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CUSTOMER DEMAND AND PLANNING EFFICIENCY IN OVERALL EQUIPMENT EFFECTIVENESS (OEE)

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DEDICATION

To my beloved mother and father

ABSTRACT

Overall equipment effectiveness (OEE) is the multiplication of availability, performance and quality which are looking into the losses such as downtime losses, speed losses and quality losses respectively. The study is carried out in an aerospace parts manufacturing company to acquire the time data of Autoclave section via the computerized recording system. In this study, planning factor is introduced in OEE and defined as the panel number loaded over the maximum number of panel affordable by autoclaves. This is to promote the optimization of Autoclave usage or the concept of On Time In Full (OTIF). In addition to that, customer demand is also incorporated in OEE through Takt Time. This evaluates Autoclaves with constant and fixed cycle time in varying performance ratio from time to time according to its real performance. This also provides a balance between the over-production issue and high utilization of equipment. The results of planning factor and Takt time incorporation show that curing of Autoclave was not planned up to its maximum capability; and the demand accepted is actually higher than its maximum capacity. After that, the OEE data once obtained is then used for versatile usages such as scheduling or planning of preventive maintenance frequency, examination of customer demand accepted with respect to Autoclave capacity, comparison of performance over the time horizon as well as the evaluation of material losses due to planning of equipment process. Among them the estimation of breakdown time (via MTBF) and priority of preventive maintenance on Autoclave is done by analyzing the availability data and the percentage of downtime composition. Another possible usage of OEE data is the calculation of material amount based on the Bill of Material (BOM) and the average of historical quality ratio data. As a conclusion, objectives are achieved since the customer demand is incorporated into OEE, efficiency of planning is examined and versatile usage of OEE value and data are demonstrated. Further study could be suggested is the possibility of implementing Takt time and planning factor in the equipment with varying cycle time

ABSTRAK

OEE adalah hasil pendarapan daripada kebolehan, keupayaan dan kualiti yang masing-masing bertujuan untuk menorakan pembaziran seperti ketidak-bolehan mesin, pembaziran kelajuan, dan pembaziran kualiti. Kajian ini telah dijalankan dalam sebuah syarikat pembuatan bahagian kapal terbang dan data Autoclave telah diambilkan dari system rekod. Dalam kajian ini, factor perancangan telah diperkenalkan dan didefinasikan sebagai pembahagiaan bilangan produck diprocesskan daripada bilangan maximum yang boleh diprocesskan oleh Autoclave. Ini adalah untuk mempromosikan konsep sempat pada masa dengan penggunaan sepenuhnya (On Time in Full, OTIF). Tambahan pula, permintaan pelanggan juga dipertimbangkan dalam OEE dengan adanya Masa Takt. Ini mengukurkan Autoclave yang mempunyai masa prosess tetap dengan nilai keupayaan yang berlainan bergantung dengan keupayaannay yang sebenarnya. Masa Takt juga menggelakkan isu yang wujud dalam penggunaan mesin dan penghasilan produk yang terlampau banyak. Akibatnya, Autoclave adalah dibuktikan tidak dirancang dengan sebaiknya ataupun sepenuhnya dan permintaan pelanggan adalah terlalu banyak jikalau berbanding dengan keupayaan Autoclave itu sendiri. Selapas itu, OEE data dan nilai telah digunakan dalam pelbagai cara yang termasuk perancangan preventive maintenance (PM), perbandingan antara permintaan pelanggan dengan keupayaan mesin, perbandingan keupayaan dari masa ke masa dan juga pemeriksaan pembaziran bahan-bahan yang disebabkan oleh perancangan yang tidak memuaskan. Antaranya, pengiraan masa mesin rosak dan keutamaan Autoclave untuk perancangan PM adalah berdasarkan analisasi peratusan kebolehan Autoclave dan data kerosakan Autoclave. Penggunaan OEE data yang lain adalah pengiraan bilangan bahan yang diperlukan ataupun dibazirkan berdasarkan Bill of Material (BOM) dan purata peratusan kualiti. Sebagai kesimpulannya, kesemuaannya objektif telah dicapaikan kerana permintaan pelanggan telah dipertimbangkan dalam OEE, keberkesanan perancangan Autoclave telah diperiksakan dan akhirnya pelbagai penggunaan OEE data telah ditunjukkan. Kajian yang sama boleh dipertimbangkan dalam masa depan untuk mengkaji mesin yang mempunyai process masa yang sentiasa berubah.

