CHAPTER – 3

Computation of Overall Equipment Effectiveness for Connecting Rod Manufacturing Operations

3.1 Introduction

This chapter covers the method to compute Overall Equipment Effectiveness (OEE) in connecting rod manufacturing operations. The OEE sheet enables companies to get a quick assessment of their operations performance. The OEE sheet discussed is a powerful tool to assess the current state and to plan the future state of enterprise operations. This sheet is employed in a leading connecting rod manufacturing industries to provide decision-makers with sufficient input to identify improvement targets and revise the ongoing operations strategy. The use of OEE sheet is demonstrated in one example considered from a reputed connecting rod manufacturing company, and some insights are extracted and mentioned regarding the sheet’s applicability for different types of manufacturing processes.

The Overall equipment effectiveness (OEE) is a hierarchy of metrics developed by Seiichi Nakajima in the 1960s to evaluate how effectively a manufacturing operation is employed and utilized. An OEE System is a powerful tool which is the best used to light up our understanding of the production process and identify opportunities to initiate improvements. The results are stated in a generic form which allows comparison between manufacturing operations in different units or manufacturing units in different industries. It is not an absolute measure but it reflects the comparative performance with each other. It is used to identify scope and direction for process performance improvement. OEE was not designed to make comparisons
from machine-to-machine, plant-to-plant, or company-to-company, but it has evolved to these common levels of misuse.

If the cycle time is reduced, the OEE will increase, as more products are produced in lesser time but it is always not true. The reduction in cycle time may have an adverse effect on the quality of the product. If the adverse effect on quality is more than the improved effect due to time saving, OEE leads towards reduction.

There may be more interrelationships between many other factors. The reduction in cycle time may have influence over rejection or rework quantity. The tool wear, initial cost, machine wear and many other factors may alter if more products are produced in lesser time. Hence all impacts to be combined for computation of OEE to be a common platform for all the operations evaluation [26].

Another example is if one manufacturing operation produces better quality at the cost of time, there may be an alteration in OEE. It depends on the impact of a change in quality and change in time over the process. The improvement in quality is higher as compared to increase in time lead towards higher OEE, but improvement in quality is lower as compared to increase in time lead towards the reduction in OEE value.

3.2 Review of other research

Overall Equipment Effectiveness is a matter of prime interest for researchers for the management of asset performance. Managing the asset performance is critical for the long-term economic and business viability. To integrate a whole organization, where free flow and transparency of information is possible; and each process is linked for integrating to achieve the company’s business goals is a real challenge.

A relationship analysis between Overall Equipment Effectiveness (OEE) and Process Capability (PC) measures to be conducted [27]. Process Capability uses the capability indices (CI) to help in determining the suitability of a process to meet the required quality standards. Although the statistical value of process capability indices $C_p$ and $C_{pk}$ equal to 1.0 indicates a capable process.
The generally accepted minimum value in the manufacturing industry of these indices is 1.33. The results of the investigation challenge the traditional and the prevailing knowledge of considering this value as the best PC target in terms of OEE. This provides a useful perspective and guides to understand the interaction of different elements of performance and helps managers to take better decisions about how to run and improve their processes more efficiently and effectively.

A measure of Six Sigma process capability using extant data from the OEE framework is introduced. Similarly, indicators of plant reliability, maintainability and asset management effectiveness were calculated taking extant data from the OEE framework [28]. The ability to compare internal performance against external competition and vice versa is argued as being a critical attribute of any performance measurement system. OEE is used to track and trace improvements or decline in equipment effectiveness over a period of time [29].

The competitiveness of manufacturing companies depends on the availability and productivity of their production facilities [30]. Due to intense global competition, companies are striving to improve and optimize their productivity in order to remain competitive [31]. This would be possible if the production losses are identified and eliminated so that the manufacturers can bring their products to the market at a minimum cost. This situation has led to a need for a rigorously defined performance measurement system that is able to take into account different important elements of productivity in a manufacturing process.

