Calculation of OEE for an Assembly Process

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Abstract

OEE measurement is also commonly used as a Key Performance Indicator (KPI) in conjunction with lean manufacturing efforts to provide an indicator of success. It quantifies how well a manufacturing unit performs relative to its designed capacity, during the periods when it is scheduled to run. It is a well-known concept in maintenance and is a way of measuring the effectiveness of a machine which evaluates and indicates how effectively a manufacturing operation is utilized. It is not however an absolute measure and is best used to identify scope for process performance improvement, and how to get the improvement. This paper investigates the utilization of OEE measure for efficient management of improvement in production performance and calculation of OEE in processing industry which assemble various parts of tractor at various lines.

Key words

Assembly process, Effectiveness, Management, OEE, Performance

I. Introduction

Lean Manufacturing: Lean Production or Lean Manufacturing is a manufacturing/production system best characterized as relentlessly eliminating waste from all of its activities and operations. Lean strives to produce products and deliver services:

- On-Time
- Using as few resources as possible
- Better than competitors
- Faster & Cheaper than competitors
- While Eliminating as Much Waste as Possible

Lean Manufacturing is the “umbrella” under which many manufacturing improvement tools are housed. Some examples include:

- TPM: Total Productive Maintenance
- 5S: Visual Workplace or Visual Factory
- Kanban: Work Signaling System
- 2-Bin: Materials Replenishment system
- Error & Mistake-Proofing: A perfect process tool
- Level-Loading: For producing mixed quantities and styles of products
- Inventory Reduction
- Kaizen Events or Improvement Events
- Continuous Improvement and Lean Culture Change
- Overall Equipment Effectiveness

A. Overall Equipment Effectiveness

Overall equipment effectiveness is a concept utilized in a lean manufacturing implementation. OEE can be defined as “A vital component of the Lean Manufacturing philosophy, OEE provides a methodology for calculating the overall effectiveness of the production environment.”

It is often shortened to just OEE. It is an established method of measuring and then optimising the efficiency of a machine’s performance or that of a whole manufacturing plant.

OEE is becoming a commonly utilized maintenance metric within lean organizations. The OEE concept normally measures the effectiveness of a machine center or process line, but can be utilized in non-manufacturing operations, also.

The high-level formula for the lean manufacturing OEE is:

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

B. The Benefits of OEE Measurement

The goal of measuring OEE is to improve the effectiveness of equipment. Since equipment effectiveness affects shop floor employees more than any other group, it is appropriate for them to be involved in tracking OEE and in planning and implementing equipment improvements to reduce lost effectiveness. An OEE solution can enable manufacturers to achieve world-class status. More specifically, it can provide benefits in three key areas:

1. Equipment
   Reduced equipment downtime and maintenance costs and better management of the equipment life cycle.

2. Personnel
   Labor efficiencies and increased productivity by improving visibility into operations and empowering operators

3. Process
   Increased productivity by identifying bottlenecks

4. Quality
   Increased rate of quality, reduced scrap

(i). Background

The OEE is defined as a measure of total equipment performance, that is, the degree to which the equipment is doing what it is supposed to do. The OEE metric that originally described by Nakajima (1988), can measure level of equipment effectiveness,
and also identify loss elements which are classified into six major groups OEE metric identifies and measures main production losses such as availability, performance and quality. Therefore OEE can be used as a key tool to improve equipments effectiveness and consequently increase productivity. Ivancic (1998), the main difference lies in the inclusion of planned downtime in the total planned time horizon. According to the presentation at the 1999 Society maintenance reliability professional conference, Rohm and Haas Corporation determined that developing hidden capacity of existing factories was ten times less expensive than building new capacity. OEE can be considered to combine the operation, maintenance and management of manufacturing equipment and resources. According to Hansen (2001) performance evaluation is one of the key tools to determine world class companies. The overall line effectiveness (OLE) was proposed by Nachiappan and Anantharaman (2006) to measure productivity of product line involving machines in series which arranged in continuous line manufacturing effectiveness of a manufacturing line (OEEML).

