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Classification of Losses in Overall Equipment Effectiveness Calculation

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ABSTRACT: The intention of elimination of losses is to improve the efficiency and effectiveness of the production and reduce the unnecessary expenses. OEE is a performance metric of the machine or process and it provides information to the user to monitor and understand the actual situation of the machine compared to the ideal situation of the machine. Although six big losses are defined in the OEE, but it is still not clearly shows the scope of improvements in availability. Most of the time, users are more focus on the breakdown rather than setup process due to breakdown losses have greater impact on the OEE percentage. Therefore, excessive setup time or changeover time is hidden in the OEE. Furthermore, the frequency of the setup process and ideal setup time is not clearly stated in the OEE. The objective of this study is to visualize the availability losses by improve the classification of availability losses. The new classification of losses is examined by real data and it showed better visualization than traditional classification of losses. It is necessary to quantify these losses with modified OEE to visualize the losses in a better way.

KEYWORDS: Overall Equipment Effectiveness, classification of losses, hidden wastes, visualization

1. INTRODUCTION

In the manufacturing sector, elimination of losses is one of the important issues to reduce the failure rate, utilize resources and remain the competitiveness of the company. Due to this demand, Overall Equipment Effectiveness (OEE) is introduced in the philosophy of Total Preventive Maintenance (TPM). OEE is not only part of the TPM philosophy, but it also can be used individually as a performance measurement of the machine or process. Nakajima had proposed six big losses that quantify the losses that available in the equipment to allow OEE users quantify the wastes in between the planned production time [1].

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The six big losses are categorized into three factors, availability, performance and quality. Availability indicates the breakdowns and setup time while minor stoppages and reduced speed are categorized in the performance. For quality, it indicates the yield losses and defects. Through the OEE metric, users able to identify the scope of improvements and build up an improvement plan based on the particular area.

However, most of the researches are focused on the breakdown problem when they try to improve the OEE in terms of availability [2]. Moreover, OEE also has weakness and may cause the hidden potential improvements invisible from the view of the production team as well as management level [3]. Then, there are wastes that cannot be quantified through the traditional approach of OEE [4]. Workers tend to lengthen the working time when perform setup or changeover process to release time pressure. The tolerance given to them might be unnecessary because they can actually reduce the lead time, but it may tolerate in the OEE which management level do not aware of this. In addition, the frequency of the changeover and setup process is invisible in the traditional OEE approach because it is mixed up with the excessive working time performed by the workers.

The intention of OEE is to improve and consummate the equipment in terms of effectiveness and efficiency from time to time. To achieve this, the visualization of wastes is one of the important elements. Problem solving cannot be done without the classification of losses and this emphasizes the importance of visualization of losses [5]. To visualize the wastes of the equipment, quantification of all the losses available in the equipment is needed. Moreover, the quantification of losses should make the wastes visible in the OEE approach and allow user to identify the scope of improvement and create an improvement plan based on it.

2. LITERATURE REVIEW

In the definition of OEE, there are six big losses available. These losses are breakdown losses, setup and adjustment losses are categorically as breakdown losses; minor stoppage and reduced speed are classified as speed losses, while rework and startup losses are quality losses [6]. However, this is not the only way of classification of OEE losses. There are two

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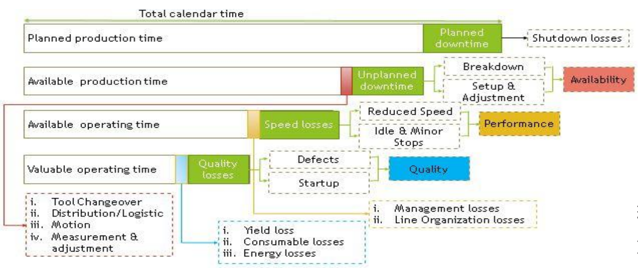
different types of classifications of losses [7]. First is the six big losses that proposed by Nakajima [1] and the other is proposed by Jeong and Philips [8].

Table 1: Comparison of classification of OEE losses [7]

OEE Factor	Nakajima (1988)	Jeong and Philips (2001)
Availability	Breakdown losses Set-up and adjustment	Unscheduled maintenance Set-up and adjustment Non-scheduled time Scheduled maintenance R&D time Engineering usage time WIP starvation time Idle without operator
Performance	Idling and minor stoppages Reduced speed	Speed losses
Quality	Defects and rework Yield losses	Quality losses

The main difference between two losses classification is the losses that will affect to the availability rate. Based on Nakajima [1], the preventive maintenance, scheduled maintenance time, off-shifts, holidays and break time are not included in the computation of planned production time. However, Jeong and Philips [8] stated that whenever the machine is stopped, it should be considered as a loss and computed in the OEE calculation. This is supported by the Wong, Chan and Chung. [9], with poor scheduling of preventive maintenance will increase the risk of dramatically disturbing production. Anyway, preventive maintenance is typically excluded from the OEE because it is assumed that preventive maintenance is unavoidable and cannot be eliminated. Furthermore, Smith and Hawkins [10] also claimed that planned maintenance is out of the OEE equation because it is assumed that planned maintenance is something that you have to do it, you can't reduce it, you can't eliminate it, so leave it in.



