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THE INTEGRATION OF OVERALL EQUIPMENT EFFECTIVENESS (OEE) METHOD AND LEAN MANUFACTURING CONCEPT TO IMPROVE PRODUCTION PERFORMANCE (CASE STUDY: FERTILIZER PRODUCER)

Adi Yermia Tobe[1)*], Denny Widhiyanuriyawan[2)], Lilis Yuliati[3)]
[1), 2), 3)]Department of Mechanical Engineering
Universitas Brawijaya Malang

Abstract *High machine downtime and large number of rejected products is still become a big problem for company as a research object in this study. Overall Equipment Effectiveness (OEE) is one of the methods used to measure the effectiveness of a machine with three measurement factors, namely; availability rate, performance rate, and quality rate. The integration of OEE measurement and lean manufacturing analysis method is employed to improve production system in company. The measurement result shows that the value of availability rate is 88.82%, performance rate 93.70%, and quality rate 98.20%; then the OEE values obtained 81.73%. The root cause is investigated by using FMEA (Failure Mode and Effect Analysis) method particularly from the RPN (Risk Priority Number).*

Keywords: *Overall Equipment Effectiveness, Six Big Looses, Seven Wastes, Non Value Added, Risk Priority Number*

1. Introduction

Increasing productivity and performance in the industrial field is a necessary and must be implemented in order to improve the competitiveness of the company. Total Productive Maintenance (TPM) is one of the planning systems to improve the quantity and quality of production through the study of the effectiveness of machines, equipment, processes and employees within a company [1]. One of the basic measurements associated with TPM is Overall Equipment Effectiveness (OEE), which is an appropriate performance measurement for overall equipment effectiveness in order to increase productivity [2].

PT. SBK is a company of agriculture especially in producing granular organic fertilizer. The company that has been established since 2005 is located in Kediri Regency. The applied production system is a job shop flow, which means the company produces the product type according to the customer demand, where the main customer is the parent company. There is only one type of product produced by this company is organic fertilizer granules (PO Granul), where the basic material comes from cow compost and chicken compost.

OEE measurement is based on three main factors: Availability, Performance, and Quality. Each factor represents a different perspective of how closely a manufacturing process can achieve production optimization. Referring to global/international standards issued by JIPM (Japan Institute of Plant Maintenance) for OEE measurement, the minimum value for availability rate is 90%, 95% for performance rate, and 99% for quality rate and for the total percentage of OEE is 85% [3].

The three OEE factors are associated with six losses that are extremely common in manufacturing (the Six Big Losses). The Six Big Losses are an excellent framework for understanding, and most importantly, for taking action, on losses exposed through OEE initiative [4].

The value of the availability rate depends on machine downtime. Availability Loss includes all events that stop production either

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planned or unplanned for a considerable amount of time. The causes of unplanned downtime recorded in this company are machine failure, unplanned maintenance, and spare part replacement. While the causes of planned downtime are machine set-up, machine adjustment, operator break time and rotation time.

The machine is working at low-speed under the ideal cycle time (reduce speed) is one cause of a low performance rate. This happens because of the lack of lubrication and dirt on the machine. Power outages conducted by PLN also affect the decrease in performance rate, which is called a small stop.

The large number of rejected products causes the low quality rate, so it takes extra time to do the rework. Rejected products occur because of the raw materials treatment are less precise, either the storage or during the crushing process.

Increasing the performance of a machine can be achieved by minimizing the frequency of small disturbances as well as increasing the operator's knowledge in solving problems faced in the field [5].

This research will integrate OEE measurement method with lean manufacturing analysis method. The OEE method is used as a preliminary calculation to find out how much the value of machine effectiveness by using historical data of production from the company. The results of these measurements will be analyzed using the methods of lean manufacturing, which serve to find and identify the dominant factors that result in losses.

The purpose of this research is to design the improvement measures, in order to minimize losses and optimize the utilization of machines, and to propose alternative solutions to solve problems facing the company, as well as choosing the best alternative solutions.

2. Research Methods

This study is related to the measurement of OEE values to support the effectiveness of the machine. Measurements are made by observing directly the conditions in the field, relating to operate the machine and the things associated with it. The observation was conducted at granulation workstation, which is a continuous production line. In this type of production line, termination on one machine will affect the entire system.

