Overall equipment effectiveness estimation for priority improvement in the production line

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Abstract: The objective of this research is to propose an enhancement of the overall equipment effectiveness (OEE) by including information on OEE estimation, value added (VA) cost, and non-value added (NVA) cost through simulation and the Taguchi experimental method. This additional information can enhance the original OEE as a key performance indicator (KPI) and act as a guide for a company in deciding on the priority improvement required. If a company relies solely on the ordinary OEE calculation, it can only arrive at a decision for priority improvement through the lowest score measured and will be in the dark as to the level of improvement required in the production line. Decision-makers in the company need to consider information other than the OEE score if their intention is to see a profound improvement in the performance of the production line. This research proposes a procedure which employs simulation and the Taguchi experimental method.

Keywords: overall equipment effectiveness; OEE; total productive maintenance; TPM; simulation; statistical experiment; Taguchi method; overall equipment effectiveness estimation; manufacture.

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1 Introduction

Manufacturing systems often operate at less than full capacity while producing quality products. Among the many reasons for low productivity are: incompatible design specifications, frequent occurrences of product defects, high machine downtime, low operator skills, etc.

Low productivity increases the operational cost, and it comes as no surprise that manufacturing companies are very much concerned about the effective utilisation of the available resources. Other significant problems related to low productivity include unfulfilled customer demands and longer lead-times. In order to increase productivity, a company will generally conduct an improvement programme aimed at reducing machinery downtime, increasing operator skills or machine capacity, reducing product defects, etc. That programme is known as total productive maintenance (TPM). The goal of TPM is to increase the productivity of the equipment in a plant by involving all the employees from the various departments (production, maintenance, technical services, stores, etc.) in the process. The most effective way to maximise output is to remove the barriers that stand in the way of equipment effectiveness. The lean manufacturing philosophy takes the same route by striving to increase efficiency through waste reduction. Similarly, ineffective machines and equipment can also be considered as 'waste'. While the TPM model provides a quantitative metric for measuring the productivity of specific production equipment, it has been observed that an appropriate measurement is required for the problem identification in order to improve and increase productivity. This entails the establishment of suitable metrics for measurement (Raja and Kannan, 2007).

Some researchers are in agreement that TPM is a reliable tool for the enhancement of equipment effectiveness and equipment output. The findings indicate that TPM not only increases the efficiency and effectiveness of manufacturing systems, but also prepares the plant in general to engage in globally competing economies (Singh and Singh, 2012).

There are six major causes for the loss of effectiveness in TPM. These are set-up and adjustments, equipment failure, reduced speed, idling and minor stoppages, reduced yield (from start up to stable production), and process defects. According to Nakajima (1988) and Wang (2005), the first two are downtime losses as they reduce the availability of the equipment, the next two are considered as speed losses as they reduce the performance level of the system, while the last two are categorised as defect losses or rejected low quality products.

Overall equipment effectiveness (OEE) is a performance indicator that covers the measurement of the six major causes for the loss of effectiveness in TPM. The OEE directly measures product quality, loss and the ability to deliver according to a schedule (Singh and Singh, 2012). Before the advent of OEE, only availability was considered in equipment utilisation and this resulted in the overestimation of equipment utilisation. The OEE methodology is a proven approach for improving the overall performance of equipment (Badiger et al., 2008). From a survey, Sohal et al. (2010) found that the OEE has typically advanced from a base measure for efficiency as the initial purpose, to being a tool to improve effectiveness for analysing data, to supporting continuous improvement objectives.

The original OEE involved three elements which have been defined by Nakajima (1988) as: (A) availability rate, (P) performance rate, and (Q) quality rate. The mathematical equation for OEE is as follows:

$$\text{OEE} = \text{A} \times \text{P} \times \text{Q} \tag{1}$$

where

$$\text{A} = \frac{(\text{loading time} - \text{down time})}{\text{loading time}} \tag{2}$$

$$\text{P} = \left(\frac{\text{ideal cycle time}}{\text{actual cycle time}}\right) \times \left(\frac{\text{actual cycle time} \times \text{output}}{\text{operating time}}\right) \tag{3}$$

$$Q = \left(\frac{\text{total number of production} - \text{number of defective products}}{\text{total number of production}} \right) \quad (4)$$

OEE percentages have become a metric to compare current equipment performance to world-class performance. The measure of 85% equipment effectiveness has become known as a 'world-class OEE'. Once used as a benchmarking score for 'world-class', the OEE has eventually become a way to compare one piece of equipment with another, even though the equipment performs different functions in different processes or even if the equipment is located in a different plant. The OEE was designed and developed to characterise and communicate the major equipment-related losses.

