Optimizing a Production System Using Tools of Total Productive Maintenance

Pradeep Kumar, Raviraj Shetty, and Lewlyn L.R. Rodrigues.

Abstract—TPM is a new maintenance strategy developed to meet the new maintenance needs and for improving productivity by making processes more reliable and less wasteful. TPM is an extension of TQM (Total Quality Management). The objective of TPM is to maintain the plant or equipment in good condition without interfering in the daily processes. To achieve this objective, preventive and predictive maintenance is required. By following the philosophy of TPM we can minimize the unexpected failure of the equipment.

With regards to Total Productive Maintenance (TPM) implementation, Indian manufacturing organizations have often been plagued with teething problems and challenges. The objective of the research is to investigate the status of maintenance improvement initiatives in Indian manufacturing organizations and suggest an Indigenous TPM Methodology for the Indian industry. Basically, the methodology comprises of identifying various types of losses and failures, the actual difficulties faced during the implementation of TPM and keeping in concern the basic principles such as 100% commitment, customer driven, management and monitoring, continual improvement, frequent auditing, employee empowerment etc.

The total productivity of machines are 0.277, 0.224 and 0.319 respectively. Thus it reflects the efficient utilization of resources (inputs) in producing goods and services (output). The Overall equipment effectiveness (OEE) for the three machines are 61.9, 61.86 and 61.85 respectively for over a period of a week. The OEE calculated is same for three machines and it gives an idea of stable production.

In the Digigo India Industry in which we did our research on TPM, But in this industry OEE of more than 61% for and the productivity values were 0.224 to 0.319. In world class manufacturing systems possesses OEE of about 75 to 80%.

Although the OEE can be improved a bit to make it more productive by reducing losses. Losses such as break down, maintenance, start-up defects, process defect and total defective output can be reduced and hence there can be significance increase in OEE and productivity. The plant already follows 5s which in itself is a bigger achievement in country like India. Thus it provides a basis and enthusiasm for other organizations to follow their footsteps.

This Industry had implemented all the latest industrial concepts ranging from 5s implementation to Lean Manufacturing systems. They had reduced the wastes to almost nil. With these adhering efforts of TPM and TQM, they were moreover like world class manufacturing this will also help in the reduction of wastes and will lead to the efficient working of the employees.

Keywords—Total Quality Management (TQM), Total Productive Maintenance (TPM), Overall Equipment Effectiveness (OEE) and Productivity.

I. INTRODUCTION

In today’s industrial scenario huge losses/wastage occur in the manufacturing shop floor. This waste is due to operators, maintenance personal, process, tooling problems and non-availability of components in time etc. Other forms of waste include idle machines, idle manpower, machine break down, rejected parts etc. The quality related waste are of significant importance as they matter the company in terms of time, material and the hard earned reputation of the company. There are also other invisible wastes like operating the machines below the rated speed, start-up losses, break down of the machines and bottlenecks in the process [1].

Total Productive Maintenance (TPM) is a new maintenance strategy developed to meet the new maintenance needs and for improving productivity by making processes more reliable and less wasteful. TPM is an extension of TQM (Total Quality Management). The objective of TPM is to maintain the plant or equipment in good condition without interfering the daily processes. To achieve this objective, preventive and predictive maintenance is required. By following the philosophy of TPM we can minimize the unexpected failure of the equipment.

Total Productive Maintenance (TPM) provides a comprehensive, life cycle approach, to equipment management that minimizes equipment failures, production defects, and accidents. It involves everyone in the organization, from top level management to production mechanics, and production support groups to outside suppliers. The objectives of continuously improve the availability and prevent the degradation of equipment is to achieve maximum effectiveness which is typically measured by the OEE [2]. An OEE rating may be used to compare different sites within an individual business group, and may influence strategic investment and other important decisions [3].