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TPM, there are 6 big losses that classified in the OEE and OEE can be said as a part of TPM, but Figure 1 showed that OEE does not cover all the possible losses in its philosophy. In ideal condition, total calendar time is the total time that company had to produce products, however, planned downtime is required to have planned maintenance, periodic inspection and statutory inspection. It also can be categorized as shutdown losses because the machine has to shut down to perform the activity as mentioned earlier. Anyway, most of the OEE users will not include this loss in the OEE calculation because they consider shutdown losses as something that must be implemented to maximize plant and equipment effectiveness [11]. In OEE philosophy, it is encouraging the situation that machine can run all the time in the planned production time [3]. However, this situation is hard to achieve due to the losses like breakdown, and setup and adjustment. Furthermore, the losses like tool changeover, logistic, motion, and measurement and adjustment will further reduce the available production time [4]. Anyhow, the available production time will not be fully utilized if speed losses are existed. The management losses and line organization losses will contribute to the speed losses also because these losses will cause the machine to delay or slow performance. These losses will cause the machine to waiting for the material, operators and work in [12]. Next, quality losses will further reduce the valuable operating time, which the machine is producing defects or products that need to rework. As mentioned by Badiger and Gandhinathan [13], the potential improvement might be unnoticed if the monitoring is not sufficient. The classification of OEE losses can be further improved to capture potential improvement in a better visualization. The Ljungberg [14] also argues that six major losses are not sufficient and it should be divided into more groups. The OEE is a good performance metric and it is simple to use but it can be further improve to quantify the wastes in a better visualization.

3. METHODOLOGY

In OEE calculation, classification of losses is essential to allow users to indicate the scope of improvement and find out the root causes to develop an effective improvement plan. OEE is the product of three main factors, availability, performance and quality. The Eqs. (1) showed the formula to calculate the percentage of availability factor. The operating time is the available time after the deduction of breakdowns and setup time from the planned production time. Planned production time is the total time without consideration of planned downtime. Then, Eqs. (2)-(3) showed the formula to calculate the percentage of performance and quality factor. Ideal cycle time is the theoretical cycle

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time that can be achieved by the machine and good pieces are the total pieces that can be proceed to the next process without rework. With all these three factors, the OEE percentage can be calculated as the Eqs. (4).

$$\text{Availability, A} = \frac{\text{Operating time}}{\textit{Plannedproductiontime}} \quad (1)$$

$$\text{Performance, P} = \frac{\text{Ideal cycle time}}{\frac{\textit{Operatingtime}}{\textit{Totalpieces}}} \quad (2)$$

$$\text{Quality, Q} = \frac{\text{Good pieces}}{\textit{Totalpieces}} \quad (3)$$

$$\text{OEE} = A \times \text{P} \times \text{Q} \quad (4)$$

As what is shown in the Eqs. (4), the OEE percentage is affected by the three main factors and users used it to identify the area to focus. Users will focus on the main factors that contribute most to the low OEE percentage to improve the production. In this case, availability factor will be focused because it has the lowest percentage among the main factors. After the identification of the lowest main factor, users will identify the scope of improvement through classification of losses. Users will analyze to the causes of low availability factor through the classification of losses and discussion will be made in term of visualization of losses.

4. RESULTS AND DISCUSSION

OEE is calculated with the real data to identify the current situation of the equipment. Figure 2 showed the results of OEE factors based on the traditional classification of losses. The breakdown and setup time losses are categorized in the availability and performance categories, minor stoppages and reduced speed while quality indicates yield losses and defects. The performance and quality factors showed high percentages which higher than 80%. However, availability factor drags down the performance of the equipment by 69.34%, which slightly below than 70%.

