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Implementation of Total Productive Maintenance (TPM) With Measurement of Overall Equipment Effectiveness (OEE) and Six Big Losses in Vapour Phase Drying Oven Machines in PT. XYZ

AnnisaaWulandari, Sampik Krisning Tyas, Erry Rimawan
Magister of Industrial Engineering
MercuBuana University
Jakarta, Indonesia

Abstract:- PT. XYZ applied Total Productive Maintenance (TPM) to improve the efficiency and effectiveness of manufacturing companies as a whole. But in the implementation it is still not optimal, this study aims to measure the value of the effectiveness of the equipment, look for the root caused of the problem and provide suggestions for improvement. The study was conducted on Vapor Phase Drying Oven machines, these machines are critical units where when there is damage to this machine, the production process will stop and will have an impact on the quality of the desired product output. This research begins by measuring the achievement of the overall equipment effectiveness (OEE) value, then identifying the six big losses that occur. The results showed that the average OEE value of the Vapor Phase Drying Oven machine was 74.26%, the value of this effectiveness was quite reasonable and showed that there was a large room for improvement. The biggest factor that affects the low OEE value is the performance rate with a six big losses reduce speed percentage factor of 62.6% of all time loss. The proposed remedial action is to carry out autonomous maintenance given to the operator, conduct training for maintenance technicians and carry out supervision of the operator regarding the cleanliness of the workplace.

***Keywords**:- Total Productive Maintenance, Overall Equipment Effectiveness, Six Big Losses.*

I. INTRODUCTION

One of the factors supporting the success of the manufacturing industry is determined by the smoothness of the production process. So that if the production process is smooth, the effective use of machinery and production equipment will produce quality products, the right time to complete the manufacture and the low cost of production. The process depends on the condition of the resources owned such as humans, machines or other supporting facilities, where the conditions in question are conditions ready to carry out production operations, both accuracy, ability or capacity.

PT. XYZ is a manufacturing company engaged in the manufacture of high-voltage electric transformers, machines that are the object of research is one of the main machines used in the manufacture of transformers, namely the Vapor Phase Drying Oven machine, this oven is used to remove the moisture content in the transformer. Vapor Phase Drying Oven machines are critical units where when damage to this machine will result in cessation of the production process and will have an impact on the quality of the desired product output, to overcome these problems appropriate steps are needed in maintenance of machinery / equipment, one of which is implementation of Total Productive Maintenance (TPM). The goal of implementing Total Productive Maintenance is to improve the efficiency and effectiveness of manufacturing companies as a whole. In other words the goal of TPM is to achieve ideal performance and achieve zero loss, which means without defects, without breakdown, without accidents, without waste in the production process and changeover process (Nakajima, 1988). Evaluation of the application of Total Productive Maintenance is done by using the Overall Equipment Effectiveness (OEE) value as an indicator and looking for the causes of ineffectiveness of the machine by calculating the six big losses to find out the influential factors of the six big losses. By doing OEE calculations, companies will know where they are and where weaknesses are and how to make improvements (Almeanazel, 2010).

The purpose of this study is to analyze the application of TPM at PT. XYZ, knows the value of Overall Equipment Effectiveness (OEE) which is based on availability, performance and rate of quality factors. Second, knowing the factors that cause the decline in effectiveness through the measurement of six big losses and identifying the dominant factors of the six factors of the six big losses and analyzing the factors that contribute the most using the fishbone diagram. And finally, provide recommendations to overcome the main problems of the six factors of the six big losses.

II. LITERATURE REVIEW

A. *Total Productive Maintenance* (TPM)

Total Productive Maintenance is a program to determine the basis of improvements in plant productivity and performance, machinery and processes involved in the overall strength of work (Nakajima, 1988). TPM is a proactive maintenance design system to improve the overall effectiveness of the equipment which includes all equipment from planning, manufacturing, maintenance and increasing achievement. The main focus of the TPM is to ensure all equipment and production equipment operate in the best conditions so as to avoid damage or delay in the production process. TPM has a goal to avoid the cessation of production processes due to unexplained breakdowns and minimize unscheduled maintenance. TPM is a process to maximize the use of equipment, through reduce downtime losses, reduce speed losses and reduce quality losses with the Overal Equipment Effectiveness (OEE) value indicator, which is a measure of the success of TPM in an organization.