II. LITERATURE REVIEW

Total Productive Maintenance (TPM) is a strategic change management approach that has considerable impact on the internal efficiency of manufacturing organizations, both in the West and in Japan [4]. TPM is an
organization-wide strategy to increase the effectiveness of production environments, especially through methods for increasing the effectiveness of equipment. It can be considered as the medical science of machines. Total Productive Maintenance (TPM) is a maintenance program, which involves a newly defined concept for maintaining plants and equipment. The goal of the TPM program is to markedly increase production while, at the same time, increasing employee morale and job satisfaction. TPM brings maintenance into focus as a necessary and vitally important part of the business. It is no longer regarded as a non-profit activity. Down time for maintenance is scheduled as a part of the manufacturing day and, in some cases, as an integral part of the manufacturing process. The goal is to hold emergency and unscheduled maintenance to a minimum. 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 [5].

A. OEE (Overall Equipment Effectiveness)

Overall Equipment Effectiveness is defined as a gauge system on equipment that measures quantities such as uptime, units produced, and sometimes even the production speed. It is not however an absolute measure and is best used to identify scope for process performance improvement, and how to get the improvement. In doing so OEE provides a complete picture of where productive manufacturing time and money is being lost and uncovers the true, hidden capability of the factory. It becomes the key decision support tool for continuous improvement programmes.

OEE provides a way to measure the effectiveness of manufacturing operations from a single piece of equipment to an entire manufacturing plant or several manufacturing plants in a group. In doing so OEE provides a complete picture of where productive manufacturing time and money is being lost and uncovers the true, hidden capability of the factory. It becomes the key decision support tool for continuous improvement programmes [6]. TPM focuses on optimizing planning and scheduling. Availability, performance and yield (i.e. acceptable quality-rate) are other factors that affect productivity [7].

OEE measurement is made up of three underlying elements [6, 8&9], each one expressed as a percentage and accounting for a different kind of waste in the manufacturing process.

\[
OEE = A \times PE \times Q \\
(Eq.1)
\]

*Availability (A):* A measure of the time the plant was actually available for production compared to the manufacturing requirements (in percentages). Any losses in this area would be due to major breakdowns or extended set up time; often referred as Uptime.

*Performance (Performance Efficiency (PE)):* The rate that actual units are produced compared to the designed output. Losses in this area would be due to slow speed running, minor stoppages or adjustments.

*Quality (Q):* A measure of good quality, saleable product, minus any waste. Loses for this element would be damaged rejects or products needing re-work (in percentages).

B. Productivity

It is the quotient obtained by dividing Output by one of the factors of Production. In this way, it is possible to speak of the Productivity of the capita, investment, raw material. According to whether output is being considered in relation to capital, investment, raw material etc. the term Productivity is often confused with the term Production. Many people think that, the better the production the greater the Productivity but it is necessarily not true. Production is concerned with the activity of producing goods or services. Productivity is concerned with the efficient utilization of resources (input) in producing goods or services (output). If viewed in quantitative terms, production is the quantity of the output produced while productivity is ratio of output produced to the inputs used.

The concept of productivity should not be confused with production. The point what I want to make here is that an increased production does not necessarily mean increased productivity.

Production is a process of combining various immaterial and material inputs of production so as to produce tools for consumption. The methods of combining the inputs of production in the process of making output are called technology that can be depicted mathematically by the production function which describes the function between input and output.

\[
Total\ Productivity \ (TP) = Output / Total\ Input \\
(Total\ Input = Human, Material, Capital and Energy). \\
Partial\ Productivity \ (PP) = Output / Human\ Input \ or \ Material\ Input \ or \ Capital\ input \ or \ Energy\ Input.
\]

C. 5S Method of Equipment Maintenance

This is a prerequisite for the implementation of TPM because of the order and logic it brings to the workplace. 5S is defined as the best practice of implementing and maintaining good and structured housekeeping. The 5S includes seiri (sort, organization), seiton (set in order), seiso (shine, cleaning), seiketsu (standardize the cleaning), and shitsuke (sustain, discipline) and referred as the five keys to a total quality environment [10,11]. It is a system to reduce waste
and optimize productivity and quality through maintaining an orderly workplace and using visual signals to achieve more consistent operational results. It consists of getting rid of unnecessary items; a place for everything in its proper place, workplace cleanliness; establishing housekeeping standards; and maintaining standards in a disciplined way.

