Hidden Wastes in Overall Equipment Effectiveness (OEE) under the study of Maynard's Operation Sequence Technique (MOST)

Puvanasvaran A. Perumal
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya
Durian Tunggal, Melaka, Malaysia
punesh@utem.edu.my

Teruaki Ito
Faculty and School of Engineering
The University of Tokushima
Minami Jousanjima-cho, Tokushima, Japan
tito@tokushima-u.ac.jp

Teoh Yong Siang
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya
Durian Tunggal, Melaka, Malaysia
ysteoh1987@hotmail.com

Nur Syafilla binti Mahamud
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya
Durian Tunggal, Melaka, Malaysia
punesh@yahoo.com

Abstract*—Overall Equipment Effectiveness (OEE) is quantifying process or entire production line by considering three main losses named time losses, performance losses and quality defect. It provides the measure of equipment so that corresponding optimization could be done. However, OEE had tolerated with many lean wastes which could be 'invisible' under its tradition definition. This includes unnecessary production which was classified as operating time and the underestimated effect of change over time. These could be minimized via work measurement, method study and study of the work, which are under the study of Maynard's Operation Sequence Technique (MOST). This paper intends to quantify the lean waste in OEE from the perspective of method and work of an operation. Operations are analyzed in every single step using MOST and redesigning the work in favor of minimal non-value added activity in the operation or production. The OEE data before and after the study of work is computed and compared to examine its effect. It is expected to provide a new insight in implementing OEE at different way and stay beware of the assumptions in OEE to avoid any hidden waste.

Keywords— Overall Equipment Efficiency (OEE), Maynard's Operation Sequence Technique (MOST), study of work, work measurement, hidden waste

I. INTRODUCTION

Overall equipment effectiveness (OEE) is widely applied in manufacturing industry to measure the effectiveness of any production equipment in a factory in terms of availability, performance and quality perspective. It quantifies and compares machine with respect to an imaginary ideal machine which always runs all the time at the ideal speed and always produces products in good quality.

However, the concept of OEE encourages the machine to run all the time without consideration of the value adding onto the product or its work in progress. In other words, the operation of the equipment could be non-value adding and is not necessarily essential. Since the production in actual is not perfect, the running or operation of an equipment is sometimes the rework or additional process which could actually be streamlined or optimized. Incorporation of planning factor, which is the ratio of total production planned over the maximum capability, is required in the measurement of OEE [1]. Some operations of equipment could be due to sub-utilization of its previous planning and somehow is considered as additional operation. In addition to that, the availability ratio of OEE measures only the ratio of total operating time over the whole production time and emphasizes only on the control and monitoring of time losses. Therefore, the aforementioned rework or additional process is treated as the operating time as per definition of availability.

[1] Puvanasvaran, A. P., Teoh, Y. S., & Tay, C. C. (2014). Interrelationship Between Availability with Planning Factor and Mean Time Between Failures (MTBF) in Overall Equipment Effectiveness (OEE). Journal of Advanced Manufacturing Technology (JAMT), 6(2).

Besides that, it is common that most of the equipment or machines in industry nowadays are operated by man power especially in the company with semi-automated or manually operated production line. It is noticeable that employee could possibly perform some excessive transportation or set up processes. This is in align to the fact that unproductive movement exists on daily task [2]. This could make some impacts on the equipment itself since unnecessary motion of employees especially during setup or loading process will increase portion of the planned downtime.

On the other hand, the semi-automated process requires the assistant of operator not only during the setup but also during the running of equipment. The unavailability or low efficiency of operator due to the unnecessary motion will contribute to delay or slow performance of equipment. From the perspective of Lean, it is considered as waste in the category of waiting, movement and unnecessary processing.

Nevertheless, the usage of historical availability as the reference in future production planning is possible [3]. The same is applicable on the historical OEE value in order to improve the production from time to time. Prior to that, the accurate definition of the availability should be established to ensure the reliability of the data set. The work measurement, method study and study of work are then carried out onto the production in order to track out any process to be optimized or could be further streamlined. It is recommended to consider the unnecessary process time as the time loss and then transform it into external setup via method study if possible. Performance measurement is important so that performance gaps between current stage and desired performance could be reduced [4].