II. Components of OEE
Three main factors make up the OEE calculation: They are
- Availability (A)
- Performance (P)
- Quality(Q)

B. Performance
Performance is in theory very simple. It is the actual achieved run rate against the ideal run rate for the machine. Often the machine ideal or optimum run rate may be the figure published by the machine manufacturer. However, we all know that the ideal run rate may be affected by the situation of the machine, heat, cold product running through etc. Purists would say you still refer to the published run rate whilst others may suggest that expected performance may necessarily be degraded by the nature of the product going through it. In a situation where the same product, with no expected variability, passing through the machine, such as a line in a bottling plant, we would expect the ideal run rate to remain constant and therefore variances may easily be identified.

\[
\text{Actual run rate} \div \text{Ideal run rate} = \text{Performance}
\]

C. Quality
The final factor on the overall OEE calculation is quality. This is simply a measure of good product divided by the total product (for the job, shift, day, week etc). This factor is then:

III. The Assembly Process
The assembly line for tractor parts has been categorized depending upon their operations they are performing. They are namely-
- ADDC line
- Transmission line
- Pre painting line
- Paint shop
- Post painting shop

A. ADDC Line
ADDC stands for Automatic Depth and Draft Control. This is used for the operation of the agriculture implements like cultivator, MB plough, disc harrow etc. ADDC system controls the depth of implement, depending upon the draft. Draft is resistance of soil which acts against the implement. ADDC is based on the principle of sensing the forces on implement hence using the hydraulic pressure to lift or lower the 3-point linkage.

B. Transmission Line
In this line the gear box, differential assembly, final drive assembly and ADDC coupling is done. The gear box assembly is called g1 and differential assembly is called g2. The various gear mechanisms used in tractor are:
- Sliding gear mechanism
- Synchro-mesh mechanism

Transmission assembly also consists of PTO (Power transmission output) that is used to run the pump for drawing out water and some implements like rotavator etc.

C. Pre Painting Line
This line includes the coupling of engine and fly feel to the transmission assembly. Then brakes clutch, steering mechanism are assembled along with the order items like weight, pressures pipe, suction pipe.
D. Paint Shop
This shop is basically in 2 categories one line itself and second sheet metal paint shop. On the line, the chassis of tractor is painted and is then baked in oven. In sheet metal paint shop consists of thirteen tank systems which include first cleaning of the material, re-dusting and rescaling, surface activation for better paint adhesion.

E. Post Painting Line
The post painting line involves the assembly of bonnet, dashboard, electrical air cleaner, water radiator, tyres etc. This also involves filling of oils like steering, air cleaner, gear box oil and diesel oil.

F. Time Matrix for each Process
Table 1: Time Matrix for Each Process

<table>
<thead>
<tr>
<th>Process</th>
<th>Operators</th>
<th>Cycle Time (in Sec)</th>
<th>Uptime</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADDC Line</td>
<td>3</td>
<td>245</td>
<td>90%</td>
</tr>
<tr>
<td>Transmission Line</td>
<td>3</td>
<td>240</td>
<td>90%</td>
</tr>
<tr>
<td>Pre paint Line</td>
<td>3</td>
<td>242</td>
<td>90%</td>
</tr>
<tr>
<td>Paint Shop</td>
<td>5</td>
<td>245</td>
<td>98%</td>
</tr>
<tr>
<td>Post paint Line</td>
<td>4</td>
<td>230</td>
<td>94%</td>
</tr>
<tr>
<td>Shipping</td>
<td>2</td>
<td>240</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>1442</td>
<td>92%</td>
</tr>
</tbody>
</table>

IV. Six Big Losses in Manufacturing Process
One of the major goals of OEE is to reduce and/or eliminate what are called the Six Big Losses the most common causes of efficiency loss in manufacturing.

Table 2: Six Big Losses in Manufacturing Process

<table>
<thead>
<tr>
<th>Six Big loss Category</th>
<th>OEE Loss Category</th>
<th>Event Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakdowns</td>
<td>Down Time Loss</td>
<td>• Tooling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Failures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Unplanned</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Maintenance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• General</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Breakdowns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Failure</td>
</tr>
<tr>
<td>Setup/Adjustments</td>
<td>Down Time Loss</td>
<td>• Setup/Changeover</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Material</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Shortages</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Operator</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Shortages</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Major Adjustments</td>
</tr>
<tr>
<td>Small Stops</td>
<td>Speed Loss</td>
<td>• Obstructed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Product Flow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Component Jams</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Misfeeds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sensor Blocked</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Delivery Blocked Cleaning/Checking</td>
</tr>
</tbody>
</table>

V. Calculation of OEE
A. Calculation for Line Balancing
1. Available time per Shift = 510 Min
2. Lunch time = 30 Min
3. Total time (1-2) = 480 Min
4. Working time in a shift @ 85% efficiency = 450 X 85% = 408 Min
5. Marketing Requirements = 4500 Tractors/month
6. Working Days in a month = 25 Days
7. No. of shift in a month = 25 X 2
8. Per shift Requirement of Tractors = 4500/50 = 90 No’s

