Measuring OEE in Malaysian Palm Oil Mills

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Abstract
Today maintenance is considered as a strategic and integral part of the business process and it is an established fact that “It creates additional value.” As the understanding of the strategic importance of maintenance has risen, so too has, the efforts to control, measure, and better manage this function. Performance Management and measurement is important because it identifies current performance gaps between current and desired performance and provide indication of progress towards closing the gaps. Carefully selected KPIs identify precisely where to take action to improve performance. OEE, a vital KPI of TPM, is used to evaluate performance of maintenance management; it is an index frequently used in the manufacturing industries to calculate the overall equipment effectiveness of a production system or part of it. This paper examines the importance of maintenance management performance evaluation, determines the effectiveness of OEE as a primary performance metric and explains its three main factors that make up the calculation process in the context of Malaysian palm oil mills.

Keywords: Key Performance Indicator, Overall Equipment Effectiveness, Performance Evaluation

1. Introduction

Globalization has expanded the Malaysian palm oil market to over 140 countries; Malaysia produced 18 million tons of palm oil in 2011. Palm oil production for the year 2011 both in Malaysia and Indonesia was 42 million tons; 86% of the world total production of 49 million tons (Oil World 2011). Though, palm oil is predominantly used for food applications, its non-
food use is growing at a fast pace. Non-food uses of palm oil and palm kernel oil (PKO) are either directly or through the oleo-chemical route. Direct applications include: the use of crude palm oil (CPO) as a diesel fuel substitute; drilling mud; soaps and epoxidised palm oil products; polyols; polyurethanes; and polyacrylates. Currently, the emerging growing demand for palm oil is due to its relatively cheap price, compared to other vegetable oils, and versatile advantage both in edible and non-edible industrial applications. In terms of supply, it will be factored by continued yield improvement in Malaysia and increase in palm oil plantation areas in Indonesia (Carter, Finley, Fry, Jackson & Willis, 2007). As one of the biggest producer and exporter of palm oil and palm oil products, Malaysia has an important role to play in fulfilling the growing global demand for oils and fats in general. For the palm oil milling sector to stay competitive, it is imperative that they elevate the maintenance management role; from a cost center to the strategic partner in business. Deficient maintenance management can severely affect competitiveness of an organization by reducing throughput, increasing inventory, and leading to poor performance. Performance cannot be managed without measurement: it provides the required information to the management for effective decision making; and is used by industries to assess progress against set goals and objectives in a quantifiable way for effectiveness and efficiency (Baluch, Sobry & Mohtar, 2010).

Prior to the early 1900s, maintenance was considered as a necessary evil. Technology was not in a state of advanced development, there was no alternative for avoiding failure, and the general attitude to maintenance was, “It costs what it costs.” With the advent of technological changes and after the Second World War, maintenance came to be considered as an important support function for operations, production, and manufacturing. During 1950-1980, with the advent of techniques like preventive maintenance and condition monitoring, the maintenance cost perception changed to: “It can be planned and controlled.” Since 1990s there has been a steady increase in acknowledgement of the strategic importance of maintenance. One of the driving factors has been the continued pressure on costs attributable to maintenance. There has also been a growth in the awareness of the part played by maintenance in managing the risk exposure of a corporation. In some instances, this is driven by legislative changes in the areas of safety and environment. In other instances, it is driven by the increased understanding of the dramatic effect that maintenance management can have on end product quality and overall organization’s profitability. While cost is the issue that generally receives the majority of attention at a corporate level, the issues associated with risk management are equally important and vital to the responsible management of physical assets. Today maintenance is considered as a strategic and integral part of the business process and it is an established fact that “It creates additional value” (Liyanage & Kumar, 2003). Tsang (2002) reported that maintenance plays a vital role in any organization using machinery and should be incorporated into an organizations’ business model. Once understood, it requires a proper strategy to exploit such potential. Strategy at any level; say at a business and functional level that will provide the company with a sense of direction, integrity and purpose (Pintelon et al., 2006). As the understanding of the strategic importance of maintenance has risen, so too has, the efforts to control, measure, and better manage this function. This paper highlights how measuring OEE for evaluating maintenance management performance in palm oil mills will help identify the factors causing poor performance, and provide an opportunity to enhance palm oil mill’s competitiveness, profits, and sustainability.
2. Maintenance Performance Measurement (MPM)