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AC	- Autoclave
BOM	- Bill of materials
DIRFT	- Do It Right First Time
ERP	- Enterprise Resource Planning
MPS	- Master Production Schedule
MTBF	- Mean Time between Failures
MTTR	- Mean Time to Repair
NVA	- Non value-added
OEE	- Overall Equipment Effectiveness
OLE	- Overall Line Effectiveness
OTIF	- On Time In Full
PM	- Preventive Maintenance
R&D	- Research and Development
TPM	- Total Productive/Preventive Maintenance
VA	- Value- added
WIP	- Work in progress

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CHAPTER 1

INTRODUCTION

This chapter is basically introducing the causes and the existing problems which initiate this study. It is followed by the background of the study and the narrowed-down objectives. By the end of the chapter is the clarification of project scope to set the boundary of the study where it should lie within.

1.1 Background

The section consists of two subsections. The first subsection is the background concerning the lean philosophy and the concept of OEE to be applied in this study. Brief introduction and explanation are included in this subsection. The second part of this section is the background of the subject of study. The introduction of autoclaves and curing process are included in the second subsection. Introduction here covers the nature and characteristic of curing process, the product types to be cured and the data required to analyze the OEE performance of Autoclaves.

1.1.1 Background of concept applied

Lean manufacturing is most frequently associated with the elimination of seven important wastes to ameliorate the effects of variability in supply, processing time or demand (Shah and Ward, 2007). Briefly, it is called lean as it uses less, or the minimum, of everything required to produce a product or perform a service (Hayes and Pisano, 1994). As Paul Dean Ceng (2006) stated in his study, "OEE is an essential metric and methodology for manufacturers pursuing a lean manufacturing strategy to emphasize zero waste in the value streams". The OEE is one of the approaches in quantifying if the utilization of equipment or machine is in lean or wasteful way. It identifies the scraps related to equipment in different sections, to take corrective measures in order to eliminate them and exploit the potential capacity of the equipment (Motavallian, 2007).

The overall equipment effectiveness index machine stands in comparison with an ideal machine which always runs at full speed and capacity at the same time produces good quality products (Rouhani, 2009). Although the data of overall effectiveness of equipment seem very simple, extracting useful information from a series of calculations is a very important and difficult task (Aliahmadi, 2003). The reasons include too much of performance measurements have been used in an organization and its resulting confusion of data definition. Besides that, various approaches which are used in the measurement of manufacturing performance could lead to large number of measurement in different hierarchical levels and most of them are contradictory (Nakajima, 1989; Kaplan and Norton, 1992; Jones, 1994).

Unavailability or infeasibility of data to be collected in the form required for each formula is another difficulty of OEE implementation. For instance, often companies struggle to define an ideal cycle time, particularly in non-machinery and less well-automated manufacture (Bamber et al, 2003). The ambiguity of the OEE implementation could further contribute to deviation in evaluating the utilization and performance of a particular equipment. "If you cannot measure it, you cannot manage it", as stated by Paul Dean Ceng (2006). Nevertheless, there is no formula or textbook which addresses the issue of over-production on highly utilized equipment and the 'ideal cycle time' that an equipment with constant and fixed process time should have. There is no guidance in clarifying the trade-off relationship between high machine utilization and low customer demand as well as the corresponding solution. Faced with these conditions, there is a necessity of innovative and simple measurement to evaluate the equipment performance incorporating the customer demand.