B. Overall Equipment Effectiveness
1. Shift Length = 8:30 Hrs = 510 min
2. Meal Break = 1 @ 30 min
3. Time losses due to various non productive event = 78 min
4. Ideal Run Rate = 12 parts / hour
5. Total Parts = 4500 / month
6. Rejected Parts (Efficiency of process 85%) = 675

C. Planned Production Time (PPT)
   = Shift Length – Breaks
   = 510 – 30
   = 480 min

D. Operating Time
   = PPT – Down time
   = 480 – 78
   = 402 min

E. Good Pieces
   = Good parts – Rejected parts
   = 4500 – 675
   = 3825

F. Availability
   = Operating time/ PPT
   = 402 Min/ 480 min
   = 83.75%
G. Performance
\[
\text{Performance} = \frac{\text{Total Parts} / \text{Operating time}}{\text{Ideal run rate}}
\]
\[
= \frac{4500/402}{12}
\]
\[
= 83.3\%
\]

H. Quality
\[
\text{Quality} = \frac{\text{Good parts} / \text{Total Parts}}{12}
\]
\[
= \frac{3825/4500}{12}
\]
\[
= 85\%
\]

I. OEE
\[
\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality}
\]
\[
= 0.8375 \times 0.833 \times 0.85
\]
\[
= 60.01\%
\]

VI. Result & Discussion
Three factors are calculated by different formulas and product of availability, performance, and quality gives OEE of process. OEE of assembly process is 60.01%.

![Graphical Representation of OEE and its Components](image)

Fig. 3: Graphical Representation of OEE and its Components

There are three main time losses during process which are downtime loss, speed loss, and quality loss. These losses are important to identify for calculation of OEE and also to suggest improvement in existing process.

Table 3: Time losses in Assembly Process

<table>
<thead>
<tr>
<th>Time</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift Length</td>
<td>510</td>
</tr>
<tr>
<td>Planned Production Time</td>
<td>480 min 30 min meal break</td>
</tr>
<tr>
<td>Actual Operating Time</td>
<td>450 min 30 min down time loss</td>
</tr>
<tr>
<td>Net Operating Time</td>
<td>428</td>
</tr>
<tr>
<td>Valuable Operating Time</td>
<td>408 min 20 min quality loss</td>
</tr>
</tbody>
</table>

![Graph for Time Losses](image)

Fig. 4: Graph for Time Losses

VII. Conclusion and Future Work
Comparison between World-Class and assembly process OEE rates:

Table 4: Comparison of World Class OEE Factor and Assembly Process Factor

<table>
<thead>
<tr>
<th>OEE Factors</th>
<th>World Class</th>
<th>Assembly Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
<td>90.0%</td>
<td>83.75%</td>
</tr>
<tr>
<td>Performance</td>
<td>95.0%</td>
<td>83.3%</td>
</tr>
<tr>
<td>Quality</td>
<td>99.9%</td>
<td>85.0%</td>
</tr>
<tr>
<td>OEE</td>
<td>85.0%</td>
<td>60.01%</td>
</tr>
</tbody>
</table>

Recent studies indicate that the average OEE rate in manufacturing plants is 60 percent. As shown above a world-class OEE is considered to be 85 percent or better. Our assembly process has 85% efficiency and 15% losses. These losses mainly are downtime losses, speed losses and quality losses which affect Overall Equipment effectiveness of the process. To minimize these losses and to achieve world class OEE there should be reduction in events which are discussed in six big losses section. The main events which are responsible for losses in assembly process are:
- Tooling Failures
- Unplanned Maintenance
- Setup/Changeover
- Material Shortages
- Operator Shortages
- In-Process Damage
- In-Process Expiration
- Incorrect Assembly

It is important to decrease these non productive events which affect efficiency of the process. They can be reduce by implementing new techniques and tools, proper inventory storage, in line assembly, skilled labors, special purpose machinery etc.

A. Future Recommendations
- The OEE metrics is very useful for monitoring the production performance and also be seen as a sustainability performance indicator.
- Future research may be done to explore the dynamics of translating equipment effectiveness or loss of effectiveness in terms of cost.
- OEE approaches can be apply in supporting technologies
- We can experience changes in implementing OEE and can Identify, overcome barriers

References
Soniya Parihar received her B.E. degree in Mechanical Engineering from Samrat Ashok Technological Institute Vidisha, M.P. India, in 2010. She is pursuing her M.tech degree in Computer Integrated Manufacturing from Samrat Ashok Technological Institute Vidisha, M.P. India for year 2010-12. Her research interests include Total Quality Management, Lean Manufacturing Technologies, Reconfigurable Mfg System (RMS) and Operations Research.


