IMPLEMENTATION OF TOTAL PRODUCTIVE MAINTENANCE AND OVERALL EQUIPMENT EFFECTIVENESS EVALUATION

Raju Ranjan  
Mechanical Engineering, N.I.T Jamshedpur, India

Malay Niraj  
Mechanical Engineering, N.I.T Jamshedpur, India

ABSTRACT

This paper focuses on a study of total productive maintenance and evaluating overall equipment effectiveness. The calculation of the overall equipment effectiveness in India Glycols Ltd, Gujarat is carried out. The big six losses in any industry (quality, availability and speed) are also presented. The data were collected through reviewing the technical documents available in Company. As a result, the Company achieved about 93% in average quality rate of overall equipment effectiveness equation and about 87% in availability in October 2017 where in average performance efficiency in October 2017 it achieved about 87.5%. The comparison between the world class standard and company results is carried out and the company is not achieved the world class availability, performance efficiency, quality rate and overall equipment effectiveness.

Based on these results, global maintenance management, and production planning were suggested to improve their maintenance procedures and improve the productivity. Also, the company needs to work hard to improve their inspection system start from the raw materials inventory to the work in process finished with finish goods inventory.

Keywords: Performance Efficiency, Quality Rate, Total Productive Maintenance (TPM)

http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=9&IType=2
1. INTRODUCTION

Total Productive Maintenance (TPM) which is one of the key concepts of Lean Manufacturing, challenges the view that maintenance is no more than a function that operates in the background and only appears when needed. The objective of the TPM is to engender a sense of joint responsibility between supervision, operators and maintenance workers, not simply to keep machines running smoothly, but also to extend and optimize their performance overall. The results are proving to be remarkable (Swanson, 2001). The concept of the TPM includes the following elements:

- TPM aims to maximize equipment effectiveness (overall efficiency).
- TPM establishes a thorough system of preventive maintenance (PM) for the equipment’s entire life span.
- TPM is implemented by various departments in a company.
- TPM involves every single employee, from top management to workers on the shop floor.

TPM is an aggressive strategy focuses on actually improving the function and design of the production equipment. The TPM aims to increase the availability/effectiveness of existing equipment in a given situation, through the effort of minimizing input (improving and maintaining equipment at optimal level to reduce its life cycle cost) and the investment in human resources which results in better hardware utilization (Schippers, 2001). TPM is designed to maximize equipment effectiveness (improving overall efficiency) by establishing a comprehensive productive-maintenance system covering the entire life of the equipment, spanning all equipment-related fields (planning, use, maintenance, etc.) and, with the participation of all employees from top management down to shop-floor workers, to promote productive maintenance through motivation management or voluntary small-group activities.

The definitions of TPM in his review about the literature of TPM he present two definitions the first one depend on the Japanese approach and the other depend on western approach are presented by Bamber (1998). 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. Now it is popular in Japanese industry and in other western countries Muhammad (2007). It is closely tied to JIT (Just in Time) and TQM (Total Quality Management) and it is extension of PM (preventive maintenance), where the machines work at high productivity and efficiency, and where the maintenance is all employee responsibility, and focus to prevent the problem before it may occurs.

A proposal of this study is to improve weaknesses of OEE by developing the existing calculating methodology. In Section 2, OEE and NEE are described shortly. In this Section, the influence of equipment performance efficiency, down time, quality rate and rework are discussed too. A description of case study is given in Section 3 as well as a comparison between the performances measures is described, while the conclusions are presented in Section 4. This methodology aims to convert machine losses into monetary units.

2. METHODOLOGY

2.1. Overall Equipment Effectiveness

In considering OEE defines six big equipment losses (Nakajima, 1988):

- Equipment failure/breakdown losses are categorized as time losses when productivity is reduced, and quality losses caused by defective products,
Implementation of Total Productive Maintenance and Overall Equipment Effectiveness Evaluation

- Set-up/adjustment time losses result from downtime and defective products that occur when production of one item ends and the equipment is adjusted to meet the requirements of another item,
- Idling and minor stop losses occur when the production is interrupted by a temporary malfunction or when a machine is idling,
- Reduced speed losses refer to the difference between equipment design speed and actual Operating speed,
- Reduced yield occurs during the early stage of production from machine start up stabilization, quality defects and rework are losses in quality caused by malfunctioning production equipment.

