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EFFECT OF HIDDEN WASTES IN OVERALL EQUIPMENT EFFECTIVENESS CALCULATION

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ABSTRACT

Overall equipment effectiveness (OEE) is commonly used as a scale in industry to indicate the effectiveness of the machine or process. Although it is just a multiplication of three criteria, availability, performance and quality rate, but it reflects the actual situation of the machine or process. OEE is one of the important elements in continuous improvement plan to assist operation team to indicate the scope of improvements. Therefore, it is important to track out all the wastes available in the calculation. However, it is not an easy task to track out wastes correctly. Although six big losses are mentioned in the OEE philosophy but there are wastes that hidden in the OEE percentages and tend to ignored by operation team. This is the obstacle for industry to achieve optimum OEE level. Therefore, the available of hidden wastes should be visualise and easy to detect. Maynard's operation sequence technique (MOST) is the suitable tool to quantify the hidden wastes in the OEE calculation since hidden wastes are referring to human interaction, movement or action. MOST is a work measurement tool that used to evaluate the manpower performance. Through MOST, a list of work standard can be constructed and used to compare with the hidden wastes. Then, a modified OEE calculation method is developed to enhance traditional OEE calculation in term of visualization of hidden wastes.

Keywords: overall equipment effectiveness, Maynard's operation sequence technique, hidden waste.

INTRODUCTION

In manufacturing sector, the improvement in effectiveness of the machine or process is important to produce quality products in a given period without stoppage. To examine the effectiveness of machine or process, OEE has proposed and implemented in the industry. Traditional OEE is consists of three criteria, availability, performance and quality rate. Although it is just a simple calculation, it can used to indicate the effectiveness of the machine or process in percentage. Moreover, OEE also narrow down the scope of improvement through the percentage of three criteria. With the scope, the improvement plan can be focus on it and reduce the wastes that available. OEE is not only a scale but part of the Continuous Improvement of industry. Therefore, achieve optimum OEE level is always the main goal of the management level.

However, traditional OEE calculation is not good enough to quantify all the wastes that available in the process. Although there are six big losses that quantified in OEE philosophy, people still face hardship when they try to trace the wastes. There are wastes that hidden in the OEE calculation and unable to identify through OEE itself. Most of the researches are focus on the reduction of breakdown time in order to improve the OEE in term of availability. Nevertheless, there are hidden wastes that influences to the OEE percentage in term of availability and performance. These hidden wastes are not quantified in the OEE calculation and tend to ignored by the operation team.

The hidden wastes that stated are the working behaviour, mechanism and environment of the manpower during the process. Although the process flows seem in good condition, but it may include additional operation that is not necessary which can be further streamlined. On the other hand, the absence of the standard of procedure will give chance to workers to lengthen the working time and delay the work. This is not showing in the OEE percentage because management level might give allowances time that should be reduced. This might due to the management level is not familiar to the process flow. Next, workers might lengthen the process time due to search for tools or materials. This will cause the machine to be idle which wasting valuable time of machine.

To visualise the hidden wastes in OEE calculation, a new model of OEE calculation is proposed. The hidden wastes are quantified in new criteria named as hidden losses and compare with list of standard. The list of standard is the benchmark for the worker to complete their tasks. Maynard Operation Sequence Technique (MOST) is used to create the list of standard. MOST is a work measurement and study of work. It is used to examine the whole process and create list of standard. Through this OEE model, the hidden wastes are visualized and magnified in the OEE calculation and management level can monitor the hidden wastes in more effective way.

LITERATURE REVIEW

Hidden wastes in OEE

Speed loss is one of the big losses stated in OEE philosophy. Speed loss is occurred when the machine is not run at full speed [1]. However, it is not the focal point of the industry [2]. The management level tends to ignore or underestimate the impact of speed losses when calculating OEE. They also stated that it is difficult to find gauge speed because speed loss is never defined properly.

Furthermore, the excessive long setup time is not concerned by the management level due to long data collection period [3]. Most of the manufacturing machine

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requiring setup process to adjust the alignment or install tools to make sure the production can run smoothly. Manpower plays an important role in setup process because most of the steps need to be performed by manpower. However, manpower tends to lengthen the setup time due to several reasons. [4] Claimed that excessive transportation and setup time are hidden in the traditional OEE calculation. The workers might look for the tools to perform changeover or setup and this lengthen the setup time needed. Then, workers also tend to lengthen the process time to obtain comfort working periods. However, this is invisible in the OEE calculation because the effect of the lengthen time is not significant and neglected by the management level.

When there is not time standard, any tasks could be finished out of planned [5]. The workers like to complete a task that usually done by them in their own way. Although they are comfort with the procedure they had, but they might have include excessive process steps which can be eliminate and shorten the process time.