B. *Overall Equipment Effectiveness* (OEE)

In evaluating and measuring the extent of the successful implementation of TPM, the measurement tool used is "Overall Equipment Effectiveness (OEE)". OEE is a comprehensive measure that identifies the level of machine / equipment productivity and its performance in theory. This measurement is very important to find out which areas need to be increased in productivity or efficiency of the machine / equipment and also can show the bottleneck area found on the production line. OEE is also a measuring tool for evaluating and correcting appropriate ways to ensure increased productivity in the use of machinery / equipment. By knowing the value of OEE, there will be many benefits that can be obtained, including:

- Be the basis for consideration whether or not you need to buy a new machine
- Avoid buying improper machines so that they are redundant
- Become a benchmark for engine speed that we demand from a machine seller
- When a new machine is being purchased is commissioning, the OEE data can be a benchmark whether or not the machine is in accordance with our request
- Know whether the productivity at the factory is optimal or not
- As a means for improvement

Mathematically from Overall Equipment Effectiveness (OEE) is formulated as follows:

OEE = *Availability* x *Performance Efficiency* x *Rate of Quality Product*

In OEE there are three measures to find out whether the equipment is able to work effectively, the three sizes are:

- *Availability*

Availability is a ratio that describes the use of time available for the operation of machinery or equipment. Availability is the ratio of operation time, by eliminating equipment downtime, against loading time. Thus the formula used to measure availability ratio is as follows:

$$Availability = \frac{Operation\ Time}{Loading\ Time} x\ 100\%$$

$$= \frac{Loading\ Time - Downtime}{Loading\ Time} x\ 100\%$$

Loading Time is the available time per day or per month reduced by the time the engine *downtime* is planned (Planned Downtime)

Loading Time = Total availability – Planned Downtime

Planned Downtime is the amount of time the machine downtime for maintenance (Schedule Maintenance) or other management activities. Operation Time is the result of the reduction of Loading Time with the time of machine Downtime (non-Operation Time) after the engine downtime is released from the planned total availability time. Machine downtime is the processing time that should be used by the engine but due to interference with the machine / equipment (equipment failures) resulting in no output being produced. Downtime includes a stop operating engine due to damage to the engine / equipment, engine replacement, implementation of setup and adjustment procedures and others.

- *Performance Efficiency*

Performance Efficiency is the product of the multiplication of Operation Speed Rate and Net Operation Rate, or the ratio of the product quantity produced multiplied by the ideal cycle time to the time available for the production process (Operation Time). Operation Speed Rate is a comparison between the engine's ideal speed based on actual engine capacity (theoretical / ideal cycle time) with the actual speed of the engine (actual cycle time). The mathematical equation is shown as follows:

$$Operation\ Speed\ rate = \frac{ideal\ cycle\ time}{actual\ cycle\ time}$$

$$Net\ Operation\ rate = \frac{actual\ processing\ time}{operation\ time}$$

Net Operation Rate is a comparison between the number of products processed (processes amount) multiplied by the actual cycle time with Operation Time. Net Operation Time is useful for calculating losses - caused by minor stoppages and decreasing production speed (reduced speed)

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Three important factors are needed to calculate the Performance Efficiency:

- *Ideal cycle (ideal cycle time / standard time)*
- *Processed amount (number of products processed)*
- *Operation Time (engine operation time)*

Performance Efficiency can be calculated as follows:

$$Performance\ Effieciency = net\ operating\ x\ operating\ cycle\ time$$

$$\frac{processed\ amount\ x\ actual\ cycle\ time}{operating\ time}\ x\ \frac{ideal\ cycle\ time}{actual\ cycle\ time}$$

$$Performance\ Efficiency = \frac{processed\ amount\ x\ ideal\ cycle\ time}{operating\ time}$$