The industrial application of OEE, as it is today, varies from one industry to another. Though the basis of measuring effectiveness is derived from the original OEE concept, manufacturers have customized OEE to fit their particular industrial requirements. Furthermore, the term OEE has been modified in literature to differentiate other terms with regard to the concept of application. This has led to widening the concept of OEE to many measures. This includes total equipment effectiveness performance (TEEP), production equipment effectiveness (PEE), overall plant effectiveness (OPE), overall throughput effectiveness (OTE), overall asset effectiveness (OAE) and overall factory effectiveness (OFE).

Major six big losses from a palletizing plant are discussed in a brewery which affects OEE [32]. The most successful method of employing OEE is to use cross-functional teams aimed at
improving the competitiveness of business [33]. Two industrial examples are discussed of OEE application and analyzed the differences between theory and practice [34]. A framework proposed for classifying and measuring production losses for overall production effectiveness, which harmonizes the differences between theory and practice and makes possible the presentation of overall production/asset effectiveness that can be customized with the manufacturers needs to improve productivity.

When machines operate jointly on a manufacturing line, OEE alone is not sufficient to improve the performance of the system as a whole. A new metric OEEML (overall equipment effectiveness of a manufacturing line) for manufacturing lines and an integrated approach to assessing the performance of a line is presented [35]. OEEML highlights the progressive degradation of the ideal cycle time, explaining it in terms of the bottleneck, inefficiency, and quality rate and synchronization-transportation problems.

3.3 Objectives of OEE

- To identify a single asset (machine or equipment) and/or single stream process related losses for the purpose of improving total asset performance and reliability.
- To provide the basis for setting improvement priorities and beginning root cause analysis.
- To develop and improve collaboration between asset operations, maintenance, purchasing and equipment engineering to jointly identify and eliminate (or reduce) the major causes of poor performance.
- To identify hidden or untapped capacity in a manufacturing process and lead to balanced flow.
- To identify and categorize major losses or reasons for poor performance.
- To track and trend the improvement, or decline, in equipment effectiveness over a period of time.

3.4 Implementation
Overall equipment effectiveness (OEE) is related measurements that report the overall utilization of facilities, time and material for manufacturing operations. It directly indicates the gap between the actual and ideal performance. It quantifies how well a manufacturing unit performs relative to its designed capacity, during the periods when it is scheduled to run.

OEE analysis starts with Plant Operating Time which is the amount of time the facility is available and open for equipment operation. Planned Production Time, excludes Planned Shutdown Time from Plant Operating Time. Planned Shutdown time includes all events that should not be included in efficiency analysis because there is no intention of running production. The events like scheduled maintenance breaks and the planned period where nothing is to be produced are considered in planned shutdown time.

The OEE measure is defined as the ability to run equipment at the designed speed with zero defects. In order to maximize OEE, the major losses should be reduced. The literature review on OEE evolution reveals a lot of differences in the formulation of equipment effectiveness. The main difference lies in the types of production losses that are captured by the measurement tool. Though the original OEE tool identifies six major losses in a production setup, other types of losses have been found to have a significant contribution to the overall production loss.

OEE breaks the performance of a manufacturing unit into three separate components. The components are Availability, Performance and Quality. These components are measurable and point to an aspect of the process that can be targeted for improvement. OEE can also be applied to any individual work center or production unit or plant level. It also allows knowing very specific analysis like shift, particular part number or any of several other parameters. The ideal value of OEE would be 100%, but achieving value up to 80 % is quite remarkable.

3.5 OEE factors and Computation sheet

Three measurable components for the calculation of OEE are as follows.

1. Availability = \[ \frac{Operating\ Time}{Planned\ Time} \]

It represents the percentage of scheduled time that the operation is available to operate. It also takes into account the fraction of Down Time Loss. It covers equipment failures,
unavailability due to accidental reasons and change over time and material shortages. Changeover time is a form of downtime which may not be possible to eliminate but can be reduced up to a considerable extent. Availability is a pure measurement of Uptime that is designed to exclude the effects of Quality, Performance and Scheduled Downtime Events.