Integration of OEE with other tools

OEE is a measure of the effectiveness of the machine or process. As stated by [6], problems cannot be easily identified through OEE itself. In other word, calculate OEE only is useless and it only indicates the current situation only. Therefore, it should be integrate with other tools to achieve another goal which improve the effectiveness of the machine or process.

[7] Use time study along with OEE measure. Through OEE calculation, the scope of improvement is found. Then, time study is implemented to find out the problem. Since the problem is found, it can be eliminated through problem solving technique. [8] Use maintenance-FMEA in improvement of OEE. They found that the die bond machine is frequent breakdown and this is showed in low OEE level. Therefore, they minimize the breakdown losses through maintenance-FMEA and create preventive maintenance. In addition, [2] using 5 why technique to improve OEE. This study is focuses on the speed losses and 5 why technique is used to analyse the root courses. Through the identification of root causes, problem solving technique is used to overcome those issues and improve the OEE level.

These tools are integrated with OEE to improve the machine or process. OEE is the indicator to monitor the improvement and create scope of improvement while other tools are used to identify the wastes in detail and provide solution to reduce the wastes.

OEE calculation

[9] Defined OEE as an important performance measure which indicates the current status of production with least calculation to measure the losses and corrective action to be taken to reduce it. However, OEE does not account all the factors that reduce the capacity and this give chance to production management to consider some losses as this is not their responsibilities [10]. Moreover, OEE did not include all the criteria that affect to production and profit. Therefore, OEE calculation is modified to fulfil the requirements of several situations.

Overall equipment effectiveness-market based (OEE-MB) estimation is used to calculate equipment effectiveness during market time [10]. Market time means the time duration for producing products which have the market, internal or external and can be sold. This modification on traditional OEE calculation is to estimate the equipment effectiveness for the periods of satisfying both internal and external customers. Internal customers are the following processing machine in the factory while the outer customers are the market for the current products.

There are a lot of examples that researchers modify the OEE calculation to fulfil the requirements of several situations or cover more criteria in the production. Although OEE calculation is widely used in industry, however it still contains weakness likes it is just a performance measure for individual equipment without consideration of relationship between target equipment and its downstream and upstream [11]. Moreover, OEE calculation also neglects the losses that occur in the unscheduled time. Therefore, total equipment effectiveness performance (TEEP) is introduced. It includes the planned downtime into the total planned time horizon to show how the maintenance can contributes to improve the productivity of the plant. However, it is limited to equipment performance level. [12] Were proposed another modification of OEE calculation to measure productivity of production line with involvement of machines in series. It is called Overall Line Effectiveness (OLE) which covers the machines in a continuous manufacturing line. In year 2007, [13] have a breakthrough in OEE modified calculation which proposed overall throughput effectiveness (OTE) metric to monitor factory level performance and detect bottleneck.

[14] Also proposed a modified OEE (OEE_m) calculation to take account the planned downtime in the OEE calculation and usability is proposed to involve in the OEE calculation.

Table-1. Classification of losses in modified OEE (OEE_m).

OEE factors	Losses
Availability	Equipment failure
Usability	Setup and Adjustment and minor stoppages
Performance	Idling and reduced speed
Quality	Defect and reduced yield

As showed in the Table-1, the classification of losses is more clear and visible for the management level to indicate the scope of improvement. As what been told by [15], the OEE does not diagnose the specific problem of machine run in lower efficiency but it gives some insight into the reason.

[16] Apply planning factor in OEE calculation to evaluate the ratio of production amount to the total capacity of the production. Through addition of planning factor, the OEE calculation can be more reliable to the industry because they can identify how well the machine is in term of usage. If the machine is run all the time at maximum speed and produce non-defect product but the products produced are not able to sell and this leads to overproduction which neglected in the OEE calculation. Therefore, they use the term, planning factor to improve the traditional OEE calculation method.

Maynard's operation sequence study (MOST)

Work study is a most effective tool for any enterprise to determine standard time and increase productivity [17].Time and motion study is essential to simplify the operation and eliminate the excessive process steps as possible. It is not only applicable in manufacturing sector but also implemented in various sectors like textile industry, medical, bank and service organizations. However, there are various types of work study and Maynard Operation Sequence Technique (MOST) is one of the most popular techniques to be used in industry. As stated by [18], MOST is a work measurement that used to compile the standard work time and maximize resource utilization by improving working method.

There are three general versions of MOST which are Basic MOST, Mini MOST and Maxi MOST. This makes the measurement of work to be a practical, efficient and inexpensive task for industry. [19] Also introduce MOST as a powerful analytical tool that helps increase productivity, improve methods, facilitate planning, establish workloads, estimate labour costs, improve safety, and maximize resources. [20] Stated that MOST classified all human movements into three basic categories and the description of each category is done by assigning value to only a few standard parameters. The three categories are general move, control move and tool use.

