

Machine effectiveness analysis with Overall Equipment Effectiveness (OEE) in printing company

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Abstract. The Overall Equipment Effectiveness (OEE) is a method used to measure the implementation of Total Productive Maintenance (TPM). This method is based on three main parameters, namely availability (run time for production), performance (machine performance compared to technical specifications), and quality (quality produced by the machine). This research begins with identifying the machine with the lowest availability and reliability values in the specified period, with the result that the 4.2 machine is the machine that will be the object of research. After measuring the OEE value against machine 4.2 the average OEE value in August was 44.44% far below the world-class standard of 85%. The yield for the availability parameter is 53.96%, performance is 83.88%, and quality is 98.18%. Based on the analysis of six big losses, it is known that the largest value of losses is setup and adjustment with 69.57% of total losses. To reduce losses, loss setup and adjustments were analyzed using Pareto diagrams, Ishikawa diagrams, and Design Failure and Mode Effect Analysis (DFMEA). It is found that the dominant cause of loss setup and adjustment is the error encoder not being connected. After the improvement of the OEE value of the 4.2 machine, it can be estimated to increase to 69.41% in the following month. It can also serve as a reference for companies, as they did not previously use OEE as a measure of machine performance. Where the company previously used reliability and availability, which were widely used to measure maintainability, overall machine performance can now be measured using OEE.

Keywords: OEE, Six big losses, DFMEA, Improvement, Effectiveness

1. Introduction

The XYZ company has several production lines, one of which is Line A, in which there are several production machines, both the main machine for the production process, as well as preparation machines and also supporting machines. Every machine so far always pays attention to the value of reliability and availability, which is obtained in the company's Enterprise Resource Planning (ERP) software. Reliability is the probability that a machine or equipment can work continuously, without failures, for a certain time interval while operating **Error! Reference source not found..** Availability is defined as the probability that a product or system performs well at all given points in time when it is used [2]. So availability signals the possibility that the system is available and working satisfactorily at a given point in time. The ERP data for the period January to June 2022, shows that the reliability target for machine 4.2 of 80% was not achieved and only has an actual reliability value of 54.88% and the availability target of 96.50% was also not achieved with an actual availability value of 95.29%. Both values indicate that performance in terms of maintenance has not been achieved. So far, the company uses reliability and availability values as a reference in seeing machine performance. Meanwhile, the assessment has not fully demonstrated the effectiveness of the machine. Overall Equipment Effectiveness (OEE) was first written in 1988 from the book introduction to TPM by Seiichi Nakajima of the Japan Institute of Plant Maintenance [3]. Before OEE, people monitored equipment performance through availability, i.e. simply by looking at the time availability of a piece of equipment to work, without taking into account the loss of speed, preparation, and also the possibility of

reprocessing a product. OEE is a tool to calculate the performance of a work tool by taking into account availability, performance, and quality [4]. The machine's low reliability value of 4.2 indicates that it has not performed at its optimal and has impacted the company's efforts to meet its production goals. To further increase the OEE value by implementing a DFMEA analysis, it is important to collect more measurements using the OEE method in addition to the factors that affect the OEE value. Measuring the effectiveness value of machine 4.2, which is known to have a low reliability value, is the main objective of this research.

2. Methods

The method used is OEE, to find out the effectiveness value of the 4.2 machine and the factors of six big losses. Machine 4.2 data for the month of August 2022 is the data utilized in the OEE calculation. The DFMEA for proposed improvements included the Pareto chart and Ishikawa chart. Furthermore, for the analysis of results after improvement using data in November 2022.

2.3.1. Overall Equipment Effectiveness

Overall Equipment Effectiveness (OEE) is a tool used to measure productivity and effectiveness at the same time [5]. OEE is a tool used to measure the application of TPM in a company [6]. OEE consists of three elements, namely availability rate, performance rate, and quality rate which will be used to calculate the OEE value of the equipment. In addition, OEE will also help identify the parts that are the cause of the low productivity of the machine. The six equipment losses cause low performance of equipment machinery called six big losses which consist of equipment failure, setup and adjustment, idling and minor stops, reduced speed, scrap and rework, and startup losses [7]. According to Najima, to get the OEE value is to multiply the availability rate, performance rate, and quality rate [5].

$$OEE = Availability \times Performance \times Quality$$

(1)

The availability rate is the amount of time a piece of time is available for a piece of equipment to work, to get an availability rate dividing the time the machine operates by the scheduled time [5].

$$Availability\ rate = \frac{Scheduled\ time - unplanned\ downtime}{Scheduled\ time} \times 100\%$$

