REDUCING THE SET-UP TIME IN A CNC MACHINING LINE USING QCO METHODS

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1. Abstract

Setups determine downtime, capacity, product quality, and to some extent costs. As much as 60% of effective capacity can be lost to setups in machining lines. A SMED will help to eliminate unwanted activities, assists to move internal set-ups to external set-ups. The applications of other specific tools such as Poka-yoke, 5’S and the specially designed Quick change fixture and Quick change jaw mechanisms can further bring down the set-up time considerably low. The low changeover time will result in increased manufacturing flexibility for SME’s.

The purpose of this study is to find out the significance of quick changeovers in machining line. The Set-up activities are a vital part of the production lead-time and so affect overall product cost. Tools like Pareto analysis, root-cause analysis and method study have been used to analyze the existing procedure of set-ups. Based on the initial studies the pallet system was proposed for vertical machining centre as quick change fixture base on which the existing stage fixtures are located. Similarly the quick change jaw system was proposed for the turning centre. The fixture mechanisms were designed to eliminate 40% unwanted activities in the design stage itself.

The Quick Change Fixtures and Quick Change Jaws were designed and validated thru real time simulation. To achieve manufacturing excellence, SME’s must take advantage of latest technological developments to improve the productivity and profitability. The right implementation of the SMED can even become a competitive advantage of any SME’s; this would bring the more business to the organization. The report confirms that the seemingly extreme benefits claimed by SMED are achievable, but only with the assistance of modern technology. Results show reduction of average set-up time from 108 minutes to less than 16 minutes. We conclude that using SMED, the machine availability can be increased.

Keywords: SMED, QCO, Setup Time

1. INTRODUCTION

Traditionally, Indian manufacturing organizations have suffered from inherent deficiencies like poor responsiveness to changing market scenarios, low productivity, poor quality, poor cost effectiveness of production systems, stubborn organizational character and structures, uncertain policy regimes, low skill and knowledge base of employees, low production automation, non-motivating work environments, high customer complaints, high utility rates, high wastages associated with production systems, high labor rigidity, high internal taxes, and infrastructural glitches. The Indian industry is faced with the challenge of adopting cost effective manufacturing strategies for staying competitive.

Searock is a supplier to auto component OEM, they are supplying the fuel injector machined parts to OE. Some of the products are shown in Fig. 1 bellow.

Fig. 4 Searock’s Product Offerings

Manufacturing industries came into the occurrence of technological and economic transformations in the Western countries in the 18th -19th century. This was widely known as industrial revolution. It began in Britain and replaced the labour intensive textile production with mechanization and use of fuels.

Since then there have been many revolutions in the manufacturing industry such as Henry Ford’s moving assembly line, Taichi Ohno’s Toyota Production System and many more have advance the manufacturing industry [1].

1.1 Lean Manufacturing

Lean Manufacturing is the buzz word in the manufacturing industry now though it is derived from TPS and Ford methods. The aim of the lean manufacturing is to identify NVA’s in the manufacturing process and eliminating them systematically by employing the lean tools.

Lean aims to eliminate wastes along entire value streams, instead of at isolated points, creates processes that need less human effort, less space, less capital, and less time to make products and services at far less costs and with much fewer defects, compared with traditional business systems. Companies are able to respond to changing customer desires with high variety, high quality, low cost, and with very fast throughput times [2].

1.2 SMED

Single Minute Exchange of Dies is a philosophy where the target is to reduce all set ups to less than ten minutes. The area of study is to improve the productivity and increase product mix in a CNC machining line by enhancing the resource capacity utilization of the company by implementing the SMED.
technique. The study comes under the area of lean manufacturing system. The lean manufacturing basically talks about the identifying the non-value added activities in the existing process and eliminating those NVA’s methodologically by employing the different lean manufacturing concepts. SMED approach is shown in Fig. 2.

Fig. 5 Set-up Change Process [3]

McIntosh, Culley, Gest, Mileham, Owen (1995) illustrated about importance of activity categorisation before implementing the SMED. This process provides information about product, machine, tools, fixtures, fasteners, housekeeping and etc to prioritise activities and take up implementation in a rigorous fashion, with full commitment at all levels without any hurdles [4].