General move indicates the free movement that related to space for object through the air while control move is a sequence that describes the movement of object when it remains in contact with a surface or when it is attached to another object during the movement. For tool use, it is a sequence used to indicate the use of common hand tools such as writing, fastening, loosening, cleaning and gauging. Moreover, the time unit used by MOST is time measurement unit (TMU). 1 TMU is equals to 0.036 sec, 0.0006 min or 0.00001 hour.

Table-2. Basic most sequence model [20].

Activity	Sequence model	Sub- activities
General Move	ABG-ABP-A	A= Action distance
		B= Body motion
		C= Gain control
		P= Placement
Controlled Move	ABG-MXI-A	M= Move control
		X= Process time
		I= Alignment
Tool Use	ABG-ABP-ABP-A	F= Fasten
		L= Loose
		C= Cut
		S= Surface treat
		M= Measure
		R= Record
		T= Think

As shown in Table-2, the sequence model of the three activities is consists of sub-activities. Each of the sub-activities will be given an index number based on the description of work done. The common scale index numbers are 0, 1, 3, 6, 10, 16, 24, 32, 42 and 54. The total index number will multiple with 10 to get the TMU and can further convert to time unit of second, minute or hour. For example, A1B0G1 A6B6P1 A0: (1+0+1+6+6+1+0) × 10 = 150 TMU or 150 TMU × 0.036 sec = 5.4 sec.

METHODOLOGY

A single wire bond machine is used to study and the data is collected based on this machine. The data needed is OEE data and MOST data. To achieve this, automated data collection (ADC) system of the machine, side observation, time study and MOST study are used to collect data. The OEE data will be collected through traditional approach then compare with the modified OEE calculation method. The data collection period is continuing for one months and ADC is important to collect actual data without delay because the response time is controlled by computer but not human.

To calculate the modified OEE calculation, MOST is the essential methods to create the ideal setup times. MOST is a work measurement that analyzes working behavior of worker in combination of simple motion and each of the simple motion were tested and standardized with certain value of time. Therefore, the setup time can be standardized through the implementation of MOST. The ideal setup times are the ideal working steps with ideal time to complete a task.

Furthermore, two new terms "Human Factor" and "Usability" are introduced in the modified OEE calculation and it is covered the lacking of traditional OEE which traditional OEE tends to ignore or neglect the effect

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of human working mechanism and behavior since it not bring great impact to the OEE percentage.

RESULT AND DISCUSSIONS

The classification of wastes for each OEE calculation method is shown in the Table-3.

Table-3. Classification of losses.

	Traditional OEE	Modified OEE
Availability	Machine breakdown, set-up, changeover	Machine breakdown
Usability	-	Frequency of ideal setup times (setup, changeover, load material, documentation)
Human Factor	-	Minor stop, idle, excessive setup, changeover time
Performance	Minor stop, reduced speed	Reduced speed
Quality	Yield loss, defects	Yield loss, defects

In traditional OEE calculation, set-up and changeover are grouped with the machine breakdown in the availability factor. However, the impact of machine breakdown is higher than set-up and changeover and this causes the set-up and changeover are tend to neglected by production team. This is supported by study of [4] where loading or setup time is invisible in traditional OEE measures since management team only compares the OEE value with examining the work method. Therefore, the modified OEE is reclassified the losses because different classification of losses lead to inconsistency in OEE calculation. The factors of modified OEE have different calculation method compared with traditional OEE. Therefore, calculation of each factors are showed at the below.

Availability, A is calculated through the ratio of operating time to planned operating time. Planned production time is the total time subtracted with planned downtime likes lunch break and planned maintenance. Planned downtime is the downtime that cannot be avoid, that must present and cannot be eliminated. For the operating time, it is the result of planned operating time minus with breakdown time in the given periods.

A= Operating time/ Planned operating time

Usability, U is the ratio of theoretical running time to operating time. Theoretical running time is the subtraction of operating time with ideal setup times. Ideal setup times indicate the total frequency of setup, changeover, documentations, loading material that involved in the operating time. To indicate the frequency of setup process correctly, the period of the ideal setup time will be calculated through MOST study and the excessive setup time is not included in Usability.

U= Theoretical running time/ Operating time

Human factor, H is the ratio of actual running time with the theoretical running time. Actual running time is calculated through the subtraction of theoretical running time with excessive setup time. The

H= Actual running time/ Theoretical running time

Performance, P is calculated through the ratio of multiplication of the output with the ideal cycle time to the running time. Total output is the total product produced by the machine without consideration of quality. Ideal cycle time is the theoretical standard cycle time that can be achieved by the machine.