- *Rate of Quality Product*

Rate of Quality Product is a better ratio of the number of products to the total number of products processed. So the Rate of Quality Product is the result of a calculation using the following two factors:

- Processed amount (number of products processed)
- Defect amount (number of defective products)

The rate of quality product can be calculated as follows:

$$Rate\ of\ quality\ products = \frac{processed\ amount - defect\ amount}{processed\ amount}\ x\ 100\%$$

C. SIX BIG loses

Activities and actions taken in TPM do not only focus on preventing damage to machinery / equipment and minimizing machine / equipment downtime. However, many factors can cause losses due to the low efficiency of the machine / equipment. The low productivity of machinery / equipment that causes losses for the company is often caused by the use of machines / equipment that are not effective and efficient, there are six factors called six big losses. Efficiency is a measure that shows how resources should be used in the production process to produce output. Efficiency is a process characteristic measuring the actual performance of resources relative to the standard set. While efficiency is another characteristic of the process of measuring the degree of achievement of the output of a production system. Effectiveness is measured from the actual output ratio to planned output. In the current era of free competition the measurement of production systems that only refers to output quantities will be misleading, because these measurements do not pay attention to the main characteristics of the process, namely: capacity, efficiency and effectiveness.Using the machine / equipment as efficiently as possible, meaning is to maximize the function of the performance of the engine / production equipment in an effective and efficient manner. To be able to increase the productivity of the machine / equipment used, it is necessary to analyze the productivity and efficiency of the engine / equipment in the six big losses. The six big losses are as follows:

- *Downtime*

- *Equipment failure / breakdown (loss due to damage to equipment)*

Machine failure (equipment failure breakdown) will result in time wasted which results in losses for the company due to reduced production volume or material losses due to defective products.

- *Set-up and adjustment, (Losses due to installation and adjustment)*

Losses due to set-up and adjustment are all set-up times including adjustment times and also the time needed for activities - activities to change a product type to the next type of product for subsequent production. In other words, the total needed by the machine does not produce in order to replace the equipment for the next type of product until a product that is suitable for the next process is produced.

- *Speed Losses*

- Idling and minor stoppages (Losses due to operating without a load or for stopping for a moment), The disadvantage of operating without a load or for stopping for a moment arises if external factors cause the engine / equipment to stop repeatedly or the engine / equipment operates without producing a product.

- Reduced Speed (Loss due to decreased operating speed), Decreasing production speed arises if the actual operating speed is smaller than the engine speed that has been designed to operate at normal speed. The decline in production speed is partly due to:
  - ✓ The speed of the engine designed cannot be achieved due to changes in the type of production or material that is not in accordance with the machine / equipment used
  - ✓ The machine / equipment production speed decreases as the operator does not know the actual speed of the engine / equipment.
  - ✓ Production speed is intentionally reduced to prevent problems with machines / equipment and the quality of products produced if produced at higher production speeds

- *Defect*

- *Rework loss (losses due to defective products or because the product works are reprocessed)*

The resulting defective products will cause material losses, reduce the amount of production, increase production waste and the cost of reworking. Losses due to rework including labor costs and the time needed to process and rework or repair product defects are few but these conditions can create increasingly large problems.

- *Reduced Yielded Losses (Losses at the beginning of production time to achieve stable production conditions)*

Reduced yielded losses are losses of time and material that arise during the time needed by the machine / equipment to produce new products with the expected quality of the product. Losses that arise depend on factors such as unstable operating conditions, improper handling and installation of machinery / equipment or mold or operators do not understand the activities of the production process carried out.

