AULA DYNA: OVERALL EQUIPMENT EFFECTIVENESS RATE AS A MEASURE FOR PROCESSES IMPROVEMENT

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1. OVERALL EQUIPMENT EFFECTIVENESS RATE

The information obtained from the evaluation of the performance of production processes and transformation systems allows directors and managers make better decisions about how to handle their production systems in a more effective and efficient way [1]. To achieve this, it is necessary to establish appropriate metrics for valuation purposes [2]. One of the most important metrics used in operating performance is the rate of Overall Equipment Effectiveness (referred to as OEE onward. This indicator is a quantitative measure that has been used increasingly in the industry not only to control and monitor the productivity of the production equipment, but also as an indicator and controller of process improvements and performance. Measurement is an important part of the task of making improvements, and will indicate whether the measures taken are giving the intended result. Also, anything that is not measured will be difficult to improve.

In this context, the OEE is able to identify development opportunities and direct efforts toward improvement areas related to the equipment or use of the process (availability), operational rate (yield) and quality. Thus, by improving the effectiveness with which the equipment and facilities work, the effectiveness of the entire production system can be increased.

OEE was proposed by Nakajima [3] as an approach to assess progress through improvement initiatives undertaken as part of the philosophy of Total Productive Maintenance (referred to as TPM onward). The TPM is understood as a set of multiple actions which seeks to eliminate losses of time due to machine interruptions [4]. The same production workers are those who perform TPM tasks autonomously, taking charge of the necessary techniques and suggesting improvements to machines involving new line designs. Once this has been established, it is very important to define a reliable and affordable system to capture, measure, analyze and evaluate the results and deviations regarding targets in a systematic way.

Nakajima [3] defines OEE as an effectiveness evaluation of the equipment metric or measure. Thus, the OEE attempts to identify production losses and other indirect and "hidden" costs that are contributing to a large part of the cost thereof. These losses are formulated as a function of a number of mutually exclusive factors [5]: availability, performance (productivity and efficiency) and quality. In essence, the OEE is calculated by multiplying these three factors as shown in equation (1):

$$\boxed{OEE(\%) = AVAILABILITY*PERFORMANCE*QUALITY} \qquad (1)$$

The relationship between the various OEE components is shown in Figure 1.