TQM is a manufacturing programme aimed at continuously improving and sustaining quality of products and processes by capitalizing on the involvement of management, workforce, suppliers and customers, in order to meet or exceed customer expectations [12]. The central concern of TQM is the design, production and supply of high-quality products to market.

III. PROBLEM STATEMENT

As organizations across the globe have faced stiff cutthroat competition in the last three decades, the Indian industry could not escape the brunt of globalization. The Indian manufacturing industry has witnessed irrepressible competition in the recent times in terms of low costs, improved quality and diverse products with superior performance. Indian entrepreneurs have understood the significance of improving maintenance performance in organizations. With regards to Total Productive Maintenance (TPM) implementation, Indian manufacturing organizations have often been plagued with teething problems and challenges. The objective of the research is to investigate the status of maintenance improvement initiatives in Indian manufacturing organizations and suggest an Indigenous TPM Methodology for the Indian industry.

The study was carried out to check for the Overall Equipment Effectiveness (OEE), Productivity of the different Machines and Total productive maintenance (TPM) in Printing Industry are checked.

IV. RESULT ANALYSIS

The results have been obtained from the weekly reports provided by the company. Weekly reports include all details of production for a particular date. Specific data has been selected in order to find the values of Overall Equipment Effectiveness and Productivity. The results are graphically plotted to find the variation of OEE of a three machine and Productivity of all machines under study is calculated period of seven days.

The stable nature which is shown in graph gives overview of the plant efficiency. All the three machines give different output but are maintained time to time to increase efficiency. Total productivity is calculated by adding human productivity and machine productivity. The productivity calculation is done in order to compare weekly output in terms of pages printed.

**HP Indigo 5500 Printing Machine – Overall Equipment Efficiency (OEE)**

<table>
<thead>
<tr>
<th>Component</th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Available Time (2<em>12</em>60min*7days)</td>
<td>10080 minutes</td>
</tr>
<tr>
<td>B</td>
<td>Scheduled maintenance (weekly once for 2hr)</td>
<td>120 minutes</td>
</tr>
<tr>
<td>C</td>
<td>Active time (a-b)</td>
<td>9960 minutes</td>
</tr>
<tr>
<td>D1</td>
<td>Recorded breakdown time (120 120 80 40 60 90 60) per week</td>
<td>520 minutes</td>
</tr>
<tr>
<td>D2</td>
<td>Production change over time (60 90 90 60 45 60 60) per week</td>
<td>390 minutes</td>
</tr>
<tr>
<td>D1+D2</td>
<td>Total</td>
<td>9170 minutes</td>
</tr>
<tr>
<td>E</td>
<td>Operating time (c-d)</td>
<td>9960-9170 = 7925 minutes</td>
</tr>
</tbody>
</table>

**F OPERATIVITY TIME (100*c/e) %**

<table>
<thead>
<tr>
<th>Machine</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP Indigo 5500</td>
<td>100*925/9960 = 92.5%</td>
</tr>
</tbody>
</table>

**G Net input (Rework=0)**

<table>
<thead>
<tr>
<th>Machine</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>HP Indigo 5500</td>
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**H Gross output**

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**I I1 Start-up defects (10 20 18 15 25 12 08) per week**

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**I2 Process defect (20 25 24 28 16 17 22) per week**

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**II+I2 Total defective output (30 45 42 34 29 30) 260 pc/print**

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**J Acceptable output 126000-260=125740 prints**

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**K D1+D2 1035 minutes**

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**L D1 120 minutes**

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**M D2 180 minutes**

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**N M Net time m1+m2+m3 (160 90 150 30 150 60) 880 minutes**

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**O T QUALITY RATE=100*I/h 100*125740/126000 = 99.70%**

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**P Q Ideal cycle time 0.049 minutes**

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**Q R Operating speed coefficient (q/o) 0.049/0.069=0.71**

