Overall Equipment Effectiveness (OEE) at the Laboratory of Structure Testing

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Abstract

Equipment maintenance on laboratory services is part of quality management to keep equipment in good condition, safe, reliable, consistent, and accurate. To ensure quality and reduce the loss of machine equipment failure, a maintenance method approach is required. Total Productive Maintenance (TPM) as a maintenance concept that maintains and improves product quality by improving machine working conditions, and reducing failure. TPM measurement were performed in one of the structural testing laboratories that impacted the service. Overall Equipment Effectiveness (OEE) is used as a statistical test tool to determine problems in order to improve the performance of equipment (availability, performance rate and quality rate) that affect the organization.The results of OEE measurements were then analyzed with the help of pareto and fishbone diagrams. The results show that the average OEE score is still lower than the world class standard, where the availability value is 84%, the performance rate is 67%, the quality rate is 99% and the OEE value is 56%.

Keywords—Maintenance; TPM; OEE; Pareto Diagram; Fishbon

1. Introduction

Maintenance is all the necessary measures to maintain the lifetime of the equipment or configuration under the prescribed conditions (Dhillon, 2006), with the aim of achieving effective and effective objectives to meet company objectives (Praasad, M. *et.al*., 2006). Successful operations can reduce downtime, improve long-term productivity and product functionality (Shirose, 1996).

A few years ago manufacturing organizations used different approaches to improve effectiveness (Roup, 1999). The evolution of care has passed through three generations of development from reactive maintenance to predictive conditions (Moubray, 1997), even Dunn (1998) to a larger generation of technology; for measuring; predicting; and diagnosing Equipment failures. In addition Pintelon and Parodi (2008), also discussed the same progress as Total Productive Maintenance (TPM), Reliability centered maintenance (RCM) and others. Therefore, organizations should have the same strategy with CBM; RCM; and TPM as reactive Retail approaches (Sharma *et al*., 2005), where organizations should implement good systems to improve quality and productivity continuously (Gupta, 2012).

Predictive maintenance (PdM) or condition based maintenance (CBM) is a maintenance strategy initiated by handling certain equipment conditions due to performance degradation (Vanzile, 1992), while RCM as an industry development approach focused on identification and stipulation of operating policies, Which are more focused on managing the risk of more effective equipment (Niu, 2010), and TPM is a maintenance activity in order to eliminate losses incurred during production (Riis *et al*., 1997).

Total Produvtive Maintenance (TPM) comes from USA as a developer of Preventive Maintenance (PM), which was developed and implemented by Nippon Denso, LTd. from Japan, as a supplier of Toyota Motor Company in 1971 (Agustiady, 2016). The TPM concept is used to keep the equipment in optimal condition by preventing unexpected damage; decreasing speed; and quality defects occurring in the operation process or minimizing losses to zero accidents, zero defect and zero breakdowns (Nakajima, 1988). In addition TPM concepts as an innovative approach to maintenance that optimizes equipment effectiveness, eliminates damage and promotes autonomous maintenance to operators through day-to-day activities involving all employees (Bhadury, 2000).

Implementation of the TPM concept not only increases the effectiveness of the overall equipment in large industries (Jain, 2015), but the application of the TPM maintenance concept can also be applied within the service organization as part of continuous improvement efforts in support of manufacturing competitiveness (Ahuja, 2008). Therefore, TPM implementation in the research that will be done is expected to fill the gap in the implementation of service organizations. The concept of maintenance in the organization of laboratory services is required to keep the equipment in good; safe; consistent and accurate connections. This research was conducted at one of the laboratory of structural testing service organization in Serpong Area, by measuring the effectiveness of test equipment with Overall Equipment Effectiveness (OEE) measurement method and performing analysis as the basis of improvement proposal through TPM approach.

