UNIVERSITI TEKNIKAL MALAYSIA MELAKA

A FRAMEWORK TO IDENTIFY OPERATIONAL FACTORS IN OVERALL EQUIPMENT EFFECTIVENESS (OEE) TOWARDS LEAN MANUFACTURING

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Management) (Hons.)

by

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ABSTRACT

Overall Equipment Effectiveness (OEE) is the product of availability, performance and quality multiply together, which are looking for the losses such as downtime losses, speed losses and quality losses respectively. This study is carried out in an aero-composite company to acquire the time data of the Autoclave section via the computerized recording system. Miscalculation of OEE for not including details of all the operational factors that involved in the operation, further causing inaccurate OEE data. In this study, a framework is developed to determine the operational factors specifically. The framework is used to calculate the OEE rate, which helps to identify the 16 losses correctly in the company for the duration of 59 days. As a result, the utilization of this framework is managed to surpass 85% OEE, which the company aimed for best practice. By specifically including the operational factors in the calculation, the OEE rate resulted in this study is 85.40%, which is comparable to the value of OEE determined by the company at a 69.65% rate. Furthermore, the framework can be used by many other companies to accurately calculate the OEE rate. This study is focused on the utilization of the framework to achieve an improvement in OEE rate by including operational factors in OEE calculations.

ABSTRAK

OEE adalah hasil pendaraban daripada kebolehan, prestasi dan kualiti, di mana pembaziran dicari untuk setiap komponen tersebut, seperti ketidak-bolehan mesin, pembaziran kelajuan dan pembaziran kualiti. Kajian ini dijalankan di sebuah syarikat aero-komposit dengan menggunakan data masa melalui sistem pengkomputeran rekod data di bahagian Autoclave. Kesilapan dalam pengiraan OEE disebabkan oleh faktor-faktor operasi yang terlibat dalam operasi itu tidak dinyatakan secara terperinci, menyebabkan data OEE yang diperolehi adalah tidak tepat. Dalam kajian ini, satu rangka kerja dibentuk untuk mengenalpasti faktor-faktor operasi dengan lebih terperinci. Rangka kerja ini digunakan untuk mengira kadar OEE turut membantu dalam mengenalpasti 16 pembaziran TPM (total productive maintenance) di syarikat itu dengan tepat, untuk tempoh masa 59 hari. Hasilnya, penggunaan rangka kerja ini berjaya mengatasi 85% OEE, yang merupakan OEE standard dunia, dan juga telah menjadi sasaran syarikat tersebut. Dengan penglibatan faktor-faktor operasi dalam pengiraan OEE secara terperinci, kadar OEE dalam kajian ini telah mencapai 85.40%, dan adalah nilai OEE yang lebih baik berbanding nilai OEE yang telah ditentukan oleh syarikat iaitu OEE pada kadar 69.65%. Tambahan pula, rangka kerja yang telah dibentuk boleh digunakan oleh syarikat-syarikat lain dalam pengiraan kadar OEE yang tepat. Kajian ini memfokuskan pada penggunaan rangka kerja untuk mencapai peningkatan kadar OEE dengan penglibatan faktor-faktor operasi dalam pengiraan OEE.

DEDICATION

To my beloved parents

ACKNOWLEDGEMENT

I would like to thank the management of company who gives me the opportunity in applying the knowledge learned and concept proposed in the production line of Autoclave curing section. Without the information and data from the company, the study could not be carried out smoothly and might be lacking in a few aspects. The information and data provided by the company encouraged my pursuit to achieve the aim of the study, and further to reach the results and conclusion of the study.

Besides that, I was in contact with many people from the company during which the implementation of the OEE. Among them include Mr. Abdul Rahman who gives support and endless effort to help out in carrying out my study. He has been aiding me in acquiring resources, which includes cooperation from man power, assessment to time data and many others. Not forgetting the other engineers and operators who are responsible on Autoclave section and my understanding regarding the Autoclave operation, which includes the process flow, characteristics and nature of manufacturing environment of the production. All of them deserve special thanks because the study will be barely accomplished without their kind assistance.

