A Computerized measurement system of machine performance for a textile industry

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Abstract. The increasing development of the textile industries has made the competition sharper. To maintain a competitive place in the market, it is critical for a textile industry to keep their production effectiveness at the highest level. Total productive maintenance (TPM) can be done to improve production performance, both in terms of quantity and quality. How successful the TPM implementation is measured by Overall Equipment Effectiveness (OEE) which shows the effectiveness level of a particular machine. The imbalance pattern between target and actual production in almost all departments in the textile industry encourages OEE analysis to determine the performance of each machine they use. However, operators are facing difficulties in measuring OEE for every machine manually. This study aims to develop a computerized database system to help measure the OEE calculation so it can help the company knows their real-time machine performance. It automates the process of OEE calculation and identify the losses associated with equipment effectiveness. The developed system is validated using the historical operational data of a Spinning Department in a textile industry.

1. Introduction
The nature of clothing as a primary need [1] makes the textile industries across the world grow continuously. The increasing development of the textile industries has made the competition sharper. To maintain a competitive place in the market, it is critical for a textile industry to keep their production effectiveness at the highest level. Optimizing the machines utilization has been attempted to get the effective production. However, the inefficient utilization of machines which is caused by the unstructured maintenance schedule has often been found. Total productive maintenance (TPM) can be done to keep the machines maintained and able to improve production performance, both in terms of quantity and quality. How successful the TPM implementation is measured by Overall Equipment Effectiveness (OEE) which shows the effectiveness level of a particular machine [2].

For a particular case, Indonesia has been known as one of the world’s largest textile manufacturers [3]. No wonder textile has been one of five major industries in Indonesia which contribute most to the country’s income [4]. Despite its highly promising aspects, Indonesia’s textile sector is still facing various challenges to compete with neighbours, especially in the last couple of years. One of major weaknesses of the Indonesian textile industries is that they still use inefficient machinery which further may reduce their competitiveness [5]. This issue can be seen from the imbalance pattern between target and actual productions which have been investigated in almost all departments in one of textile industries in Indonesia. It therefore encourages OEE analysis to see whether their machines perform well or not. However, the production process complexity using numerous machines makes OEE difficult to measure manually.
Literature review identified that maintenance measurement using OEE has been widely used in various types of industries including textile. Decision support tools or computerized systems have also been introduced to perform the OEE measurement in industry automatically. However, no previous tools have been built for textile case. This research observed this as potential improvement area in the field of maintenance. A computerized database system is therefore developed to help the textile industry do the data recording, calculating and displaying the OEE value for each machine. The system is implemented to the Spinning department in a textile company in Indonesia.

The remainder of this paper is structured as follows. Section 2 summarizes the related literature, particularly that on OEE implementation. Section 3 describes the research methods. In section 4, the framework of database system development and the case study analysis are presented. Finally, Section 5 presents the conclusions and thoughts on future research.

2. Literature review
TPM by Nakajima [2] has been the most favourable and widely applied in industries. The success of TPM implementation is measured using overall equipment effectiveness (OEE). Prior studies have addressed OEE and its importance to evaluate the machines’ performances in textile industry [6, 7, 8]. As the OEE results were still under world class standard (85%), therefore the studies delivered suggestions for improvements.

To ease the OEE measurement, there were many researches which utilized database system to implement TPM in various types of industry which use OEE as the key performance index. In beverage sector, OEE was implemented in a bottle production plant which focused on the micro downtime analysis [9]. The data for OEE calculation were collected daily by the production staff and stored in a common database. The OEE results were analysed and the time loss was examined for each machine. A descriptive and statistical analysis are carried out in investigating the primary causes of waste in terms of time. The result showed that micro downtime (downtime or stoppage lower than 15 minutes but with high frequency) covers 57 percent of inefficiency. In food industry, machines’ failures within the croissant line production are identified from the OEE calculation using Excel as the database system [10]. Different from the previous cases, the OEE was also used in transportation sector in terms of supply chain and logistics [11]. In a form of application software, the OEE with some adjustment could evaluate the transportation route efficiency.

Overall, it can be concluded that the concept of OEE by Nakajima [2] is still appropriate to measure the success of TPM implementation in any industries until today. As the OEE calculation requires various data, it is reasonable to use database management system to perform the data storage and OEE calculation.

3. Research methods
In this section, the research framework is explained along with the methods and tools employed. The following provided framework is also used as the guidance for designing the OEE database system.

3.1. Analysis of the plant
At first it is necessary to understand the production process and equipment in the whole plant in the selected textile company. Plant analysis is done through direct observation and investigating the historical data of the whole production process. These are also aimed to determine which process to use for the case study. As the production process involves four major departments along with the complex processes, spinning department as the starter is defined as the object to simplify the analysis. Since a series of processes with various machines are also involved in spinning department, a work station with the highest problem record is selected.

3.2. Literature study
This step is done to review any literature related to the OEE implementation in textile industries so we can understand how to define the required data for OEE formulation. Besides, literature review is also
carried out to investigate whether the use of database system to calculate OEE in textile industry already exists or not so that we know how beneficial this study to the related field.

3.3. Database architecture system design
Two diagrams are used to help the reader understand the process of designing the OEE database, which are data flow diagram (DFD) and entity relationship diagram (ERD). DFD is aimed to illustrate how the data flow between entities. The entities involved in OEE database are operator and maintenance. Operator refers to the shop floor-staff who will do the data entry, while maintenance acts as production process controller. The designed DFD becomes the base of ERD design. ERD maps the data used for the database system. The detailed DFD and ERD are further explained in the next section.