(2)

$$Availability\ rate = \frac{Operation\ time}{Scheduled\ time} \times 100\%$$

(3)

Performance rate is the percentage of the machine running at the designed speed. In other words, it is the actual speed of the machine that is related to the design speed of the machine. Here the designed

speed measurement excludes the effects of quality and availability. To get a performance rate by dividing the actual rate or speed at which the machine produces a product by the speed of the machine according to its design or standard rate [5].

$$\text{Performance rate} = \frac{\text{actual rate}}{\text{standard rate}} \times 100\%$$

(4)

Quality rate is the percentage of products that meet quality standards compared to the products produced. To get a quality rate is to divide a quality product by the total product produced [5].

$$\text{Quality rate} = \frac{\text{goods unit}}{\text{total units}} \times 100\%$$

(5)

23.2. Pareto Chart

Definition of a Pareto chart is a graphic representation of the frequency with which a particular event occurs. This is a ranking order chart that displays the relative importance of variables in a data set and can be used to set priorities regarding improvement opportunities. The basic rule of the Pareto is that 80% of the problems are caused by 20% of the causes [8].

23.3. Failure Mode and Effect Analysis

Improving OEE on existing machinery is carried out after measuring the value of OEE. Furthermore, the first analysis that can be used is Pareto analysis, which can then be further analyzed using one of the analytical tools such as failure mode and effect analysis (FMEA) [9]. Failure mode and effect analysis is a research methodology used to evaluate a failure in a system, process, service, or design. FMEA defines, analyses and mitigates failures that have already been experienced and or will occur. The risk priority number (RPN) is the result of this method, and RPN is the result of the third multiplication of severity, occurrence, and detection assessment elements [10]. FMEA is divided into two main types, namely, design FMEA (DFMEA) and process FMEA (PFMEA). FMEA design consists of 7 steps divided into 3 main processes: the analysis system, failure analysis and risk mitigation, and risk communication [11].

23.4. Ishikawa Diagram

It is also called the fishbone graph. It is in the form of a fishbone or Ishikawa diagram, which is a diagram that shows the causes useful for finding or analyzing the cause of the problem, the Fish Bone Diagram is the best method to represent an easy and standard way to look for the underlying cause, whether technical or other [12].

3. Results and Discussions

24.1. Calculation of Overall Equipment Effectiveness

Complete results for the calculation of OEE values each day can be seen in table 1 results of OEE value calculations.

Table 1. OEE value calculation results

Date	Availability rate	Performance rate	Quality rate	OEE
8/1/2022	72.39%	85.26%	99.30%	61.29%
8/2/2022	55.46%	84.97%	98.38%	46.36%
8/3/2022	50.61%	75.99%	98.43%	37.86%
8/4/2022	51.38%	79.62%	97.90%	40.06%
8/5/2022	65.78%	84.58%	98.28%	54.68%
8/8/2022	56.93%	85.26%	96.74%	46.96%
8/9/2022	68.30%	84.88%	98.25%	56.96%
8/10/2022	30.17%	85.95%	98.10%	25.43%
8/11/2022	24.73%	71.72%	95.75%	16.98%
8/12/2022	66.71%	83.54%	97.26%	54.20%
8/15/2022	72.52%	88.19%	98.83%	63.20%
8/16/2022	57.89%	89.68%	98.70%	51.24%
8/17/2022	70.28%	92.99%	98.77%	64.55%
8/18/2022	37.00%	88.99%	96.92%	31.91%
8/19/2022	4.68%	68.71%	96.31%	3.10%
8/22/2022	43.78%	80.14%	98.33%	34.50%
8/23/2022	32.51%	65.00%	97.70%	20.65%
8/24/2022	59.39%	83.44%	97.49%	48.31%
8/25/2022	57.62%	75.28%	97.50%	42.29%
8/26/2022	77.70%	85.02%	99.10%	65.46%
8/30/2022	66.91%	86.27%	98.43%	56.81%
8/31/2022	64.29%	86.61%	98.45%	54.82%

Based on table 1, it is known that the availability value for the 4.2 machine is still far below the global standard. Because no value has reached 90% throughout August 2022. The highest availability rate is only 77.70% which occurred on August 26, 2022. The lowest availability rate is 4.68% which occurs on August 19, 2022. The average availability rate in August was 53.96%. The distance between the highest and lowest values for the availability rate also indicates fluctuations in the availability rate value that are erratic and far from stable. The cause of the low availability rate value will then be further analyzed with six big losses. From table 1, it can be seen that the 4.2 machine has poor performance because it is always below the value of 95% as the world standard for performance rate. The highest performance rate is 92.99% on August 17, 2022. Meanwhile, the lowest performance rate is 65.00% on August 23, 2022. With an average value of 82.37%, the performance rate needs to be improved. Table 1 shows that there are high fluctuations or ups and downs in quality. The highest point was on August 1, 2022, with a quality rate of 99.30%. The lowest value is 95.75% which occurred on August 11, 2022. The average quality rate in August was 97.95% still below the standards of world-class companies with a quality rate threshold of 99.9%.