Anyhow, I would like to thank my supervisor, PM IR. DR. Puvanasvaran, because of his support and encouragement on the progress of the study. His guidance had been very informative and helpful for me to carry out this study. His experience and knowledge is the strong support which could not be found anywhere else and that had been very valuable for me. Lastly, my special thanks would be given to my parents for their emotional and physical support that encouraged me to continue this study without giving up.

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATI ONS

OEE	-	Overall Equipment Effectiveness
TPM	-	Total Productive Maintenance
AC	-	Autoclave
WCM	-	World Class Manufacturing
C/T	-	Cycle time
OLE	-	Overall Line Effectiveness
LA	-	Line availability
LP	-	Performance efficiency of the flow line
LQ	-	Quality efficiency of the flow line
OT	-	Operating time
CT	-	Calendar time
LPQP	-	Line production quality performance efficiency
CNC	-	Computer Numerical Control
ESP	-	Electrical submersible pumps
TWT	-	Total workover time
BTWT	-	Best time achieved
RIH	-	Run in hole with downhole equipment
POH	-	Pull out of hole of the equipment such as ESP
CMMI	-	Capability Maturity Model Integration

TABLE OF CONTENT

CHAPTER 1

INTRODUCTION

This chapter basically introduces the causes and the existing problems which initiate this study. It is also including the background of the study and the focused objectives. By the end of the chapter, the project scope will be clarified to set the boundary of the study where it should lie within.

1.1 Background

This section consists of two subsections. The first subsection is the background involving the relation between the operational factors and the concept of overall equipment effectiveness (OEE). A brief introduction and explanation are included in this subsection. The second portion of this segment is the background of the field of work. The introduction of Autoclaves and curing process are included in the second subsection. The selection of Autoclaves and the data required are also included in this part.

1.1.1 Background of OEE concept with operational factors

Elimination of wastes has become important and necessary in the competitive world of industries. The wastes developed from the failure cessation of built facilities, with extensive investment, besides other waste, including defective

products, certainly should be eliminated. The enticing productivity, cost, inventory, quality and delivery all depend on the adequate operation of the company's equipment (Hemant and Pratesh, 2012). In order to eliminate the existing wastes, many tools and techniques in Lean Manufacturing can be applied. One of the Lean Manufacturing tools and techniques is the application of overall equipment effectiveness (OEE) in industries. The OEE is important and have been vastly used as metrics of performance in the manufacturing area, particularly for companies that applied total productive maintenance (TPM) (Wudhikarn, 2012).

OEE is a way to monitor and improve the efficiency of the manufacturing process. OEE has become an accepted management tool to measure and evaluate plant floor, machines and equipment productivity. OEE is a valuable tool that can help to unleash hidden capacity and therefore reduce overtime expenditures and allow deferral of major capital investment. It helps to reduce process variability, reducing changeover times and improving operator performance. OEE empowers manufacturing companies to improve processes and in turn ensure quality, consistency, and productivity measured at the bottom line.

OEE measures the percentage of number of a product or part produced without defects versus the capacity of product or part that could be generated according to the equipment's design. A machine or process that has an OEE of 100% is generated at its maximum designed capacity with zero defects (Mohamed Hamed Ahmad, 2013). According to Huffman (2014), OEE is a measurement tool leading to a perfect production; where OEE score is set to 100%, where it takes into account of all losses (downtime losses, speed losses, and quality losses). But as it is almost impossible to achieve the perfect production, the OEE world-class rate of 85% is the best score to be set as a benchmark in Lean Manufacturing (Fast, 2011).