The equipment time model is introduced in Fig. 1 (Gomaa, 2003). This figure shows that the OEE depends on availability rate, performance efficiency and quality rate. Therefore, OEE increases with the increase of these three elements. Increase in availability rate reduces buffer inventories needed to protect downstream production from breakdowns and increases effective capacity.

\[ t_1 = \text{Planned down time}, \quad t_2 = \text{Unplanned down time}, \quad t_3 = \text{Standby time} \]
\[ t_4 = \text{Speed losses time}, \quad t_5 = \text{Quality losses time}. \]

**Figure 1** Equipment time model.

Reduced buffer inventories lead to decreased lead times since jobs are not waiting as long in queues. This capability of shorter lead-times improves the firm's competitive position in terms of delivery and flexibility since it is easier to deliver multiple products or versions of products with shorter lead times. OEE is calculated by obtaining the product of availability of the equipment, performance efficiency of the process and rate of quality products expressed by Jostes and Helms (1994):

\[
OEE = \text{Availability (A) } \times \text{Performance efficiency (PE) } \times \text{Rate of quality (Qr)} \quad (1)
\]
2.1.1. Availability

The available time can be defined as the time of production to operate the equipment minus the other planned downtime like breaks, meetings etc. The down time can be defined as the actual time for which the equipment is down for repairs or changeovers. This time is also sometimes known as the breakdown time. The output of this formula gives the true availability of the equipment. This value is used also in the overall equipment effectiveness formula to measure the effectiveness of the equipment. The availability is calculated as the required available time minus the downtime and then divided by the required available time. This can be written in the form of formula as (Almeanazel, 2010 and Afey, 2012):

$$\text{Availability} = \frac{\text{Total time} - \text{Total downtime} \times 100}{\text{Total time}}$$

(2)

2.1.2. Performance efficiency

The performance efficiency can be defined as the ideal or design cycle time to produce the item multiplied by the output of the equipment and then divided by the operating time. This will give the performance efficiency rate of the equipment. The formula to calculate the performance rate can be expressed as (Gomaa, 2003):

$$\text{PE} = \frac{\text{Total Actual amount of product} \times 100}{\text{Target amount of product}}$$

(3)

2.1.3. Quality rate

The quality rate can be expressed as the process quantity minus the volume or number of defective quantity then divided by processed quantity. The quality rate can be expressed in a formula as (Chana et al., 2005):

$$\text{Quality rate} = \frac{\text{Processed Quantity} - \text{defective quantity} \times 100}{\text{Processed quantity}}$$

(4)

Where, the quality defects mean the amount of products which are below the quality standards i.e. the rejected items after the production process. This formula is very helpful to calculate the quality problems in the production process (Mobley, 2002).

2.2. Net Equipment Effectiveness

Is a characteristic number for the so-called net entire plant effectiveness. The characteristic number developed following the OEE (gross entire plant effectiveness). Into the net entire plant effectiveness losses are also included, which develop for effects at a plant and on production have. The formula to calculate the performance rate can be expressed as (Gomaa, 2003).

$$\text{NEE} = \text{Uptime ratio} \times \text{Performance efficiency} \times \text{Rate of quality}$$

(5)

$$\text{Uptime ratio} = \frac{\text{Uptime}}{\text{Used time}}$$

(6)

$$\text{Used time} = \text{Total time} - \text{total downtime} - \text{standby time}$$

(7)

$$\text{Uptime} = \frac{\text{Average sound product}}{\text{Planned product rate}}$$

(8)
2.3. World Class OEE

World class OEE is a standard which is used to compare the OEE of the firm. The percentage of World Class OEE is given in Table I (Kailas, 2009).

<table>
<thead>
<tr>
<th>OEE Factors</th>
<th>OEE world class</th>
</tr>
</thead>
<tbody>
<tr>
<td>A %</td>
<td>90.0</td>
</tr>
<tr>
<td>PE %</td>
<td>95.0</td>
</tr>
<tr>
<td>Qt %</td>
<td>99.9</td>
</tr>
<tr>
<td>OEE %</td>
<td>85.0</td>
</tr>
</tbody>
</table>

3. CASE STUDY

India Glycols Ltd has been taken as case study this company is applying restricted quality inspection system in addition it has ISO 9001:2000, in 2004. The company produces anhydrous Sodium Sulphate and Sodium Chloride refined salt, Magnesium sulphate Heptahydrate (Epsom salt), Sodium chloride Pure. In anhydrous Sodium Sulphate plant most failure probably occurred. The company has an old record for the previous maintenance work on the production line for anhydrous Sodium Sulphate plant, and the time loses that are observed in the production process in October 2016 and 2017 were recorded.