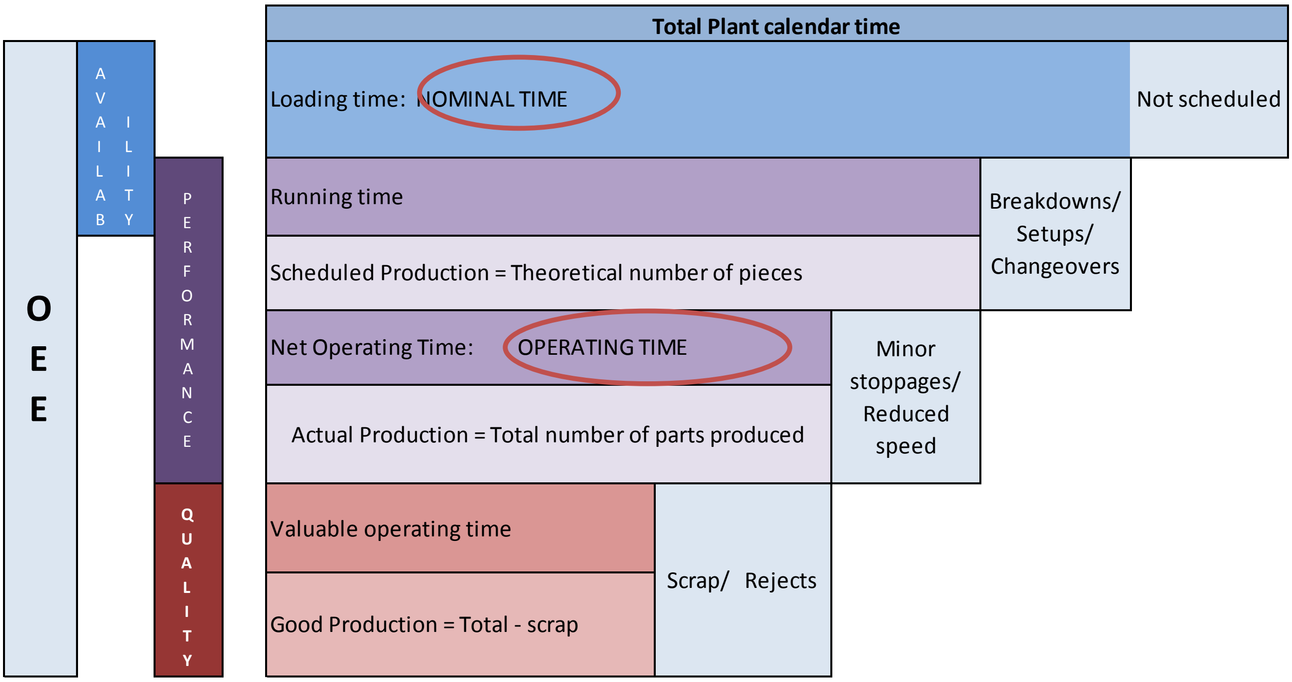

Fig. 1. Components of the OEE indicator outline

According to this outline the different ratios can be calculated as shown in Equations (2-5).

$$\text{AVAILABILITY (\%)} = \frac{\text{Operating Time}}{\text{Available Time}} = \frac{\text{Available time- Downtimes (breakdowns/setups)}}{\text{Available Time}} \quad (2)$$

$$\text{PERFORMANCE (\%)} = \frac{\text{Net Operating Time}}{\text{Running Time}} = \frac{\text{Real Production}}{\text{Scheduled Production}} = \frac{\text{Ideal Cycle Time*Output}}{\text{Running Time}} \quad (3)$$

$$\text{QUALITY (\%)} = \frac{\text{Valuable operating time}}{\text{Net Operating Time}} = \frac{\text{"Good" parts}}{\text{Actua Production}} \quad (4)$$

$$\text{OEE (\%)} = \frac{\text{"GOOD" PRODUCTION}}{\text{THEORETICAL OUTPUT IN AVAILABLE TIME}} = \frac{\text{Valuable Operating Time}}{\text{Available Time}} \quad (5)$$

This indicator does not try to justify the reasons for the deviation, but to identify the losses in order to eradicate the root causes. Any expression to calculate the OEE should be based on identifying the causes and preventing the equipment to reach its maximum performance. Thus, the OEE is not only a metric, but it also raises a framework for improving the process. That is, it states which parts of the process are likely to improve.

2. TYPES OF LOSSES IN OEE

Losses are any activities that absorb resources without creating value [6]. If losses are classified by their causes, the following losses can occur:

1. Equipment failure;
2. Process: the way of using the equipment during the production process;
3. External: due to factors that cannot be improved by the factory's maintenance team, such as a lack of raw materials, a lack of staff or a fall in demand.

The latter are not considered by the OEE, as they are not the responsibility of the maintenance or production teams. However, the ones due to equipment failures and process, which vary throughout the day, are those which cause the

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decrease in the equipment or machine effectiveness. Thus, in a machine or equipment operation, three types of losses (waste or "muda") can be distinguished shown in Fig.1:

1. **Time Loss**: the machine or equipment should be working but it does not.

a) Breakdowns: when a component of a machine completely loses its initial operating conditions, causing its mandatory stop and for the element to be replaced by a technician. The settings of the machine until it again reaches its rated speed are included within the time of breakdown.

b) Changeovers: when for some reason (format or batch change, lack of supply of materials...) the machine stalls.