In this section, we give formal description about integration of Overall Equipment Effectiveness (OEE) and Lean Manufacturing in supporting the research. Furthermore, related concepts and theories are additionally considered, such as Total Productive Maintenance (TPM), Pareto Chart, Fishbone Diagram, Value Stream Mapping (VSM), and FMEA (Failure Mode and Effect Analysis).

The starting point of this study is the OEE value calculation, where the result of the calculation would be a reference to know how effective machine operation in a production process. OEE measurement can also be the basis to find out the causes of the losses [6].

Six Big Looses or six major losses are derived from the theory of Total Productive Maintenance (TPM) which was introduced and developed by Nakajima in 1971 at the Japanese Institute of Plant Maintenance. In the framework of the assessment, the activities that cause losses (six big losses) on the OEE calculation will be converted into waste (seven wastes) in the VSM, which consists of: Overproduction, waiting, transport, over processing, inventory, motion and defect [7].

Lean Manufacturing is simply a group of Strategies for the Identification and Elimination of the Waste inside the Value Stream [8]. Waste factors will be translated into the type of activity and then given an assessment, so that can be found what activities need improvement or even eliminated, which is also called NVA (Non Value Adding Activity). The activities are included in the category of NVA will be used as the basis for the calculation of the RPN (Risk Priority Number) in the FMEA method [9].

A case study the process industry is used to explain a correlation between OEE and FMEA. To compute OEE and RPN, it is required to calculate the value of each parameter [10]. The results of the RPN calculation will be the basis for taking corrective and preventive measures that must be done by the company in order to improve the performance of machinery.

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3. Result and Discussion

In this section, we provide the steps and computational results on OEE, the identification of losses and its cause factors. The computational result were based on observation 3 periods of data (January - March 2017) consists of 45 working days and 90 work shifts. The source of data were both from direct observation in the field and interviews with related parties.

3.1 Availability Rate

Availability rate is the ratio of operation time, by eliminating equipment downtime, to loading time. The formulas used to measure availability are:

$$Availability = \frac{Run\ Time}{Planned\ Production\ Time}\ x\ 100\% \ldots\ldots\ldots\ldots (1)$$

In determining the value of availability rate, the data that must be known to be the basis of calculation is in Table 1.

Table1. Data for Availability Calculation

Production Time	Total Time (minute)
Total Time/ Loading Time (45 days, 2 shift @ 9 hours) = 90shift x 9 hours (540 minute)	48.600
Planned Downtime (60 minute x 90 shift)	5.400
Unplanned Downtime/ Stop time	4.830
Total Downtime (Planned downtime + Unplanned downtime) = 5.400 + 4.830	10.230
Planned Production Time (loading time – planned downtime) = 48.600 – 5.400	43.200
Run time / Operation time (loading time – downtime) = 48.600 – 10.230	38.370

By referring to table 1, we can compute the value of the availability rate:

$$Availability = \frac{38.370}{43.200}\ x\ 100\%$$

$$= 88,82\ \%$$

The results of the calculation of table 1, shows the availability rate of 88.82%. It indicates the process has not fulfill the global standard value of 90%. The low value of the availability rate due to the high engine stops time (downtime), which resulted in the loss (losses).

3.2 Performance Rate

In addition, we compute the performance level of a machine (performance rate), which obtained from the ratio of the product quantity generated multiplied by the cycle time ideally to the time available for the production process (operation / run time). The formula to calculate performance value as follows:

$$Performance = \frac{(Ideal\ Cycle\ Time\ x\ Total\ Pieces)}{Run\ Time}\ x\ 100\% \ldots. (2)$$

Furthermore, we compute the ideal Cycle Time, which indicate the cycle of process time achieving by the machine in the production process in the optimal state or the machine does not experience barriers in production. In determining the value of the performance rate of the machine, the data that required shows in Table 2.

Table 2. Data for Performance Calculation

Production Data	Total
Total Products produced (for 45 days, 90 shifts)	1.797.600 Kg
Run Time / Operation Time (Same as table 1)	38.370 minute
Ideal Cycle Time	Machine capacity (3ton/hour) = 50kg/minute Then **ICT = 0,02 min/kg**

Based on data in table 2, the value of performance rate is defined as follows:

$$Performance = \frac{(0{,}02\ x\ 1.797.600)}{38.370}\ x\ 100\%$$

$$= 93{,}70\ \%$$

The value of performance rate (93,70%) consider below the standard set 95%. The low value of the performance rate is influenced by the decrease in engine

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performance from the ideal cycle time, thus causing the total product to be reduced.