2. Theoretical Review

2.1 Evolution of Maintenance

The maintenance function has undergone a serious change in the last three decades, maintenance activities have been limited to reactive tasks of remedial action or replacement of goods. Here is the progress of the maintenance concept that has been developed as follows, *Breakdown maintenance (BM)*, this is an early maintenance concept implemented before 1950, where improvements are made after equipment fails / stops or declines in performance (Wireman, 1990). Whiele corrective maintenance (CM) 1957, as a concept of equipment failure, so equipment failures can be eliminated and equipment can be maintained easily (Steinbacher, 1993). After BM, there’s *Preventive maintenance (PM)*, another concept introduced in 1952 which is done after a certain period of time or the amount of machine use (Herbaty, 1990). After PM, there is *Predictive maintenance (PdM)* or condition based maintenance *(CBM)*, is a diagnostic technique for measuring physical condition, such as temperature, noise, vibration, lubrication and corrosion (Brook, 1998). Followed by *reliability centered maintenance (RCM)*, this concept was established in 1960, as a process used to determine the need for maintenance of physical assets in the operating scheme by identifying the function of the asset, the cause of failure and the effects of failure (Samanta *et al*., 2001), and *Total productive maintenance (TPM)* as the last maintenance concept, the development of productive maintenance concept implemented in 1971, as an innovative maintenance approach that optimizes equipment effectiveness, removes damage and promotes autonomous maintenance to operators through daily activities (Bhadury, 2000).

2.2 TPM Concept

TPM is one of the innovation concepts from Japan, where Nippon Denso, LTd. was the first company to implement and develop TPM concept in 1960. TPM is a team oriented maintenance program and equipment based on participation by emphasizing maintenance of equipment involving operators, and together operators perceive the performance of equipment for prevention and predictive maintenance (Majumdar, 2012).

2.3 Purpose of TPM

According to Majumdar (2012) the main objective of the TPM is to improve overall productivity by three key points, first is maintain and improve product quality by improving machine working condition, improving quality and reducing failure and increasing production; second is reduce equipment maintenance costs by reducing the maintenance workforce, with the assistance of autonomous maintenance ie operator maintenance; and the last are increase production volume through, that has been devided as follows: increased machine availability bydecreasing machine breakdown time; and improves engine processing by eliminating engine efficiency.

2.4 OEE Methode

OEE is a method used as a measuring tool in the application of TPM program to keep the equipment in ideal condition by eliminating six big losses equipment, in addition OEE is used to measure the performance of a produtif system, clearly identify the root of the problem And the factors causing it to make the improvement effort become focused (Ansori, 2013).

2.5 Implementation of OEE

According to Almeanazel (2010) OEE can be applied to several different levels in the manufacturing environment, which is OEE can be used as a "benchmark" to measure the overall performance of the plant as a whole. In this case the initial OEE size can be compared with the next OEE size, so as to quantify the level of improvements made by classifying followed value: if the OEE value is calculated for a single manufacturing line that can be used to compare performance in the plant, thus highlighting each equipment's performance; or if the machine process works individually, OEE measurements can identify the worst machine performance, then indicate where to focus on TPM resources.

2.6 Six Big Loses

The OEE metrics originally developed by Nakajima (1988) to measure the effectiveness of equipment and also identify the various losses classified into six large losses. The six losses are equimpment failure, setup and adjustment losses, idle and minor stoppage, reduced speed, defect in process, reduced yield. The six losses are derived from the three losses that form the basis for the measurement of availability, performance rate, and quality rate.

2.7 OEE Measurement

The measurement of OEE values on the TPM method is to measure the performance of a productive system, with the aim of increasing the overall equipment effectiveness (Shirose, 1989).

- *Availability ratio (A)* measures the overall time at which the system is not operating due to equipment breakdown, production preparation and adjustment:

$$\mathrm{A} = \frac{\text{loading time} - \text{downtime}}{\text{loading time}} \text{ x } 100$$

- *Performance efficiency (P)* is measured as the ratio of the actual operating speed of the equipment to the ideal speed based on the design capacity:

$$\mathrm{P} = \frac{\text{theoretycal cycle time x processed amount}}{\text{operating time}} \text{ x } 100$$

