Overall Equipment Efficiency (OEE) Enhancement in Manufacture of Electronic Components & Boards Industry through Total Productive Maintenance Practices

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Abstract. In an environment of intense global competition, both creative and proven strategies need to be considered in order to bring about the effectiveness and efficiency in manufacturing operation. Total Productive Maintenance (TPM) is one of the effective maintenance strategy in enhancing the equipment effectiveness and to achieve a significant competitive advantage. This research paper addresses the impact of three TPM pillars namely planned maintenance (PM), autonomous maintenance (AM) and focused maintenance (FM) on overall equipment effectiveness (OEE) of die attach equipment in the production line of semiconductor industry. The effect of TPM on the OEE is also investigated depending on the equipment types, in where die attach process consist of two models- CANON and ESEC. The primary data was collected from an organization's database and was analysed by SPSS V23. The preliminary results of the analysis showed that the performance of OEE in ESEC is better than the CANON after the implementation of TPM. The analysis also showed that out of the three TPM practices deployed, planned maintenance of equipment by production and maintenance team played the biggest role in increasing the equipment effectiveness. In conclusion, this study provides insights the importance of implementing TPM in order to succeed in a highly demanding market arena.

1 Introduction

Malaysia government had launched the Economic Transformation Programme (EPT) in order to sustain and elevate country to developed-nation status by 2020. In various sectors in EPT, the Electrical and Electronics (E&E) NKEA sector is one of the key contributor to offset the hit taken from low oil price and the growth of Malaysia economy [1]. Hence, measure has been implemented by the E&E NKEA to enhance the capability and capacity of electronic manufacturing companies. In today's rapidly change environment, more and more companies are replacing their reactive, fire-fighting strategies for maintenance to proactive strategies, the TPM is an aggressive and promising strategy for improving maintenance performance in order to succeed in a highly demanding market arena.

In order to sustain and stay competitive, Malaysian semiconductor companies is urged to upgrade their facility and embrace automation and smart manufacturing. However, recent trends indicate that most of the system in use are not performing as intended, so far as cost effectiveness in term of their operation and support is concerned, in manufacturing system, some of the equipment often not fully utilized, with low productivity and thus the costs of producing products are high, reports show that 15% to 40% of total production cost is attributed to maintenance activities in the factory. Another study of Wireman [2] mentioned that the cost estimation for maintenance in selected companies increased from $200 billion in 1979 to $600 billion in 1989. Each company has their own focus on TPM implementation or the focus part of maintenance department. This study on semiconductor companies also led to interest on determine the effect of TPM on the OEE, in which OEE recognized as a metric to determine the effectiveness of TPM. It is also crucial to determine the effectiveness of TPM to improve OEE.

With the increased of global competition, the semiconductor companies is forcing to implement world class maintenance techniques will improve equipment utilization and thus reducing capital expenditure. This research is to understand the different elements of TPM that influence the effectiveness and efficiency in a manufacturing company.

2 Literature review

To begin with summary of the empirical view of the relationship between TPM and OEE, an understanding of basic conception of maintenance function is a need to be developed. Maintenance is the execution of activities that ensure the physical assets continue to do what their users

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want them to do. The goal of any well run maintenance organization is to have the lowest cost of the sum of maintenance program, it is responsible for controlling the cost of manpower, materials, tools and overhead. According to Cross [3], the maintenance cost in the UK manufacturing industry is around 12-23% of the total factory operating cost. In last three decades, maintenance function has undergone serious change through many phases. The implementation of TPM is important in a manufacturing company and has the significant impact and relationship on manufacturing performance, in term OEE [4]. Hence, the main goal of TPM is to maximize equipment effectiveness and OEE is used as a measure.

TPM is an innovative strategy that developed at Nippondenso, Japan in 1971. Ahuja et al. [5] stated the TPM contains of three words, start with the word TOTAL which is emphasized to involve overall workforces from top to bottom in every aspect of equipment maintenance. Next word is PRODUCTIVE which signifies to ensure the operation is efficient maintenance problems/costs. While the last word MAINTENANCE is to ensure the equipment is keeping in a good condition.

Basically, the practices of TPM often known as the pillars or elements of TPM. Through its unique eight-pillar methodology, TPM is used for excellent planning, organizing, monitoring and controlling practices [4]. Pillar 1- autonomous maintenance: It is based on the concept that the equipment operators accept and share responsibility with the maintenance for the performance and health of the equipment. Pillar 2- Focused Maintenance: This concept is aim for small improvement by carried out continuously and involve entire workforce. Pillar 3- Planned maintenance: Is a system where the maintenance jobs and equipment stoppages are scheduled based on predicted or measured failure rates. Pillar 4- Quality Maintenance: Focus on achieving the zero defects and address the equipment problem and root causes. Pillar 5- Education and Training: Provide the knowledge of what daily maintenance is require to the operators to ensure the optimal operating condition of equipment. Pillar 6- Safety, Health and environment: Is used to create a safe workplace and an environment that will not be damaged by the process and procedure. Pillar 7- Office TPM: Focus on the improvement of the productivity and efficiency of administrative functions. Pillar 8- Development Management: Encourage the continuously developing ideas and procedure that can lead to the creating of maintenance improvement initiatives.