Nakajima (1988) proposed a formula to determine the OEE percentage rate; where the three OEE components are multiplied together. The formula have been widely used in the implementation of OEE, especially in production. Based on the OEE formula proposed by Nakajima (1988), it is understood that OEE is made up of 3 components; which are Availability, Performance and Quality. The percentage rate of each component differs from the OEE percentage rate. But each component must

be able to contribute in achieving the OEE percentage rate, at best towards the OEE world-class standard percentage rate at 85%. Each of the OEE components is influenced by some operational factors related to the 6 major losses in industries. This leads to OEE percentage rate are also affected by operational factors, whether towards improvement or failure of OEE implementation. However, there are more of the operational factors that usually are lacking in the OEE calculation that affect the OEE percentage rate. Each of the operational factors need to be included in the appropriate OEE components in order to determine the ideal OEE percentage rate that is comparable to the world-class standard. Therefore, operational factors play an important role to determine the OEE to create the Lean Manufacturing environment.

1.1.2 Background on the subject of study

The study is carried out in an aero-composite company. The company is applying OEE in most of the machines and equipment involved in the production. However, this study shall be focusing on the Autoclaves only, in which several of the machines are comprising a manufacturing section in the company. The Autoclave is used to harden the ply materials from the lay-up process. Lay-up process as the supplier process of Autoclave curing process, is actually to stack up one ply onto another in the amount and at the orientation as per the design of aerospace parts. The ply materials after being cured by autoclave will become harden aeroplane parts for assembly of different area in different aeroplane model. Autoclave curing process is a critical process in the production because the parts that encountered defects due to the curing process cannot be reworked. This is where the wastes occurred in the production and needed to be eliminated.

The manufacturing section composed of 8 Autoclaves, and their dimensions are all different from each other. Due to the matter of dimension, their capacity or maximum curing capacitance is then different as well. This means the operating time for an Autoclave will differ from others because the operating time is impinged by the capacity loaded inside. The operating time is included in the OEE calculation

with the consideration of a few operational factors. In this study, nonetheless, will only be focusing on two of the worst Autoclaves operated out of all 8 Autoclaves. Improvements can be made for these two Autoclaves in terms of their OEE rate, which can further contribute in the production.

The OEE data that are used for this study is based on the past record of the Autoclaves' operation. For the record, the OEE calculation methods that are used to attain the OEE percentage rate will be evaluated in order to determine the operational factors included in the OEE calculation. The OEE calculation methods used in the company will be compared to the ones used in past studies. When the best method is clarified, it will be implemented in the company to achieve the company target of the OEE rate at 85%, constituting the operational factors that induced in the Autoclaves' operation.

1.2 Problem statement

Based on the OEE formula (Nakajima, 2008), operational factors have already been included in calculating OEE. The target of OEE is to achieve the world-class OEE standard at 85%; with availability in abundance of 90%, performance efficiencies in profusion of 95%, and quality surplus of 99% (Robbins, 2008). Currently, the OEE rate of Autoclaves in the company is lower that the world-class standard, affected by the rate of all three components of OEE, as shown in Figure 1.2(a). The figure shows the fluctuation of OEE calculation for the Autoclaves in the case-study company, which is caused by the data that is always calculated wrongly due to lacking of operational factors in the Autoclaves' operation.