- *Quality rate (Q)* is focused on quality loss in the form of how many damaged products occur related to the equipment, which is then converted into time with the understanding of how much time the equipment is consumed to produce the damaged product:

$$\mathrm{Q} = \frac{\text{processed amount} - \text{defect amount}}{\text{processed amount}}$$

- *Overall equipment effectiveness (OEE)*
  TPM uses OEE as a quantitative metric to measure the performance of a productive system, with the aim of improving overall equipment effectiveness:

  OEE = A x P x Q

The size of OEE is the formulation and implementation of the TPM improvement strategy (Ljungberg, 1998). TPM has a standard value of availability rate ratio of 90%, performance efficiency rate 95%, and quality rate 99% (Levitt, 1996). The 85% OEE score is considered a world-class performance (Blanchard, 1997).

3. Research Methodology

The TPM concept uses the OEE measurement method to measure the performance of a productive system, with the aim of increasing the overall equipment effectiveness (Huang *et al*., 2002).

3.1 Data Source

Data required in this study include:
(1) number of working days and hours of work (available time);
(2) the length of time stops the production set by the company include meeting, rest, maintenance (planned downtime);
(3) long time machine downtime (Failure & Repair and Set Up & Adjustment);
(4) old time idle equipment and idle and minor stoppages;
(5) period cycle time (Ideal Cycle Time and Actual Cycle Time);
(6) total production (Processed amount);
(7) number of production defects (reduced yield and reject & rework component);
(8) machine maintenance history.

3.2 Equipment Selection

The selection of test equipment that will be used as case study of this research is the type of material characteristic test equipment with static test machine. Static test machine equipment is an instrument used as a mechanical test to measure the resistance of a steel material to a static force. The data is obtained from the Structural testing laboratory in Puspiptek Serpong area. The selection of such equipment is based on data on the high use of tools that impact on services. Table 1. shows the comparison of data accumulation testing of the use of static test facility for the period of January 2016 to February 2017:

Table 1. Use of The Static Test Facility

Description	Static Test UPM1000 kN) (testing)	Static test UPM 200 kN (testing)	Static test UPM 100 kN (testing)	Total Testing
amount	46557	21246	224	68027

Source: B2TKS Material Study Data

Based on the usage data of the tool in Table 1. above, UPM 1000 kN test equipment will be used as research material to measure OEE value.

3.3 Data Processing

Data processing is done by using microsoft excel software which includes data: working day and monthly operation time, total monthly test product, planned monthly shut down and monthly losses downtime. The data is used as the basis for measuring OEE values. In Table 1. shows the results of data processing to measure components and OEE values.

4. Research Result

4.1 Measurement of Availability Value

Availability is a ratio that describes the utilization of the time available for the operation of the tool or machine.

Table 2. Data Equipment Operations

Month	Working time		Total product (testing)	Planned shutdown (min)	Downtime losses (min)
	(day)	(min)			
Jan 16	18	7884	4015	1460	1122
Feb16	19	8322	3418	1565	912
Mar16	21	9198	3541	1725	1224
Apr16	18	7884	3376	1490	878
May16	20	8760	3608	1610	914
June16	14	6132	2719	1110	692
July 16	10	4380	2252	830	525
Augu16	22	9636	4946	1760	1125
Sept 16	19	8322	3616	1565	1412
Oct 16	20	8760	4494	1640	1049
Nov16	18	7884	3945	1430	935
Dec 16	1	438	151	75	45
Jan 17	15	6570	3369	1175	1405
Feb 17	19	8322	3107	1565	1409

Availability values shown in Figure 1:

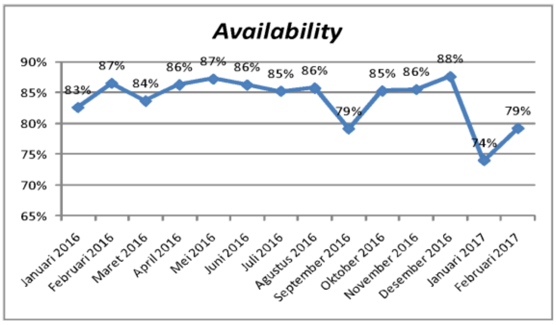

Figure 1. Value Availability Ratio

4.2 Measurement of Performance Rate

Performance rate is a ratio that describes the ability of the equipment to produce goods. The performance rate set out in Figure 2:

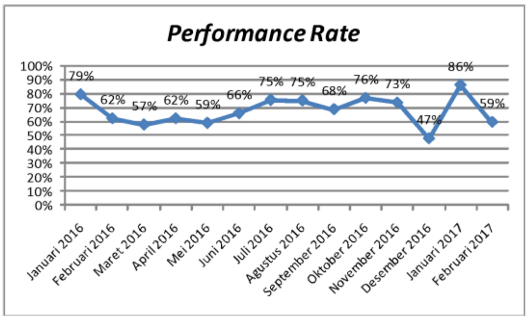

Figure 2. Performance Ratio Value

4.3 Measurement of Quality rate value

Quality rate is a ratio that describes the ability of the equipment in producing products that conform to the standards. Two main factors are needed in measuring the Quality rate ie total production and reject product data. The Quality ratio shown in Figure 3:

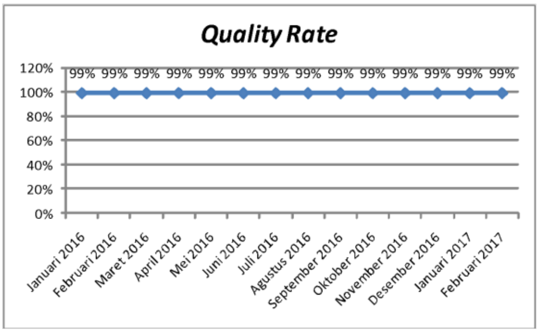

Figure 3. Value Quality Rate

4.4 Measurement of OEE Value

OEE factor values consisting of Availability, Performance efficiency rate, and Quality rate. The OEE values obtained are shown in Figure 4:

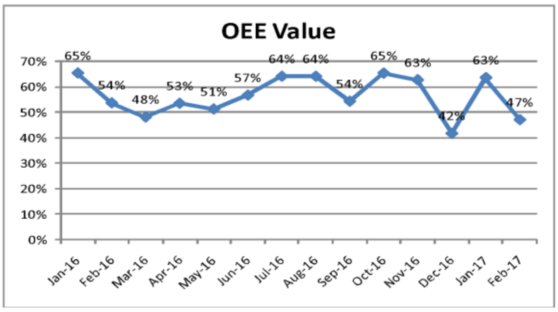

Figure 4: OEE Value Trend

4.5 Measurement of Performance Losses

Calculate the performance loss first calculated total product test sample that should be tested.The average number of performance loss time factors can be seen in Table 3. and Figure 5:

Table 3. Percentage Performance Loss Time

Loss	Time (min)	Percentage (%)
Performance loss	22116	59%
Setup & adjustment	11599	31%
Breakdowns	2046	5%
Idling & minor stoppage	1645	4%

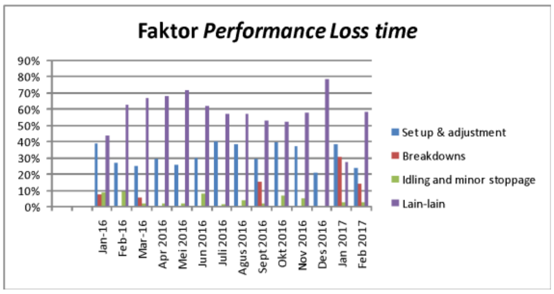

Figure 5: Performance Loss Time Comparison

5. Discussion

5.1 Value Availability Discussion

The availability value of the measurement results is 84%, where the value is still below the average availabillity value still below the world class of 90% (Levitt, 1996). However, availability value is still in reasonable level condition.

5.2 Value Performance Rate Discussion

Based on the results of the measurement the average performance rate shows that it is still below the world class performance rate, where the world class performance rate is 95% (Levitt, 1996) or above 95% (Nakajima, 1988), while the performance rate of the measured result is 67 %. One of the factors that affect the low value of performance rate is the old machine equipment and testing process.