After designing the database system using DFD and ERD, the step continues to the database development. This study utilized MySQL as the database management system (DBMS) for evaluating machine OEE. MySQL has been widely use and user-friendly so that this DBMS is selected for this study. The multithread and multi-user attributes in MySQL are compatible to maintain the data and information flow related to the machine OEE in the plant. This DBMS employment may also be the integration instrument between operators, maintenance division, and managers. MySQL may fasten the OEE results information flow to the company so they can decide what to act immediately.

3.4. Data collection – case study
Refers to Nakajima [2], the OEE value is obtained from the multiplication of availability, performance, and quality, as in equation (1).

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OEE = \text{Availability} \times \text{Performance} \times \text{Quality}
\] (1)

Those three parameters in OEE are leveraged by the six big losses as the inefficiency causes [9, 12]. Those are as follows:

- setup and adjustment or planned stops (availability)
- failures or unplanned stops (availability)
- micro downtime or small stops or idling and minor stops (performance)
- speed loss or slow cycles (performance)
- defects or production rejects (quality)
- material lack or reduced yield (quality)

Data collection process related to the relevant losses above is carried out as the input for the OEE database. It is also necessary to define the period over which data will be compiled.

3.5. Data input for OEE calculation – case study
The collected data are inserted to the database system. Once the data are inserted to the database, the user can get the visualization of OEE results as feedback.

3.6. Results analysis
The OEE results from the database are visualized by Bar chart and Control chart. The calculation using DBMS is validated by comparing its OEE results with those obtained by Microsoft Excel. Having obtained the validated OEE results, the next step is to interpret the value based on the OEE standard (85%) and identify the most critical contributor to the poor OEE (if any) in order to investigate which aspects need to be improved.
4. Results and Discussion

4.1. Database modelling

4.1.1. Data flow diagram. Operator and maintenance act as data connector in OEE measurement. Figures 1 and 2 illustrate two levels DFD for the OEE database.

![Figure 1. DFD level 0 for OEE database](image1)

![Figure 2. DFD level 1 for OEE database](image2)

Figure 1 shows the data flow for “Calculating Machine OEE” in general then be explained in detail by figure 2. “Data Entry Form” from operator will go through the process to get “OEE Analysis Result”. Maintenance plays an important role as they analyze the OEE result and decide what to do to maintain high OEE.

4.1.2. Entity relationship diagram. As shown in figure 3 that the OEE database is composed by four entity sets: DB Machine, DB Material, DB Data Input, and DB OEE. The developed ERD is continued with building table for each entity set.
4.2. Case study: a textile industry in Indonesia

The case study took place in a textile company which is headquartered in Central Java, operates in both textile and garment world market and owns the biggest such plant in Indonesia. It has engaged with various brands across the world by producing various types of products, such as fashion wear, military uniforms, and work wear. Starting as a conventional family company in 1966, this company has now reached a high level of sophistication and employed more than 18 thousand domestic and foreign professional staffs.

It runs its business through production process departments (spinning, weaving, dyeing/ printing/ finishing, and garment) and non-production departments and owns few subsidiaries. Due to its complexity it requires a comprehensive maintenance system. The company has arranged a maintenance division to maintain the plant in order to meet the required output. However, it has been investigated from the historical data in a couple of years that the actual production in almost all departments are rarely able to fulfill their targets. It encourages OEE analysis to determine the performance of each machine. In fact, the daily production data records are mostly still collected manually. No wonder if there is no OEE analysis for each machine they use. This study therefore built the database system which is aimed to help the data record process as well as calculate the OEE for each machine. In order to see its performance, the developed database system is implemented to Spinning department as the first process which is substantial for the next continuing processes. It operates 24 hours in 7 days with 3 shifts, 8 hours per shift. Spinning department consists of five major processes, which is illustrated in figure 4.

![Figure 3. ERD for OEE database](image-url)
4.2.1. Observing the daily report in March – April 2018, Carding has been identified to have high losses, thus we investigate Carding machine for OEE analysis. The data are taken from the database which consists of information about six big losses in 34 Carding machines. Figures 5 – 7 show the OEE results for Carding.

**Figure 4.** Flow process in spinning department.

**Figure 5.** OEE of carding machines in March – April 2018 (mean of one month production per unit of machine).
4.2.2. The OEE value for each machine unit in Carding is illustrated in figure 5. It can be seen that around 32% of Carding machines have lower OEE than the average. It shows that the Carding machines do not display the same performance in production. Figure 6 explains that in average, performance parameter has the largest gap with its standard around 12.3% which mostly decreases the overall OEE value. It can be concluded that for this case, the most losses have occurred or found in Carding regarding to small stops and speed loss. Speed loss refers to the differences between capacity design and actual capacity of particular machine, whereas small stops are the stoppage in short period with high frequency. Since it explains the average value, thus we can investigate the most impactful machine(s) to the fall in average performance value. Similar investigation can also be executed for other parameters.

Figure 6. Comparison between standard and actual OEE of all carding machines

Figure 7. Performance parameter of carding machines

Figure 7. Shows that there are 13 machines which have performance value lower than the average, with three lowest values are machine ID 32, 8, and 4. Therefore, further step can be done by focusing
on identifying the causes of losses happen in those three machines which caused the performance value decrease the most.

5. Conclusions
This research has developed a framework of computerized database system for OEE measurement. It was then applied to a textile industry in Indonesia. The results show that the average OEE value of Carding machines in Spinning department of the observed textile industry is still below 85% so that it has not conform to the OEE standard yet. Having obtained the OEE results, the company will be able to identify the losses which mostly decrease the effectivity. Failure mode and effect analysis (FMEA) may be a tool option to identify and prevent any losses. Further, the company may identify the possible solutions for eliminating losses and improving the production performance.

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