Overall Equipment Effectiveness Improvement of Annealing Furnace by Implementation of Total Productive Maintenance (TPM) - A Case Study

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Abstract

In manufacturing industry proper maintenance is necessary in order to get maximum production without any loss due to failure of machines or any mechanical parts. Maintenance costs can account for 15-40% of total manufacturing costs. Appropriate maintenance management can help to minimize these costs. Quality and Maintenance of manufacturing systems are closely related functions of any organization. Today’s competitive environment requires more effective equipment management. Total productive maintenance (TPM) and Total Quality Management (TQM) are the new approaches along with other concepts to achieve World Class Manufacturing system. The goal of any TPM program is to advance productivity and quality along with increased employee spirits and job satisfaction. In this paper experience of implementing Total Productive Maintenance is shared and investigated for annealing furnace in Bright Bar shop of an integrated steel plant. Overall Equipment Effectiveness is used as the measure of success of TPM implementation. The various losses linked with the overall equipment effectiveness are determined. The TPM pillars are implemented in order to eliminate losses and to improve productivity. The data before and after TPM implementation were compared. The analysis concludes that focused TPM implementation over a reasonable time period can advantageously contribute towards significant manufacturing performance improvements.

Keywords: Total Productive Maintenance (TPM), Overall Equipment Effectiveness (OEE), Annealing Furnace, Equipment Management, TPM Implementation

I. INTRODUCTION

In today’s competitive environment the manufacturing companies are facing many challenges to achieve the goals of the organization successfully. The maintenance management is among one of the problems faced by them commonly. Maintenance costs can account for 15 to 40 % of total manufacturing costs. Appropriate maintenance management can help to minimize these costs. One approach for improving the performance of maintenance activities is to implement and develop TPM strategy.

TPM is defined as an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns, and promotes autonomous maintenance by operators through day-to-day activities involving the total workforce [1]. TPM addresses equipment maintenance through a comprehensive productive-maintenance delivery system covering the entire life of the equipment and involving all employees from production and maintenance personnel to top management [2].

In the highly competitive environment, to be successful and to achieve world-class-manufacturing, organizations must possess both efficient maintenance and effective manufacturing strategies [3]. TPM represents a shift in the way progressive world-class companies think about maintenance. It is a radical departure from the traditional view of breakdown maintenance. TPM is a methodology and philosophy of strategic equipment management focused on the goal of building product quality by maximising equipment effectiveness [4].

Total productive maintenance (TPM) is new maintenance strategy developed to meet the new maintenance needs, TPM is an American style of productive maintenance which has been modified and improved to fit in the Japanese industrial environment [5]. TPM is a maintenance system defined by Nakajima [1] in Japan, which covers the entire life of equipment in every division including planning, manufacturing, and maintenance. It describes a synergistic relationship among all organizational functions, but particularly between production and maintenance, for continuous improvement of product quality, operational efficiency, capacity assurance and safety [8]. A well-conceived TPM implementation program not only improves the equipment efficiency and effectiveness but also brings appreciable improvements in other areas of the manufacturing enterprise [9].
II. THEORETICAL FRAMEWORK

S. Nakajima, [1] is also known as the godfather of TPM. His book introduction to TPM explains that maintenance techniques are held responsible for completing maintenance tasks within a scheduled time frame while still meeting production constraint. The main objective of TPM is to achieve a reliable manufacturing system [3]. Ahuja and Kumar investigated the effects of successful TPM initiatives on competitive manufacturing. Their study also examined the implications of strategic TPM implementation initiatives in an Indian manufacturing organisation [4]. Jagtar Singh, Vikas Rastogi and Richa Sharma, [10] reviews all the Total Productive Maintenance (TPM) Pillars, TPM Implementation methodology and the contribution of TPM towards improving manufacturing performance. Kadiya Pinjal Navinchandra, [11] provides a review of the goals and benefits of implementing Total Productive Maintenance, and also focusing on calculating the overall equipment effectiveness in one of Steel Company in India, and it also discuss the big six losses in any industry.

Ranteshwar Singh, Ashish M Gohil, Dhuval B Shah, Sanjay Desai, [12] explains the implementation of TPM in a machine shop and identifies the loss associated with equipment effectiveness. All the pillars of TPM are implemented in a phased manner eliminating the losses and thus improving the utilization of CNC machines. Chetan S Sethia, et al [13] focusing on calculating the overall equipment effectiveness in Rolling Mill, and it also discuss what called the big six losses in any industry (the quality, availability and speed). After calculating the OEE of the company a result company achieved 93.48% in quality factor of overall equipment effectiveness equation and 70.90% in availability where in performance it got 90.03% and the result is compared with the World class OEE. TPM system is a maintenance plan involving a general new concept for maintenance of machinery and equipment. Ultimate goal of TPM system is to increase production in order to increase spirit and satisfaction of the workers about the work [14]. Raffaele Iannone and Maria Elena Nenni, [15] gives the introduction to the fundamental of OEE, and also some interesting issues concerning the way to implement the index are investigated.