2. Performance = \( \frac{\text{Ideal Cycle Time}}{\text{Operating Time}} \)

It represents the speed at which the Work Center runs as a percentage of its designed speed. It takes into account Speed Loss, which includes any factors that cause the process to operate at less than the maximum possible speed when running. It covers operator efficiency, variation in feeds, substandard materials and machine tool wear. Ideal Cycle time is the minimum cycle time that the process can be expected to achieve in optimal circumstances. It is also called as Theoretical Cycle Time or Design Cycle Time. Performance is a pure measurement of speed that is designed to exclude the effects of Quality and Availability.

3. Quality = \( \frac{(\text{Total production} - \text{Defectives})}{\text{Total Pieces produced}} \)

It represents the good units produced as a percentage of total units produced. It takes into account Quality Loss, which accounts for produced pieces that do not meet quality standards, including pieces that require rework. Quality is a pure measurement of Process Yield that is designed to exclude the effects of Availability and Performance.

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

Hence, OEE considers all three factors i.e. availability, performance and quality. These three measures indicate the degree of conformation to output necessities. OEE gives one magical number which is a measure of usefulness and effectiveness. It includes three numbers which are all useful individually as the circumstances vary from day to day. It also helps to visualize performance in modest terms. This is in agreement with the definition in literature that OEE measures the degree to which the equipment is doing what it is supposed to do base on availability, performance and quality rate. OEE percentages are useful when tracking and trending the performance effectiveness (reliability) of a single piece of equipment or single-stream process over a period of time.
Determining how management intends to use the OEE score is a very important reflection in the planning process for executing an OEE System. If the score is used as a mean to penalize or reward, the staff may be encouraged to manipulate the data, which will dilute the impact of potential assistances from OEE. It is, therefore, necessary to focus one’s attention beyond the performance of individual equipment toward the performance of the whole manufacturing works. The ultimate objective of any factory is to have a highly efficient integrated system and not brilliant individual equipment [36].

The details are prepared as shown in Table 3.1, for machining operations of a product to compute OEE to enlighten the working environment of shop floor activities.
### TABLE 3.1 Computation Sheet of OEE for each operation

<table>
<thead>
<tr>
<th>Operation No.</th>
<th>Operations</th>
<th>Down Time</th>
<th>Planned Production Time</th>
<th>Operating Time</th>
<th>Availability (%)</th>
<th>Time per pc. (sec.)</th>
<th>Ideal Rate pcs/hr</th>
<th>Total pcs produced/hr</th>
<th>Performance (%)</th>
<th>Rejection/Rework</th>
<th>Good pcs</th>
<th>Quality (%)</th>
<th>OEE (%)</th>
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<tr>
<td>10</td>
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<td>510</td>
<td>435</td>
<td>85.29</td>
<td>40</td>
<td>82</td>
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<td>75.34</td>
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<td>73</td>
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<td>65</td>
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<td>445</td>
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<td>70</td>
<td>47</td>
<td>35</td>
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<td>31</td>
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<td>510</td>
<td>440</td>
<td>86.27</td>
<td>67</td>
<td>49</td>
<td>39</td>
<td>79.59</td>
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<td>34</td>
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<td>47</td>
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<td>80.85</td>
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<tr>
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<td>86</td>
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<td>B.E. Chamfer</td>
<td>85</td>
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<td>425</td>
<td>83.33</td>
<td>40</td>
<td>82</td>
<td>71</td>
<td>86.59</td>
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<td>88.73</td>
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<tr>
<td>150</td>
<td>Notch (SPM*)</td>
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<td>510</td>
<td>435</td>
<td>85.29</td>
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<td>430</td>
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<td>69</td>
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<td>88.41</td>
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<td>14</td>
<td>41</td>
<td>74.55</td>
<td>54.6</td>
</tr>
</tbody>
</table>