Whenever talking about work movement, method study or study of work, Maynard's Operation Sequence Technique (MOST) is often considered as the most appropriate tool to be implemented. It is a technique of work measurement that concentrates on the movement of people and the stuffs that relate in workstation, which will be further analyzed to get the normal time for the particular operation. The Basic MOST analysis is a complete study of an operation or a sub-operation which a worker should perform an activity using a standard time with the average between 20 second to 2 minutes [5]. Non-value added activities in any particular operation could be easily tracked out by using the technique. In short, there are three activities of sequences need in MOST for describing manual work.

a) General Move Sequences (GMS), which describes a free movement that related to space for object through the air,

b) Controlled Move Sequences (CMS), which describes the movement of an object when it remains in contact with a surface or it is attached to another object during the movement,

c) Tool Use Sequence (TUS), which describes the use of common hand tools. However, the sequence covers the use of hand tools such as writing, fastening or loosening, cleaning, and gauging.

In addition, the use of brain also describes a mental process as tool use. Table 1 shows the sequence model and parameters based on the Basic MOST system [5]. The summary of sequence model and parameter based on the different activities involved in Basic MOST.

Table 1: The sequence model and parameters based on the Basic MOST system [6]

Activity	Sequence Model	Parameters
General Move	ABG ABP A	A: Action distance; B: Body Motion; G:Gain Control P: Placement
Control Move	ABG MXI A	M: Move Controlled; X: Process Time; I: Align
Tool Use	ABG ABP ABP A	F: Fasten L: Loosen; C: Cut S: Surface; M:Measure R: Record T: Think

[2] Abu Talib B. & Daiyanni D., (2010).Time and Motion Study in Determination of Time Standard in Manpower Process, 3rd Engineering Conference on Advancement in Mechanical and Manufacturing for Sustainable Environment, Kuching, Sarawak, Malaysia

[3] Puvanasvaran, P., Teoh, Y. S., & Tay, C. C. (2013). Consideration of demand rate in overall equipment effectiveness (OEE) on equipment with constant process time. Journal of Industrial Engineering and Management, 6(2), 507-524.

[4] Samad, M. A., Hossain, M. R., & Major, S. (2012). Analysis of Performance by Overall Equipment Effectiveness of the CNC Cutting Section of a Shipyard, 2(11), 1091–1096

[5] Kjell, B.Z, Maynard's Industrial engineer handbook (5th Edition),: MOST, allowance, stopwatch time study, Northbrook, England, pp. 5.73-5.101,17.21-17.82

[6] Kjell, B.Z., (2003). MOST: Work Measurement Systems, 3rd Ed., United States: CRC Press

II. METHODOLOGY

The paper starts from the study on a wire bond process in a semi-conductor company. The process is measured as per definition of traditional OEE. The effectiveness of the production line is quantified by using the data as obtained from time study to mark the origin before any improvement by MOST. In addition to that, observation of the process and work study were carried out at the same time. The work study is useful in order to re-design the wire bond process so that the equipment could be utilized optimally or at higher effectiveness. The wire bond process is then analyzed once again using OEE to quantify the improvement after the work study. The discussion and observation about the hidden wastes via the comparison between OEEs.

Site observations were carried out throughout the operation repetitively for several cycles to verify if the actual flow is same to the standard operation procedure. Time data was also collected for a few months using stopwatch. The advantage of performing time study using stopwatch is that the time data could be taken as many times as required and its snap back mode which enables the observer to record any incidence occurs during the time study. The incidence here includes the unnecessary processing or unproductive motion which could possibly be eliminated without affecting the quality of the wire bond. For the time data which could not be recorded manually by the observer, which is the running time of the wire bond, real time monitoring system will be referred to obtain the data. The time data collected is shown in Table 2.

