OVERALL EQUIPMENT AND ENERGY EFFECTIVENESS AS ONE OF THE KEY PERFORMANCE INDICATORS IN MANUFACTURING

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Abstract

The paper explores Overall Equipment Effectiveness concept or OEE as one of the key performance indicator of Total Performance Manufacturing. The main scope of this paper is the detailed description of the concept and its possible extension with energy efficiency factor.

Key words: Effectiveness, key performance indicator, availability, performance, quality.

INTRODUCTION

According to European Commission [1] manufacturing is still the driving force of the European economy, contributing over 6.500 billion euro in GDP and providing more than 30 million jobs. It covers more than 25 different industrial sectors, largely dominated by SMEs, and generates annually 1.500 billion euro of value added.

However, the average efficiency in manufacturing plants, measured on the so called Overall Equipment Efficiency (OEE) index, is only 60% (and a world-class rate is 85%). In practice of manufacturing plants, the generally accepted world-class goals for each factor are as follows 90% of Availability, 95% of Performance and 99.9% of Quality, whereby as already mentioned a composite OEE number is higher than 85% [4].

The loss from inefficiencies in production could thus be as high as 1.000 billion euro annually. The OEE index is used in most manufacturing companies as a key metric in TPM (Total Productive Maintenance) and LEAN Manufacturing to provide a consistent way of measuring the effectiveness of the production.

Worldwide, industry consumes almost one-half of all the commercial energy used [2] and is responsible for roughly similar shares of greenhouse gases. An increasing number of manufacturing companies are facing a supply chain, which is demanding quantification of the carbon footprint and demands for future reductions. In order to stay competitive in the 21st Century; companies need to be include sustainability in their production optimisation schemes.

Hence, the aim of this paper is to explore the performance metrics for Total Performance Manufacturing.

OEE DESCRIPTION

According [4] OEE stands for Overall Equipment Effectiveness. Essentially, it is a single figure that signifies the utilisation of a machine. This can be at a job level, shift level or overall level.

The Overall Equipment Effectiveness is a “best practice” way to monitor and improve the effectiveness of manufacturing processes, i.e. machines, manufacturing cells, assembly lines, etc. The OEE gives us a consistent way to measure the effectiveness of TPM and other initiatives by providing an overall framework for measuring production efficiency. OEE reduces complex production problems into simple, intuitive presentation of information.

Three main factors make up the OEE calculation. They are: Availability, Performance and Quality. These are expressed as a percentage and then the three factors are multiplied together to give you a single OEE figure – again expressed as a percentage.

The point of the final calculation is that it gives you a single figure to measure, and then compares, your OEE. Therefore you may compare the OEE between jobs. This will allow you to see which jobs run well and which ones don’t. You can then take corrective action.

You may compare shifts – and gain an insight to whether one shift performs better than another – again you can investigate the underlying reasons and take action to improve the OEE.

You may compare machines within, or across several plants. You may even compare different manufacturing plants where similar product are manufactured and understand underlying reasons why one may have a better OEE than another, and then take corrective action.

Ultimately you can, if the data is available, compare your OEE to that of your competitors or industry best and put plans in place to reach the best in class. Like best practice initiatives you may look at industries that have similar characteristics to your own and then try to emulate practices that improve your OEE to the levels they sustain.
DESCRIPTION OF OEE COMPONENTS

Overall Equipment Effectiveness’ analysis starts with definition of the amount of time a facility is open and available for equipment operation (Total Operating Time).

If we subtract a category of time called Planned Shut Down from Plant Operating Time, which includes all events that should be excluded from efficiency analysis because there was no intention of running production (e.g. breaks, lunch, scheduled maintenance, or periods where there is nothing to produce). The remaining available time is so called Planned Production Time.

Availability takes into account Down Time Loss, which includes any Events that stop planned production for an appreciable length of time (usually several minutes – long enough to log as a trackable Event). Examples include equipment failures, material shortages, and changeover time. Changeover time is included in OEE analysis, since it is a form of down time. While it may not be possible to eliminate changeover time, in most cases it can be reduced. The remaining available time is called Operating Time or actual production time [4].

Performance takes into account Speed Loss, which includes any factors that cause the process to operate at less than the maximum possible speed, when running. Examples include machine wear, substandard materials, misfeeds, and operator inefficiency. It is the actual achieved output (expressed in elements produced) against the ideal output for the machine (expected production).