3.3. Quality Rate

Quality rate is the ratio of good products to the total amount of product produced. The formula used for the measurement of this ratio is:

$$Performance = \frac{Good\ Product}{Total\ Product}\ x\ 100\% \text{.................... (3)}$$

The data needed to determine the value of the quality rate are in Table 3.

Table 3. Data Number of Products

Number of Production	Amount (Kg)
Total Product (Same as table 2)	1.797.600
Reject Product	32.270
Good Product = Total Product – product reject	1.765.330

By referring table 3, the value of the quality rate can be defined as:

$$Quality = \frac{1.765.330}{1.797.600}\ x\ 100\%$$

$$= 98,20\ \%$$

Quality standard value predetermined rate is about 99%. Therefore, the calculation result of quality rate as 98.20% indicated the quality has not achieving the standard.

3.4. OEE calculations

The OEE value is calculated by multiplying the value of availability, machine performance and product quality capacity. Based on the results of the calculation of availability, performance and quality rate that has been done before, it can be determined the amount of OEE value is by the formula as follows:

OEE (%) = ((Availability (A) × Performance (P) × Quality (Q)) × 100 % ....(4)

= (0,8882 × 0,937 × 0,982) × 100 %

= 81,73%

From the OEE calculation above it can be seen that the value obtained is 81,73%, which means that it is still below the set global standard of 85%. Therefore, it can be concluded that the performance of the machine on PT.SBK still not optimal and needed some improvements for the effectiveness of the machine is getting better.

3.5. Six Big Losses

From the above calculation results show that the percentage of the three OEE factors that are availability, performance and quality are still below the applicable standards. It can be concluded that there are losses that occur during the production process, which must be traced to find the point of the real problem. In the concept of OEE this loss is categorized in six major losses or commonly called the Six Big Losses. Based on observations during the research and data obtained from the company, it can be sorted the factors causing losses as listed in the Table 4.

Table 4. Types of losses and causal factors

Type of Losses	Faktor Penyebab Losses
Unplanned Stop (Breakdown Losses/ Equipment Failure)	Conveyor failure
	Motor drive failure (Pan / Rotary)
	Wear on bearing and gear
	Waiting for Material
Planned Stop (Set up & Adjustment Losses)	Set-up Machine
	Heating Furnaces
	Briefing/Meeting
Small Stop (Idling and Minor Stop)	Feeding mistake
	Power suplay off (PLN)
Slow Cycles (Reduce Speed)	Bad lubrication
	Dirt on certain engine parts
Production Reject (Processes Defect)	The furnace temperature is too high or too low
	The addition of excessive water during the granule process
Startup Reject (Reduced Yield)	Moist material
	Material density

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From the data of downtime recorded previously both availability loss and performance loss, the pareto diagram can be defined to sort the downtime of the machine based on the total time and percentage of events, as shown in Figure 1.

3.6. Conversion Losses into Waste

In order to find the root of the problem (root cause) causing losses, further analysis is needed using methods related to lean manufacturing concept. Based on the concept of lean manufacturing, the first step that must be done is to convert these types of losses into waste form. Moreover, the activities that occur during the production process were classified into types of losses that converted into waste as shown in Table 5.

Considering the results of the conversion in table 5, we identify types of waste included in the group waiting, unnecessary motion, defect and inventory.

The types of waste are translated into activity-related forms of process flow. Furthermore, the activities are classified into NVA (Non value adding activity) or NNVA (Necessary but non value adding activity) as shown in Table 6. Eight types of activities included in the NVA category are activities that should not occur in a production system in PT.SBK.