*SPM*: Special Purpose Machine
Equations:

A. Availability = \(\frac{\text{Operating Time}}{\text{Planned Time}}\) x 100 %

B. Performance = \(\frac{\text{Actual produced Quantity}}{\text{Ideal production Quantity}}\) x 100 %

C. Quality = \(\frac{(\text{Total production} - \text{Defectives})}{\text{Total Pieces produced}}\) x 100 % = \(\frac{(\text{Good pcs produced})}{\text{Total Pieces produced}}\) x 100 %

D. Overall Equipment Effectiveness = Availability x Performance x Quality

3.6 Analysis

The data sheet prepared indicates the gray area of the shop floor. There is a need to emphasize the last manufacturing operation, i.e. bush boring and bush pressing. The quality of this operation is lower as compared to other operations. This is because of more rework needed in this operation to have desired quality. The team of manufacturing unit targets to improve this aspect as it is one of the most crucial steps.

The team initiated the deep study of bush pressing and bush boring operation which includes many parameters. The fish bone diagram prepared for this operation as shown in Fig. 3.1. The following actions were taken and appropriate corrections implemented to have better quality at this stage.

- Alignment (straightness) of the fixture checked and found correct.
- The spindle axial alignment checked and corrected with necessary action.
- Tool wear measured for a lot size and suggested to alter the tool change frequency as the previous one was inadequate.
- Measuring instrument checked with master calibration unit and found correct.

Operator interviewed for his fitness to the work and asked for necessary improvement.
Results and discussion

3.7 Results and discussion

The tool change frequency altered from 500 pcs to 400 pcs in bush boring operation. The impacts of employed actions are represented in the graph. There is a reduction in variation in the center distance parameter (Fig. 3.2 and 3.3). There is a reduction in rework (Fig. 3.4), rejection (Fig. 3.5) and customer complaints (Fig. 3.6) for this parameter.
Results and discussion

FIGURE 3.2: Variation in Center Distance before implementation (More variation)

FIGURE 3.3: Variation in Center Distance After implementation (Less variation)

FIGURE 3.4: Rework % (monthly)

FIGURE 3.5: Rejection % (monthly)

FIGURE 3.6: Customer Complaints (monthly)
3.8 Limitations for using OEE system

- The percentage calculation of OEE is statistically cannot be said valid. A calculated OEE percentage assumes that all equipment-related losses are equally significant and any improvement in the value of OEE is a positive improvement for the whole plant. This may not be true for all the cases. For example, the calculated OEE percentage does not consider that two percent improvement in quality may have a bigger impact on the business than does a two percent improvement in availability.

- Calculated OEE is not valid for benchmarking or comparing various processes, assets or equipment. It is a relative measure of a specific single asset effectiveness associated with it over a period of time. However, OEE can be used to compare identical equipment in identical situations producing identical output.

- The calculated OEE cannot be used as a corporate level measure. It is just an estimated measure of selected equipment effectiveness only.

- Also, it does not measure maintenance effectiveness because most of the loss factors are not under the direct control of the maintainers.

3.9 Summary

OEE System identifies the problem area and accurately the symptoms of each problem. However, the real opportunity lies in the ability to determine the root causes for each loss, and then to implement effective corrective actions to abolish them. OEE Systems can also be used to gather supplementary data, create and report against improvement plans/agendas, and verify or authenticate the actions taken to resolve the issues identified.

To achieve a successful implementation and to optimize the success of an OEE System, organizations must focus to ensure an assurance to practice it as a fundamental, organization-wide tool to drive continuous improvement in an effective mode. OEE can be applied to manufacturing, petrochemical processes and environmental equipment. Overall, OEE can be
Future Scope

visualized in a single statement as, *Implementation of OEE System can be compared to switching on the light in a darkened chamber. Nothing has changed, but the things can be seen more clearly.*