Overall Equipment Effectiveness Improvement by TPM and 5S Techniques in a CNC Machine Shop

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Abstract

In the generation of agile manufacturing, the machines and its functions are also becoming complex. OEE of a machine plays an important role in present scenario where delivery and quality are of prime importance to customer. The paper reports a case study for improving OEE with help of TPM and 5S techniques using a systematic approach.

The present aimed at minimizing the breakdowns, increasing performance and quality rate of machine thus improving the effectiveness. Initially the machine history was analysed which helped in finding the bottleneck machine. The OEE was found to be 43% in the identified bottleneck machine. Further, a TPM team was formed to devise a systematic approach to improve the effectiveness. The project has been addressed in three aspects; namely Availability, Performance and Quality which quantify OEE of a machine. The TPM techniques such as Preventive Maintenance, Cleaning with Meaning, Pokayoke & Kaizen were effectively applied on the machine.

The result obtained from the TPM approach showed that the OEE was improved from 43% to 72% which indicated the desirable level in all manufacturing industry. To sum up, total saving per annum due to increased effectiveness was around Rs 4,53,000/-. 

Key Words: Overall Equipment Effectiveness (OEE), TPM, SOP, Kaizen, Pokayoke and 5S.

1. INTRODUCTION

In this age of agile manufacturing the global competition characterized by both technology push and market pull has forced the companies to achieve world-class performance through continuous improvement in their products and processes. Today, various innovative techniques and management practices such as total preventive maintenance (TPM); total quality management (TQM); business process reengineering (BPR); enterprise resource planning (ERP) and just in time (JIT), etc. are becoming popular among the business houses. [1]

Abbreviations

OEE Overall Equipment Effectiveness
SMED Single Minute Exchange of Dies
SOP Standard Operating Procedure
TPM Total Particulate Materials
TQM Total Quality Management

TPM has been depicted as a manufacturing strategy comprising of following steps:

- Maximizing equipment effectiveness through optimization of equipment availability, performance, efficiency and product quality;
- Establishing a preventive maintenance strategy for the entire life cycle of equipment;
- Covering all departments such as planning, user and maintenance departments;
- Involving all staff members from top management to shop-floor workers
- Promoting improved maintenance through small-group autonomous activities.

Fig. 1 TPM Pillars

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Fig. 2 OEE Methodology

This metric has become widely accepted as a quantitative tool essential for measurement of productivity in manufacturing operations. The OEE measure is central to the formulation and execution of a TPM improvement strategy. TPM has the standards of 90 per cent availability, 95 per cent performance efficiency and 99 per cent rate of quality. An overall 85 per cent benchmark OEE is considered as world-class performance. This case study aims in bringing the OEE near to 75% and gradually move up towards world class manufacturing. [2]

TPM employs OEE as a quantitative parameter for measuring the performance of a production system. OEE is the core metric for measuring the success of TPM implementation program (Jeong and Phillips,
The overall goal of TPM is to raise the overall equipment effectiveness.

\[ \text{OEE} = \frac{\text{Availability (A)} \times \text{Performance efficiency (P)} \times \text{Rate of quality (Q)}}{100} \]

where

\[ \text{Availability (A)} = \frac{\text{Loading time – Downtime}}{\text{Loading time}} \times 100 \]

\[ \text{Performance efficiency (P)} = \frac{\text{Processed amount}}{\text{Operating time/theoretical cycle time}} \times 100 \]

\[ \text{Rate of quality (Q)} = \frac{\text{Processed amount – Defect amount}}{\text{Processed amount}} \times 100 \]

Fig. 3 Calculation of OEE [5]

2. PROBLEM DEFINITION

Historical organizational data showed the Overall Equipment Effectiveness (OEE) value was very low compared to the general manufacturing scenario. Due to which the machines were not utilized effectively and hence production rate and volume was affected.

Figure 4 shows the OEE value of 2 machines LT-2 & Max 65 respectively. These machines had lower OEE values compared to other machines. These machines were a part of cell in line production. They were hindering line efficiency.

The graph clearly shows the OEE values of the machines for the past 3 months. LT-2 has 43% efficiency which was far below world class performance of 85%.

2.1 Problem Statement and Project Objective

This study focused on achieving the following objectives using TPM & 5S methodology:

- Analysis the problems using Quality tools & evaluate through Statistical Process Control techniques.
- Redesigning of cell system to have better productivity and reduction of head counts in the cell.
- Training of employees to achieve autonomous maintenance of the machines in the cell layout.
- Maintaining 5s in the machine surrounding.
- Replicating success across the different machines in the cell layout.

3. MODEL CONSTRUCTION AND SOLUTION

The project focused on improving the OEE of the machines as it was the major concern for lower productions, loss of time and money. Figure 5 data shows how it was affecting the production.