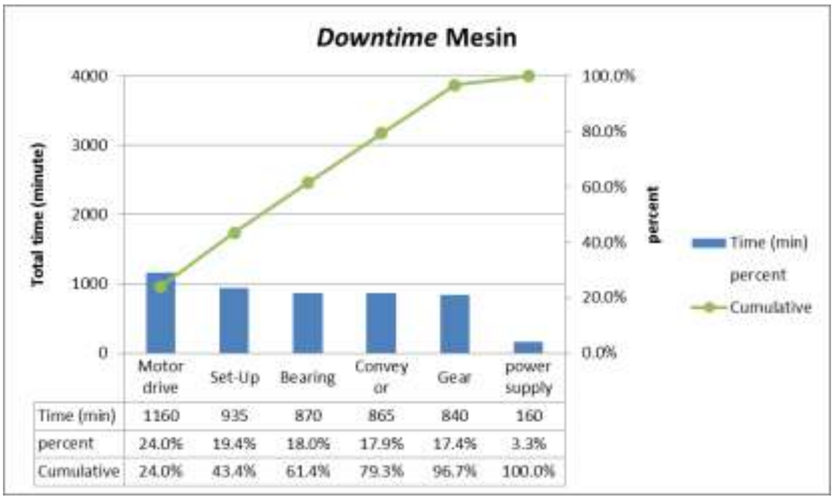

Figure 1. Pareto chart of machine downtime

Table 5. Conversion Losses into Waste

No	Faktor Losses	Losses Category	Waste Category
1	The machine is not working at the time of operation for setup	Set up & Adjustment Losses	Waiting
2	Awaiting material availability for processing	Unplanned Stop	Waiting
3	The engine is off for repair	Breakdown Losses (Equipment Failure)	Waiting
4	The machine works more slowly due to dirt or less lubrication	Slow Cycles (Reduce Speed)	Transport
5	The furnace temperature is too hot or less due to operator negligence	Production Reject (Processes Defect)	Motion
6	Additional excess water by the operator	Production Reject (Processes Defect)	Motion
7	Product rework	Production Reject (Processes Defect)	Defect
8	Initial material conditions are not good for processing	Startup Reject (Reduced Yield)	Inventory

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Table 7. RPN Assessment

No	Cause of Failure	Severity (S)	Occurrence (O)	Detection (D)	RPN (O).(S).(D)
1	Store material (animal compost) or fuel (coal) in the open space.	3	4	2	**24**
2	Heating furnace is too long at the time of machine setup.	4	3	3	**36**
3	Late add fuel when the furnace temperature decreases.	4	2	2	16
4	Adding too much water during the granule process.	2	2	3	12
5	No lubrication periodically.	4	3	4	**48**
6	When crushing the initial material is not smooth.	2	3	2	12
7	Late when feeding the material into the pan granulator machine.	3	2	3	18
8	Delaying clean up the dirt on the machine.	4	3	4	**48**

These NVA activities will be used as the basis for RPN (Risk Priority Number) calculations in the FMEA method. There are three criteria that become the basis of determining RPN that is Severity (S), Occurrence (O) and Detection (D). RPN calculation results can be seen in Table 7.

From the results of the RPN assessment can be seen there are four types of activities that have the highest value, which means will be a major concern in the improvement effort. This RPN assessment becomes the basis for taking corrective and preventive measures that would be undertaken by the company in order to improve machine performance.

The following are some of the suggestions given to the company and management to be considered in performing remedial measures:

a) Maintenance
The highlight above is the problem of engine lubrication, which is currently maintenance schedule applied by the company only once a week. Therefore, it is proposed that the cleaning schedule be added more frequently than usual.

b) Cleanliness
The largest type of dirt is dust from animal compost therefore it is advisable for the company to add the number of blowers or cyclones. In addition, receive tools to clean a place that is difficult to reach by people also need to be considered.

c) Material Treatment
Material treatment both raw materials (animal composts) and fuel (coal) should be more concerned in order to avoid moisture. Currently materials and fuel stored in the open space and covered only with tarpaulins. Making a covered place (having a roof) needed to protect the material from both rain and sun.

d) Human Resources
Although the standard procedure that has applied considered good enough, but education and training for employees still need to improve. This activity is needed to improve employee's productivity both at the operator level and at the supervisory level to the manager.

4. Conclusions

Based on data analysis shows that the value of availability rate is 88.82%, performance rate 93.70%, and quality rate 98.20%; then the OEE values obtained 81.73%. The dominant factor of losses is high downtime due to mechanical motor breakdown that is 24% or 1160 minutes, and duration of setup time is 19.4% or 935 minutes.

Types of activities that are at the root of the problem include: no lubrication periodically, delaying clean up the dirt on the machine, heating furnace is too long at the time of machine setup, material storage (animal compost) and fuel (coal) in the open space. The solutions offered to PT.SBK as a step to increase machine performance improvements

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are by: revise the machine maintenance schedule to be more frequently, improving more practical hygiene procedures and adding aids, making a special storage place closed for materials and fuel, as well as conducting training to employees at all levels.

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