The results of the OEE calculation show that the 4.2 machine is still far from the global standard which is at 85%. The highest value that can be achieved by a 4.2 machine is 65.46% which was obtained on August 26, 2022. The lowest value is 3.10% which was obtained on August 19, 2022. From a long range between the highest and lowest values, the August 2022 OEE average of 44.44% was produced. Losses on the 4.2 machine will then be categorized into six big losses, where each element will be calculated for each given loss amount. The time lost in August 2022 was 10,721 minutes, meaning

that the 4.2 machine lost 55.56% of the total time reserved for production, which can be seen in Table 2.

Table 2. Six big losses the 4.2 machine

Six big losses	Minute	Losses
Breakdown losses	1425	13.29%
Setup and adjustment losses	7459	69.57%
Idle and minor losses	1678	15.65%
Reduce speed losses	0	0.00%
Scrap and rework losses	127	1.19%
Start-up losses	32	0.30%

24.2. Pareto analysis

The Pareto chart is used to determine the most dominant losses of the six big losses. Where this chart is obtained based on table 2 of six big losses on the 4.2 machine, which then uses Minitab software to display the Pareto chart in figure 1.

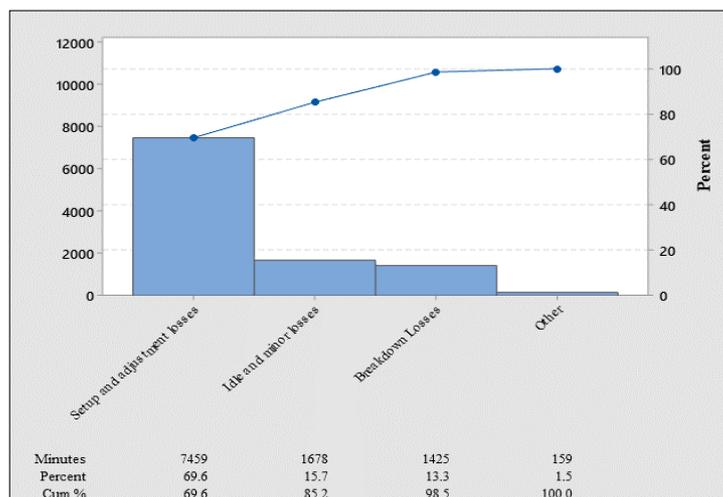


Figure 1. Pareto chart of six big losses.

From Figure 1, it can be seen that the largest losses are setup and adjustment which accounts for 69.6% of the total losses that occur. Furthermore, it was followed by idle and minor stoppage losses which contributed 15.7% losses, and breakdown losses were in third place with 13.3%. Based on figure 1, it can be concluded that set-up and adjustment are the dominant causes of low OEE on 4.2 machines, and these losses are part of the cause of the low availability value on 4.2 machines along with breakdown losses. Once it is known that the dominant losses are set up and adjusted the next step is to collect damage data obtained from the machine. The data collected is error data that causes the machine to stop so it needs to be set up and adjusted both by the operator, technician, and quality control department. In the data collected in August 2022, there were 5,012 types of errors, with the total number of errors being 31,682 which has been represented in Figure 2.