The figure 5 shows the breakdown time in minutes for the month of June, July & August respectively. As we can see the LT-2 machine had more breakdown minutes in every month.

The total Breakdown minutes of each machine for 3 months is given below:

- LT-2 Machine – 30,100 min
- LT-16 Machine – 12,300 min
- Max-65 Machine – 14,000 min

Production Loss: It can be seen that total of 30,100 minutes of production was lost due to the machine breakdown which comprises of around 4 weeks of production for the span of 3 months.

Time Loss: The cycle time for single part on LT-2 was 4 min, hence a loss of 30,100 min of production means: 30,100 / 4 = 7525 parts.

Money Loss: For machining cost/piece is Rs 120, hence a loss for 7525 parts would be 7525 * 120 = Rs 9,03,000/-. The data gives the clear picture of breakdown of machines and the losses which the company was facing.

Based on the data and considering the performance factor, availability factor & quality factor, OEE of the machines was computed. Figure 6 shows the OEE for three months consecutively.

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As it can be seen in the figure 7, there are 3 machines in the cell in which 2 machines are for turning LT-2, LT-16 and S33 for milling. Conventional drilling,
slitting and deburring machines are present in the line in addition to CNC machines.

![OEE of machine for 3 months](image)

**Fig. 6 OEE details of 3 months**

**Fig. 7 Cell layout in the company**

From the figure 8 we can clearly see that LT-2 machine is the bottleneck machine in the cell and it was hindering the production of the cell due to its high cycle time and frequent breakdowns.

On an average we get 36,900 min of productive time considering 410 min per shift excluding all the breaks in the shift. Considering 120 pieces per shift on average we get

\[
120 \times 190 = 22,800 \text{ Rs / shift}
\]

If we consider 10,000 min (per month), 0.27% of time was lost in breakdown of machine. Hence,

\[
0.27 \times 22,800 = 6156 \text{ Rs / month}
\]

Total of 6156 Rs was lost every month due to the breakdown of the machine which indeed is a huge loss of time & money in the industry standards. It was necessary to improve the OEE of LT-2 and hence the production line through TPM and 5s activities in the cell.

**Fig. 8 The comparison’s of machines**

![Machine layout in the cell](image)

**Fig. 9 Machine layout in the company**

As we can see in the flow chart (figure 9), LT-2 is in the middle of cell. The parts processed from the LT-16 are piled up before LT-2 because cycle time of LT-16 was 3 min & LT-2 was 4 min. Due to the slow cycle rate & breakdowns, the parts are not sufficiently passed on to next m/c for processing and hence causing the stoppage of line. Thus hindering the production and reducing the efficiency of the downstream machines.

3.1 Analysis for Low OEE

Figure 10 shows the cause and effect diagram which indicates the aspects to take corrective action. Operator Awareness: For any machine to run effectively the operator should be well experienced and capable enough to handle the machine. The operators were not well trained to operate the machine and any minor abnormalities found could not be rectified. Though the machine was capable of producing quality goods, due to manual error the quality was lost.

Vibration: This was the most common problem in all the machines. The vibration increases as the machine gets old or due to clamping problems. Due to constantly moving parts inside the machine the wear and tear of the parts are natural. The vibration level is more then this wear tends to happen faster and thus resulting in breakdown of the machines.

Coolant Leakage: One of the main reasons for breakdown of the machine was friction between moving parts, which can be reduced by providing adequate amount of coolant. Excessive coolant leakage was found in the present study and coolant had to be refilled daily.

Lack of standardized procedure: Operating procedure was not given. No shadow board near machines about the operating procedure of machines and lack of visual management made it difficult for any operator to produce the parts consistently. SOP (Standard Operating Procedure) was not in place. In addition, Process Flow chart was not provided.

Maintenance Frequency: Periodic maintenance was not in place and only when the m/c stopped, the maintenance was carried out. Preventive maintenance was not planned for any of the machines in the cell.

Checklist Points: The critical points of the machine, which required frequent attention was not identified. This led to frequent breakdown of the machine. Lack of checkpoint identification may be one of the reasons for low OEE.

<table>
<thead>
<tr>
<th>S/No</th>
<th>Machine (Model)</th>
<th>OEE (%)</th>
<th>Cycle Time (Minutes)</th>
<th>Parts/Shift</th>
<th>Breakdown (Minutes)</th>
<th>Average of 3 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LT-16 (ACE)</td>
<td>60</td>
<td>3</td>
<td>135</td>
<td>12,100</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>LT-2 (ACE)</td>
<td>40</td>
<td>4</td>
<td>115</td>
<td>34,100</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>S-53 (Mazino)</td>
<td>62</td>
<td>3</td>
<td>140</td>
<td>11,800</td>
<td></td>
</tr>
</tbody>
</table>
3.2 Corrective Action

The reasons for low OEE were listed. A systematic approach to increase OEE to acceptable level was attempted using TPM and 5S techniques. The following section provides information about the approach.