Table 2: The cycle time of each step in the wire bond process obtained from time study

No	Operation/ Activities	Cycle Time	
		Second	Minute
1	Loading new lot into machine	34.02	0.567
2	Machine set up and running	34.00	0.567
3	Wire bond running time	3378.00	56.300
4	RTI (300 units per magazine)	0.01	0.002
5	Unload lot from machine	24.42	0.407
6	Fill in lot traveler	7.80	0.13
7	Key in MES	53.76	0.896
8	Send lot	13.68	0.228
Total		59.093 minutes 0.9849 hours	

MOST is performed to concentrate on the movement of people and the stuffs that relate in workstation. It is analyzing the movement and gets the normal time for all the activities stated in Table 2. These sub-activities are determined in sequence model as mentioned in Table 1, which is including of the parameter that recognized in a reasonable sequence. In addition to that, the sequence model defines the actions that always take place in direct order when the man or object is being moved. The MOST common scale index numbers are 0, 1, 3, 6, 10, 16, 24, 32, 42 and 54. From that, the index based on the descriptions of work done can detect the suitable value of the scale. The sequence model is simply adding all the index values and multiplying by 10 to get the TMU for the activities. The total of findings is multiplied by 0.036 to convert them into time unit of second. For example the standard time in TMU for sub activities A270B0G0 A0B0P0A270 :

(270+0+0+270)*10 = 5400 TMU,

of which 5400 * 0.036 seconds = 194.4 seconds

The sequence models and parameters in the MOST define the actions and activities involved in wire bonding process with improved productivity as show in Appendix A. The aforementioned unproductive labor movement could be one of the inconsistent operations which further leads to variation in cycle time [7]. Unproductive labor movement especially during setup process had been eliminated and the improvement is examined via the measurement of OEE.

[7] Lee, J., Lapira, E., Bagheri, B., & Kao, H. A. (2013). Recent advances and trends in predictive manufacturing systems in big data environment.Manufacturing Letters, 1(1), 38-41

III. RESULTS AND DISCUSSION

The Basic MOST is conducted to evaluate the parameter and an index value for all sub operations involved. Appendix A shows the mechanism of Basic MOST finds and minimizes the non-value added movement by using the parameter sequence model on wire bond workstation. It is noticeable that each of the sub-activities in wire bonding process was broken down into details up to the number of steps taken from one location to another during setup as well as the motion done in order to take tools.

Comparison between the actual data obtained from time study in Table 2 and the analysis or redesign of the process using MOST approach in Appendix A in terms of total duration elapsed. Small changes in the movement involved such as the movement of employee or distance between workstations can lead to drastic reduction in non-value added activities. There are also related to arrangement of material and another process, and the use of tools as well. The improvement of the setup could be quantified as below.

Time collected from time study= 59.097 minutes,

Time by MOST analysis to reduce non-value added activities (Table 2) is 28350 TMU * 0.036 second/ 60 minutes = 17.01 minutes.

The analysis had yielded the optimization time of around 42.093 mins, which is about 71.23% of improvement. From the perspective of OEE, the setup time is categorized as the planned downtime since it is required by each processing from the beginning. Lower downtime from the MOST study means larger portion of uptime or operating time is possible for the wire bond machine and also the availability. Prior to the quantification of the aforementioned optimization, it is essential to exclude those activities in the MOST study which could be performed concurrently with the running of wire bond machine, i.e. external setup after the machine was started. Total time elapsed on external setup after machine running is 1990 TMU, which equals to 1.19 minutes.

It can be said that total planned downtime incurred before the operation of wire bond machine is around 15.81 minutes (17.01-1.19) as suggested by MOST study, marks 73% of improvement from 59 minutes. However, the quantification of OEE could tell the different story by comparing the availability ratio before and after the MOST study.

