria Method is to merge the relative ability of a possible choice to deliver a desired criterion with the relative weighting of that criterion. To do this, an L-shaped matrix with all the options on the vertical leg and all the criteria considered on the horizontal leg is made. This matrix will give relative value of a number of options when considered against a collection of independent criteria, the option giving the higher option is taken for fabrication.
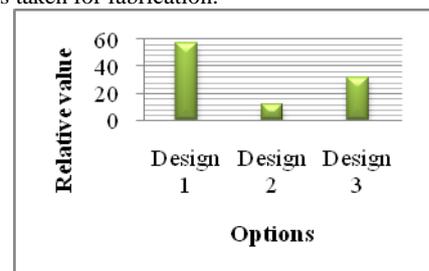

Fig. 8 Graph showing options against their relative value

The Full Analytical Criteria Method gives a higher Relative value to propose design one. So it is selected for implementation.

Fig. 9 Component clamped on fixture

Fig. 10 Machining using fixture

4.1.6 Outcome

1. Easy clamping and unclamping of the component
2. Eliminate component dialing
3. Reduces time spend for cleaning before loading another component.

4.2 Tool trolley

Another factor that came up during the analysis of the time study which contributed to the high non value added time was the time wasted looking for tools.

4.2.1 Observation

It was observed that lot of time was wasted looking for tools during the machining of side cover.

4.2.2 Solution

To introduce a tool trolley which can accommodate the tools required for machining of the side cover

Fig. 11 Tool trolley

4.2.3 Outcome

Eliminated the time wasted looking for tools and accessories.

4.2.4 S Implementations

5S is the name of a workplace organization methodology that uses a list of five Japanese words which are seiri, seiton, seiso, seiketsu and shitsuke.

Fig. 12 Before implementing 5S

Fig. 13 After implementing 5S

Fig. 14 QC before implementing 5S

Fig. 15 after Implementing 5S

4.3.1 Outcome

1. Cleaner Factory

2. Easy location & access to tools, consumables etc

3. Lower time loss searching for files, tools, fixtures etc

4. Brings in an attitude to question everything that is in sight

4.4 Standard Operating Procedure

Standard Operating Procedures, also known as SOPs, are created to provide specific documentation for various processes, usually highly-technical processes. The purpose of a SOP is to carry out the operations correctly and always in the same manner. It is found that, there was no standard operation procedure used for doing the setup process.

4.4.1 Observations

Less experienced workers were finding it difficult to work on the machine.
Operators were taking more time to do setting of the machine.

4.4.2 Implementation

SOP is implemented and it is displayed near the milling machine, so that operator can read it when doing the machining. Table 6.13 shows standard operating procedure for finish boring and drilling operation.

4.4.3 Outcome

Skilled and semiskilled operator can load the component

> * Rejection of the component is eliminated
> * Setting time for component setting will be reduced
> * Chance of errors and accidents get reduced

5. RESULTS AND DISCUSSION

5.1 Introduction

This chapter discusses the result obtained after the implementation of the improvements. A study has being conducted to find out the results after the implementation of the above improvements

5.2 Reduction in Cycle Time of Finish Boring and Drilling

The results of the comparison study showed that the lead time of side frame has being reduced from 136.12 to 86.75. The reduction of lead time was a result of the cascading effect of all the improvements carried out in the machine shop.
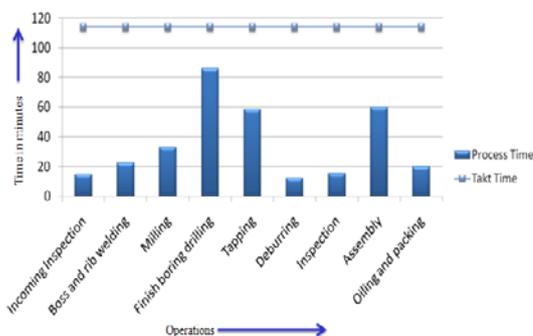

Fig. 16 Individual process time against takt time after improvements

The table below shows the comparison of process time in Finish drilling and boring before and after the implementation of improvements.

5.3 Reduction in Lead Time of Side Frame.

Time studies Carried out after the implementation of the fixture, tool trolley, SOP and 5S showed a considerable reduction in lead time of the process. The lead time of the process was reduced from the current 318 minutes to 268 which correspond to all most 15% reduction.
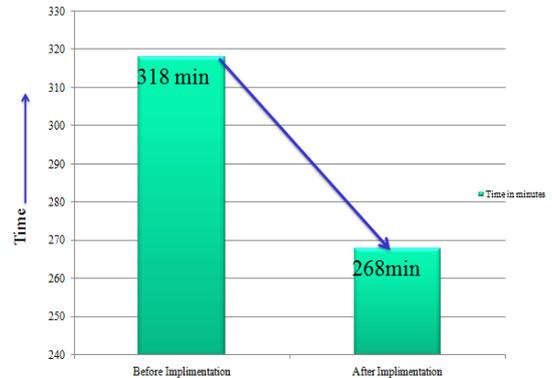

Fig. 17 Comparison of lead time after Implementation of Improvements

5.4 Calculation of Cost Benefits of the Project

After the implementation of the study there were cost benefits in terms of both labour cost and Machining cost. The total cost benefit obtained was the sum of cost savings in labour cost and machining cost which is shown in the tables below.

5.5 Validation

A time study was conducted to validate the results. The process time for individual operations were collected on four different dates as shown in the table below. The result of the time study validates a significant reduction in the cycle time of finish boring and drilling after the implementation of improvements.

Cost Benefit of the study	
Total Labour charge savings per annum	Rs.15680/-
Total Machining cost savings per annum	Rs.109760/-
Total Cost Benefits per annum	Rs.125440/-

Table 3. Total cost benefits of the project

6. CONCLUSIONS

In order to successfully complete the study by reducing the lead time of the side cover a background study was conducted to understand the problem and tools that can be analysed to analyse the problem. Various tools such as process mapping, time study, Takt time study, why-why analysis etc were used to analyse the present situation. From the analysis it was clear that a particular process contributed much to the total lead-time of the process as it had a cycle time higher than the Takt time. So this has being chosen as the pilot area to be attacked.

The process was further analyzed to find out the major activities contributing to the process and came to the conclusion that by implementing fixture and further improvements cycle time can be reduced and thereby reducing the total lead time which is the aim of the project.

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