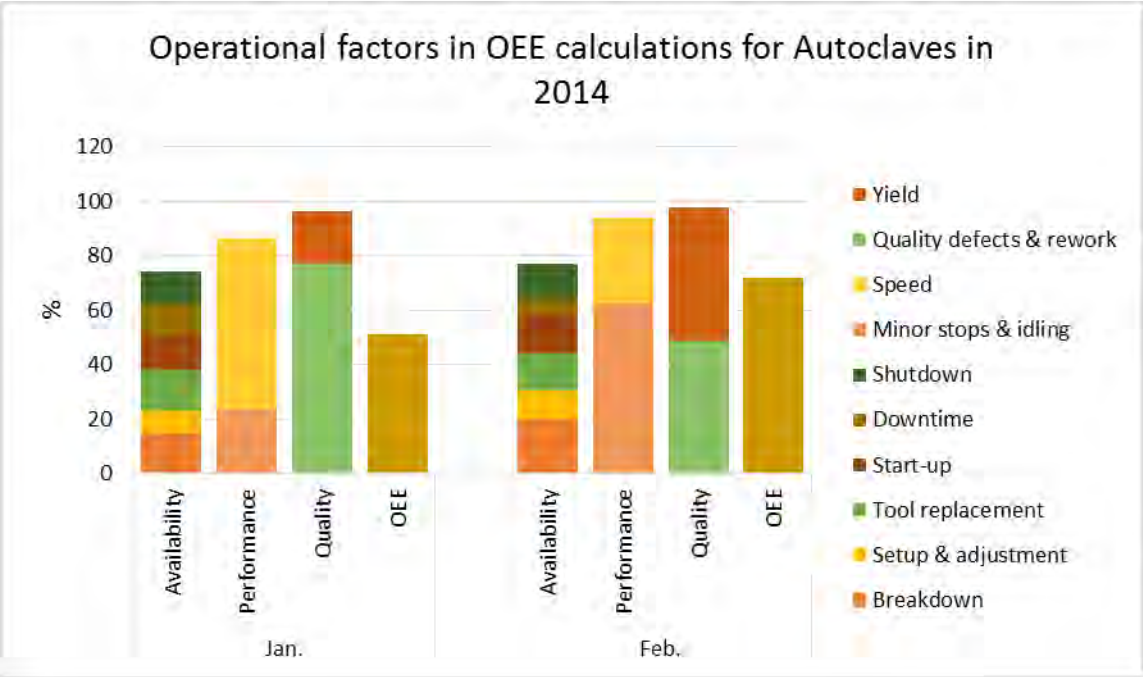

Figure 1.2 (a) Operational factors in OEE calculations of Autoclaves

One of the challenges in calculating OEE is that the details of operational factors need to be included specifically to determine the percentage rate of each OEE components, which further will arbitrate the OEE rate. But these operational factors tend to be ignored, lacking or wrongly input into the OEE formula, leading to miscalculation of OEE, further causing inaccurate OEE data obtained. The operational factors in the company has been determined by using the company's recorded data for all Autoclaves in January and February 2014. The operational factors that involved in calculating OEE of Autoclaves in the company is shown in Table 1.2 (a).

Table 1.2 (a) Operational factors that involved in calculating OEE of Autoclaves in an aero-composite company

Operational factors that are precisely used in calculating OEE	• Breakdown • Setup and adjustments • Start-up • Shutdown • Minor stops and idling • Speed • Quality defects and rework • Tool replacement • Energy • Yield
Wrongly calculated operational factors or operational factors that have been calculated, but not included in OEE	• Operating motion • Line organization • Internal logistics • Measurement and adjustments • Consumables
Operational factors that have never been involved in calculating OEE	• Management

Within the duration of 59 days, there are quite a number of errors detected in the process of determining the OEE rate due to the operational factors are miscalculated or wrongly calculated to cause inaccurate OEE data. The problem further causes fluctuation of OEE calculation for the Autoclaves. The operational factors are yet to be improved for a better OEE result for the Autoclaves' operations in the company.

The operational factors that have been determined, contributing towards the performance and effectiveness of the OEE for the 59 days of the data taken. The

performance of OEE is determined based on the company's recorded data of OEE that had been obtained as shown in Table 1.2 (b).