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**S S PERFORMANCE RATE (utilization) (P*R) 97.41*0.71= 69.30%**

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**T OVERALL EQUIPMENT EFFECTIVENESS (OEE) 69.30*99.70*89.60/100= 61.90%**

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**TABLE I**

<table>
<thead>
<tr>
<th>Printing Machines</th>
<th>HP Indigo 5500</th>
<th>HP Indigo 3050</th>
<th>HP Indigo 3500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability (%)</td>
<td>89.60</td>
<td>93.07</td>
<td>89.45</td>
</tr>
<tr>
<td>Performance</td>
<td>69.30</td>
<td>66.58</td>
<td>69.29</td>
</tr>
<tr>
<td>Efficiency (PE) (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality (%)</td>
<td>99.70</td>
<td>99.84</td>
<td>99.80</td>
</tr>
<tr>
<td>Overall Equipment Effectiveness (OEE)</td>
<td>61.90 %</td>
<td>61.86 %</td>
<td>61.85 %</td>
</tr>
<tr>
<td>Human productivity</td>
<td>2.87</td>
<td>2.88</td>
<td>2.87</td>
</tr>
<tr>
<td>Machine Productivity</td>
<td>0.63</td>
<td>0.49</td>
<td>0.72</td>
</tr>
<tr>
<td>Total productivity</td>
<td>0.277</td>
<td>0.224</td>
<td>0.3195</td>
</tr>
</tbody>
</table>

![Fig.1 OEE of Printing Machines](image)

Fig.1 OEE of Printing Machines
This gives the general overview and comparison at one go while comparing daily output thus facilitating the owners to find out if any discrepancy is there. In this industry Human productivity varies from 2.87 to 2.88(Table 1, Fig.3), Machine productivity varies between 0.49 to 0.72 and total productivity of the Industry 0.224 to 0.319. There is a variation in Machine productivity and total productivity.

The total productivity of Industry is 0.277, 0.224 and 0.319 respectively (Table 1 & Fig.3). Thus it reflects the efficient utilization of resources (inputs) in producing goods and services (output). The OEE for the three machines are 61.9, 61.86 and 61.85(Table 1, Fig.1 & 2) respectively for over a period of a week. The OEE calculated is same for three machines and it gives an idea of stable production.

**V. CONCLUSION**

Digigo India uses a total of three Indigo presses manufactured by HP, costing almost 5 to 6 crores to each of them. Although it’s a huge investment, but it surely serves the purpose as it includes numerous advantages of finest quality of prints apart from almost zero wastes or any kind of misprints. It works on a double daily shift constituting a production rate of 800 to 1500 prints per hour for double sided and single sided printing respectively.

Digigo is the only industry in Manipal Industrial Area which follows 5s and standardize their all product output with maximum consumer satisfaction. This is attributed to the fact by their OEE calculation is near about 62%, which is by far very good according to industry standards. The OEE calculation for 3 machines is almost same, this shows they are stable in production and there is no fluctuation regarding the OEE.

While finding the OEE for the HP Indigo presses, we concluded that the Productivity and OEE of those presses were very good and farther from the world class manufacturing systems. We found the Total Productivity as 0.273 (average), there is little change in human productivity 2.87 to 2.88, but variation in machine productivity from 0.49 to 0.72 and there is variation in total productivity 0.224 to 0.319. If machine utilization taken care Total productivity can be increased and OEE as more than 60% for all the three presses where as we know that a world class manufacturing system possesses a OEE of about 75 to 80%. But in this industry if Machine productivity taken care so we can increase total productivity as well as OEE also.

Through the questionnaire we came to know that this Industry followed the Lean manufacturing technique implemented effectively, TPM assessment partially implemented, 5S assessment, implemented effectively, they strictly follow from top management to Lower level management and TQM Implemented fully and manufacturing performance was good where internal scrap and rework was very low. And housekeeping and planned maintenance was very good. They almost totally agreed in the effective implementation of TPM and TQM.