The manual data collection method consisted of a paper template, where the operators filled in the cause and duration of a breakdown, and comments could be made about minor stoppages and speed losses. Both number of processed parts and planned number of processes parts was registered in the template. The production data such as processed products, good products, loading time, operating time, etc. are collected in Tables II and III.

<table>
<thead>
<tr>
<th>Item</th>
<th>October 2016</th>
<th>October 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total time (day/month)</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>Planned product rate (t/day)</td>
<td>350</td>
<td>340</td>
</tr>
<tr>
<td>Average down time (h/month)</td>
<td>124</td>
<td>93</td>
</tr>
<tr>
<td>Average stand by time (hr/day)</td>
<td>62</td>
<td>62</td>
</tr>
<tr>
<td>Total actual product rate (t/day)</td>
<td>330</td>
<td>317</td>
</tr>
<tr>
<td>Sound product rate (t/day)</td>
<td>300</td>
<td>295</td>
</tr>
<tr>
<td>Defect product rate (t/day)</td>
<td>30</td>
<td>22</td>
</tr>
</tbody>
</table>
4. RESULTS AND DISCUSSION

Calculations of measuring the OEE and NEE metrics for anhydrous Sodium Sulphate are done according to proposed losses structured. Results are shown in Table III. In order to evaluate availability in NEE metric, calendar time (To) is used and in OEE metric, used time is used.

In the Table IV, the first row shows quantities of A which are achieved according to available time and are used for OEE calculation. The second row shows quantities of PE which are achieved according to average actual product rate and are used for OEE calculation. In the other rows are respectively proposed quantities of quality rate, used time, uptime ratio, OEE and NEE.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A (%)</td>
<td>83.34</td>
<td>87.5</td>
<td>-4.16</td>
</tr>
<tr>
<td>PE (%)</td>
<td>94.3</td>
<td>86.76</td>
<td>7.54</td>
</tr>
<tr>
<td>Qr (%)</td>
<td>91.1</td>
<td>93.2</td>
<td>-2.0</td>
</tr>
<tr>
<td>OEE (%)</td>
<td>71.52</td>
<td>70.6</td>
<td>0.92</td>
</tr>
<tr>
<td>Used time (day/month)</td>
<td>23.25</td>
<td>24.54</td>
<td>-1.29</td>
</tr>
<tr>
<td>Uptime (day/month)</td>
<td>19.93</td>
<td>21.29</td>
<td>-1.36</td>
</tr>
<tr>
<td>Uptime ratio (%)</td>
<td>85.72</td>
<td>86.76</td>
<td>-1.04</td>
</tr>
<tr>
<td>NEE (%)</td>
<td>73.6</td>
<td>70.0</td>
<td>3.60</td>
</tr>
</tbody>
</table>

Table V shows the comparison between world class and company. This table shows that the company is not achieved the world class A, PE, Qr and OEE. So, the company needs to work hard to improve their system machines and reduce the waste time. Also, needs to work hard to improve their inspection system start from the raw materials inventory to the work in process finished with finish goods inventory.
Comparison between of OEE and NEE during the period of study are shown in Fig. 2. This figure shows that the OEE in October 2017 decreased with respect to the OEE values in October 2016. This may be due to breakdown losses and downtime losses. Also, this figure shows that the NEE in October 2017 increased with respect to the NEE values in October 2016.

4. CONCLUSION
The performance measurement for production process is very important for sustaining firms. Managers make decisions from this correct evaluation. Therefore appropriate measurement is necessarily established. Moreover, the accuracy of global performance evaluation is essential to improve and succeed in a business goal. The data were collected through reviewing the technical documents available in the statistical population. The calculated percents for the overall effectiveness of the company’s equipment and production process, the A of the machinery, the PE of the machinery, Qr and the OEE of the machinery in October 2017 were 87.5, 86.76, 93, and 70.6 percent, respectively. The comparison between world class and company is carried out. It is found that the company is not achieved the world class A, PE, Qr and OEE. So, the company needs to work hard to improve their system machines and reduce the waste time. There are three main techniques will have a very good impact to improve the production process and make the maintenance process more effectively, computerized maintenance management system, production planned, and total quality management, those techniques will help the company to operate at high rate of performance without losses.
ACKNOWLEDGEMENTS
The author wishes to express his thanks to the staff members of the India Glycols Ltd. for their support during carrying out this work.

REFERENCES:

Implementation of Total Productive Maintenance and Overall Equipment Effectiveness Evaluation