Patel, Shaw, Dale (2001) illustrated that how smaller organisations are approaching the set-up time reduction and mistake proofing. The paper mainly talks about the barriers of implementing these techniques such as lack of financial support, resistance to change, lack of strategic planning and lack of knowledge and training. In smaller companies always management hesitates to change [5].

Claire and Richard (2001) have talked about the fundamental requirements before implementing the SMED phase introduced by Shingo. The case study of textile industry in this paper reveals that the foundations for SMED can be built with following prerequisites, • Teamwork approach to communication; • Visual factory control; • Performance measurement; and • Kaizen to simplify both assessment & measurement [6].

Imen (2005) illustrated in one of his collection that how techniques like 5S’ and visual controls helps in successfully implementing SMED, showed that how to reduce trial runs and control and also expressed that SMED is not only suitable to industries it can also be used from bakery to the office works. The collection also shows that SMED is not the only approach to reduce set-up time [7].

Das, Baki, Li (2009) have illustrated changeover optimization. It addresses the issues of machine loading, tool allocation, and part type grouping with the intent of developing an operation sequencing technique capable of optimizing operation time, non-productive tool change times, and orientation change times. They have basically approached with computational method to solve these problems. [8].

Bikram Jit Singh, Dinesh Khanduja (2010) have talked about the manufacturing excellence. They have illustrated SMED as one of the technique for organisations to achieve manufacturing excellence. In the paper they have explained how the Indian SME’s are approaching these concepts. The paper basically talks about the implementation steps of SMED like how to separate internal & external set-ups, how to optimize, also talked about the cost analysis of set-up change [9].

- The literature survey reveals that the implementation of SMED will improve the productivity and reduces the running cost of the machines.
- The data gathering and analyzing the data with appropriate tools will certainly helps to identify the problems.
- The prerequisites are to be categorized before approaching the SMED for better results.
- Significance of operators’ training in order to make the system work, stabilize and to continuously improve the same.
- The importance organization involvement to make the successful implementation of the system [10].

2. PROBLEM STATEMENT

Due to high change-over time between the product changes the company is losing the production and is not able to cope up with the increasing demands from the customers. Currently the line is producing low product mix and high quantity which is piling up WIP. Due to this the cash is blocking in the WIP and since Searock is a service industry they have to have a high cash flow turnaround in order to gain more profit and less interest flow to the bankers. If Searock wants to be competitive in their service line they should aim at high product mix with less WIP in place.

2.1 Aim:

“To reduce set-up time from 2.5 hrs to less than 10 min on CNC machining line by employing SMED technique”.

2.2 Objectives:

- To carry out literature review on proven SMED techniques.
- To carry out web survey on advanced QCF techniques and quick change jaws.
- To study existing CNC machining line changeover process methodology.
- To segregate and optimize internal set-ups and external set-ups.
- To identify similarities in operations between all products and generalize cutting tools.
- To design feasible QCF’s for vertical machining centre.
- To design quick change jaw mechanisms for turning centre.
- To build project team for SMED implementation.
- To implement SMED and to measure the benefits.
- To standardise the process.

2.3 Methodology

- Literature review was carried out on SMED by referring journals, books, manuals and web published article to understand the essence, methods and benefits from the technique.
- Web survey was made on advanced QCF techniques to design better fixture mechanism and quick change jaw mechanisms to reduce turnaround time during change-over process.
The time and motion study was carried on existing changeover process and recorded to understand the time taken, process followed by the operators during the changeover process.

After the time study the activities were identified and segregated into internal set-up activity and external set-up activity.

The Cutting tool segregation matrix was prepared considering the similarities between the operations amongst all product lines and special purpose cutting tool design methodologies were proposed to reduce the number of cutting tool counts that are being used currently.

The quick change fixture designs were proposed by referring the advanced pallet system mechanisms for vertical machining centre to reduce internal set-up time and to accommodate multi products.

The quick change jaw designs were proposed for turning centres by referring the proven web research data to accommodate all product lines.

The design simulation was carried out to find out the benefits virtually before the actual implementation.

The estimated investments, payback period time and the economic benefits were calculated for the implementation of newly designed system with the help of real time simulation studies.