5.3 Discussion of quality rate values

Quality rate describes the ability of equipment to produce products that conform to standards. The results of the test samples performed on laboratory tests averaged 99% based on the SNI standard specification. According Nakajima (1988), the value of world class quality rate is above 99%.

5.4 OEE value discussion

Based on the measurement results, the overall value of availability, performance rate, quality rate, and OEE are varied. In Table 4. shows the comparison of word class OEE.

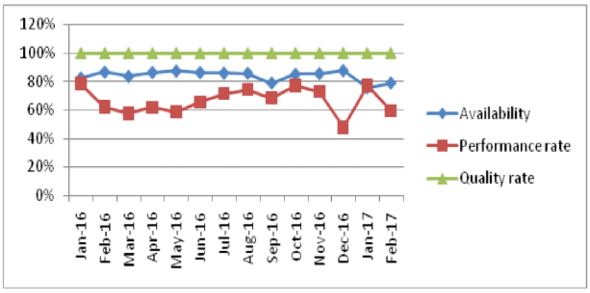

Figure 6: OEE Comparison

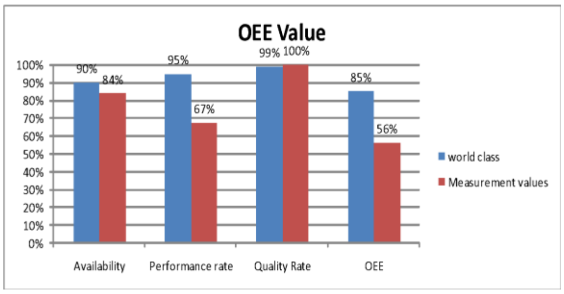

Figure 7: World Class Comparison & Measurement Results

5.5 Discussion of Losses and Causes

The OEE measurement results it is known that the average performance rate has the lowest value of 67% of the other two components. This low value is influenced by performance loss, set up & adjustment, breakdowns, and idling and minor stoppage and other factors. Table 4. shows the following large percentage loss:

Table 4. Percentage of Loses

Loss	Time (min)	Percentage (%)	Cumulative (%)
Performance loss	22116	59%	59%
Setup & adjustment	11599	31%	90%
Breakdown	2046	5%	96%
Idling & minor stoppage	1645	4%	100%

By knowing the cause of the dominant loss, then the priority can be determined by handling using pareto digram.

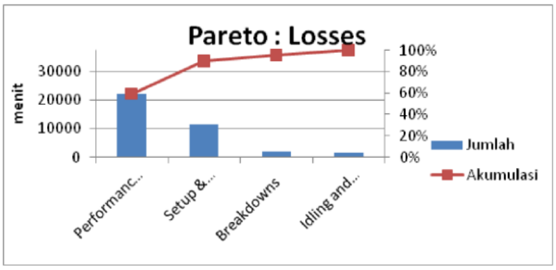

Figure 8: Pareto Diagram of Losses

The three components described in the Pareto diagram, performance loss, setup & adjustment and breakdown factors are the three causes of the low performance value of UPM 1000 kN test equipment.

Therefore, based on the results of discussions and brainstorming done, the next analysis will use a causal diagram (fishbone) to determine the root cause of loss due to performance loss, setup & adjustment and breakdown.

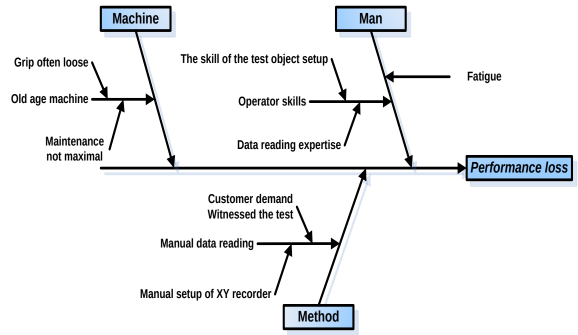

Figure 9: Fishbone Diagram Performance Loss

From Diagram of Fishbone Performance Loss, there's proposed improvement at each factor. On the machine factor: improved planned, proactive and preventive maintenance system; encouraging operator's sense of ownership and build PM with check sheet. On the man factor: improving operator's skill technique in performing appropriate and effective testing; and improve co-ordination among operators in the testing process; improve organizational culture; and ensure a safe working environment. And for the last factor which is method factor: identify and group test samples and effective use of time.

