Written by Robert C. Hansen
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***If overall equipment effectiveness (OEE) improvement is used as an aggressive business strategy, a productive manufacturing operation will evolve faster*.**

Companies have used a variety of approaches to help optimize their processes. A few have been successful. But optimizing the effectiveness of a complex operation is difficult because many separate entities are constantly in motion, in a parallel fashion, having interactive impact on key manufacturing parameters: raw materials, process control, quality, reliability, waste, throughput, delivery, and testing, among others.

To better understand how well a manufacturing area is performing and to identify what is limiting higher effectiveness, overall equipment effectiveness (OEE as referenced in Introduction to TPM by Seiichi Nakajima, Productivity Press, Cambridge, MA) brings the manufacturing aspects of efficiency, throughput rate, and quality into one common metric.

No single measure is able to capture the essence of how strong or healthy the manufacturing business is; however, OEE is one statistic that quickly measures how healthy that process is relative to the planned operating schedule, and begins to reveal the hidden factory.

All operations and supporting functions should understand their impact on manufacturing effectiveness and be focused on common improvement goals. Recognizing that successful manufacturing areas are data driven and are led by synergistic multi-task leadership teams is a start in moving to higher productivity for both the area and the plant.

The technical community is a key entity responsible for reliable equipment and processes. Often when they react to the crisis of the day, they find that the root cause of the crisis has cross-functional sources. A proactive maintenance and reliability manager will be more valuable to his area by developing OEE metrics and displaying the equipment reliability portion of the metric. This can lead two ways either the greatest opportunity is equipment reliability (or it is equal to other opportunities and valuable to improve) or other opportunities are greater and resources can be moved to properly support the highest need.

Technically skilled craftsmen with first-hand knowledge of processes can be vital assets providing data driven, common sense solutions for cross-functional improvement teams. Such teams, focused on key limiters, can readily turn opportunity dollars into bottom-line savings. As key improvements are implemented, equipment reliability will eventually become properly supported.

The practice example included here shows a fictitious snapshot production period with a range of incidents to practice categorizing opportunities and developing OEE formulas demonstrating that the three approaches provide exactly the same OEE. Even areas without good data collection can still get accurate OEE using the simplest method for computing OEE (method 3).

All manufacturing areas should be able to answer the following questions for each format of product produced:

- How much product meeting specifications was made?
- How much time was scheduled or allowed for production of that product?
- What is the ideal or expected cycle time or speed for units of that product? (For lack of ideal cycle time or speed, use the value generated by the best four days out of the past year.)

With this information, the simplified computation method can generate an accurate OEE for each product format produced, and a combined OEE for the area can be generated by prorating the individual product format OEEs by the percent of production schedule time used in making each specific product. Even areas with good data collection should confirm OEE using the simplified method. All methods should reconcile; if not, assume the lowest value is correct and the other methods have overlooked an area of opportunity.

The power of OEE is unleashed by doing a quick, simple analysis of all major processes or key equipment systems on the plant site. Then examine the individual results from each area:

- < 65 percent. Hidden dollars are slipping through your fingers. Get help now.
- 65 to 75 percent. Passable only if quarterly trends are improving.
- >75 percent. Pretty good, but don't stand still. Drive to world class (>80 percent for

batch processes and >85 percent for continuous processes).

Using the OEE metrics and establishing an equipment performance reporting system to assist in categorizing the details of the hidden factory will help any manufacturing area focus on the critical success parameters for their business. Knowing what to work on is the most vital step in making major progress.

A Pareto chart of the OEE categories should reveal the biggest success limiters. Forming cross-functional teams to solve root cause problems in those areas will drive the greatest improvement in effective manufacturing.

Being effective at running processes when they are scheduled to run is a key step in low-cost manufacturing. To compete long term on a global basis, a manufacturing operation first needs to address OEE and then determine how effectively the capital equipment is being used rela-tive to the total time available in a year. Many case histories for equipment-intensive processes show that a manufacturing operation with high OEE will have the lowest unit manufacturing cost. Therefore, total effective equipment performance (TEEP) should approach the guideline levels for OEE listed above. (TEEP refers to the percentage of calendar time equipment is running at speed and making good product.)

OEE can be accurately computed with little effort. It brings three key interactive areas of manufacturing into one metric in a way that reflects the efforts of the whole community. By revealing the hidden factory opportunities in a disciplined data system, one can readily focus on the impact areas to prioritize improvement efforts. Maintenance and reliability managers, proactively using OEE, can help their organizations understand the breakthrough areas needed for significant gains. **MT**

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Overall Equipment Effectiveness Practice Example

These definitions are suggested as the minimum set for nearly every key manufacturing area. Large Processes should accumulate information on each key step. The categories serve to provide enough detail to be able to focus priorities and reveal areas of major opportunity without providing so much incremental information that a long time is required to form the big picture. Agreed-uppn categories for understanding the areas of opportunity allow a company to benchmark similar areas both internally and externally. To be successful at benchmarking, all events need to be categorized so total reconciliation supports credibility.

The following fictitious production period of 40 hours with a log sheet categorizing the events helps clarify the definitions. Nakajima's OEE formulas and three methods of computing OEE are shown. Regardless of the approach used, the OEE percent and the various loss percentages should total 100 percent. All events need to be categorized without miscellaneous or other categories.

Key definitions:

- *Total time:* every minute of the clock. For a year, it would be the total calendar (60 min. x 24 hrs. x 365 days). This is sometimes called calendar time.
- *Overall equipment effectiveness (OEE):* how effectively the process is running when it is scheduled to run.
- *Asset utilization:* the percentage of total time the equipment is running.
- *Total effective equipment performance (TEEP):* percentage of total time the equipment is running at speed making good product.