While OEE methodology incorporates metrics from all equipment manufacturing states guidelines in a measurement system that helps the company to enhance the equipment performance and thus, reduce the equipment cost of ownership [4]. The OEE concept is becoming well-known and his widely used as a quantitative tool that important for productivity measurement especially in semiconductor manufacture operations. Firstly, OEE used as a "benchmark" by comparing the initial OEE measures with future OEE values, thus quantifying the level of improvement require. This led to the improvement of maintenance policy and affect continuous improvement in the manufacturing system. Secondly, an OEE values of one manufacturing line can use to compare with the other line performance across the operation, which can help to identify the poor line performance and improvement needed [6]. Thirdly, OEE measurement is an effective way to analyzing and identifying the efficiency of a single machine, and then help in indicating where to focus for TPM resources. OEE tool is designed to identify the disturbances to the manufacturing process as the disturbances often lead to serious problem that can reduce the equipment effectiveness. The losses are measure by OEE, in where it is calculated by obtaining the product of availability of the equipment, performance efficiency of the process and rate of quality products. Equation 1 shows the calculation of OEE

OEE= Availability (A) X Performance Efficiency (P)

$$\text{X Rate of Quality (Q)} \qquad (1)$$

3 Research methodology

This study used primary data. Real time data was recorded by software to provide valuable equipment data for improvement, which known as Global Operator User Interface (GOUI) system. It is a middleware system between Equipment Tracking Interface (ETI) and different company's system. The main purpose of GOUI is to control equipment, process monitoring, manage user, verify material, data logging, efficiency losses measurement and so on without refer back to the machine vendor. Besides, SECS/GEM standard is also use as the interface protocol for equipment to communicate with the host and vice versa. It defines messages, equipment state and scenarios to enable factory software to control and monitor production equipment. With these software, the system can be measure and evaluate in all areas of production and offers users a comprehensive overview of the efficiency of production equipment at any time. Besides that, the main applications for the semiconductor industry – electronic manufacturing and micro-systems technology standard (SEMI E10 and SEMI E58 standards) is also applied. It is an ideal measurement in where it can assist manufacturing to monitor the machines and automatically determine availability indicators (SEMI E10, 1992) [7].

The data was collected and monitored weekly and from two different model of machines in die attach process- CANON and ESEC. Since Canon was a new machine model that started to run production on September 2016, hence the data started collected from the September 2016 and end on March 2017 due to time limitation of this study.

Figure 1 shows the TPM's variables used in this study are maintenance (FM), autonomous maintenance (AM), and planned maintenance (PM).
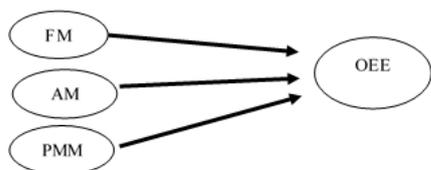
2

Fig. 1. Theoretical Framework

4 Result3s and discussion

In this part, the data for both model types of equipment is combined and two sample dependent or pair mean analysis was performed to determine the effect of the implementation of TPM pillars and OEE.

The independent t-test was used to compare the means between two unrelated group (CANON and ESEC) on the same continuous, dependent variables (OEE). The hypothesis for this study can be express as:

H0: μCANON = μESEC (Means of CANON and ESEC are equal.)

H1: μCANON ≠ μESEC (Means of CANON and ESEC are not equal.)

In the sample data, two variables had been used: Model and OEE. The Model variable consist of CANON and ESEC, which function as the independent variable in this T test, while the OEE is function as dependent variables and is a numeric duration variable (%). The result of analysis are summarized in Table 1 and 2.

Table 1. Group statistic of independent T-test

Model OEE	N	Mean	Std. Deviation	Std. Error Mean
Canon	31	72.49	8.42	1.51
ESEC	31	81.92	3.52	0.63

The first section, Group Statistics, provides basic information about the group comparisons, including the sample size (n), mean, standard deviation, and standard error for OEE by group. In this study, 31 weeks data had been collected for CANON and ESEC, respectively. The mean of OEE for CANON is 72%, and the mean OEE for ESEC is 82%.

Table 2. Independent T-test output

	Levene's Test for Equality of Variances		t-test for Equality of Means							
	F	Sig.	t	df	Sig. (2 tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		
								Lower	Upper	
Equal variances assumed	9.648	0.003	-5.97	60	.000	-9.337	1.639	-12.62	-6.06	
Equal variances not assumed			-5.69	40.202	.000	-9.337	1.639	-12.65	-6.02	

Second section, Independent Samples Test, displays the results most relevant to the Independent Samples t Test. There are two parts that provide different pieces of information: Levene's Test for Equality of Variances and t-test for Equality of Means. This study showed that the P= .003 is less than the significance level of 0.05. Hence, the null of Levena's test is rejected and concluded the variance in OEE of CANON is significant different than the ESEC. This also mean that the data need to be referred was the "Equal variance not assumed" row for the t-test results. The negative sign of T-values indicated that the mean of OEE for the first group, CANON is significantly lower than the mean of OEE for the second group, ESEC. Based on the result, below statements can be concluded:-

There was a significant difference in mean of OEE between CANON and ESEC

T (60) = -5.695, P=.003, which is less than the established significant level of 0.05.