Append Although the OEE can be improved a bit to make it more productive by reducing loss by improving performance rate (efficiency) as indicated above in the table1. Losses such as break down, maintenance, start-up defects, process defect and total defective output can be reduced and hence there can be significance increase in OEE and productivity. The plant already follows 5s which in itself is a bigger achievement in country like India. Thus it provides a basis and enthusiasm for other organisations to follow their footsteps.

**APPENDIX**

**APPENDIX 1**

**Lean Manufacturing Implementation**

1. Our plant is safe, clean, and well organized. When guests come to visit our plant, there is no need to do some extra cleaning

   ![Lean Manufacturing Implementation](image)

   **Fig.2 Printing Machines 1. HP Indigo5500, 2.HPIndigo 3050, 3.HPIndigo 3500 Availability, Performance, Quality and OEE.**

   ![Lean Manufacturing Implementation](image)

   **Fig.3 Productivity of Human and Machines**

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   **APPENDIX**

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   **Lean Manufacturing Implementation**

   1. Our plant is safe, clean, and well organized. When guests come to visit our plant, there is no need to do some extra cleaning

   Yes, it corresponds to our plant

   No, it does not apply to our plant

   2. Material is moved only once and as short distance as possible in appropriate containers

   Yes, it is very important

   No, it is not so important
No, it does not apply to our plant to our plant

No, it is not so important

No, it is not so important

3. The production pace is based on the actual orders from the costumers and is regularly updated on daily or hourly basis.

No, it does not apply to our plant

No, it is not so important

No, it is not so important

5. Our suppliers are highly-dependable and reliable. We constantly track their delivery accuracy and quality record as a matter of policy. This way, there is no need to do quality control on most incoming goods.

No, it does not apply to our plant

No, it is not so important

APPENDIX 2

TPM ASSESSMENT

A. Is your plant maintenance efficient and total productive?

How well do these Maintenance audit statements correspond to your facility?

1. The need for preventive maintenance is determined for every machine.

No, it does not apply to our plant

Yes, it corresponds to our plant

2. The production personnel are responsible for most of the maintenance inspections on their machines.

No, it does not apply to our plant

Yes, it corresponds to our plant

3. Production personnel are trained for maintenance work, and easy-to-understand instructions are readily available for every operator on duty.

No, it does not apply to our plant

Yes, it corresponds to our plant

4. What is to be done, who is responsible, and when it was last time it was checked/repaired is clearly communicated to everybody.

No, it does not apply to our plant

Yes, it corresponds to our plant

5. Production personnel are well trained in trouble shooting and maintenance jobs. They can describe malfunctions clearly and offer help during heavy repair works.

No, it does not apply to our plant

Yes, it corresponds to our plant

6. What ratio of all maintenance work are planned in advance?

Less than 20%

At least 80%

7. "As our machinery is reliable, our maintenance personnel need to work during dayshifts only."

No, it does not apply to our plant

Yes, it corresponds to our plant

8. We use reports from the computerized maintenance management system (CMMS) to make decisions.

No, it does not apply to our plant

Yes, it corresponds to our plant

9. We are using a mathematical model or computer aid to determine the right level of spare part inventory.

No, it does not apply to our plant

Yes, it corresponds to our plant

10. All levels of management are committed to maintenance issues and regular audits are carried out.

No, it does not apply to our plant

Yes, it corresponds to our plant

APPENDIX 3

5S Assessment

1. We work actively to maintain 5S by employing auditing tools and other systems.

No, it does not apply to our plant

Yes, it corresponds to our plant

2. All employees are trained in 5S.

No, it does not apply to our plant

Yes, it corresponds to our plant

3. All levels of staff are committed to 5S.

No, it does not apply to our plant

Yes, it corresponds to our plant

4. We have a top-management policy on how to handle 5S issues.

No, it does not apply to our plant

Yes, it corresponds to our plant

5. All 5S routines are updated by appointed personnel.

No, it does not apply to our plant

Yes, it corresponds to our plant
REFERENCES


www.jjmie.hu.edu.jo