2 Research background

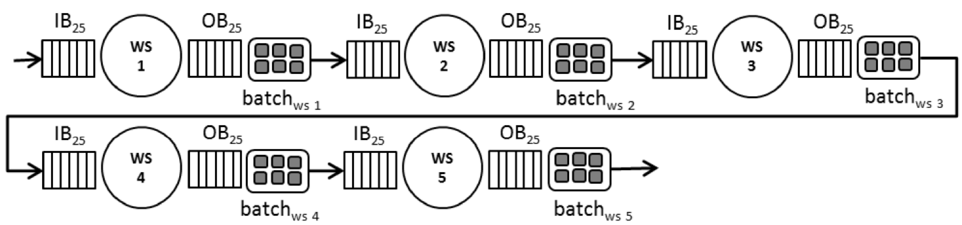
The role of OEE in performance measurement and decision support will be enhanced if it can provide more information, especially on how improvements can be estimated in relation to cost and OEE element scores. This is relevant because companies regularly measure productivity with due consideration to the operational cost. Several OEE developments related to cost calculations with reference to the OEE elements are as follows:

- Wudhikarn et al. (2010) proposed a new indicator that could prioritise problematic machines by showing production loss in a monetary unit through the OEE method. In line with the OEE method, the presented indicator still analyses losses in three elements, but reveals the outcome in saving cost instead. The losses in each element are dissimilar and depend on resource usage.
- Sheu (2006) proposed the concept and analysis of overall input efficiency (OIE) to complete the calculation of full machine efficiency which the research called total equipment efficiency (TEE). The research revealed that the OEE is apparently only concerned about the output aspect of machine efficiency.
- Tekin and Gözlü (2012) developed a methodology called 'Analysis of Costs Resulting from Manufacturing Losses' based on the ABC model in order to measure costs resulting from manufacturing losses. The aim of this study was to provide a decision support approach for estimating the cost of tools for the managerial staff of companies to reorder cost reduction priorities and initiate the recovery of manufacturing losses through TPM activities. In this study, the OEE metric was used for identifying the performance of individual manufacturing units.

All these studies shared the same general objective, which was to enhance the OEE concept by including cost calculations in the production process to support decision-making. This is because the OEE is not equipped to measure losses attributed to production costs. It is a rare situation in manufacturing that a 1% downtime loss has the same business or financial impact as a 1% efficiency loss or a 1% quality loss.

The OEE can also serve as a tool for improving the examination of data to support continuous improvement objectives. In an actual situation, decision-makers in a company need to consider much more than just the OEE score. Among others, they need to deliberate on buffer size, number of products, work in progress (WIP), queue times, batch in this production line. Defective products were disposed. The average route time between WS was 0.33 minutes. The work hours in the CH4H6 model were set at 9 hours per day. This simulation model had been verified and validated in the same way as the verification and validation of the CML. The experiment was conducted in the $L_4(2^3)$ OA with ten replications for each experiment.

Figure 7 CH4H6 line model layout



The scheme of the OEE enhancement can be seen in Table 13. It can be implemented for other case studies, even with different simulation models and different experimental designs by using the Taguchi method approach.

Table 13 indicates that the focus of improvement in the CH4H6 line would be the performance element. In addition, the OEE estimation after only the performance improvement by this condition in the experiment increased by 2.0%. Moreover, the VA cost and NVA cost reduction could be estimated for each element only or for all OEE elements.

Table 13 OEE enhancement scheme on CH4H6 line

OEE calculation	*Availability*	*Performance*	*Quality*	*OEE*
	93.8%	15.6%	97%	14.15%
OEE element contribution measurement by simulation experiment				
Balance for each different level (Δ)	Δ*Availability* □	Δ*Performance*	Δ*Quality*	*OEE estimation with all OEE element*
	(–) 0.9%	(+) 2.0%	(–) 0.9%	
OEE +Δ (OEE estimation) by each OEE element	14.06%	16.15%	14.06%	14.13%
VA cost and NVA cost measurement by simulation experiment for each OEE element				
Balance for each different level (Δ)	Δ*Availability* □	Δ*Performance*	Δ*Quality*	*Cost estimation*
VA cost balance	(–) 296	(–) 929	(+) 214	(–) 1011
NVA cost balance	(–) 2412	(–) 1668	(+) 2291	(–) 1798

7 Conclusions

This OEE enhancement scheme provides a company with the appropriate information for decision-making on priority improvement in the production line. By using the Taguchi method and simulation as an experimental tool, this scheme can measure and estimate the contribution for each OEE element to an OEE score. This procedure can be implemented in a specific WS or in a production line if the factory is made up of more than one manufacturing line. There are four types of enhancement information. The first type is the OEE itself, the second is the OEE element contribution measurement, the third is the OEE element measurement by the value added cost (VA cost), and the fourth is the OEE measurement by the non-value added cost (NVA cost). They provide measurements for each OEE element in order to observe the extent of the influence the simulation experiment has on the OEE elements and scores. Other OEE enhancement implementations on another simulation model showed that the procedure can be implemented in other case studies as well. The work plan for the future is to continue with the same procedure and include more level experiments in order to observe the characteristic of the OEE elements in relation to the OEE scores.

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