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Measurement of Production Line Performance Based on OEE Extension

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The objective of this research is to propose an extension of the Overall Equipment Effectiveness (OEE) by including information on OEE prediction through simulation modelling and experiments procedure (SMEP) in order to extent the benefit of OEE as key performance indicator (KPI). To succeed in total productive maintenance (TPM) implementation, a company needs to have the expertise in deciding which workstation or production lines needs priority improvements. This process simulation approach enables the decision-makers to forecast the output of manufacturing processes and the effectiveness of TPM, based on the input values. This study reveals the feasibility of the proposed decision support system. SMEP is able to address the complex interdependent input parameters in manufacturing line and provides the company with time to react to emerging problems evaluate potential solutions and decide on TPM implementation.

Key Words: *Decision Support, Overall Equipment Effectiveness, Total Productive Maintenance, Simulation, Taguchi Method, OEE,*

1. Introduction

Previous study [1, 2] targeted to address the gap between lean practitioners and simulation based approach, in terms of expertise in utilizing simulation software tools. This study focuses on implementing the total productive maintenance (TPM) principles through integration of simulation model and experiment procedure (SMEP). The simulation model is built using Arena simulation software, while Taguchi experiment design method is used to design the experiments. TPM uses overall equipment effectiveness (OEE) index to indicate equipment and plant effectiveness. The technique works to eliminate six big losses i.e. caused by equipment failure, and set-up adjustment (grouped as down time); due to idling, minor stoppage and reduced speed (grouped as speed losses); and caused by process defects and reduced yield (grouped as defect products). The main objective of implementing TPM principle is to maintain sustainability of the company. TPM principle is based on the implementation of a series of steps or pillars as presented at the Japan Institute of Plant Maintenance (JIPM) .The JIPM promoted the TPM, which includes the OEE in 1971. These eight pillars are shown in Figure 1 (Ahuja, and Kamba, 2008).

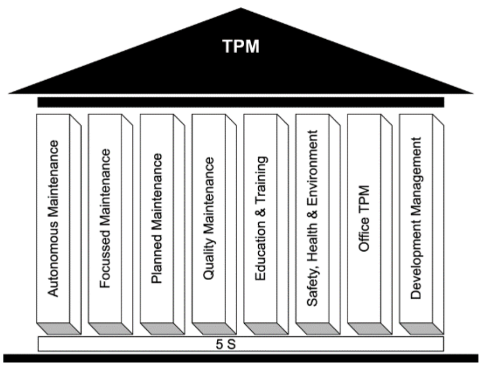

Figure 1. Eight Pillars approach for TPM as suggested by JIPM

SMEP is a procedure capable of supporting real-time decision making by providing benefit of simulation model and experiment design to assist decision-makers in companies in their decision to implement TPM principles. With SMEP, the performance of a production line can be measured and its characteristic can be recognised through OEE index measurement. The process can be repeated countlessly until the desired results are achieved. By using this process simulation approach, the decision-makers are able to forecast the output of manufacturing processes and the effectiveness of TPM, based on the input values. This provides the user time to react to emerging problems, evaluate potential solutions and decide on TPM improvement [1, 2].

2. Simulation Modelling

This study focuses will be on the crimping manufacturing line (CML) for all coolant hoses in Section 2 (Figure 2). The CML simulation model was built before the experiment commenced. This model has been developed in previous study [3]. It consisted of three workstations (WS) where the procedures for machining, testing and marking were carried out. The layout of the model can be seen in Figure 2. The parameters for the CML were as follows: The demand for coolant hose products was 600 units comprising of 300 units of coolants CH4 and CH6, and 300 units of coolants CH8 and CH10. The product time between arrivals was 120 minutes. Product per arrival for each product = 100 units and maximum arrival = 3 units. Using triangular random distribution (TRIA), the annotation representing the random distribution TRIA(min value, most value, max value), WS1 process time $t_{0,1}$ = TRIA(0.5,1,1.5); WS2 process time $t_{0,2}$ = (0.5,0.75,1); WS3 process time $t_{0,3}$ = TRIA(1,1.25,1.5). Changeover occurred for every product type in WS1 and WS3.The total time for changeover in WS1 was 40 minutes, while in WS3, the total time for changeover was 20 minutes.

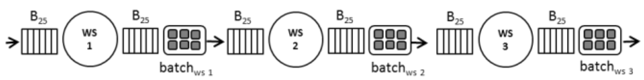

Figure 2. Layout of the CML Model

The simulation model of CML was verified and validated by comparing the simulation results with the mathematical approach calculation using Little's Law. The model is verified and validated with comparing simulation software results with confidence interval statistical calculation with 95%.

3. Experiment Design Based on Taguchi Method Approach

The objective of experiment is to measure OEE element characteristics in the CML using simulation method and analysing the result with Taguchi method. To accomplish this, the control factors in this experiment are in relation to the OEE elements of (A) availability rate, (P) performance rate, and (Q) quality rate with two variation levels each, as can be seen in Table 1. The variation of control factors will be implemented in the Orthogonal Array (OA) experiments. Each experiment simulation runs 10 replications with each control factor variation. In order to measure the control factors for A, P, and Q "failure," "speed loss," and "product defect", these OEE elements were respectively assigned to the CML simulation model in accordance with the levelling of control factors in the OA experiments. The Taguchi method is not applied roundly because the main objective is to identify the OEE element with the highest contribution based on variations in the control factor level. Hence, in this research, the Taguchi method is not used for optimization.