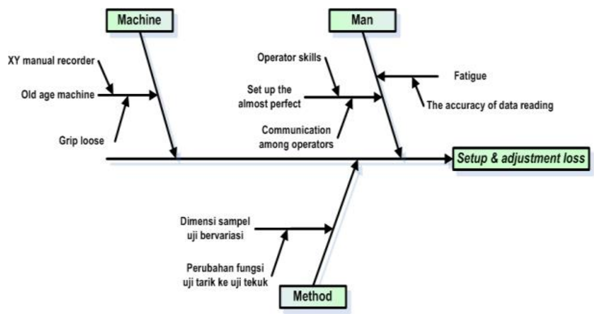

Figure 10: Fishbone Diagram Setup & Adjustment Loss

From Diagram of Fishbone Cause of Setup & Adjustment, there's proposed improvement at each factor. On the machine factor: improved planned, proactive and preventive maintenance system; encouraging operator's sense of ownership; and build PM with check sheet. On the man factor: improving operator's skill technique in performing appropriate and effective testing; improve co-ordination among operators in the testing process; improve organizational culture; and ensure a safe working environment. And for the last factor which is method factor: identify and group test samples and effective use of time.

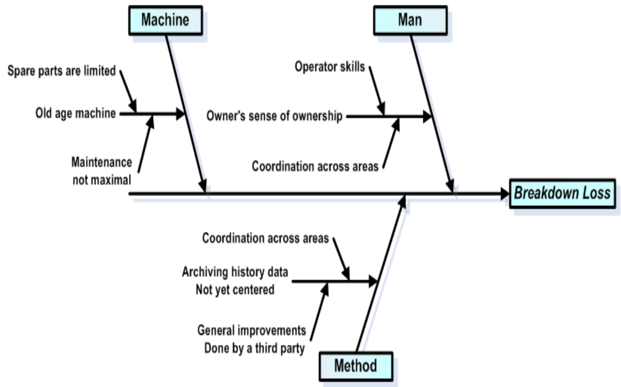

Figure 11: Fishbone Diagram Breakdown Loss

From Diagram of Fishbone Causes Breakdown Loss, there's proposed improvement at each factor. On the machine factor: identify problems that arise before a failure occurs and fixed planned, proactive and preventive maintenance systems. On the man factor: increase operator knowledge of the machines and equipment they handle; responsible for routine maintenance (cleaning, lubricant inspection, bolt tightening) performed by the operator; and combine the collective talents of human resources within the organization to make continuous improvement. And for the last factor which is method factor: preparing the loog book for recording of equipment usage; utilize the effective time and human resources available in the handling of damage; and increased competence in learning proactive and preventive maintenance techniques.

6. Conclusions

In this research, the effectiveness of static test equipment with TPM method has been done. The average availability rate of 84%, where the availability of december 2016 is 88%, the highest value, while the lowest occurred in january 2017 of 74%. The low value is affected by downtime.

The average performance rate of 67%, where the highest performance rate is 86% in february 2017, while the lowest is 47% in december 2016. The value is affected by downtime due to setup and breakdown. Average grade quality rate is 99%.

The average value of OEE is 56%, where the highest OEE value is 65% in January and October 2016 and the lowest OEE value is 42% in December 2016 and February 2017. The low value of OEE is influenced by the value of performance rate.

Based on the pareto diagram analysis, the low OEE score is affected by performance loss of 59%, set up & adjustment of 31%, breakdowns by 5%, and idling and minor stoppage by 4%.

7. Suggestions

This study has some limitations such as OEE measurement using only one test equipment, and no cost analysis for the rejuvenation of old equipment. Therefore, for further research can do a cost analysis for the rejuvenation of old machine tools.

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