3. DATA COLLECTION AND ANALYSIS

The SMED methodology consists of two phases. In the first phase, a distinction is made between internal and external setup tasks. Internal setup operations are those that must be performed when the machine is stopped. These operations occur on-line to the machine. External operations are those that can be performed while the machine is in operation. It is more efficient to perform these tasks off-line from the machine. Once the operations are classified as either external or internal, the external operations can be moved off-line to reduce machine downtime.

The under-utilization of expensive capacity is bad enough, but lengthy setups have other undesirable effects on manufacturing resources. One of these is increased inventory as a result of manufacturing in larger lot sizes. Large lot sizes instituted to reduce the number of setups performed, result in an increased work-in-process (WIP) and finished goods inventories. Consistent with EOQ, production schedulers and planners frequently cite setup costs as a major factor in determining lot sizes.

To understand the severity at the site various analytical studies were carried out and are reported in the coming chapters.

3.1 Time Study

Initially the time study was carried out to understand the different activities involved, process methodologies followed and time take for those activities during the changeover process.

The activities were sub-grouped by considering the similarities to ease the further analysis process. The data is recorded in table 1 as shown bellow and further the column chart is plotted as shown in Fig. 3.

<table>
<thead>
<tr>
<th>Sub-grouped Activity for Pareto Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Parameter</td>
</tr>
<tr>
<td>Process Parameter</td>
</tr>
<tr>
<td>Adjustments</td>
</tr>
<tr>
<td>Human Casualty</td>
</tr>
<tr>
<td>Trial</td>
</tr>
<tr>
<td>Product Change</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Fig. 6 Average set-up time of activities

3.2 Pareto Analysis

After the time study, Pareto analysis was carried out to find out the potential activities to be targeted to solve the set-up problem. The calculations were carried out and are shown bellow in table 2.

<table>
<thead>
<tr>
<th>Causes</th>
<th>Avg. COT</th>
<th>Cumulative%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Parameter</td>
<td>56.00</td>
<td>95.7%</td>
</tr>
<tr>
<td>Adjustments</td>
<td>29.33</td>
<td>43.5%</td>
</tr>
<tr>
<td>Human Casualty</td>
<td>10.67</td>
<td>16.1%</td>
</tr>
<tr>
<td>Trial</td>
<td>6.67</td>
<td>6.2%</td>
</tr>
<tr>
<td>Product Change</td>
<td>4.67</td>
<td>10.6%</td>
</tr>
</tbody>
</table>

The Pareto analysis shown in Fig. 4 reveals that the first three causes cover 89.44% of the total avg. set-up time. The company has a real problem in process parameter setting, so there is need of process re-engineering.

3.3 Cause and Effect Diagram:

The cause and effect analysis was carried out to understand the potential root causes for the current problem of the company. The brain storming session was conducted and the many problems were listed in the...
session, further the potential causes were listed into the fish bone diagram shown in Fig. 5 bellow.

**Fig. 8 Cause and Effect Diagram**

### 4. SOLUTION PROCEDURE

The interpretations and the brainstorming sessions during the data gathering stage helped to frame the solution methodologies, they were framed as per the sub-grouped activity as explained in bellow Fig. 6:

- **Product Change**
  - Reduce Movement
  - Dedicate space within the cell

- **Process Parameter Setting**
  - Separating internal & External setups and optimizing them
  - Using the Flexible QCF-bases for VMC's
  - Using the Quick Change jaws for turning centers
  - Cutting tool segmentation to reduce the no. of tool change
  - QC line optimization through reduced set-up variations

- **Trials**
  - Enhancing repetitive performance of the line
  - Reducing trials through repetitive performance

- **Adjustments**
  - Use of proven QCF's and chuck jaw with minimal adjustments
  - Employing plant-wide in the setup change

- **Human Casually**
  - Initiating reward programs like (Target Achiever of the month)
  - Motivational Programs

**Fig. 9 Solution Framework**

While analyzing the setups for the machining centres, the machines were shut down while the mounting bolts for the new fixture were being located. This task was considered part of the internal setup process. As a result of this the set-up times were considerably high. If the similar activities are moved to external set-up process then the set-up time would come down by 50%. Typical activities during this phase include pre-positioning of fixtures and tools needed for the next setup.