Project was divided into three parts as OEE is product of three parameters namely 1) Availability 2) Performance 3) Quality.

Formation of TPM Team for the improvement of OEE: A TPM team was formed in the company which involved operators, supervisors and managers (figure 11). The team motive was to initiate TPM activities in the cell and then to horizontally deploy it to the other stations of the company. Team decided to convert the bottleneck machine into the model machine. This was done by educating the operators about the importance of TPM and was necessary in the present situation.

Availability approach: The teams were then given assignments on different parts of the m/c where they had to do cleaning with meaning, i.e. the purpose of this was to find the abnormalities of the machine and then act upon it suitably. The team members were segregated according to the machine parts and they were given certain responsibilities which they had to do while cleaning with meaning. The outcome of the cleaning with meaning programme is shown further.

TPM tags were used for identification for tagging the abnormalities found in the machine. The abnormalities found in the machine are in figure 12 which is tagged and made easy for identification.

Performance approach: To improve performance, machine cycle time was focused upon which was the second cause for inefficiency. Kaizens were adopted on the machine. To reduce the cycle time two points were considered,

1) To combine the tools if it is feasible
2) To see the operations and to see whether it could be improvised

From the options it was found that both the possibilities could be implemented to improve the current process. The modification done is explained in the following section.

TPM team members conducted a brainstorming session and came with some ideas and created a Cause & Effect diagram shown in figure 14 for the high cycle times.
Improper loading: Sometimes due to the operator laziness and monotonous nature of the work, job was loaded improperly. The dimensional variation may occur due to the low pressure created on job and extra time was required to do machining.

Vibration: The vibration in any machine was undesirable resulting in loosening of tool post and hence loss of machining effectiveness of the tool.

Material Hardness: It depends upon the nodular structure and the carbon content. During heat treatment they may vary which makes the machining difficult and this can result in high machining time. Usually in a lot of 200 pieces 2 pieces are found to be hard.

Lack of suitable inserts: Generally carbide inserts are used for machining of cast materials. The grade of inserts plays an important role in effective machining. The inserts used could machine 200 pieces and further usage caused slowdown of machining.

Tool change frequency: The maintenance chart did not specify the tool change frequency. The tool was only changed when it was broken, indicating that the later parts of the lot taking longer time for machining than earlier ones due to wear and tear of the tool. [4]The team focused on actually improving the operation speed itself rather than searching for faults in process. After recording the time of each of operation they found out that on two operations the process could be improved and made faster. The improvements done are shown below.

1) To reduce the cycle time by combining the tools for k type (a type of job machined in that machine) and 2nd set up operations

The idea was to combine the tools, which would reduce the tool from 4 to 2 hence reducing the cycle time.

The figure 15 shows the tools which were used before combining of the tools, diameter 15.5, 12.5 mm, and boring bar rough and boring bar finish were used separately earlier.

![Fig. 13 Pareto graph of abnormalities](image)

![Fig. 14 Cause and effect for high cycle time](image)

![Fig. 15 Tools used for K type operations](image)
As it can be seen from the figure 3.11 stepped carbide drill was used instead of diameter 15.5 mm crown lock drill, diameter 12.5 mm HSS drill and CCMT boring bar rough. This resulted in reduction of cycle time from 4 to 3 minutes.

**Fig. 16 Combined tools used for K type**

2) To eliminate the extra setting by providing a rigid clamping in the first set up.

The idea was incorporated as the processing time was more due to the second setting leading to faulty clamping, lesser cutting area and gripping area. Figure 17 shows the second set up wherein the cycle time is higher. The idea was to eliminate the second set up as it could be done in first set up itself with some clamping alterations. [2]

**Fig. 17 CNC set up details**

A revised process plan was made for single set up with holding at bigger ends of the part so that the pressure can be high and the cutting area could be increased. A photograph of the clamping device is shown in figure 18.

**Fig. 18 Graph showing the details of set up**

**CNC Set up details of LT-2 k type**

<table>
<thead>
<tr>
<th>Time in minutes</th>
<th>2000</th>
<th>3500</th>
<th>5000</th>
<th>7500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting Time/Min</td>
<td>1.71</td>
<td>1.76</td>
<td>1.93</td>
<td>2.06</td>
</tr>
<tr>
<td>Load/Unload</td>
<td>0.20</td>
<td>0.24</td>
<td>0.28</td>
<td>0.32</td>
</tr>
<tr>
<td>Approve</td>
<td>0.10</td>
<td>0.16</td>
<td>0.20</td>
<td>0.24</td>
</tr>
<tr>
<td>Total</td>
<td>2.01</td>
<td>2.16</td>
<td>2.39</td>
<td>2.54</td>
</tr>
</tbody>
</table>

Figure 19 shows the total time required for the machining with 1st and 2nd set up which sums up to 2264 minutes for a batch of 500 nos (per day)

Figure 19 shows the combined set up with the help of holding clamp designed especially for operation. The total set up time was reduced to 1599 min compared to 2264 min.