➢ *Cause and Effect Diagram*

Improved processes involve taking action on causes that are variations. With most practical applications, the number of possible causes for a particular problem can be very large. This diagram, known as fish bone diagram, was introduced for the first time in 1943 by Prof. Kaoru Ishikawa (Tokyo University). This diagram is useful for analyzing and finding factors that have a significant effect on determining the output quality characteristics of work. In this case the method of brainstorming will be quite effective to be used to find the factors that cause the occurrence of work irregularities in detail. The steps are as follows:

- Develop a flow chart from the area to be repaired
- Define the problem to be resolved
- Do brainstorming to find all possible causes of the problem
- Organize the results of discordant suggestions in a rational category
- Create a causal diagram that accurately displays the relationships of all data in each category.
- To find out the factors that cause the deviation in the quality of work, there are five significant main factors that need to be considered, namely:

✓ Man (Human)
✓ Work Method (Working Method)
✓ Machine / Equipment (Machines or other work equipment)
✓ Raw Material (Raw Material)
✓ Work Environment

Mentioning one by one the causes of cause and effect only shows all possible causes of certain problems which are grouped according to rational categories. This type of cause and effect diagram is ready to give the possibility to approach the contradictory suggestions that are being used.

The cause and effect diagram has a number of uses. The creation of a diagram is an education by itself. Organizing knowledge from these groups is a guide to discussion and often inspires more ideas.

III. METHODOLOGY

A. Data collection

Data collected will be input at the data processing stage. In data collection this research uses secondary data that is collecting engine breakdown data, machine stand-by, and planned maintenance on the engine, operating time data, production amount and number of defects. Data taken from the month of Meret 2017 to August 2017. Data obtained from the recap of the daily data of PT. XYZ is the engine disruption time, including its duration, type of engine failure, and cause of damage every day.

B. Framework

Data processing in this study is carried out quantitatively, the data obtained in the study will be processed and analyzed so that it can provide a clear work system. The following are the stages of research at PT. XYZ, the research stages can be seen in Figure 1.

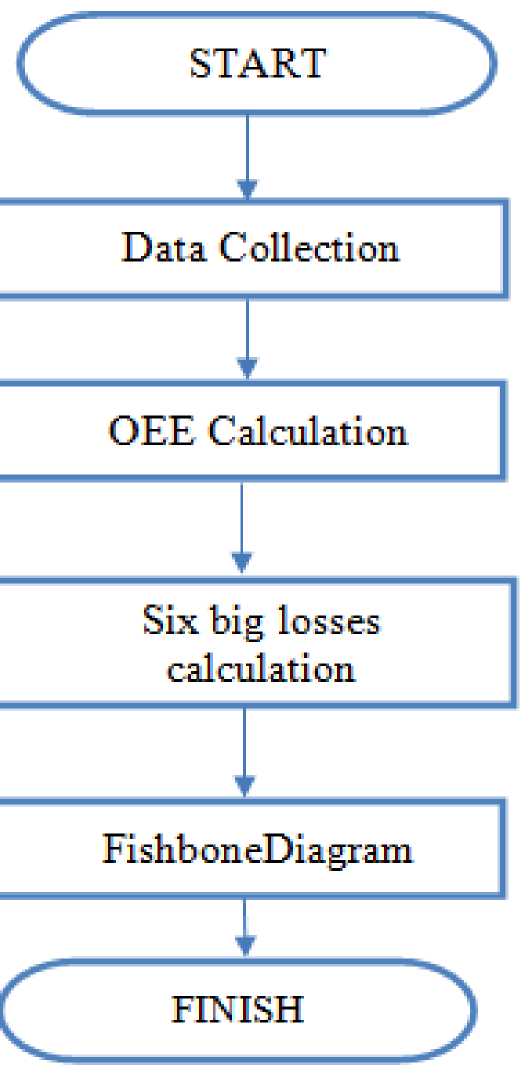

Fig 1

IV. RESULTS AND DISCUSSION

The following are the results of the data obtained:

Month	*Breakdown*	Planned downtime (minute)	Setup (minute)
March	270	19600	923
April	45	18200	787
May	75	11115	985
June	60	15807	898
July	120	4010	892
August	855	6530	878

Table 1:- Data breakdown time, planned downtime and oven setup

Month	Available Time (Minute)	Product Processed (unit)	Good Product (unit)	Total Rework (unit)	Actual Process Time (menit)
March	40320	3	3	0	19365
April	43200	4	4	0	23850
May	44640	4	4	0	31995
June	43200	4	4	0	26340
Jule	44640	5	4	1	39525
August	44640	5	4	1	36045