III. RESEARCH METHOD

This research is based on improvement of overall equipment effectiveness and reduction of total cost of maintenance of annealing furnace in bright bar department of an integrated steel plant. The work started with the identification of various problems such as time losses, defect in quality, performance of machineries and operators etc. These problems are then solved out by implementing TPM strategy. There is some visual improvement and increased productivity is obtained after successfully application of TPM.

The steps involve in the methodology section consists of selection of area for implementation of TPM, selection of equipment, selection of parameter involved, finding various losses and implementation of TPM.

In coil annealing furnace the process starts with loading of hot rolled alloy steel coil of 5.5mm to 32mm diameter of different grade such as 52Cr4Mo2V, ER90SG, EN45A, SAE9254 etc. in the furnace. The cycle time for heating coil depends upon the grade of coil and customer requirements. Two types of annealing process can be performed softening and spheroidised annealing. By annealing process the parameters to be controlled are hardness and decarburisation level.

IV. RESULT ANALYSIS

During annealing process the coils need to be loaded on the furnace which is time taking as one lot containing maximum 30 MT coil. After completion of annealing process the coil is unloaded from the furnace which is again a time consuming process and after every cycle of annealing cleaning of furnace is require. The pipe line supplies also need to be flush for cleaning of any breakage or dirt. This loading, unloading and cleaning process consumes most of the productive time and should be minimized to have a better performance.

In this experiment to analyze the effect of TPM implementation on coil annealing furnace we collect data before TPM and after TPM for the month of September 2015 and Jun 2016. The operational data sheet for both the month is studied. In both months several difference found in the area of production, maintenance cost and quality.

Table 1 shows the operation log book data sheet for month September 2015 before TPM and Table II shows the operation log book data sheet for month June 2016 after TPM. Table III shows the six big losses that affect OEE before and after TPM implementation which is further used to calculate the overall equipment effectiveness.

<table>
<thead>
<tr>
<th>Lot</th>
<th>Grade</th>
<th>Quantity (MT)</th>
<th>Cycle Time(Hrs)</th>
<th>Actual Time(Hrs)</th>
<th>Time/Speed Loss (Hrs)</th>
<th>Loading Time (Hrs)</th>
<th>Cleaning Time (Hrs)</th>
<th>Unloading Time (Hrs)</th>
<th>Quality Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>52Cr4Mo2V</td>
<td>25</td>
<td>42</td>
<td>48</td>
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<td>49</td>
<td>7</td>
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<tr>
<td>4</td>
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<td>3</td>
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<td>38.5</td>
<td>41</td>
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<tr>
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<tr>
<td>7</td>
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<tr>
<td>8</td>
<td>SAE9254</td>
<td>27</td>
<td>33</td>
<td>42</td>
<td>9</td>
<td>3</td>
<td>1.5</td>
<td>2</td>
<td>Rejected</td>
</tr>
</tbody>
</table>
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Table 2 - Operation Log Book Data Sheet for Month June 2016 after TPM

<table>
<thead>
<tr>
<th>Lot No</th>
<th>Grade</th>
<th>Quantity (MT)</th>
<th>Cycle Time (Hrs)</th>
<th>Actual Time (Hrs)</th>
<th>Time/ Speed Loss (Hrs)</th>
<th>Loading Time (Hrs)</th>
<th>Cleaning Time (Hrs)</th>
<th>Unloading Time (Hrs)</th>
<th>Quality Report</th>
</tr>
</thead>
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<tr>
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<td>26</td>
<td>38.5</td>
<td>44</td>
<td>5.5</td>
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<td>1</td>
<td>1.5</td>
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<td>ER90SG</td>
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<td>38.5</td>
<td>46</td>
<td>7.5</td>
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<td>1</td>
<td>1.5</td>
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</tr>
<tr>
<td>3</td>
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<td>42</td>
<td>48</td>
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<td>1.5</td>
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<td>1.5</td>
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<td>38</td>
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<td>39</td>
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<td>1</td>
<td>1.5</td>
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<td>5</td>
<td>2</td>
<td>1</td>
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</tr>
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<td>1</td>
<td>1.5</td>
<td>Accepted</td>
</tr>
<tr>
<td>13</td>
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<td>42</td>
<td>47</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>1.5</td>
<td>Accepted</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>356</td>
<td>513</td>
<td>584</td>
<td>71</td>
<td>26</td>
<td>13</td>
<td>19.5</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 - Six Big Losses that affects OEE before and after TPM