**Fig. 19 Graph showing improved time**

The above improvements helped in improving the cycle time from an average of 4 min to 3.5 min.

Further Kaizens were carried out on the machine to improve the setting time, to reduce the operator movements and make the setting hassle free.

From the figure 20 it can be seen that the total operator movement was reduced from 5 meters to 0.5 meters resulting in less operator movements. The idea was incorporated during the setting time when operator was moving a lot instead of setting. Further, a shadow board was made near the machine and required tools for machine was placed beside it as seen in the figure. Totally 4 m per setting was reduced and this was horizontally deployed to all of the remaining machines [3]

**Fig. 20 Kaizen sheet**

From the Figure 21 it can be seen that coolant leakage was observed and it had to be cleaned every shift due to overflow. The root cause for the problem was that the puppet spring was missing in the turret due to which the coolant overflow occurred.
The coolant had to be filled every shift and the tool wear and tear was more due to insufficient supply and overheating of tools. The team then made a one point lesson (OPL) and displayed in shadow board and spare springs were given to operator and instruction was given on removing & replacing the springs.

Per month the breakdown on an average is
Before implementation of TPM
30,000 / 3 = 10,000 min and 10,000 / 30750 = 32%
35% of time was lost in availability of the machine only due to breakdown.
After implementation of TPM
9200 / 3 = 3067 min and 3067 / 30750 = 9.9% ~ 10 %
10 % of time was lost in availability of the machine presently due to breakdown and hence 90% of time was available for production.

Improvement in availability was 22%

4.2 Performance Results

A total of 10 hrs of total set up time was saved by the combination of two operations.

To calculate the performance of the machine we need to consider the parts produced in the shift using the cycle time. The performance of machine is based on the output per shift

Before
Cycle time = 4 min
Parts produced = 68 parts / shift
Set up time = 37 hours
Due to the heavy set up time involved the parts produced are very less resulting in low performance.
Performance = (cycle time * quantity produced) / total available time
After = ( 4 * 68 ) / 410 = 67 %
Cycle time = 3 min
Parts Produced = 120 / shift
Set up time = 26 hours
Performance = ( 3.5 * 100 ) /410 = 85 %
Improvement in Performance was 18%
4.3 Quality Result

The machine was producing quality products with just 5% rejection rates. The quality level did not demand any improvement. However it was necessary to sustain the current level of quality.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
<td>68%</td>
<td>90%</td>
</tr>
<tr>
<td>Performance</td>
<td>67%</td>
<td>85%</td>
</tr>
<tr>
<td>Quality</td>
<td>95%</td>
<td>95%</td>
</tr>
<tr>
<td>OEE</td>
<td>43%</td>
<td>72%</td>
</tr>
</tbody>
</table>

Quality sustained at 95%: Results

4.4 Cost Savings

The cost of component after machining – 190 Rs
Casting cost – 110 Rs
Machining contribution on the component = 40%
Machining contribution of LT-2 m/c = 15% = 0.15*80 = 12 Rs/pc
Expected output = 140 pc/shift
Added value per shift = 140 * 12 =1680 Rs
Added value per Day = 1680* 3 =5040 Rs
Value added per day before the project is = 5040 * 0.40 =Rs 2016/- (considering 40% of OEE)
Present value added per day is = 5040 * 0.70 = Rs 3528/- (considering 70% of OEE)
Therefore extra income of Rs 1512/- per day.
Hence 1512*300 = Rs 4, 53,600/- per annum.
Net saving of Rs 4, 53,600/-

5. CONCLUSION

The performance of 72%OEE was attained i.e. an increase of 28% in OEE which would represent annual earnings of Rs. 5 lakhs. To achieve this target, efficient maintenance was in place, Autonomous maintenance teams were developed and better communication and teamwork work was promoted. The company devised an efficient data recording systems, so that up to date and accurate information was made available to management. The following points has given competitive advantage to the company as, [5]
- OEE parameters were focused with systematic approaches
- Availability, Performance and Quality are the three focused parameters
- Availability was improved from 67% to 90%, Performance was improved from 68% to 85% and Quality was sustained at 95%.
- To increase the OEE all the three parameters had to be increased individually.
- 5S was implemented in the cell layout.
- Due to increase in OEE the production rates and the delivery time was improved.
- Approximately around Rs. 5 lakhs per annum was saved due to increase of OEE

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