Table 1: Control Factor and leveling for the experiment.

Name Factor	Control Factor	Level 1	Level 2
A	Unplanned Downtime Failure (in minute) for each WS, using triangular distribution (Availability)	WS1 TRIA(30,45,60)	WS1 TRIA (45,60,75)
		WS2 TRIA(15,20,30)	WS2 TRIA (20,25,30)
		WS3 TRIA(20,30,40)	WS3 TRIA (30,40,50)
P	Performance Rating for each WS (in minute) using triangular distribution (Performance)	WS1 TRIA(0.5,1,1.5)	WS1 TRIA(0.5,1.2,1.5)
		WS2 TRIA(0.5,0.75,1)	WS2 TRIA (0.5,0.9,1)
		WS3 TRIA(1,1.25,1.5)	WS3 TRIA (1,1.4,1.5)
Q	Quality	90%	95%

4. Simulation Experiment Result

Table 2 reflect the outcomes of the simulation experiments. It also describes each variation, including the OEE value for each WS for all the experiments. As can be seen in Table 2, the average OEE score for all the WSs for the highest condition of OEE values was attributed to the sixth experiment and the lowest to the seventh experiment. In addition, for the WS that has the lowest score OEE is WS2, which mean the priority improvement will be focused at WS2.

Table 2: Result of Experiment

No. Exp.	A	P	Q	OEE WS1	OEE WS2	OEE WS3	OEE Overall
1	1	1	1	62.7%	47.1%	78.4%	62.7%
2	1	1	2	65.7%	48.8%	82.1%	65.5%
3	2	2	1	62.0%	46.2%	75.6%	61.3%
4	2	2	2	65.1%	47.8%	79.3%	64.0%
5	1	2	1	64.7%	49.0%	78.8%	64.2%
6	1	2	2	67.4%	50.8%	82.1%	66.7%
7	2	1	1	60.5%	45.4%	75.6%	60.5%
8	2	1	2	63.8%	47.8%	79.8%	63.8%

The purpose of this stage is to identify the OEE element with the highest influence on the OEE score. There are three types of measurements for this experiment as mentioned earlier. The OEE measurement displayed in Table 3 shows that the availability element has the highest delta value for the gap between level 1 and level 2, while the performance element has the lowest delta value. The measurements in Table 3 are OEE scores for all WSs. The delta value denotes that if the availability element is switched from level 1 to level 2 or from level 2 to level 1, then the difference in values (delta) of OEE is 2.9%. The OEE contribution is measured by grouping the result for each level on each WS. Delta denotes the gap value between level 1 and level 2 for each OEE elements. The overall OEE in CML is shown in Table 3. The performance for all WS has same result, in the 3rd rank, since in this experiment implement only minor changes in increasing the value of cycle time. It considers their machines capacity. The quality factor imposes the highest influence for overall OEE score, and availability factor in the second rank. Based on these result, the priority improvement should focused on availability element in WS2, which has the lowest OEE score, and the highest score of delta value. It shows that availability in WS2 has the significant contribution to OEE score improvement.

Table 3: Response Table for Mean Overall OEE WSs

Level	Availability	Performance	Quality
1	64.8%	63.1%	62.2%
2	62.4%	64.1%	65.0%
Delta (Δ)	2.4%	0.9%	2.9%
Rank	2	3	1

Table 4: Results of Simulation and Experiment by Using the Scheme

OEE Calculation	Availability	Performance	Quality	OEE
	91.22%	75.59%	92.5%	63.78%
OEE Element Contribution Measurement by Simulation Experiment				
Balance for each different level (Δ)	∆Availability	∆Performance	∆Quality	OEE Estimation with All ∆OEE element
	(+) 2.4%	(-) 0.9%	(+) 2.9%	
OEE +Δ (OEE estimation) by each OEE element	66.18%	62.68%	66.38%	68.18%

In Table 4, average data was used as reference for the scheme. As can be seen, this scheme can provide a contribution measurement for each OEE element and a measurement of estimation by level varying. This additional information will go a long way in helping decision-makers in the company to conduct an effective evaluation on priority improvement.

5. Conclusion

This OEE enhancement scheme provides company with appropriate information for decision-making on priority improvement in the production line. By using 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. From this point of view, it can be concluded that SMEP gives more benefit to the users regarding TPM implementation. By using simulation models, and experiment design, it can provide more advance awareness of implementation of TPM principles to the real environment through simulation modelling. The production line characteristic can be recognized and analyzed it by using this procedure. It will give more benefit to the decision-makers especially those requiring an advance advantage of TPM principle. For future work, this research will be expanded to user interface development in order to make it easier to be used by the user. Feasibility studies will also be conducted to ensure that SMEP is beneficial to decision-makers, feasible and operable.

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