Availability ratio before MOST = (Scheduled Production time- unplanned Downtime) / Scheduled Production Time

= (960 mins- 120 mins- 59.097 mins)/ 960 mins * 100% = 81.34%

Availability ratio after MOST = (Scheduled Production time- unplanned Downtime) / Scheduled Production Time

= (960 mins- 120 mins- 15.81mins)/ (960 mins) * 100% = 85.85%

It is noticeable that the availability had merely improved from 81.34% before MOST study to 85.85% after the MOST study. The 4.5% of improvement is considerably small as compared with the drastic change in setup time of around 73%. In addition, the change in availability ratio will be further diluted or 'unseen' in the measure of OEE. Since the quality and the performance of the wire bond machine or speed of process could not be improved via the MOST study, both of the ratio in OEE will remain the same as per data from observation and time study in following section:

Performance ratio = Ideal cycle time / (Operating time/ Total pieces)

= 0.011 / (122067/ 6,000,800) = 49.16%

Quality ratio = (Total production – number of defect in pieces) / Total Production

= (6,000,800- 4800) / 6,000,800 = 99.92%

These data yield the measure of OEE before and after the MOST study, which is shown as below:

OEE before MOST study

= Availability ratio * Performance ratio * Quality ratio

= 81.34% * 49.16% * 99.92% = 39.95%

OEE after MOST study

= Availability ratio * Performance ratio * Quality ratio

= 85.85% * 49.16% * 99.92% = 42.17%

The computational result above had shown that drastic improvement in external setup time of around 73% could only lead to merely 2.22% of improvement in OEE measure. The finding here is not talking about the lessened importance of setup or loading time in the measure of OEE, but it is emphasizing on how the OEE itself had been tolerating the lengthy workflow or incorrect working procedure. The suboptimal workflow could be the hidden waste of OEE. This is because the only focus of OEE in term of availability, or rather to be encouraged by availability, is to keep the equipment running. This is not always a right concept because some of the running time of the equipment could possibly be omitted or not essential. In order to make clear of the aforementioned hidden wastes, there is necessarily to list down some of the identified problems and lean waste as in Table 3:

Table 3 Summary of the problems and lean wastes identified in Wire Bonding process

Problem	**Lean waste and description**	**Root cause**
Lot sent is not per scheduled time Machine is not available	Waiting for lot from its supplier process, die attach (Waiting)	Scheduling problem. Lack of standard operational procedure.
Lengthy loading time. Additional alignment is required.	Finding of new available machine (Motion) Waiting of operator (Waiting)	Loading of new lot.

The waiting time and lengthy loading or setup time in the wire bond process are two of the problems which adversely affected the uptime of wire bond machine. Even though it had been quantified by the availability ratio in OEE, it could actually be reduced by providing a guidance for the operator especially during setup, loading and unloading of product. During the setup, the unavoidable motion of operator had been studied under MOST and a guidance in term of TMU or limit of time had been suggested. The limit of time had considered the distance between the operator and working place, use of tool and the space. Therefore, it is considered as reasonable under the study and should not be exceeded during that particular operation in order to reduce the unnecessary workflow, operation and transportation. In addition to that, the guidance is useful to promote more efficient unloading of lot from wire bond machine and this could reduce the possibility of next awaiting lot traveler. With the reference to the guidance, the operational time of man power could be known and controlled very well. This is very important to prevent any problematic scheduling in term of operator set up time and the exact time of wire bond machine is required. Problem in scheduling will affect the flexibility in production operations, full utilization of men and machines, and also the coordination between men and machines [8].

IV. CONCLUSION

In short, the hidden wastes which had been tolerated by OEE include unnecessary motion, lengthy or impropriate method of set up which further lead to higher time losses. OEE is said to be tolerating with these losses because it is impossible to track out the lean waste in term of motion or impropriate method by using OEE measures. This could be proven from the outcome that 73% of improvement in the setup process could merely lead to 2.22% of improvement in OEE measure. This highlights the lessened emphasis on the so-called hidden wastes like transportation and motion. As a conclusion, the study revealed that MOST study could minimize the unproductive movement which further reduce the downtime of wire bond machine. The aforementioned hidden wastes in OEE are revealed under the MOST study by considering the space of working area, distance between operator and work place as well as the nature of the job. It is recommendable to implement OEE along with other tools like MOST.