Table 2:- Data Production

A. *Data processing*

➢ *OEE Value Measurement*

After the data is collected, the next step is to do data processing. To obtain an OEE value, a calculation for Availability, Performance efficiency and Rate of quality products is performed, processing data using the help of Excel 2013 software. For the results of processing data OEE Value is obtained from the Vapor Phase Drying Oven for 6 months from March 2017 to August 2017 is shown in Table 3. Ideal which is the standard of world-class companies that is equal to 85% (Dal, 2000). This value with the composition of the three ratios is as follows:

- Availability of 90% or more
- Performance rate of 95% or more, and
- Quality rate of 99% or more

Bulan	Availability	Performance Rate	Quality Rate	OEE
1	94.24%	88.49%	100%	83.40%
2	96.67%	95.33%	100%	92.16%
3	96.84%	70.97%	100%	68.72%
4	96.50%	87.16%	100%	84.11%
5	97.51%	72.69%	80%	56.71%
6	95.45%	79.17%	80%	60.46%

Table 3:- OEE Value of Vapor Phase Drying Oven Machine

➢ *Analysis Six big losses*

After obtaining the OEE value, then the process of identifying six big losses is carried out for 6 months. From the data obtained, the six big losses that occur are shown in Table 4. as follows:

Six Big Losses	Total Time Losses	Presentase
Reduce Speed	33120	62.6%
Rework Loss	11520	21.8%
Setup and Adjustment	5363	10.1%
Idling and Minor Stoppages	1470	2.8%
Equipment failures / Breakdown	1425	2.7%
Yield/scrap Loss	0	0.0%
Total	52898	100%

Table 4:- PresentaseFaktor Six Big Losses

The six big losses above can clearly show the effect of the six big losses on the effectiveness of the Vapor Phase Drying Oven machine. It can be seen that reduce speed is the dominant factor that causes low OEE values.

➢ *Analisa Diagram SebabAkibat(fishbone diagram)*

Analysis of the causes of six big losses factors that result in low machine effectiveness in OEE calculations are carried out using a causal diagram (fishbone diagram). The dominant factor that influences the amount of productivity and efficiency of the engine is reducing speed. Figure 2. Shows a causal diagram (fishbone) for the factor of reducing speed on the Vapor Phase Drying Oven machine.