2. **Speed Loss**: the machine or equipment is operating, but is doing so below its maximum specification speed.

a) Minor stoppages: the machine does not operate at a constant speed and suffers short, intermittent interruptions. For example: blocks produced by frequency sensors or jams in the conveyors, etc.

b) Reduced speed (slowdown): the difference between the speed currently set and the theoretical or designed speed. Occasionally, the production rate is reduced to prevent other losses such as quality defects and breakdowns.

3. **Quality Loss**: the machine or equipment produces products that do not meet quality requirements.

a) Scrap (waste): products that do not achieve the quality requirements.

b) Rejects: operations performed on products that are not good at first (for not achieving quality requirements), but can be reprocessed into "good" products.

The OEE only considers "good" units as those which meet approval ~~at~~ the first time, not those which need to be reprocessed.

3. OEE FACTORS

The first big block loss rate affects the *Availability* and the main objective is to identify the problems caused by breakdowns and stoppages in order to work on their causes, and thus eliminate them systematically. Addressing them is essential for having some system, or at least a simple calculation spreadsheet to obtain this information with the desired frequency, from which data could be collected and stratified. Elaborate diagrams could be made, such as the cause-effect diagram known as the Pareto chart, and more sophisticated tools such as histogram or control charts could be used. In Equation (2) the available time refers to the total available equipment time after deducting time spent on planned activities that may have interrupted production, for example: calendar, schedules and planned maintenance, employee break time, process improvement initiatives or testing equipment, maintenance by the operator of the machine (cleaning teams…), operator training, etc.

The second large block of losses affects operating *Performance*, which measures the performance level of the equipment considering downtime losses, minor interruptions losses and a lower speed than the designed speed (see Equation (3)). The dead times are periods when it was not planned to produce for legal reasons, Holidays, lunch, scheduled maintenance, etc., which are called Planned Stoppages. This may be handled in the same way as the availability, and with SMED techniques (Single Minute Exchange of Die-change time in single digits or less than 10 minutes).

For the third block loss rate, *Quality* measures the fraction of the output, which achieves the quality standards reflect that a portion of the time is used in the manufacturing of parts with defects (see Equation (4)). Techniques of the first block can be used again, adding some statistical tools such as Process Capability based in dispersion studies (Cp or Cpk). Within this context, the Six Sigma methodology can be used as a quality metric, aiming to eliminate variability in the processes to achieve a more consistent quality. The known Rolled Throughput Yield (referred to as RTY onward) measures the total output of a factory and is seen as a chain of manufacturing processes systems. From this point of view, the total performance, or RTY, will be the product of the individual performance of each of the processes that are a part of this chain or system (First Time Yield, referred to as FTY onward~~s~~). Therefore, the overall system performance (RTY) is calculated as shown below in Equation (6):

$$RTY = FTY_1 * FTY_2 * FTY_3 * \ldots . * FTY_N \tag{6}$$

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FTY_i being the individual performance of each of the N workplaces, equipment or lines, forming a part of the process or system. It is calculated as the number of good units by the total units produced in the process, or what is the same, the Quality rate calculated in OEE.

4. BEYOND MEASURE OEE

The purpose of the OEE, as originally defined by Nakajima [3], is to assess the progress made by TPM initiatives through a measure of the individual equipment. However, because its use in industry is increasing, further research has sought to expand the scope of the OEE to processes or entire factories. Furthermore, evaluation of its scope has also been expanded with the inclusion of more elements of the production process in addition to the availability, performance and quality. For example, Nachiappan and Anantharam [2] define the overall effectiveness of a continuous product line. However, almost all descriptive studies of OEE based on their metrics are used to gain knowledge and understanding of the research problem, and they usually do not apply explanatory and/or predictive statistical analysis considerations. Thus, the published results so far provide very general conclusions regarding the behavior of the OEE. Given this need, Caro and Ortiz [7] present a quantitative approach to looking for the application of statistical analysis and statistically identifying explanatory factors of this indicator.

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