Table 1.2 (b) Overall OEE rate in January and February 2014

Month	Autoclaves (AC)	Availability	Performance	Quality	OEE
Jan.	AC1	57.00%	94.00%	100.00%	53.58%
	AC2	81.00%	94.00%	100.00%	76.14%
	AC3	82.90%	96.70%	100.00%	80.16%
	AC4	79.00%	96.70%	100.00%	76.39%
	AC5	80.00%	92.80%	100.00%	74.24%
	AC6	70.00%	92.00%	100.00%	64.40%
	AC7	69.70%	95.40%	100.00%	66.49%
	AC8	74.00%	99.00%	100.00%	73.26%
Feb.	AC1	80.00%	94.00%	100.00%	75.20%
	AC2	72.00%	86.40%	100.00%	62.21%
	AC3	73.00%	88.70%	100.00%	64.75%
	AC4	75.00%	96.00%	100.00%	72.00%
	AC5	81.30%	86.60%	100.00%	70.41%
	AC6	77.40%	93.70%	100.00%	72.52%
	AC7	70.00%	97.00%	100.00%	67.90%
	AC8	65.00%	98.00%	100.00%	63.70%

The rates for the availability, performance, quality and OEE are shown in Table 1.2 (b). The OEE rates are obtained based on the operational factors mentioned before that have been involved in OEE calculations. The data from Table 1.2 (b) are translated into a graph form as shown in Figure 1.2 (b). The fluctuation of the OEE rate achieved are caused by the miscalculations of OEE for not including details of all the operational

factors or wrongly calculated of operational factors that involved in the operation, further causing inaccurate OEE data.

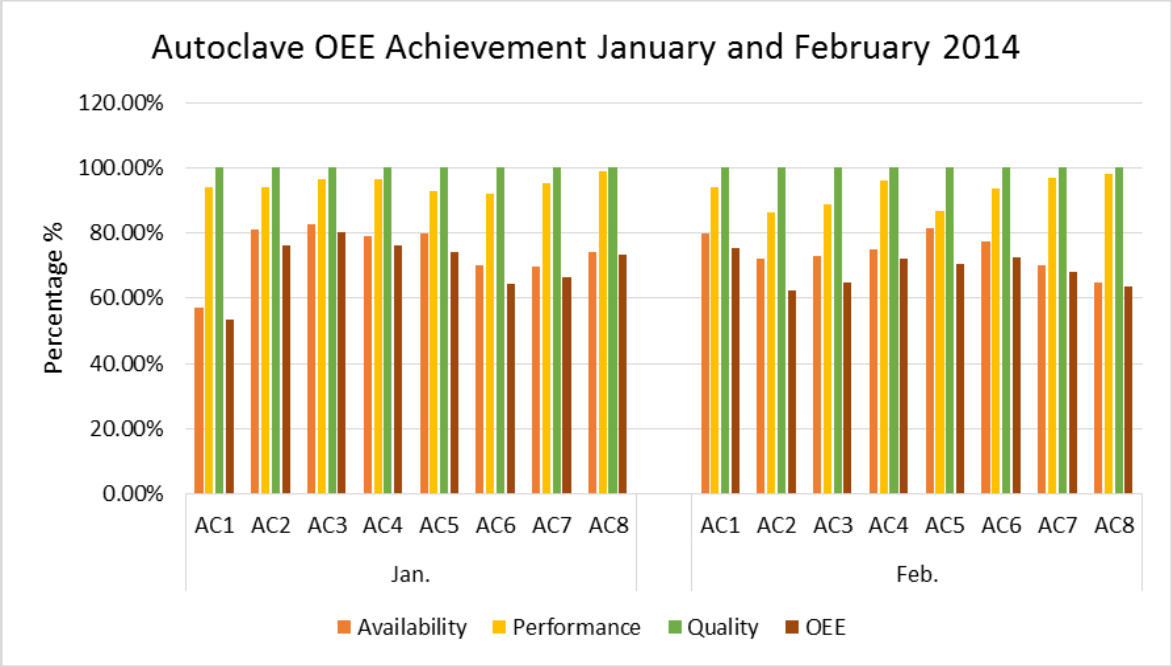

Figure 1.2 (b) OEE rate in January and February 2014

Figure 1.2 (b) shows that the OEE rate for all Autoclaves are observed to have barely reached 80% rate, which is incomparable to the world-class standard at 85% rate. The performance of OEE for the Autoclaves is too far to reach the world-class standard. Thus, the effectiveness of the Autoclaves is also not sufficient enough, according to the OEE result based on the Autoclaves performance. The overall value of the OEE and its components for January and February 2014 is shown in Table 1.2 (c).

