OVERALL EQUIPMENT EFFECTIVENESS:
THEORY AND APPLICATION

OEE WORKSHOP
Presented by: ROBERT VERMEULEN
Evolution of OEE

The TPM concept, launched by Nakajima in the 1980’s, provided a quantitative metric called Overall Equipment Effectiveness (OEE) for measuring productivity of individual equipment in a factory. It identifies and measures losses of important aspects of manufacturing:

• Availability
• Quality
• Performance

OEE is the degree to which our equipment is doing what it is supposed to do.
Evolution of OEE

Analysis of OEE then led to the addition of more performance measures to fit different industries’ requirements:

- **TEEP** = Total Equipment Effectiveness Performance
- **PEE** = Production Equipment Effectiveness
- **OFE** = Overall Factory Effectiveness
- **OTE** = Overall Throughput Effectiveness
- **OAE** = Overall Asset Effectiveness
- **OLP** = Overall Labour Productivity

The workforce strives to improve OEE by eliminating Six Big Losses
OEE Calculation

\[ OEE = Ar \cdot Pr \cdot Qr \, [\%], \]  

Where:
- \( Ar \) = availability rate;
- \( Pr \) = Performance rate;
- \( Qr \) = Quality rate.
OEE Calculation

\[ B = A - \text{Planned stoppage}, \quad (2) \]

**Availability** gives us what percentage of time the equipment is actually running, at its total capacity.

- \( A = \) All considered working time (Total Work Hours)
- Planned stoppage represents contractual breaks, etc.
- \( B = \) Planned work time for equipment
OEE Calculation

\[ C = B - Downtime, \]  
\[ (3) \]

- **B** = Planned working time
- **Downtime** represents total time for unscheduled stops (changeover time and adjustments)
- **C** = Actual Working Time
OEE Calculation

• Availability rate can be written as follows:

$$Ar = \left(\frac{C}{B}\right) \cdot 100 \%.$$  (4)

• C = Actual Working Time
• B = Planned Working Time
OEE Calculation

\[ E = D - \text{Reduced speed}, \]  \hspace{1cm} (5)

- Reduced speed represents the loss from running at speeds less than optimum
- \( D = \text{Target output according to ideal cycle time} \)
  \( \text{(ideal cycle time per part} \times \text{net operating time)} \)
- \( E = \text{Actual output} \)
OEE Calculation

• If using the time ratio, the actual cycle time per part can be calculated from the Running Time (C) and Actual Output (E):

\[ \text{Actual cycle time} = \frac{C}{E} \text{ [time/part]} \] (6)
OEE Calculation

• Performance rate can be written as follows:

\[
Pr = \frac{E}{D} \cdot 100 = \frac{\text{idealcycletime}}{\text{actualcycletime}} \cdot 100[\%].
\] (7)

• E = Actual Output
• D = Target Output
OEE Calculation

\[ G = F - (\text{scrap, rejects}). \]  

\[ \text{Quality Rate} = \left( \frac{G}{F} \right) \cdot 100 \, [\%]. \]
OEE Calculation

• Using the above formula’s, the OEE rate can be expressed as:

\[
OEE = \frac{C}{B} \cdot \frac{E}{D} \cdot \frac{G}{F} \quad \text{[\%].}
\] (10)
### OEE Model

#### A. TOTAL OPERATING TIME

<table>
<thead>
<tr>
<th>Availability</th>
<th>B. Net Operating Time</th>
<th>Planned stoppage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C. Running Time</td>
<td>Downtime</td>
</tr>
<tr>
<td>Performance</td>
<td>D. Target Output</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E. Actual Output</td>
<td>Reduced speed</td>
</tr>
<tr>
<td>Quality</td>
<td>F. Actual Output</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G. Good Output</td>
<td>Scrap, Rejects</td>
</tr>
</tbody>
</table>

**LOSS EFFECTIVENESS**
OEE Example

• Refer to handout exercise
TPM-OEE Productivity Model
<table>
<thead>
<tr>
<th>Six loss category</th>
<th>OEE measure</th>
<th>Reason for Loss</th>
<th>Countermeasures</th>
</tr>
</thead>
</table>
| Planned downtime or external unplanned event | Availability | • Changeovers  
• Asset care  
• Planned Maintenance  
• Material shortages  
• Labour shortages | • SMED – quick changeover techniques  
• Benchmarking  
• Planned downtime log and matrix |
| Breakdowns                            | Availability | • Equipment failure >5mins  
• Major component failure  
• Unplanned maintenance | • Asset care or preventative maintenance  
• Lubrication  
• Root cause analysis  
• Electrical thermographs or vibration analysis |
## OEE - Six Loss Calculation

| Minor stops | Performance | • Equipment failure <5mins  
| • Fallen product  
| • Obstruction  
| • blockages | • Targeted reduction of MTBF  
| • High speed cameras  
| • Tick sheets for further analysis  
| • OEM audit and servicing |
| Speed loss | Performance | • Running lower than rated speed  
| • Untrained operator not able to run at nominal speed  
| • Machine idling | • Optimising line control  
| • Training and awareness of line balance theory |
| Production rejects | Quality | • Product out of specification  
| • Damaged product  
| • scrap | • Error proofing  
| • Six Sigma  
| • Targeted analysis of reject area to analyse cause |
| Rejects on start up | Quality | • Product out of specification at start of run  
| • Scrap created before nominal running after changeover  
| • Damaged product after planned maintenance activity | • Precision settings  
| • Ensure machine availability on start up  
| • Complete all checks before start up |
## Six loss Calculation