The final factor on the overall OEE calculation is quality. This is simply a measure of good product or output divided by the actual output (total product for the job, shift, day, week, etc.). An element for discussion here is whether you include expected set up waste within the figures.

We now simply multiply the figures together to get OEE Index, where
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\text{Availability} \times \text{Performance} \times \text{Quality} = \text{OEE}
\]
Efficiency improvements have often little or no effect, because more products are being rejected at higher production speed. Other reasons for sub-optimal production are the time it takes to change the production setup and production stops due to lack of robustness to small changes in the working condition. If the output of quality approved product lags far behind the capacity of the installed machinery the installed machine has a hidden production capacity, i.e., the capacity is not being used for the production of good products. How your machine performs in comparison to an ideal machine i.e. a machine, which always operates at maximum speed and with a quality rate of 100%, is determined by losses in availability, performance, and quality. The OEE indicates how effectively the machine is being used compared to the ideal machine (OEE = 100%). The diagram in Figure 1 illustrates how the OEE is determined.

TAKING ENERGY CONSUMPTION INTO CONSIDERATION AND EXTENSION OF OEE

As can be seen, the OEE index is a pure economic efficiency metrics. However, manufacturing is a major consumer of energy. It is becoming increasingly clear that the quantitative assessment of various factors affecting industrial energy consumption is essential for forecasting industrial energy demand and particularly estimating energy requirements of alternative manufacturing strategies.

In practice, ambitious world-class goals for each component factor can be quite different: availability 90%, performance 95%, and quality 99.9%. Worldwide, industry consumes almost one-half of all the commercial energy used [2], [3] and is responsible for roughly similar shares of greenhouse gases. An increasing number of manufacturing companies are facing a supply chain, which is demanding quantification of the carbon footprint and demands for future reductions. In order to stay competitive in the 21st Century, companies need to be include sustainability in their production optimisation schemes.

Manufacturing operations are among the most energy-intensive in the world. For instance in Germany industry is responsible for around 40% of the total energy consumption. Moreover industry energy use is responsible for almost 30% of all greenhouse gas emissions, which contribute to global climate change.

Energy management approaches and measurement and verification protocols are becoming more and more a significant issue in manufacturing environment. Nowadays energy data and information are not easily available and often they are disaggregated, thus their analysis and the consequent optimization strategies are very difficult to be implemented. In general when the energy managers try to implement energy monitoring applications, they find themselves drowning in the volume of data generated. Thus it becomes important to define and apply Key Performance Indicators (KPIs) to summarize volumes of data into a few critical “nuggets” of actionable information.

By combining the OEE KPI calculation with the energy management technologies it is possible to define a new KPI: the OEEE Overall Equipment and Energy Efficiency index.

This key performance indicator will be applied to get an effective tool for machinery management to measure or document improvements in energy or WAGES (Water, Air, Gas, Electric and Steam or in general energy consumption) usage.

In conclusion the above mentioned OEE will be extended with the energy consumption parameter to encompass energy management.

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\text{OEEE} = \text{OEE} + E
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\[
\text{OEEE} = \frac{\text{Availability} \times \text{Performance} \times \text{Quality} \times \text{Energy}}{}\
\]

So we have defined a new metrics by adding energy to the OEE index, thus creating a new key index, the OEEE (Overall Equipment and Energy Efficiency), with the following four components:

- **Availability** looks at the down time loss, which is the time the production is stopped, compared to the planned production time. Availability is a function of equipment failures, material shortages, and changeover time.
- The **Performance component** is also a function of down time, changeover time and speed loss, i.e. factors that results in the process operating at less than maximum speed due to machine wear, misfeeds, and operator inefficiency.
- The **Quality component** depends on the amount of produced items that fails to meet quality standards and thus will have to be either rejected or reworked.
- The **Energy component** is a function of the total energy consumption used in the production process. To incorporate this new part of index we need to know detailed lifecycle energy or CO₂ expressed, e.g. in MJ or in kg. Also major processes or components for product generation have to be very well described using business process modelling of particular processes or subprocesses. There is also very important to collect uninterrupted sequences of data from all physical devices consuming energy.
CONCLUSION

Decreasing the energy consumption is becoming more and more crucial in many businesses around the globe.

Taking into account manufacturing industry with all is also affected with optimization of energy consumption. Manufacturing operations are among the most energy-intensive in the world. To develop a new KPI we have extended the traditional Overall Equipment Effectiveness index with energy consumption aspects.

There is still a question open how will we collect and measure energy consumption data from particular physical devices and how to automatist all processes.

References