1.1.2 Background of subject of study

The study is carried out in an aerospace part-manufacturing company. Within the company, a manufacturing section comprises of several Autoclaves is chosen as the subject of study and all the time data is gathered from that. The time data here refers to the beginning time and ending time of all curing processes which are recorded by computerized data system. The time data is then interpreted and analyzed in this study to achieve the objectives and obtain the results. The autoclave is used to harden the ply materials from the layup process. Layup 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 design of aerospace parts. The ply materials after being cured by autoclave will become harden aero plane parts for assembly of different area in different aero plane model. These different aero plane parts for various aero plane models are referred as product type in this study.

The manufacturing section comprises of 6 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 that the maximum number of a particular product type could be loaded into an Autoclave is different from others. In this study, the maximum number of panel could be loaded into autoclave is dependent on the dimension of autoclave and panel itself. The data of maximum number could be loaded for each panel type is obtained from the system which records the beginning and end of curing time, number of panels loaded and types of packages cured.

Besides that, there are several products types with different customer specification, designs and process requirement are to be cured by the Autoclave section. Consequence of that, the curing recipe of all product types may be different and has to be cured according to their curing recipe. This means that only those products with same curing recipe can be cured together.

Curing recipe controls the length of curing process required by a particular product type. Those product types with same curing recipe means that the requirement of temperature and pressure are same and this allow them to be cured together. Since the curing recipe for a particular product type is always same, this contributes to the constant curing time of a product type from time to time.

In addition to that, not all product types can be cured by all Autoclaves available. Thermal survey of a particular product type should be carried out in advance on the Autoclave before the product is being cured. This is to investigate the thermal profile such as the distribution of temperature and pressure within the Autoclave during the curing process. A product type is allowed to be cured by the Autoclave once the thermal profile is qualified and the product panel is in good condition after the curing process. In this company, one particular product type is dedicated to be cured by not more than 3 Autoclaves due to the constraint of thermal survey.

At last, since the curing recipe is fixed and constant from time to time, there is no improvement can be done to shorten the curing time. The only variable can do to improve the productivity of the curing process is to increase the amount of product loaded per each curing slot. Another option can be considered is to choose the Autoclave according to their dimension. In other words, small amount of products are recommended to be cured in relatively small Autoclave to prevent the waste of non-utilized capacity.

1.2 Problem statement

One of the problems in lean implementation is the lack of direction of planning and adequate project sequencing (Bhasin and Burcher, 2006). From the same perspective in OEE implementation, it can be observed that the importance of planning is usually being neglected. In other words, a high value of OEE does not mean that the machine is fully utilized since the production rate is initially determined by planning. This effectiveness of the planning is neglected or not evaluated in OEE implementation. Regarding to this problem, there are some studies performed evaluating the planning factor as the percentage of production time planned for or realized over the total theoretical production time (Wauters and Mathot, 2007; Icso, n.d.). In those studies, the planning factor was used to evaluate the efficiency of production planning in determining the maximum utilization of the equipment. Even that, Icso (n.d.) had suggested retrofitting the existing equipment for better performance rate which is beneficial from a higher production speed. The similarity of these studies performed is that the machine utilization is not planned over the maximum capability of equipment. Over the similar issue, there is a need to formulate an effective lean process, as suggested by Puvanasvaran et. al. (2009), on the employee's development aspect to unlock the infinite potential of their workforce. This could be implemented in machines or equipments in this case by planning the production rate of existing machine up to the maximum capacity.

On the other hand, there is no specific value for so-called "world-class OEE" regardless of 85 percent OEE which has been cited frequently. This means the action of maximizing and pursuing for high OEE value may not be justifiable. According to Williamson, optimum level of OEE depends on the capability or capacity of the asset, the business demands, and whether or not it is a constraint in the process flow. The idea is that high production rate implied in high OEE (availability) especially in the period with low business demand will contribute to expensive inventory handling cost. Besides that, the ideal cycle time is always difficult to be defined whereas the speed loss, minor stoppage, and idling are hardly to be differentiated from the waiting time (Bamber et al, 2003; Kenis, 2006). On the other hand, the setup and adjustment time which are increasing accordingly with the product mix in manufacturing company will adversely affect the OEE value (Mileham et al., 1997). Frequent setup or loadings are required in the environment of mass manufacturing and this will adversely affect the availability of the equipment. This means the compromise between mass manufacturing and OEE emphasis and this is actually very illogical from the perspective of business. Therefore, there is a need to improve the productivity of a manufacturing organization with respect to different product mixes at the same time considering the customer demand, and defining performance ratio of machines with fixed and constant process time in pursuing high OEE value (Hilmola, 2005).