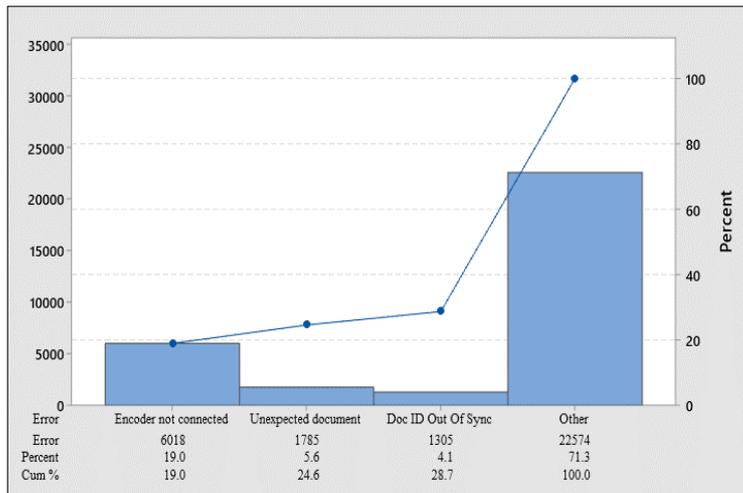


Figure 2. Pareto chart of setup and adjustment

Based on the Figure 2 Pareto chart, the cause of setup and adjustment for the most errors that appear in encoder not connected and unexpected document, which contributes 19% and 5.6% of the total errors that appear, respectively. The compulsive number of the two errors was achieved at 24.6% which can be inferred as the dominant cause based on the Pareto 80/20 principle.

24.3. DFMEA analysis

The first step of the DFMEA is to define everything related to the analyzed object. The object of analysis is the 4.2 machine with the components that are the problem being the encoder and transport parts. This DFMEA is implemented by the author who is part of the technicians who handle the 4.2 machine, the full DFMEA analysis can be seen in figure 3.

Item Name: DFMEA 4.2		FMEA Team: Ultras			Prepared by: Fatihul Azmi Adha		FMEA Date: 10 October 2022		Revisions #: 0				
Structure Analysis (Step 2)		Function Analysis (Step 3)			Failure Analysis (Step 4)			Risk Analysis (Step 5)					
Next Higher Level	Focus Elements	Next Lower Level	Next Higher Level	Focus Element Function	Next Lower Level	Failure Effects (S)	Failure Mode	Failure Causes	Current Prevention (O)	Current Detection (D)	RPN	Action Priority (AP)	
4.2 Machine	Encoders	Encoders, pulleys, junction boxes	Converts movement or position into electrical signals	Provides a timing reference for product movement in the capture and sort process	The encoder pulley is connected to the transport which then produces a signal which is then forwarded through the junction box to the computer to be used as a position reference in image capture for each existing camera, and the sorting process for the final product.	The machine stopped	BQIS Status Incident : Image acquisition encoder not connected	BQIS computer does not receive a signal for the capture process	Tighten pulley, check encoder connection, reset junction box	An error appears on the Machine Computer and BQIS Computer	7	560	H
	Transport	Motors, belts, pulleys, rollers, gates	Become a product transport line	Transmits the rotary motion of the motor into the product transport line	By changing the rotational motion of the motor which is connected to the gear and pulley, which are then interconnected with the belt where each corner has a roller. The transport machine works from front to back which are interconnected and work at the same speed so that the product can be sorted at a predetermined output by movement from the gate.	The machine stopped	Pre Shred Tracking 3: Unexpected document	The machine reads the product in the wrong place	Check transport, adjust tension, replace belt, replace pulley.	An error appears on the Machine Computer	7	448	H

Figure 3. DFMEA

The last step in DFMEA is optimization, of the two encoder failures and the transport, the author will only optimize the encoder failure. The first reason is due to the higher RPN value, and the second reason is that the failure of the encoder is the responsibility of the author's work unit. The optimization carried out is by improving, namely by collecting the cause of the problem "BQIS Status Incident:

Image acquisition encoder not connected". Based on the collection of the cause of the problem on the encoder using the 4M1E method (Material, Method, Man, Machine, and Environment) using the Ishikawa diagram to find the cause of the problem and shown in figure 4.