Maintenance has been defined as the combination of all the technical and administrative actions, including supervision, intended to retain an item, or restore it to a state in which it can perform a required function (IEC, 2006); whereas, maintenance management is the process of directing maintenance organization effectively. The scope of maintenance management should, therefore, cover every stage in the life cycle of technical systems (plant, machinery, equipment, and facilities): specification, acquisition, planning, operation, performance & evaluation, improvement, and disposal (Murray et al., 1996). Performance measurement and evaluation is the process of quantifying the efficiency and effectiveness of actions; it is a systematic, rigorous, and meticulous application of scientific methods to assess the design, implementation, improvement or outcomes of a program (Neely et al., 1995, and Rossi et al., 2004). For nearly 30 years, the performance measurement literature has focused on developing relevant, integrated, balanced, strategic and improvement-oriented performance measurement systems (Bititci et al., 2005).

As maintenance is an important support function in business operations with significant investment in physical assets it plays an important role in achieving organizational goals (Tsang, 2002). The issues and challenges associated with MPM concern: relevance; interpretability; timeliness; reliability; validity; cost & time effectiveness; ease of implementation; and updating and maintenance for regular use by stakeholders at various levels. Some of the impelling reasons behind demands on maintenance performance measurement are that: it measures value created by the maintenance; justifies investment; and helps to revise resource allocations.

Performance measurement is a fundamental principle of management and its measurement is important because it identifies current performance gaps between current and desired performance and provides indication of progress towards closing the gaps. Carefully selected key performance indicators (KPIs) identify precisely where to take action to improve performance, (Weber & Thomas 2005). Overall Equipment Effectiveness (OEE) is a vital KPI of Total Productive Maintenance (TPM), a widely practiced maintenance management strategy that is used to evaluate performance of maintenance management.

3. TPM and OEE

In today’s global economy, the survival of companies depends on their ability to rapidly innovate and improve. As a result, an increasing search is on for methods and processes that drive improvements in quality, costs and productivity. They are adopting and adapting best in class; manufacturing practices and improvement processes. As part of these benchmarking efforts TPM has been identified as a best in class manufacturing improvement process (Robinson & Ginder, 1995). From generic perspective, TPM can be defined in terms of OEE which in turn can be considered a combination of the operation maintenance, equipment management and available resources (Chan et al., 2005). The term “Total Productive Maintenance” was first used in the late 1960’s by Nippondenso, a supplier of electrical parts to Toyota (Robinson & Ginder, 1995). TPM has also been defined as a plant improvement methodology which enables continuous and rapid improvement of the manufacturing process through the use of employee involvement, employee empowerment and closed looped measurements of results (Robinson & Ginder, 1995). The goal of TPM is to maximize equipment effectiveness, and OEE is used as a measure (Waeyenbergh & Pintelon, 2002). TPM helps to raise the OEE value by supplying a structure to facilitate the assessment of losses, and subsequently giving priority to dealing with the more serious offenders (Eti et al., 2004).
In an industry, ideally, equipment should operate 100% of the time at maximum capacity giving an output of 100% good quality product. However, this seldom happens because there are losses which occur in a real life situation that differentiate between the actual and the ideal performance. OEE needs to be measured in every organization that is committed to eliminate equipment or process related wastes through implementing TPM along other initiatives such as: lean Manufacturing; Operational Excellence; and World Class Manufacturing etc.

OEE is an index frequently used in the manufacturing industry to calculate the overall equipment effectiveness of a production system or part of it. The index itself was presented as an overall metric in the TPM concept (Nakajima, 1988). KPIs are the metrics (a metric is a standard of measure) that an organization chooses to use as their measures of process performance. They can vary among industries and among individual processes. To begin managing by metrics, an organization must first collect meaningful and pertinent data; information that is important to the operation of the business which is then converted into one or more KPIs. These tools can be used to immediately evaluate the performance of a process variable, as well as provide a means for tracking that variable over time. Some typical KPIs for manufacturing and maintenance include: operating cost; asset availability; lost time injuries; number of environmental incidents; OEE; operational availability (OA); return on investment (ROI); and asset utilization. However, OEE being an important KPI of TPM, an extensively practiced strategy in industry worldwide, is used in this article to evaluate the efficiency and effectiveness of maintenance management performance, in Malaysian palm oil mills. OEE has been selected for its ease of grasp, understanding and interpretation by the maintenance management and technicians alike. Most other maintenance optimising models, such as Markov decision processes, are stochastic in nature, which is not only difficult to grasp but also difficult to understand and interpret and are barely practitioner friendly. Measurement is an important requirement of continuous improvement process; it is therefore necessary to establish appropriate metrics for measurement purposes. OEE is a hierarchy of metrics which evaluate and indicate how effectively a manufacturing operation is utilized. The results are stated in a generic form which allows comparison between manufacturing units in differing industries.