Following is the results for Multiple regression analysis for the pair model as shown in Table 3.

Table 3. ANOVA of Multi Regression Analysis for CANON and ESEC.

ANOVA[a]

Model 1	Sum of Squares	df	Mean Square	F	Sig.
Regression	3434.604	3	1144.88	159.525	0.000[b]
Residual	416.250	58	7.177		
Total	3850.854	61			

a. Dependent Variables: OEE
b. Predictors: (Constant), FM, PM, AM

F- Ratio in the ANOVA Table 3 is used to determine the overall regression model is a good fit for the data. The table showed that independent variables statistically significantly predict the dependent variable, F (3, 58) = 159.525, p< .05. It indicated that the regression model is a good fit of the data.

Coefficients is a statistical measure of the degree to which changes to the value of one variable predict change to the value of another [8]. Table 4 shows the impact of independent variables- PM, AM and FM on the dependent variables of OEE.. The results yielded from the multiple regression showed that the significance level of planned maintenance and autonomous are less than the established significant level of 0.05, so they had significant impact on OEE, in where planned maintenance: t(61) = 14.398, P= .000 and autonomous maintenance: t(61) = 6.539, P= .000. For the focused maintenance, there is no significant impact on OEE with t (61) = .538, P= .593, in where the P value >.05.

Table 4. Coefficients of Multi Regression analysis for CANON and ESEC

Mode l 1	Unstandardized Coefficients		Standadized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
(Constant)	11.586	12.865		.90	.372	-14.167	37.340		
PM	.501	.035	.775	14.39	.000	.431	.571	.643	1.555
AM	.218	.033	.429	6.54	.000	.151	.284	.433	2.309
FM	.076	.142	.037	.538	.593	.218	.361	.393	2.548

Multicollinearity in regression is viewed as disadvantage, because it practically inflates unnecessarily the standard errors of confidents in regression. The tolerance and VIF is used to determine the multicollinearity. There are various recommendation for the acceptable of VIF have been published in the literature. Perhaps more commonly, a value of 10 has been recommended as the maximum level of VIF [9-10]. However, a recommended maximum VIF value of 5 [11] and even 4 [12] can be found in the literature. In this study, the VIF of three independent variables (PM: T= .643, VIF= 1.555; AM: T= .433, VIF= 2.309; FM: T=.393, VIF= 2.548) are less than the established value of 10, so this indicated that there were no inter-correlation between the predictor of interest.

The general form of the equation to predict the relationship between the OEE and TPM variables (PM, AM and FM) was showed as below:

$$Y = 11.586 + 0.501 X1 + 0.218 X2$$

Where Y was the overall equipment effectiveness (OEE) and X1, X2 are the TPM practices of planned maintenance and autonomous maintenance respectively. Both the Y and X are measured in percentage, %.

The regression equation established by taking all factors into account constant at zero, the OEE rate will be at 11.586. It also indicate that for every unit increase in planned maintenance practices would actually result in a .501 increase of OEE, while every unit increase in the implementation of autonomous maintenance would also result in .218 increase of OEE.

5 Conclusion

In the nutshell, this study show that there is a significant and positive relationship between the implementation of total productive maintenance (TPM) practices at the semiconductor company from the September 2016 to March 2017 and the improvement in the overall equipment effectiveness (OEE) rates that was witnessed in the organization during that time period. The combined effect of the implementation of the three TPM practices of planned maintenance, autonomous

maintenance and focused maintenance was an increase in all of the indicators of equipment effectiveness.

The finding of the study is supported by Paropate and Sambhe [13] who also performed a study on the implementation of TPM in a midsized cotton spinning plant in India. Their study proved that with established of TPM, the overall equipment effectiveness improved from 68.9866% respectively before TPM implementation to 71.465% respectively after TPM implementation.

The study of Sharma et al.[14] also support the result, in where the study is proved that TPM leads to increase in efficiency and effectiveness of manufacturing system in term of OEE index. In addition, the finding of Ateka [15] also highlighted that the increased quality and improved productivity as the key benefits resulting from TPM implementation. The study was examined the adoption of TPM practices in large manufacturing firms located in Mombasa County and also stated that the most important critical success factor of TPM is co-operation and involvement of both the operators and the maintenance workers in equipment maintenance.

This research is a cross-sectional study as the study will be carried out on a particular phenomenon and population at a particular time. Due to the time limitation and complexity of the data, the study could not be able to carry on for whole production line in the company. Therefore, the study was only focused on the equipment models of bottleneck process- die attach. Furthermore, the study used primary data in the company. Due to the sensitivity of the information, and the obligations placed on the researcher and the custodians of the information, the study was not able to establish more data points, and to obtain data for a longer time period, thereby limiting the scope of the period under the study.

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