In the second phase of SMED, all aspects of the setup, both internal and external, are streamlined to make them more efficient. Internal setup efficiency results in labor savings and less downtime machine capacity. External efficiency does not directly improve downtime, but gives better utilization of labor. Since at the factory or line level labor can be a constraint on doing setups, it can also indirectly reduce downtime, as we will illustrate. The methods used are similar to business process re-engineering: look at all the activities that go on, and design faster ways to do them. The new methods often include: replacing general tooling, fixtures, and adjustment mechanisms such as screws with special purpose equivalents which require little or no adjustment, and will only fit in the correct orientation; using color coding and spatial layout to make items easier to find and harder to make errors with; using floating workers who assist machine operators with each setup; pre-stationing or pre-loading raw materials for the next batch. Small, highly specific changes to machines and even to product designs are sometimes used. Wherever possible, fool proofing is used to either make errors impossible, make them obvious when they occur, or reduce their effects.

Based on the solution frame work the new QCF and quick change jaws were proposed. These design change are directly impacting on the process parameter set-up time and are estimated to bring down the time by more than 75%. Process re-engineering is estimated to bring down the set-up time by another 10%. Totally the project target is to bring down the set-up time by 85%.

#### 4.1 Quick Change Jaw Concept Design

Currently the operators are using the traditional lathe chucks for each product and they are replacing the whole chuck due to product geometry variations. For one of the product operator is replacing only jaws to accommodate the product. The traditional jaws are used currently and the replacement time of the jaw is considerably high. Due to the high number of part count, also trial and error alignment of bolts and tightening and loosening the bolt time is more.

To avoid the trial and errors and to eliminate the whole chuck replacement theory the new quick change jaws are designed. And the jaws are designed to accommodate all the three products on to the single chuck.

In the quick change jaw concept as shown in Fig. 7 there is hard jaw which is permanently attached to the chuck body and only the soft jaws are changed to accommodate the multiple product. To avoid the adjustments the dowel pin holes are provided on both the soft and hard jaw to ease the alignment. Earlier the operator had load two different chucks to run three products due to the product geometry variation and now the larger existing chuck is used and only the top soft jaws are going to be changed.

**Fig. 10 Proposed Quick change jaw Concept**

The bellow Fig. 8 shows the schematic arrangement of changeover process on turning centers. The special jaws arrangements are shown for individual...
products which were designed to reduce the COT process time.

Fig. 11 Proposed Quick change jaw Process

4.2 Quick Change Fixture Concept Design

The current fixtures are fixed directly on to the machine bed and every time the product change happens the machine has to be shut down and then traditionally all the nuts and bolts are taken off and then the fixture. Similarly the fixture loading is traditionally done to accommodate the next product in queue. In this case also the part counts are more as explained for the chuck concept and this is the main reason for the high changeover time.

Currently the production is run on three VMC’s and the capacity utilization is very low due to the high changeover time.

The proposed design has two major halves one is the fixed half and the other one is moving half as shown in Fig. 9. The working procedure of the QCF goes like this:

- The base plate will be permanently fixed on to the machine bed with the nuts and bolts.
- The Pallet will be accommodated with the products.
- The QCF works on pick and place mechanisms.
- The locking of the pallet works on snap mechanism and for unlocking pneumatic air is used.

Fig. 12 QCF Design

The bellow Fig. 10 shows the schematic arrangement of changeover process on vertical machining centres. The pallet arrangements are shown for individual products which were designed to reduce the COT process time.

Fig. 13 Proposed QCF Process

Two different variants were proposed for the implementation it was basically for accommodating the existing fixtures on to the pallet system.

5. DESIGN VALIDATION STUDIES

The feasibility study was also carried out for the design which again by involving all the concern people. The analysis reveals the system implementation feasibility.

Likewise the feasibility study was carried out for jaw change system also and the designs were freeze as explained in the earlier chapter.

As part of validation process, the proposed designs were simulated considering the real time processes on the line. Simulation was carried out in the Solid works shown in Fig. 11 bellow and the results were gathered to support the expected results from the new concepts.