4. Data Collecting Issues and Challenges

Collecting the data from operators on the performance factor is not always a reliable measure. If the mill decides to settle on manual data collection there is a hereditary problem in that; manual forms are often filled in at the end of shift and may not reflect the truth of what is happening. This is not because there is an inherent dishonesty in machine operators. The problem is that ‘remembering’ what happened in terms of set up time, run time and downtime including the reasons is subject to the ‘witness effect’. This means that you may get several witnesses to a crime but it is unlikely that they will all describe the suspect precisely and the same!

The longer the time between the event and the recording; the greater the inaccuracy you will get. Some companies may insist that the data is recorded at the end of the job or at the end of the shift; some even at the end of the week. This method will entirely compromise the factor that contributes to the OEE figure. It is likely that the figure will be overstated and the mill’s OEE will be higher than it genuinely is. There will also be a danger that the figures recorded will also be the ‘target’ figures. This means that if the operator is allowed to take 20 minutes to set-up a machine he or she may always take 20 minutes, or record 20 minutes, even if it is
less. It matters, of course, if the mills are not finding out the truth they may not be revealing the hidden capacity that may be utilized to improve the performance (and the OEE) of their investment. In some palm oil mills, for example OEE can appear improved by actions such as purchasing oversize equipment, providing redundant supporting systems, and increasing the frequency of overhauls; investment in higher installed mill capacity and purchase of redundant standby critical equipment, such as spare ‘boilers’, ‘presses’, ‘decanters’, and turbines etc. are some of the examples that compensate for their operational inefficiencies.

Some may suggest that collecting data manually as the events happen may be the answer - but the reality is that any manual method would actually also impair the OEE figure simply through the act of collecting it. The solution is that the recording of all the factors needs to be automatic or as unobtrusive, as possible. Proper sensors installed strategically can provide the data required. This can be addressed by installing a simple ‘heartbeat’ sensor to monitor if the machine is running or not and at what speed. In the event of the machine stopping, the operator simply has to record the reason for the stop through a scan of a barcode. This ease of use will provide the mill with ‘machine truth’. This is the starting point to not only implementing OEE measurement but gaining the power to improve it. At the initial stage, though, mills may use generic single machine OEE form similar to the one designed by this author; template shown in Table: 1. Maintenance daily service log recordings can also be used to cross check the down times.

Self contained more sophisticated sensing devices are available, that can report what is happening at the machine in near real-time. It gives instant insight to the machine performance at a job, shift and machine level. A critical element of the sensing devices is a light emitting diodes (LED) text display that is located near the machine to provide feedback on performance to the operator. The nature of the feedback relating to current production rate, if the machine is running or idle, the current OEE and other vital signs gives them the information required to help them run the machine in a more efficient manner. Most operators welcome the objective measurement and feedback from the LED, and that motivates them to achieve greater efficiencies. Importantly, the user interface for the person managing the plant is very intuitive and reveals through meaningful representation of the data what can be improved. Data thus collected can be triangulated; individual machine or a production line downtime recorded in maintenance daily logs should enumerate with the downtime recorded in the production operational availability logs. Any discrepancies observed would direct to non-maintenance related losses; such as operator errors encountered due to incompetent machine operators. Collection of data for calculating OEE for individual machines or equipment can also be done through daily production logs; it can be computed to obtain operational history of critical machines and equipment on daily, weekly, monthly, or annual basis for comparison and improvement. There is a variety of maintenance and production management software available that can be utilized to maintain downtime and repair history of the machines & equipment as well as complete production lines through organized maintenance daily service log and work order management system support; a Malaysian developed computer maintenance management system (CMMS) software “CWorks” is adequate for most manufacturing operations including palm oil mill applications (there is also a free version of ‘CWorks’ available). Work Order (WO) management system is an integral part of CMMS and helps to build up operational history of the critical machines and equipment; it helps to track various costs pertaining to specific assets such as cost of labor, and parts etc.
5. OEE Calculation Explained

OEE is an aggregated productivity measure that takes into consideration the six big losses that affect the productivity of equipment in production systems (Venkatesh, 2006). Equipment failure, setup, and adjustments are related to the downtime and expressed in terms of availability. Idling and minor stoppages, together with reduced speed, are related to speed losses and expressed in terms of the performance rate. Finally, process defects and reduced yield are related to defects and expressed in terms of the quality rate. Three main factors that make up the OEE calculation; Availability, Performance, and Quality are expressed as a percentage and are multiplied together to give a single OEE figure, also expressed as a percentage; Table 2, designed by this author, depicts a generic daily production log & OEE for a single mill template. The three factors involved in this calculation are independent of each other; i.e. variations in one of the three factors will not affect the other two. Normally, OEE figures can be found from 30-95 per cent (Ljungberg, 1998; Ahlmann, 1995).