Table 1.2(c) Comparison between company data and world-class standard

OEE components	Average OEE for January and February 2014	OEE world-class standard (Robbins, 2008)
Availability rate	74.21%	90.00%
Quality rate	100.00%	95.00%
Performance rate	93.81%	99.90%
OEE rate	69.61%	85.00%

The gap of the percentage rate of OEE between the average OEE for Autoclaves in duration of 59 days and the world-class standard is quite big. Improvement needed to be done in order to increase the OEE rate value of the Autoclaves. With the increment of the OEE rate, subconsciously the performance and effectiveness of the OEE can also be improved. Therefore, the operational factors need to be defined promptly to be included in the OEE calculation in order to obtain the precise OEE rate so that it is comparable to the benchmark rate.

1.3 Objectives

Based on the stated problem, the objectives of this study are defined. With an aim to improve the OEE rate in the case-study company, the objectives of this study are:

i. To determine the operational factors that involve in calculating OEE.
ii. To evaluate the performance and effectiveness of OEE in an aero-composite company.
iii. To develop a new framework for the company usage.

The objectives have been detailed out as follows:

i. The operational factors that have been included in calculating OEE for the Autoclaves need to be identified in order to determine the best method to be used

in calculating OEE. From that, the operational factors that have been lacking in calculating OEE or any errors in calculating OEE are able to be detected. Thus, the operational factors that have influenced on the Autoclaves' operation can be defined clearly and shall be included in the OEE calculation method.

ii. After implementing the best method chosen to calculate OEE, the performance and effectiveness of OEE in Autoclaves operations are monitored to ensure efficiency of the method used. The OEE rate is targeted to increase and exceeding the current OEE rate and is comparable to the OEE rate of the world-class standard.

iii. A framework is designed as a guideline to implement the operational factors in calculating OEE. The operational factors must be correctly identified in the case-study company to achieve a more accurate OEE result. With the aid of the framework, the OEE rate of the company is expected to be improved and is comparable to the OEE of world-class standard.

The objectives of this study are to be accomplished. The objectives are the guidelines for this study to be strategized in order to attain the findings that are sought for this study.

1.4 Significance of the study

Since the implementation of OEE has been widely used in the production industry, the OEE has to be defined precisely; focusing on the calculation methods, in order to evaluate the level of OEE effectiveness in specific areas in the manufacturing environment. This study is necessitated to improve OEE performance and effectiveness of Autoclaves' operation. This is possible by including details of all operational factors, implement best practice in calculating OEE and achieve an accurate OEE rate. This study is also significant in reduction of defects due to machine maintenance. The implementation of increase productivity of the case study company and can indirectly be profitable for their customers.

1.5 Scope of the study

The study shall be focusing on the analysis of the operational factors that affecting the performance and effectiveness of OEE for all Autoclaves' operations in the company. The investigation covers the identification of operational factors applied in the company. The lacking and inaccurately calculated operational factors of the company are to be identified and improved by reviewing the errors in the OEE calculation made by the company. The method in calculating OEE in the case-study company is also investigated to observe the level of involvement of operational factors in the OEE implementation. The OEE data that are focused on for this study will be the ones on all the Autoclave machines in the company. Since the company has newly installed a new Autoclave recently, that particular Autoclave is also involved in this study to be investigated regarding the performance and effectiveness of the OEE. Besides that, the percentage of improvement for all Autoclaves on the difference of OEE result compared between the ones calculated originally by the company with the ones that is calculated using the aid of the framework is presented in this study. Therefore, the improvement made in this study can be proved by doing so.