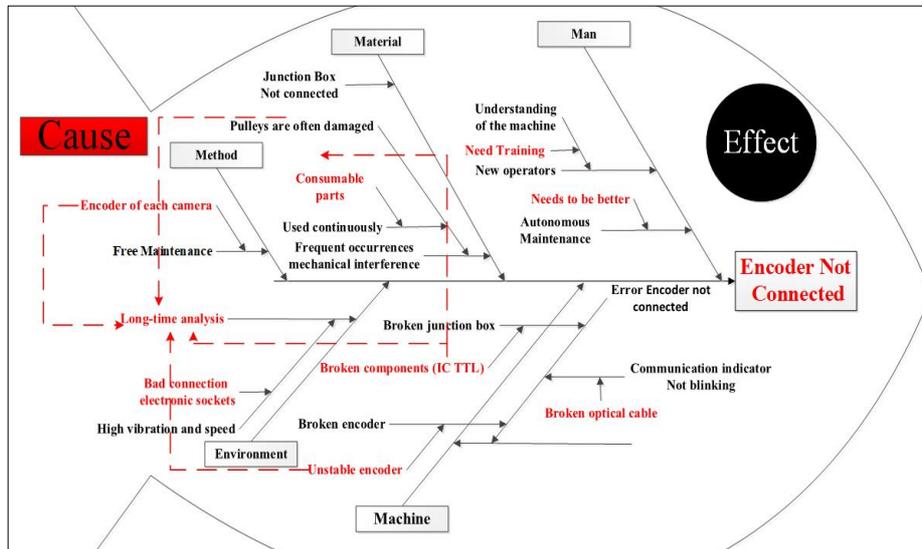


Figure 4. Ishikawa diagram

Based on the analysis of the cause-and-effect diagram, it is known that what can be done to facilitate the detection of encoder failure is to reduce the analysis time in case of encoder failure. The improvement made is to reduce the number of encoders on the machine, from five encoders for five cameras to one encoder. One of the reasons is that by reducing the encoder, it will be easier to analyze related to the failure mode "BQIS Status Incident: Image acquisition encoder not connected". With the reduction of the encoder, the possibility of encoder damage is also reduced, in addition, the spare parts needed are also reduced. While related to the analysis is with the centralization of the encoder, if the error that arises on the BQIS computer is all cameras then damage occurs on the encoder side, both the encoder is damaged, and the pulley is problematic. However, if the damage that appears is only one of the cameras, then there is a problem with the junction box of the camera. This improvement can reduce the analysis time if previously determined damage to the encoder side and the junction box side.

24.4. Result

After improvements, especially in errors referring to not connected encoders, in November 1,298 errors appeared. Down by 78.43% from the previous 6,018 events, if other variables are ruled out, or just consider the decrease that occurred in the not connected encoder error, there was an increase in the availability rate value from 53.96% up to 84.28%. With the increase in the availability rate value and assuming the performance rate and quality rate values do not change, the OEE value also increases to 69.41% from the previous 44.44% as shown in Figure 5.

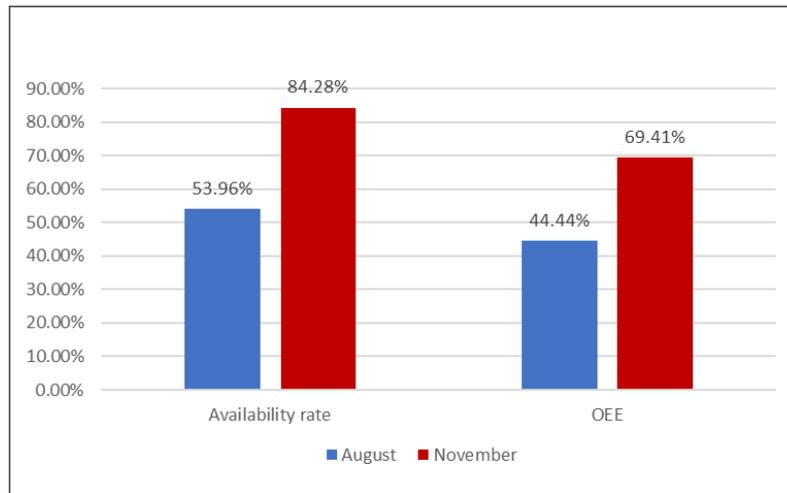


Figure 5. Estimating availability rate and OEE values against not-connected encoder errors

4. Conclusion

The following are conclusions that can be drawn from research that has been carried out:

1. From the results of the study, it can be seen that the OEE value for the 4.2 machine in the printing company in August 2022 is 44.44% with an availability rate parameter value of 53.96%, a performance rate of 83.88%, and a quality rate of 98.18%. Machine performance may be measured using OOE. It could be used in companies as it previously only used reliability and availability as a reference.
2. The results of the identification of six big losses, it is known that the losses that occur on the 4.2 machine include breakdown time, setup and adjustment, idling and minor stoppage, start-up losses, and defect or rework losses. The largest loss value is setup and adjustment of 69.57% of total losses.
3. To determine the cause of high losses in setup and adjustment, the Pareto chart, DFMEA, and Ishikawa diagrams are used. It is known that BQIS Status Incident: Image acquisition encoder not connected is the dominant cause of further improvement. After the improvement was implemented, there was a decrease in errors for BQIS Status Incident: Image acquisition encoder not connected from 6,018 to 1,298 in November 2022. So that if you do not consider other variables that have changed, there is an increase in the availability rate value to 84.28% and followed by an increase in the OEE value to 69.41%.

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