The point of the final calculation is that it gives a single figure to measure, and then compares OEE. Therefore manufactory may, on a single machine perhaps, compare the OEE between jobs; this will allow business to see which jobs run well and which ones do not. One can then take corrective action, may compare shifts and gain an insight to whether one shift performs better than another or investigate the underlying reasons and take action to improve the OEE. Businesses may compare machines within, or across several plants and may even compare different manufacturing plants where they make similar product and understand underlying reasons why one may have a better OEE than another, and then take corrective action. Ultimately, if the data is available, businesses may compare their OEE to that of their competitors or industry’s best and put plans in place to match the best in-class. Like best practice initiatives businesses may look at industries that have similar characteristics to their own and then try to emulate practices that improve their OEE to the levels they can sustain. Though data for this is readily available through production logs and financial statements that most palm oil mills maintain through some sort of manual or computerized generic spreadsheets, dummy figures have been used here to illustrate OEE calculations. Let’s take a look at each factor in turn.

5.1 Availability - The calculation for availability is simply the actual production time, including set up, out of the planned production time. Time that is lost due to downtime through machine failure, lack of input materials, lack of operator(s), as a series of examples; will be set against the calculation. Therefore the actual consumed time divided by the available time will give a figure, expressed as a percentage that is a factor that contributes to the overall OEE calculation. The availability rate is the time the equipment is really running, versus the time it could have been running (Table: 2, column 15).

\[
\text{Availability Rate} = \frac{(\text{Operating Time} - \text{Downtime})}{\text{Operating Time}} \quad \text{(Eq #1)}
\]

5.2 Performance - The next factor, performance, is in theory very simple. It is the actual achieved run rate against the ideal run rate for the machine. Often the machine ideal or optimum run rate may be the figure published by the machine manufacturer. However, it is well known that the ideal run rate may be affected by the situation of the machine, heat, cold product running through etc. Purists would still refer to the published run rate while others may suggest that expected performance may necessarily be degraded by the nature of the product going through it. In a situation where the same product, with no expected variability, passing through the machine, such as a line in a bottling plant or CPO production line, one would expect the ideal run rate to remain constant and therefore variances may easily be identified. However, if looked at another example, such as a machine used in packaging carton manufacture, then the machine performance can be degraded by the size of the input product or the number of slots and folds or the quality of the material. In this situation one may wish to measure the performance against the degraded expected run time rather than, or maybe as well as, the ideal run rate. Performance rate is the quantity produced during the running time, versus the potential quantity, given the designed speed of the equipment (Table: 2, column 16).

\[
\text{Performance Rate} = \frac{\text{Total Output}}{\text{Potential Output at Rated Speed}} \quad \text{(Eq #2)}
\]
Majority of palm oil mills that belong to first and second generation mills do not run their equipment on variable speeds. The whole manufacturing line runs at one speed; it is either running or not running, there is no slow or fast run mode in the process line. However, provision has been made for the ones who do run on variable speed and it is reflected in the ‘performance rate’ calculations.

5.3 Quality - this is simply a measure of good product divided by the total product; for the job, shift, day, week etc. (Table: 2, column 17).

\[ \text{Quality Rate} = \frac{\text{Good Output}}{\text{Total Output}} \quad (\text{Eq} \#3) \]

The quality rate is percentage of good parts out of total produced sometimes called “yield”. In case of palm oil mills it is the CPO produced; within spec and out of spec.