<table>
<thead>
<tr>
<th>Six loss category</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned downtime or external unplanned event</td>
<td>Planned downtime / Total production time</td>
</tr>
<tr>
<td>Breakdowns (&gt;5mins)</td>
<td>Major fault time / Total production time</td>
</tr>
<tr>
<td>Minor stops (&lt;5mins)</td>
<td>Minor fault time / Total production time</td>
</tr>
</tbody>
</table>
| Speed loss                              | \[
|                                          | (Output / Ave speed \times Total production time) \) \ - \ (Output / Rated speed \times Total production time) \] |
| Production rejects                      | Rejects in prod / Actual speed \times Total production time                |
| Rejects on start up                     | Rejects on start up / Actual speed \times Total production time            |
In a 480 minute shift:
On a machine rated at 100 products output per minute
Maximum output = 480 mins x 100 units = 48000 units

Shift info:
- Output (Good Production) = 32000 units
- Speed = 98 units per minute
- Planned downtime = 82 mins
- Bottleneck loss due to B/down = 30 mins
- Rejects (in process) = 1255 in 8 hr shift

Output (OEE) = 32000 / 48000 = 66.66%
480mins x 66.67% = 320 mins
Total Loss = 160 mins
OEE Example

Six Loss Calculations:

**Speed loss**
Max theoretical units possible at actual speed = $98 \times 480 = 47040$
= $(32000/47040) - (32000/48000) = 68.03\% - 66.67\% = 1.36\%$
$480 \times 1.36\%$

= $6.53$ mins / 480 = (1.36\%)

**Planned downtime**
= $82$ mins / 480 = (17.08\%)

**Breakdown**
= $30$ mins / 480 = (6.25\%)

**Rejects** = $1255 / 98$ (actual running speed)
= $12.81$ mins / 480 = (2.67\%)

**Minor stops** = $480 - 320 - 6.53 - 82 - 30 - 12.81$
= $28.66$ mins / 480 = (5.97\%)

Total loss = $160$ mins = (33.33\%)
OEE Example

OEE Calculations:
(Time in mins)

<table>
<thead>
<tr>
<th></th>
<th>Production time</th>
<th>Time less availability loss</th>
<th>Time less performance loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability Loss</td>
<td>Planned downtime</td>
<td>82</td>
<td>368</td>
</tr>
<tr>
<td></td>
<td>Breakdowns</td>
<td>30</td>
<td>333</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>112</td>
<td>12.81</td>
</tr>
<tr>
<td>Performance Loss</td>
<td>Speed loss</td>
<td>6.53</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Minor stops (&lt;5mins)</td>
<td>28.66</td>
<td>12.81</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>35.19</td>
<td>12.81</td>
</tr>
</tbody>
</table>