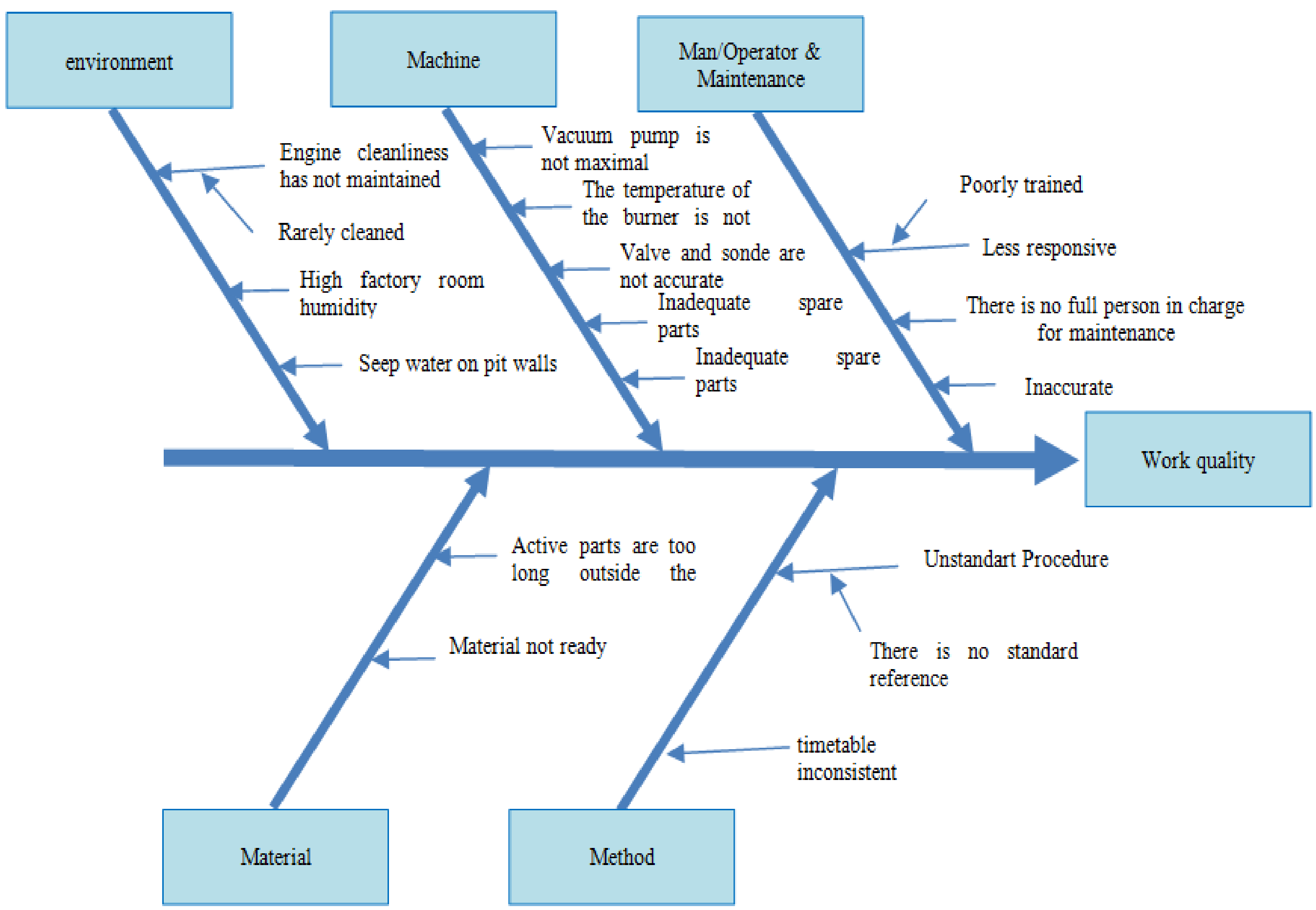

Fig 2:- Fishbone diagram causes the biggest losses

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V. CONCLUSION

Based on the results obtained can be concluded as follows:

- Based on the calculation of Overall Equipment Effectiveness (OEE) on the Vapor Phase Drying Oven machine for the period March 2017 - August 2017 the Overall Equipment Effectiveness (OEE) value is found to range from 56.71% to 92.16%, if taken on average OEE value of 74.26% is considered reasonable, which means that there is a large room available for improvement.
- The dominant loss that causes the low OEE value on the Vapor Phase Drying Oven machine during the period March 2017 - August 2017 is a reduce speed with 33120 minutes total time losses or 62.6% of the six factors of the six big losses.
- The factors that cause the reduce speed which are the top priorities are:
- Human factor: inaccurate, less responsive, there is no full responsibility for maintenance.
- Material factors: Active parts are too long outside the room, the material is not ready / yet to come.
- Method factors: Nonstandard maintenance procedures, inconsistent maintenance schedules
- Machine factor: Parts are inadequate, spare parts are inadequate, valve and sonde are not accurate, burner temperature is not reached, vacuum pump is not maximal
- Environmental factors: The wall of the water seepage pit, the high humidity of the factory room, the cleanliness of the engine is not maintained

SUGGESTION

Suggestions that are expected to provide input and benefit for companies based on the results of this study are:

- Cultivating awareness of all employees to take an active role in increasing productivity and efficiency for the company and for themselves from the operator level to the top management level.
- Performing OEE calculations on each machine is always carried out, so that informative data is obtained for maintenance and continuous improvement (continuous improvement) in an effort to increase the effectiveness of machine use. Using the OEE relative method is easier and can be done by each operator.
- Training operators and maintenance personnel in order to improve the ability and expertise of operators in tackling the problems that exist in machines / equipment so that companies can implement Autonomous Maintenance to be able to increase productivity and production efficiency in the production process, especially in the Vapor Phase Drying Oven.
- Make standardization for maintenance both for maintenance technicians and operator maintenance levels

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