5.4 OEE - To arrive at OEE; simply multiply the figures together; dummy figures, in the following calculation, have been taken for illustration only (Table: 2, column 18).

\[ \text{OEE} = \text{Availability Rate} \times \text{Performance Rate} \times \text{Quality Rate} \quad (\text{Eq} \#4) \]

For ease of use and interpretation at the shop level, all the information is negotiated, using simple formulae, through linked spreadsheet cells containing readily available data. OEE figure thus obtained can be improved upon; in terms of Availability mills can look at activities that reduce unplanned downtime: this may be putting engineers on call, making sure; mills have critical spares, input products (raw materials) do not run out, and that the operator is ‘available’. Performance may be addressed, dependent perhaps on the machine and industry, by good maintenance routines to maintain speed, or in a degraded environment, redesign of product if necessary to achieve the planned or ideal run speed. Quality of course can be addressed, perhaps, by improved maintenance routines or improved quality of raw materials, amongst others. There will be debate within organizations about what should actually be within the overall factors; and there are flexible interpretations of this. One may think that agreeing about an OEE initiative and the measures is a complex task: and depending on one’s organization it may well be; however, it is the smaller of the challenges one will face.

6. Conclusion

OEE is embodied in the first of the original ‘Pillars of TPM’; it guides all TPM activities and measures the results of these loss-focused activities. This use of OEE evolved into the current Focused Improvement Pillar, one of eight TPM Pillars (Nakajima, 1989). The goal of measuring OEE is to improve the effectiveness and reliability of equipment. Since equipment effectiveness affects shop floor employees more than any other group, it is appropriate for them to be involved in tracking OEE and in planning and implementing equipment improvements to reduce lost effectiveness.

Collecting the data for OEE will: teach the operator about the equipment; focus the operator’s attention on the losses; grow a feeling of ownership of the equipment. The shift supervisor or line manager is often the one who receives the daily operating data from the operator and process it to develop information about the OEE. Working hands on with the data: give the supervisor/manager basic facts and figures on the equipment; help the supervisor/manager give appropriate feedback to the operators and others involved in equipment improvement; and allow the supervisor to keep management informed about equipment status and improvement results.

OEE breaks the performance of a manufacturing unit into three separate but measurable components: Availability, Performance, and Quality. Each component points to an aspect of
the process that can be targeted for improvement. OEE may be applied to any individual Work Center, or rolled up to Department or Plant levels. It is an important measure of efficiency and improvements in OEE have a direct positive effect on the bottom line; by understanding it and improving it, businesses are getting a greater return on their investment (ROI). This tool also allows for drilling down for very specific analysis, such as a particular product or Part Number, Shift, or any of several other parameters; it also gives businesses a valid comparative measurement across their own plant, across sites, and potentially against their competitors.
References


### Annexure

#### Oil Press OEE (Asset #006-A)

<table>
<thead>
<tr>
<th>Date</th>
<th>Time in Shift</th>
<th>Breaks &amp; Lunch</th>
<th>Scheduled Maintenance Time</th>
<th>Meets etc Non Production Time</th>
<th>Setup Adjustments</th>
<th>Minor Stoppages</th>
<th>Breakdowns</th>
<th>Speed Loss</th>
<th>Setup Available for operation</th>
<th>Net time machine worked</th>
<th>Total Production of CPO (Tons)</th>
<th>Out of Spec CPO &amp; Slush oil recovery</th>
<th>Availability Rate</th>
<th>Performance Rate</th>
<th>Quality Rate</th>
<th>OEE = Availability x Performance x Quality Rate</th>
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**Table: 1 – Single Machine OEE Template**

#### Individual Mill Daily Production Log & OEE Template

<table>
<thead>
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<th>Date</th>
<th>Time in Shift</th>
<th>Breaks &amp; Lunch</th>
<th>Scheduled Maintenance Time</th>
<th>Meetings etc Non Production Time</th>
<th>Setup &amp; Adjustments</th>
<th>Minor Stoppages</th>
<th>Breakdowns</th>
<th>Speed Loss</th>
<th>Total Time Available for operation</th>
<th>Net Time Machine Worked</th>
<th>Total Production of CPO (Tons)</th>
<th>Out of Spec CPO &amp; Slush oil recovery</th>
<th>Availability Rate</th>
<th>Performance Rate</th>
<th>Quality Rate</th>
<th>OEE = Availability x Performance x Quality Rate</th>
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**Table: 2 – Individual Mill Daily Production Log & OEE Template**
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<th>Scheduled Maintenance Time</th>
<th>Meetings etc. Non Production Time</th>
<th>Setup &amp; Adjustments</th>
<th>Breakdowns</th>
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<th>Time Mill available for operation</th>
<th>Net Time Mill Worked</th>
<th>FFB Processed (Tons)</th>
<th>Total Production of CPO (Tons)</th>
<th>Out of Spec CPO &amp; Slush Oil Recovery</th>
<th>Availability Rate</th>
<th>Performance Rate</th>
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Table: 3 - Multi Mill OEE Template