Besides that, the OEE value once being evaluated is just a displayed value and indication of current machine utilization only. Most companies are focusing on the comparison of particular asset (equipment) with itself over the time horizon via the usage of historical data (Williamson, 2006). The common usages of the OEE metrics are the identification of major losses, problem investigation for capital expenditures and enhancement of capacity (Abidian inc., n.d.; Fuss & O'Neill Manufacturing solution, n.d.). The story behind the value is seldom tracked out and another possible usage of OEE value is not optimized. So, there is a need for internal flexibility within manufacturing system which requires changes of traditional organization methods to manage, measure, and mindset of management and employees on the role (Sweeney, 1990). This can be done by quantifying the instantaneous production rate at manufacturing site, as well as comparing the utilization of a particular machine regarding to the customer demand and examining the corresponding planning of production using OEE data.

1.3 Objectives

Customer demand nowadays consists of multiple products with different process parameters requirement. This makes the number of product being loaded during each production slot with respect to maximum capacity is very important. As a consequence, an overall measurement covering all the product mix does make sense rather than multiple measurements for every of single product produced by the particular equipment. In addition to that, balance between equipment utilization with the customer demands becomes more important to prevent over-production. In order to facilitate the optimization of equipment utilization, all of the issues stated have to be overcome via the objectives stated below:

i. To quantify the customer demand into OEE value and to quantify the performance ratio for an equipment with constant cycle time.

ii. To measure the efficiency of production planning in affecting the machine utilization.

iii. To demonstrate three (3) usages of new-defined OEE measurement to facilitate the planning and engineering of a particular production section.

The concept applied and assumptions formulated throughout the study are:

i. Williamson (2006) suggested that the optimum level of OEE depends on several factors such as capacity or capability of equipments, business demand and condition if it is a constraint of process flow. Additionally, the pursuit of high OEE will lead to overproduction because it is measured based on the cycle time but not based on the Takt time (Harada, n.d.). In view of that, it is a necessity to incorporate the customer demand in OEE implementation to avoid overproduction during pursuing high equipment utilization.

ii. The ideal cycle time in the computation of performance is commonly confused or does not exist for those equipments with constant cycle time. This is because the cycle time for the equipment is fixed as per process requirement and literally same as the ideal cycle time. It can be concluded that the performance ratio of those equipments are always 100% in traditional OEE approach, and this indicates that there is no improvement can be done on equipment to increase the productivity in traditional approach.

iii. A good management metric should cover all products produced or processed in equipment instead of measuring them individually. This is to consider the impact of product mixes on the machine utilization in term of the changeover time (availability) and the overall performance ratio. This is because whenever the OEE is calculated individually, the waiting time or setup time between two processes is neglected and this will contribute to overrated availability. Therefore, a metric which covers all product types processed in equipment and visualizes the overview of the actual utilization. This is to ensure that an overall improvement decision can be made to improve the total performance of the equipment in whole.

1.4 Significance of the study

Manufacturing environment nowadays is characterized with mass production and demand comprises of numerous product mixes. This has necessitated the concept of On Time In full (OTIF) to be more important. OTIF is a concept which emphasizes maximum loading in each production loading and hence reduces the necessity of additional production. In that any under utilization of machine causes more changeovers in production, which will further contribute to lower equipment availability and effectiveness. Often times, however, traditional approach of OEE neglected the importance of utilizing equipment up to its maximum capacity. As a result of that, equipment with high OEE value does not mean high utilization but could probably because that particular machine runs at most of the time, at or close to ideal speed, and produces least defect. There is no concern on number of input loaded per each production slot. Even though there were some studies including the concept of planning factor in computation of OEE (Wauters and Mathot, 2007; Icso, n.d.), but it is just evaluated in term of time (gross operating time over total calendar time). This definition could be simplified in total calendar time approach. In order to overcome the limitation like this, this study will adapt and evaluate the planning factor in terms of the number of product loaded in each production slot. With the significance in this study, the efficiency of planner is examined from time to time to seek for optimization of machine usage.