Availability (368/480) = 77%
Performance (333/368) = 90%
Quality (320/333) = 96%

OEE = 0.77 x 0.9 x 0.96 = 66.7%
# OEE Rating

<table>
<thead>
<tr>
<th>AREA</th>
<th>TRADITIONAL (RATING 1 TO 2)</th>
<th>ACCEPTABLE (RATING 3)</th>
<th>WORLD CLASS (RATING 4 TO 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong> OEE Measurement Process</td>
<td>OEE incomplete, limited analysis of results, no clear improvement priorities.</td>
<td>Improvement targets and cross functional accountabilities set. Routine reviews support actions leading to OEE improvement</td>
<td>OEE measures are integrated at all levels of the business and deployed across the supply chain to improve service levels for strategic partners.</td>
</tr>
<tr>
<td><strong>2</strong> Focussed Improvement</td>
<td>No regular improvement team activity. Top down driven, ad hoc improvement process, Accountabilities unclear</td>
<td>All critical equipment has defined focussed improvement tactics. All personnel involved in focussed improvement projects supported by coaching as necessary.</td>
<td>Focussed improvement goals have progressed from sporadic to chronic loss reduction, leading to process optimisation and extended MTBI.</td>
</tr>
<tr>
<td><strong>3</strong> Visual Management</td>
<td>No formal visual controls. No sustainable evidence of 5S to create Flow</td>
<td>Visual controls used to stabilise and sustain normal conditions (see at a glance status know the game plan and keep it simple.)</td>
<td>Visual management is used to support progress towards optimum conditions. Formal visual management policy is part of New equipment procurement process.</td>
</tr>
<tr>
<td><strong>4</strong> People Development</td>
<td>No links between skill development and OEE improvement priorities</td>
<td>Training and skill development programmes are linked to accountabilities for focussed improvement</td>
<td>Self managed teams set and drive performance improvement using OEE systems designed for their use.</td>
</tr>
<tr>
<td><strong>5</strong> Scope of OEE process</td>
<td>Limited accountability for provision of data accuracy. Lots of ‘data’ but limited Information Trustworthiness dubious</td>
<td>Company-wide OEE system in place, fully documented. Floor to Floor(F2F) Equipment Losses differentiated from Door to Door(D2D) Management Losses. OEE training part of core competence. Accepted standard data for all processes.</td>
<td>OEE improvement Forecasts set for 3 to 5 year horizon with 1 year in detail. OEE improvement goals support strategic drivers and delivery of capital ROI goals.</td>
</tr>
<tr>
<td><strong>6</strong> Hidden Loss Model/Goal Deployment</td>
<td>Value of a 1% Improvement in OEE not defined. Mechanistic cost reduction targets are defined without clear route for delivery. Tend to look for head count cost reduction.</td>
<td>Focussed improvement priorities are set based on hidden loss model potential. Deployment of accountabilities re F2F v.D2D and delivery of improvement is coordinated at a cross functional level.</td>
<td>Hidden loss analysis is extended to improve supply chain effectiveness and reduce logistics complexity for strategic partners.</td>
</tr>
<tr>
<td><strong>7</strong> Use of Financial Information</td>
<td>Cost data not shared or deployed, mostly used for financial management purposes.</td>
<td>Hidden loss model correctly predicts links between cost drivers and effectiveness levels for fixed as well as variable costs</td>
<td>Loss model is used to forecast supplier and customer total cost of ownership to drive NPD features and assess the value of enhanced services.</td>
</tr>
</tbody>
</table>
Myth No 1 – An OEE level of 85% is ‘World Class’

It certainly is not if you are running, say, a flour mill or off-shore oil platform! In these cases if you’re not hitting 90%+ OEE then you’ll soon be out of business. We did not let the Japanese finish off the sentence of what they told us 25 plus years ago – which is that ‘85% is World Class… for a typical machining centre that has a significant number of changeovers’
OEE Myths

**Myth No 2** – OEE is a management tool to use as a benchmark and comparator
This misses the point of OEE as a manufacturing floor problem solving tool. Also beware of not comparing like with like - not just ‘apples with apples’ but ‘bramleys with bramleys’! Other benchmark comparator points to ask are:

- How big an impact does the number and variety of product changes have on availability?
- Who sets the standards for performance rates? (is it production planning, equipment supplier or engineering?)
- How big an impact do manning levels and skill levels have on the cycle time?
- Are all minor stoppages being recorded?
- Are we measuring all aspects of quality including packaging materials?
Myth No 3 – OEE should be calculated automatically by computer
The computation approach is far less important than the interpretation. Whilst calculating manually or inputting manually you can be asking ‘why?’
Myth No 4 – OEE on non-bottleneck equipment is unimportant

OEE provides a route to guide problem solving. The main requirement is for an objective measure of hidden losses even on equipment elsewhere in the supply chain especially if it generating controllable waste or non-value adding.
Myth No 5 – We do not need anymore output, so why raise the OEE

Management’s job is to maximise the value generated from the company’s assets. This includes business development. Accepting a low OEE defies commercial commonsense. If you are able to increase the OEE from say 60% to 80% by tackling the relevant six Losses, you will have increased the productive capacity of that asset by 33% - which means you can produce the same output in 2/3rds of the current time, or make 33% more in the same time. Either way it gives you a choice of flexibility at 80% OEE that you do not enjoy at 60%
**Myth No 6 – OEE is not useful because it doesn’t consider planned utilisation losses**

For example, labour co-ordination losses and material supply losses. Remember the OEE is not the only one used. Others will include productivity, cost, quality, delivery, safety, morale and environment. Often these ‘door-to-door’ losses (as opposed to equipment based ‘floor-to-floor’ losses) are vitally important. There is no ‘one size fits all’ approach to OEE. The trick is to adapt OEE to your business (as opposed to blindly adopting it in the classic sense). What you must not do, however, is corrupt it so it becomes unrecognisable and does not point you at the problems or opportunities.
Thank you!
• MUNTEANU, et al. "POSSIBILITIES FOR INCREASING EFFICIENCY OF INDUSTRIAL EQUIPMENT." *Series I: Engineering Sciences - Transilvania University of Brasov • Vol. 3 (52), 2010: 199 - 205.