P= (Total output × Ideal cycle time)/ Running time

Quality, Q is calculated by dividing the total good part produced with the total output.

Q= Total good part/ Total output

The calculation of both traditional OEE and modified OEE is showed in the Table-4 through same set of data. The modified OEE is the multiplication of availability, usability, human factor, performance and quality.

$OEE_m = A \times U \times H \times P \times Q$

Table-4. Traditional OEE calculation.

OEE factor	Calculation
Availability	$\frac{(63772 - 19552)}{63772} = 69.34\%$
Performance	$\frac{(29323 \times 1.3405)}{44220} = 88.89\%$
Quality	$\frac{(29323 - 5266)}{29323} = 82.04\%$
OEE	50.57%

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Table-5. Modified OEE calculation.

OEE Factor	Calculation
Availability	$\frac{(63772-3542)}{63772} = 94.45\%$
Usability	$\frac{(60230-1704.996)}{60230} = 97.17\%$
Human Factor	$\frac{(58525.004-14305.004)}{58525.004} = 75.56\%$
Performance	$\frac{(29323 \times 1.3405)}{44220} = 88.89\%$
Quality	$\frac{(29323-5266)}{29323} = 82.04\%$
OEE	50.57%

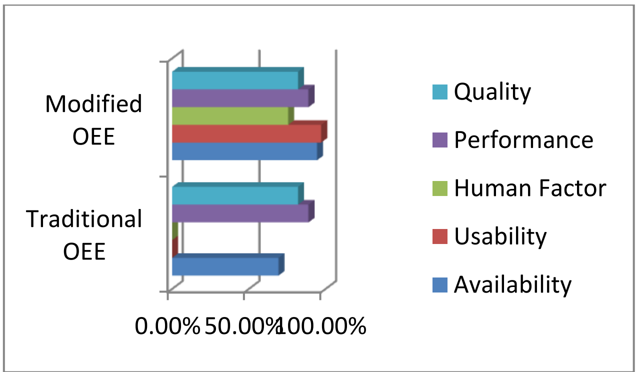

Figure-1. Comparison between traditional OEE and modified OEE.

Tables 4 and 5 showed the result of OEE calculation in traditional approach and modified approach. Although both of the result showed that the OEE percentage is same but the way to present the efficiency and effectiveness of the machine is different. The existing of usability and human factor allow users to identify or quantify the wastes in easier way. In traditional approach, the percentage of availability is 69.34% and the main causes of low availability might be due to high machine breakdown rate or long setup time. However, the poor visualization of wastes in traditional approach causes the users face difficulty when identifying the scope of improvement or gets some insight to the causes. Therefore, the modified OEE possess better visualization of wastes because the setup wastes are quantified in usability and human factor while availability is only indicates the breakdown losses. Through the modified OEE calculation, the main reason of low OEE is identified which is the low human factor percentage. Then, production team can make the improvement plan accordingly.

From Figure-1, the percentage of availability and performance for modified OEE is higher than traditional OEE due to the classification of losses like setup time, changeover, minor stop and idle are arranged to usability and human factor. However, the existing of usability and human factor drag down the percentage of modified OEE and it shows the hidden wastes that ignored or neglected in the traditional OEE. The frequency of the losses that classified in the usability is not showed in the traditional OEE but it is indicated in the usability which management level able to identify the abnormal frequency of setup or changeover through this factor. Nevertheless, usability cannot cover all the hidden wastes and human factor is introduced. Human factor indicates the excessive setup time that hidden in the traditional OEE and mostly due to the behavior of manpower. Although the percentage of each OEE method have no significant difference, but the indication of the scope of improvement can be made better through the modified OEE because it has better visualization.

CONCLUSIONS

In this study, the lacking of traditional OEE due to tolerate the hidden losses likes excessive working method, unnecessary motion, high frequency of changeover and setup. It is hard to track out the hidden losses through traditional OEE and this brings difficulty to user to identify the scope of improvement. Therefore, a modified OEE calculation is proposed and new term 'human factor' is used to identify the lengthy time that used to perform work. Human factor is focus on the tasks performed by the manpower because manpower used to lengthen the working time to get comfort time. With this factor, the excessive time is traceable and observable for the management level and operation team. On the other hand, term 'usability' is used to indicate the frequency of setup and changeover process that available in the daily production. The frequency of setup and changeover process might reduce the available operating time but it is hard to indicate in traditional OEE. Therefore, usability is used in modified OEE. In conclusion, the modified OEE able to give better visualization to the user and the hidden losses are not neglected or ignored. To further improve this study, simulation is needed to validate the strength of modified OEE calculation method and discover the potential of modified OEE calculation method.

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