In addition to that, a good management metric is badly desired and appreciated to be implemented in a complex manufacturing environment. A simple and comprehensive metric (de Ron and Rooda, 2005) which incorporates all product types is important. This is to provide a brief measurement of current condition and to enable on-time decision making based on actual data. Besides that, a good management metric should be characterized with ease of data collection (Harada, n.d.). In view of that, flexibility is a must for a good management metric so that it could be adapted and measured from time to time. As such, creativity could be promoted in achieving the flexibility and competitive advantage (Oke, 2003; Yung and Chan, 2003; Sanchez and Perez, 2001; Gerwin, 1993; Jordan and Graves, 1995; Upton, 1995a cited in Ooi, 2005). The flexibility stated can be obtained by defining the measurement in aggregate unit which covers all product mixes of the equipment. In this study, the aggregate unit is calculated accordingly with the schedule of the production based on their corresponding importance factor named weighted averaging factor.

In most companies which are implementing OEE as their equipment performance evaluation, the customer demand and production rate are in the trade-off relationship and hardly to be balanced. Inappropriate management between these two parameters could lead to over-production or idling machine, and sometimes the shortage of production. However, the machine utilization and overproduction should be not always in opposite standpoint and could be working together. It is possible to avoid or minimize the side-effect of over-production in the path pursuing high equipment utilization. Significance in this study shows that the performance ratio is possibly incorporated with customer demand via the introduction of Takt time. The concept of Takt time in OEE computation has not only balanced the issue of overproduction and machine utilization, but it quantifies various performance ratio on the equipment with constant cycle time according to fluctuating customer demand.

As a short summary, this study is examining the validity of OEE universal implementation in various types of manufacturing environments, and some of them were known to be improperly used. Various elements are introduced in this study to enable OEE computation. This study is providing new angle in looking at the possibility and flexibility of modifying the traditional OEE approach to adapt the OEE measurement. The modifications made are according to different manufacturing nature, which is determined by the types of equipment used. This study seeks to create an impact on the OEE computation which covers the considerations stated above via the following significances and novelties in OEE:

i. Customer demands to avoid over-production issue.

ii. Aggregate unit to cover all product mixes and types produced.

iii. Planning factor to promote On Time In Full (OTIF).

iv. Total calendar approach to track out total downtime wasted.

1.5 Scope of the study

This study is focusing on the computation of single OEE measurement over six Autoclaves to cover all the product mixes. The products are cured with fixed curing time and are all constant as per curing recipe. A single measurement is desired to be simple and comprehensive to quantify the condition of all product types in utilizing the equipment.

The scope of study also attempts to introduce and implement the concept of Takt time in pursuit of high OEE level. This is to promote the balance between production rate and the customer demand. In order to ascertain the generic and applicable characters of the new OEE, a make-to-order type of industry with various product types, Autoclave with different sizes and capabilities are selected as the subject of study to represent the sample of manufacturing process with constant cycle time.

This study does not attempt to demonstrate the implementation of OEE on those equipments with varying cycle time from time to time within a product type. Such equipment as this will have its ideal cycle time in defining the performance ratio. Besides that, the integration of OEE metric with other lean tools is not demonstrated in this study since the usage of OEE as a management metric is the only concern and analysis tool in this study

In addition to that, this study is focusing on the Autoclave section only but not other manufacturing cell or the effectiveness of equipment over the company wide is not within the scope of the study. According to Williamson (2006), OEE is not intended for use as a corporate or plant level. It is just a measure of a selected equipment effectiveness only. This is