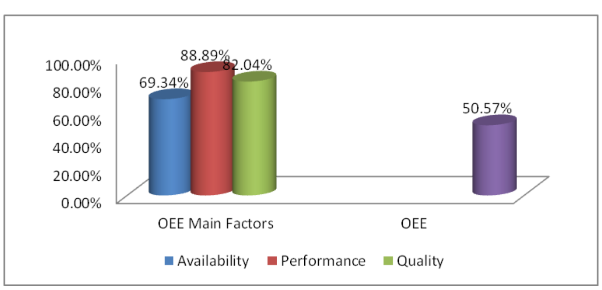

Figure 2: Percentage of OEE main factor

It is clearly shown that the main contributing factor to the low OEE percentage is availability factor. It has the lowest percentage and further affects to the OEE percentage. With this OEE result, users can focus on the losses of availability because it is the main problem to be tackled. However, users are unable to identify the scope of improvements specifically because there are breakdown and setup losses in the availability factor. They have further to analyze the losses to indicate the scope of improvement. This showed that the classification of the losses in the traditional way is not applicable for user to identify waste in short time. In other word, the poor visualization of losses caused lengthens the time to identify the scope of improvement. Moreover, management level cannot identify or monitor the actual situation of the production because of the weak visualization of wastes. They have to further investigate to the data to visualize the losses which are excessive and time wastage.

Table 2: Definition of Losses in Modified OEE

Availability Losses	Definition
Breakdown	The unplanned downtime that occurred and force to stop the machine and repair.
Frequency of setup process	The total number of ideal setup or changeover process that perform during the planned production time.
Excessive setup time	The unnecessary or excessive setup or changeover time after deduction of ideal time from actual time.

In traditional way of classification, the losses that fall in the category of availability are breakdown and setup losses. However, it is found not efficient because the definition of setup losses can be differentiated into two. It is used to visualize the problem of the long setup time. The frequency of the setup process and excessive setup time are actually two available problems that lead to long setup time with different causes. The frequency of the setup process is due to the management decision while excessive setup time is the unnecessary working step or redundant working time that performed by the manpower. The breakdown losses are the unplanned downtime that stops the machine from operating and reduce the planned production time.

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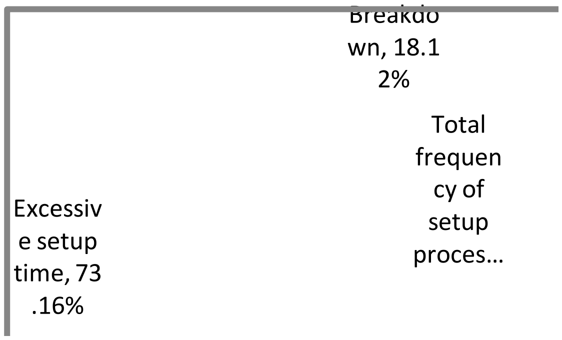

Figure 3: Losses Distribution in Availability Factor

As shown in the Figure 3, the major distribution to the low availability is due to the long setup time. Long setup time might due to several issues and mostly is due to the excessive setup or changeover time performed by the workers. However, this is not the only reason of the long setup time, but it may cause by the high frequency of the setup and changeover process during the production time. Excessive setup time is the unnecessary time that used to perform setup or changeover process. Maynard Operation Sequence Technique (MOST) is used to standardize the setup or changeover time [15]. The standardized time is used as the ideal time [16]. The frequency of the setup or changeover process is calculated as the product of frequency and ideal time [17]. As shown in the Figure 3, the setup losses are separated into two and it showed that the main loss contributes to the low availability is excessive setup time [18]. Now the losses are visualized and user can tackle on the main losses and develop improvement plan.

5 CONCLUSION

OEE is used to monitor the actual situation of the equipment and indicate the scope of improvement. Researchers develop the classification of losses in their own way to utilize the OEE metric with specific purposes. In the OEE measurement, there might have conflict when users try to indicate the scope of improvement, especially in the availability factor, because the user cannot identify the scope with the OEE percentage. They have to further investigate to get a clearer image of the losses. Furthermore, setup time can be separated into the frequency of the setup process and excessive working time. In this case, the setup time is the major cause to the low availability and mostly affected by the excessive setup time but it can be different in different situation. OEE can be used by the management level to monitor the current situation of the production, but there are limitations because setup time and breakdown are falling into one category. The setup and changeover process still require manpower and manpower tend to lengthen the working time to release time pressure. In addition, the frequency of the setup and changeover process might be increased due to some reasons and management level cannot quantify it through OEE. The people in charge might hide this without acknowledging to the management level. OEE scale cannot show these details and might lead them into the wrong way because most of the people will focus on the breakdown losses rather than setup losses. To overcome this issue, visualization is very important and this could be done with the modification on classification of OEE losses. The next stage of the study should come out with the new formula to quantify the frequency of the setup process and the excessive setup time performed by the workers in the modified OEE calculation.

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