<table>
<thead>
<tr>
<th>S. No</th>
<th>Losses</th>
<th>Description</th>
<th>Time Taken (Hrs)</th>
<th>Before TPM</th>
<th>After TPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Machine failure losses</td>
<td>In stuffing box, leakages found during operation. Mechanical seal of the stuffing box was replaced.</td>
<td>12</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Set-up and adjustment losses</td>
<td>Unloading time + cleaning time + loading time</td>
<td>78</td>
<td>58.5</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Start-up losses</td>
<td>Time taken for load program and check all the components and safety valves is ok or not.</td>
<td>12</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Minor stoppage losses</td>
<td>Record received from minor stoppage data sheet.</td>
<td>15</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Speed losses</td>
<td>Excess time taken during cycle differ from original cycle</td>
<td>81.5</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Defects and rework</td>
<td>Time taken for rejected lot</td>
<td>42</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1: Six big losses - before and after TPM
Overall Equipment Effectiveness (OEE) Calculation

OEE is a result can be expressed as the ration of the actual output of the equipment divided by the maximum output of the equipment under the best performance condition. The Overall Equipment Effectiveness was originated from the Total Productive Maintenance practices, developed by S. Nakajima at the Japan Institute of Plant Maintenance, the aims of TPM is to achieve the ideal performance and achieve the Zero loss [1], which means no production scrap or defect, no breakdown, no accident, no waste in the process running or changeover. The quantification of these accumulations of waste in time and its comparison to the total available time can give the production and the maintenance management a general view of the actual performance of the plant. And it can help them to focus the improvement on the bigger loss.

B. OEE Calculation

The OEE can be calculated by using formula

$$\text{OEE} = \frac{\text{Valuable Operating Time}}{\text{Running Time}}$$

Where:
- Valuable Operating Time is the net time during which the equipment actually produces an acceptable product;
- Running Time is the actual number of hours that the equipment is expected to work in a specific period (year, month, week, or day).

The formula indicates how much the equipment is doing what it is supposed to do and it captures the degree of conforming to output requirements. It is clearly a measure of effectiveness.
Now in other way

\[
\text{Availability (A)} = \frac{\text{Operating Time}}{\text{Running Time}}
\]

\[
\text{Performance (P)} = \frac{\text{Net Operating Time}}{\text{Operating Time}}
\]

And

\[
\text{Quality (Q)} = \frac{\text{Valuable Operating Time}}{\text{Net Operating Time}}
\]

So through a bottom-up approach based on the Six Big Losses model, OEE breaks the performance of equipment into three separate and measurable components: Availability, Performance and Quality.

1) Availability indicates the problem caused by down time losses.
2) Performance indicates the losses caused by speed losses.
3) Quality indicates the scrap and rework losses.

From the above equation the Availability, Performance and Quality are calculated for both the condition that is before TPM and after TPM. With these values the OEE can be calculated as

So from eq. (1) formula the OEE can be calculated by

\[
\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality}
\]

From the above equations we calculated result for before TPM implementation and found Availability 0.83, Performance Efficiency 0.806, Quality 0.895 and OEE 0.5987 and for after TPM implementation found Availability 0.88, Performance Efficiency 0.85, Quality 1.0 and OEE 0.748. The comparative result is shown in Fig. 4.

![OEE Comparison](image)

Fig. 4: OEE Comparison

V. CONCLUSION

After successful implementation of total productive maintenance (TPM) the following can be concluded:

1) The results shows that after implementation of TPM Overall equipment effectiveness and production rate are increased and the defect and rework were decreased.
2) The maintenance cost and mean time to repair also decreased.
3) Elimination of wastage of time like downtime losses, decrease in rework and rejection of work can be obtained.
4) By implementing TPM increase in equipment availability and increase in rate of performance is observed.
5) Increase in Overall Equipment Effectiveness (OEE) and as a result overall productivity of the industry also increases.
6) Through TPM cost can minimized and quality can be improved by reducing and minimizing equipment deterioration and failures.
7) Appreciated team work can be established with the involvement of employees.
8) Autonomous maintenance activities can be performed with total employee participation.
9) It is an aggressive strategy focuses on actually improving the function and design of the production equipment.
10) It can be also seen that variation in process can be reduced and controlled by the implementation of TPM.

REFERENCES

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