ACKNOWLEDGMENT

The author would like to express his acknowledgement to sponsor of a fund due to the financial support throughout the period at which research was carried out. The short term fund provided is coded PJP_2014_FKP(6C)S01354.

[8] Mugwindiri, K., Nyemba, W. R., Madanhire, I., & Mushonga, R. (2013). The Design of a Production Planning and Control System for a Food Manufacturing Company in a Developing Country , using Simulation ., 2(6), 116–15

Appendix A: The Basic MOST using the parameter sequence model on wire bond workstation

Sub operation	**Parameter and value**	**TMU**	**Min**
Walk 154 steps to wire bond process	$A_{270}B_0G_0\ A_0B_0P_0A_{270}$	5400	3.24
Get personal protective equipment and put it on	$A_{16}\ B_0\ G_0\ M_{15}\ X_0\ I_{10}\ A_0$	410	0.246
Walk 10 steps to the supervisor's area for a briefing	$A_{16}\ B_0\ G_0\ M_1\ X_{1800}\ I_0\ A_{16}$	18330	10.998
Get machine hours sheet and walk 10 steps to the information board	$A_{16}B_0G_0\ A_0B_0P_0A_{16}$	320	0.192
Update daily information based on machine hours	$A_3B_0G_1A_3B_0P_1R_{16}A_1B_0P_1\ A_6$	320	0.192
Get schedule and walk 10 steps to before cure area.	$A_{16}B_0G_1A_3B_3P_6T_1A_0B_0P_6\ A_{16}$	490	0.294
Get a new lot and walk 7 steps to machine using the trolley	$A_{16}\ B_3\ G_3\ M_1\ X_3\ I_1$	270	0.162
Walk 5 steps into the machine	$A_{10}B_0G_3A_0B_0P_0A_0$	130	0.078
Transfer the lot into rack awaiting	$A_6B_0G_3A_1B_0P_6A_1$	170	0.102
Put the magazine in each section	$A_0B_0G_0A_0B_0P_3A_0$	30	0.018
Clip the lot traveler in wire bond machine	$A_1B_0G_3A_0B_0P_3A_6$	130	0.078
Press the button, the machine starts to run the wire bond machine	$A_3\ B_0\ G_0\ M_1\ X_3\ I_1\ A_1$	90	0.054
Checking the condition of gold wire (Machine running)	$A_1B_0G_0A_1B_3P_3T_1A_0B_0P_0\ A_3$	120	0.072
Walk 4 steps into the wire bond machine	$A_6B_0G_3A_0B_0P_0A_6$	150	0.09
Arrange the output beside the machine	$A_3B_0G_3A_3B_3P_6A_3$	210	0.126
Check the condition of the machine	$A_6\ B_0\ G_0\ M_1\ X_1\ I_0\ A_0$	80	0.048
Adjust or set the position of gold wire	$A_1B_0G_1A_1B_0P_1C_{16}A_1B_0P_{10}$	130	0.078
Connect the 90 degree end of point to the middle part	$A_1\ B_0\ G_0\ M_1\ X_0\ I_0\ A_0$	20	0.012
Walk 17 steps to MES with bringing the lot	$A_{32}B_3G_3A_0B_3P_6A_6$	470	0.282
Get 5S checklist from the storage compartment	$A_0B_0G_0A_0B_0P_0\ R_{10}\ A_1B_0P_1A_0$	120	0.072
Walk10 steps to wire area and check on all items regarded on the checklist	$A_{16}B_0G_0A_0B_0P_0\ R_{10}\ A_1B_0P_1A_0$	280	0.1608
Walk 4 steps to wire bond machine in QA table and get a checklist from upper holder	$A_6B_0G_0A_0B_0P_0\ T_1\ A_0B_0P_0A_6$	130	0.198
Check and tick all items as per checklists	$A_0B_0G_0A_0B_0P_0\ R_{10}\ A_1B_3P_0A_0$	140	0.084
Sign on checklist, and place checklist back to document holder	$A_1B_0G_3A_0B_0P_0\ R_{10}\ A_0B_0P_0A_0$	140	0.066
	TOTAL	**28350**	**17.01**