- *Loading time (scheduled time, planned production time):* time that normal operations are intending to make product, and includes all events that are common to meeting delivery schedules (for example, changeovers, setups, information downloads, unplanned stoppages for equipment/people/quality, testing).

- *Operating time (run time, uptime):* when the system is making product.
- *Excluded time:* normally planned time not scheduled for production. This would include scheduled maintenance downtime (preventive maintenance and shutdowns planned at least a week in advance); scheduled meetings; experiment time (if the product is not going to be sold); planned training (if no product is made); headroom time such as holidays, Sundays, and weekends; no product scheduled (including unplanned headroom for completing orders early due to good performance); etc.

- *Quantity of good product:* amount of product conforming to specifications. It should not include volume that is on hold or may be condemned. If product is transferred and later found to be no good, the waste percentage should be indicative of the loss. However, if the loss is due to a specific root cause, then it should be noted in the comments column that the waste percentage includes a specific problem.

- *Expected cycle time or speed rate:* best speed or cycle time rate for key equipment or the flow line bottleneck for the size and format of the product being made. For example, if key equipment or a flow line bottleneck is designed and accredited for 17 seconds, and cycle time equals 3.53 units/minute for a certain size, then this rate is to be used for that size or format for all products. If a slower rate is used for a difficult product within that family of products, then the reduction in OEE should be noted in the comments column so the loss due to nonmanufacturable product can be recognized and communicated.
- *Stop time (ST):* both planned and unplanned. ST Operations is planned stop time for operational actions such as product changeovers or size changes, standard testing, planned material loading, required documentation, etc. ST Induced is unplanned stop time when the line is down due to external reasons such as lack of materials or supplies, lack of people, lack of information, unplanned meetings, etc.

- *Downtime (DT):* unplanned machine downtime events. DT Technical is due to any equipment failures affecting the machine or process that cause unplanned downtime including peripheral equipment (utilities, sprinklers, doors, humidifiers, etc.), equipment failure due to maintenance errors, equipment-caused dirt or scratches, etc. DT Operations is caused by not following procedures or operating outside of specifications, operator error, etc. DT Quality includes problems caused by nonconforming supplies or raw materials, process control problems, unplanned testing, nonmanufacturable product, dirt from the product or process, etc.
- *Waste:* total waste rate of the normal process. This includes structural waste, incident waste, testing waste, and recall waste. (Note that companies often exclude structural waste. Agreeing to include it would make it visible.) Unplanned waste that is generated while running the equipment should be captured here with a reference to the root cause of the incident.
- *Speed loss:* percent reduction of OEE due to running the equipment slower than the best expected rate for the size and format or product family. This is the lost time difference between required time for the expected rate or cycle and the actual time used to make the product. (In the example, the equipment was operated at half the run rate for 340 minutes. Therefore, 170 minutes were lost due to speed resulting in a 9.3 percent reduction of OEE due to speed loss [170/1830 = 9.3 percent].)

- *Quality rate:* number of good units divided by the total units produced. The units could be items, square feet, cubic feet, gallons, barrels, etc.

CALCULATION METHODS

Using the example, three methods of calculating OEE are shown. Note that accurate OEE can be determined from theoretical cycle time, number of good units, and scheduled time. An event time record is not required, except for detailing profitable TPM opportunities. The example covered 240 blocks of 10 minutes. Assume an accredited rate of 4 units per minute (15 seconds cycle time) and 3.5 percent waste or 96.5 percent yield for normal production activity.

Actual units produced =(1000 minutes x 4 per minute) + (340 x 2 per minute) = 4680, including 160 contaminated (no good) units.

Number of good units produced = (4680 – 160) x 0.965 = 4362 good units

Overall quality rate = number of good units/total units = 0.932

Method 1: Using Nakajima formulas
Loading time = 2400 - 570 = 1830 minutes

Availability = (1830 – 490) / 1830 = 0.732

Units produced = 4680

Actual cycle time = [(1000 + 340) / 4680] x 60 = 17.18 seconds

Operating speed rate = 15 seconds / 17.18 seconds = 0.873

Performance efficiency = 1.0 x [4680 x (15/60)] / 1340 = 0.883

OEE = 0.732 x 0.873 x 0.932 = 59.6%

Method 2: Using event time records

Scheduled time = 2400 - 570 = 1830 minutes

Run time = 1000 + 340 = 1340 minutes

Speed rate = [(1000 x 1.0) + (340 x ½)] / 1340 = 0.873

Availability = 1340 / 1830 = 0.732

OEE = 0.732 x 0.873 x 0.932 = 59.6%

Asset utilization = 1340 / 2400 = 55.8%

Total effective equipment performance = .558 x 0.873 x 0.932 = 45.4%

Method 3: Using product based calculations

Theoretical run time = 4362 good units produced / 4 per min = 1090.5 min

Schedule time = 2400 - 570 = 1830 minutes

OEE = 1090.5 / 1830 = 59.6%

TEEP = 1090.5 / 2400 = 45.4%

Losses:

Waste loss = (40 minutes of contamination + [0.035 x (1170 - 40 minutes)])/1830 minutes = 4.3%

Speed loss = 170 minutes/1830 minutes = 9.3%

ST Operations loss = 170 minutes/1830 minutes = 9.3%

ST Induced loss = 60 minutes/1830 minutes = 3.3%

DT loss = (150 minutes + 30 minutes + 80 minutes)/1830 minutes = 14.2%

Losses (40.4%) + OEE (59.6%) = 100%

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