Fig. 14 Simulation steps

6. RESULTS AND DISCUSSIONS

The virtual analytical results were brought out to consider the SMED techniques proposed are feasible. After the activity segregation as internal and external activities some were eliminated in the design stage itself, some were converted to random occurrence and many were converted to externals. Only few critical activities were internal and optimized.

Overall setup changes included addition of a third operator to most lines and shifts.

Since the third operator has less effect on setup times and it reduces line downtime. It also leads to reduced labor content and elapsed time in both on-line
and off-line setup. This reduces labor cost and increases production flexibility. The plant did not keep systematic data on magnitude and causes of rework. Miscellaneous benefits, many unanticipated. For example, it now takes less than five minutes to reconcile the bill of materials to the placement machine program and find discrepant part numbers. As a result this is being done well in advance, and when problems are found they no longer disrupt the actual parts preparation operation.

6.1 Expected Set-Up Time

The table 3 shows the expected set time is down by six times less than the current time. The set-ups were optimized from internal type to external type, many were eliminated and some were minimized.

Table 20 Expected COT

<table>
<thead>
<tr>
<th>Process Parameter</th>
<th>1st set-up Turning Time(Min)</th>
<th>2nd set-up Turning Time(Min)</th>
<th>3rd set-up Machining Time(Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting</td>
<td>9</td>
<td>7</td>
<td>11.5</td>
</tr>
<tr>
<td>Adjustments</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Human Casualty</td>
<td>1</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Trial</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Product Change</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>13</td>
<td>18</td>
</tr>
</tbody>
</table>

6.2 Estimated Investments

It is important to have the expected investment and the payback period of the investments. For the current implementation the following estimations are proposed shown in table 4.

Table 21 Cost Estimation of Implementation

<table>
<thead>
<tr>
<th>Description</th>
<th>Qty/hrs</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pallet Set</td>
<td>3 Sets</td>
<td>INR 55,800</td>
</tr>
<tr>
<td>Quick Change Jaw</td>
<td>3 Sets</td>
<td>INR 9,600</td>
</tr>
<tr>
<td>Additional Machining</td>
<td>7 Hrs</td>
<td>INR 5,250</td>
</tr>
<tr>
<td>Assembly &amp; Tryout</td>
<td>12 Hrs</td>
<td>INR 2,400</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>INR 73,050</td>
</tr>
</tbody>
</table>

It is always important for service industries like Searock to concentrate on new technology rather than concentrating on deliveries.

6.3 Economic Benefits

The table 5 shows the expected economic benefits from the SMED implementation. These results were drawn by considering the operation period of one year and the results reveals that the benefits are huge in the long run.

Table 22 Economic Benefits

<table>
<thead>
<tr>
<th>Description</th>
<th>Old COT</th>
<th>New COT</th>
<th>% Change</th>
<th>Saving/ Yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setup Downtime,</td>
<td>2.6</td>
<td>0.3</td>
<td>88.61%</td>
<td>INR 576,700</td>
</tr>
<tr>
<td>Off-line setup time,</td>
<td>3.1</td>
<td>1.05</td>
<td>66.13%</td>
<td>INR 75,200</td>
</tr>
<tr>
<td>Line operators</td>
<td>2</td>
<td>3</td>
<td>50.00%</td>
<td>-INR 96,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>INR 555,900</td>
</tr>
</tbody>
</table>

The expected investments for the SMED technique, for the tooling as shown earlier INR 74,000 (one time investment) and for an additional operator cost about INR 96,000/yr. The total investment is about INR170,000 The economic benefit calculated comes to about INR 555,900 excluding the operator cost. The period for the one time investment amount is less than six months. The economic benefits calculation clearly shows there is lot to gain from this investment in the long run for the company.

6.4 RESULTS COMPARISON

The comparison chart as shown in Fig. 12 clearly shows that there is huge opportunity for improvement in the set-up time. The set time is going to be down by six times lesser than the current time.

Fig. 15 Result Comparison

7. SUMMARY

From the present study, we find reduction of average set-up time from 108 minutes to less than 16 minutes. We thus conclude that using SMED, the machine availability can be increased.
8. REFERENCES


