Proposal Improvement to Increase Equipment Effectiveness and Reduse Waste Levels in SME Plastic Straw Prodecer with a Total Productive Maintenance Approach and Waste Assessment Model

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ABSTRACT

The existence of waste in a production line causes production equipment and production systems to be ineffective and inefficient. It's the same with an SME that produces plastic straw products in a city in Indonesia. BNL50 machine that produces plactic straw, often experiences problems such as breakdowns and minor stoppages. Thus, the amount of total production is low and the delivery of customer orders is often delayed. The purpose of this study was to give improvement proposed to the company based on the equipment effectiveness and the significant waste. The method that used in this study is Total Productive Maintenance approach using Overall Equipment Effectiveness (OEE) and Six Big Losses, as well as identification of the most dominant waste in the production line using the Waste Assessment Model (WAM). The average value of the effectiveness of the BNL50 machine for four months calculated by OEE is 87.40% with reduced speed losses as the highest losses value which causes the low OEE value. With the WAM method, the highest value were found, that is waiting. Suggestions for improvement given to the SME company is implementing 5S and the pillars of TPM as well as making SOPs for operator training, material mixing composition, and machine hygiene standards.

Keywords: *Total Productive Maintenance (TPM), Overall Equipment Effectiveness (OEE), Six Big Losses, Waste Assessment Model (WAM)*

1. INTRODUCTION

Nowadays the growth of the manufacturing industry is increasing rapidly. Along with this growth, business competition among manufacturing companies is getting tougher. One way that a company can do to maintain its existence in this condition is to keep their production systems in an efficient and productive state so the company can improve product quality and minimize production costs.

The SME that located in a city in Indonesia produces plastic straws that supplying the straw product to bottled water companies. Based on the observation data in the past year, almost every day the machines experience breakdown and minor stoppages. So this problem results in waste such as waiting because there are breakdowntimes for machine to be repaired. This breakdown has an impact on production times that are longer than the specified time so that it is often to be late in sending consumer orders.

Based on the statement of the head of production, the delay in the delivery of consumer orders is caused by production facilities that are only given maintenance if the machine is completely breakdown or can be called breakdown maintenance. This type of maintenance is a machine or equipment repair that is carried out after it fails to perform the desired function [1]. The problem of the BNL50 machine because of the breakdown maintenance include the reduced speed of the machine in the melting process, the machine is clogged with rough dough so that it cannot go down to the straw formation section, and product defects are also produced.

Total Productive Maintenance (TPM) is a lean approach that is compatible with the problems faced by the company. TPM is useful as a means to increase productivity, minimize breakdown, and maximize efficiency. One of the main measures in TPM in measuring the efficiency of production equipment is Overall Equipment Effectiveness (OEE) and Six Big Losses [2]. The OEE method is designed to identify losses consisting of breakdown losses, planned downtime losses, minor stoppages, reduce speed losses, rejects on startup and rejects in process.

The company also need to identify waste in the production process, so that the level of waste can be reduced and the effectiveness and productivity of the production process can be increased. The method that can be used to identify waste is using the Waste Assessment Model method. The WAM method is a method used to calculate the value of waste in a work area using 2 assessment questionnaires, including the Waste Relationship Matrix (WRM) and the Waste Assessment Questionnaire (WAQ) [3].

2. LITERATUR REVIEW

The effectiveness of production equipment greatly affects the quality of a company's production process. The value of effectiveness depends on how the production equipment is maintained. Appropriate and controlled maintenance activities for machines play an important role in the smooth running of a production process.

TPM can reduce equipment losses by implementing focused and planned maintenance [4]. Jain, et al (2014) concluded that SMEs need to adopt improvement concept like TPM to sustained survival of these industries in future will be very difficult in this competitive environment [5]. Afefy (2013) studied and concluded that one of the important and widely used measurement of equipment performance in manufacturing is OEE [6]. Moreover, to increase the effectiveness, waste in production system is also have to be identified. Rawabdeh (2005) presented a new model for performing an assessment of different types of waste in a jobbing shop environment [3]. Robecca, et al (2020) analyzes production system of product X and found that defect has the highest percentage so improvement purposes can be given to the company [7].

2.1. Lean Manufacturing

Lean manufacturing is a concept that was developed to optimize the utilization of resources through the minimization of existing waste [8]. In lean manufacturing, the expenditure of resources other than to create value for the end customer is a waste, and thus becomes a point that must be eliminated [9]. The goal of lean manufacturing is to produce products and services at the lowest cost and with the fastest time required by consumers [10].

2.2. Waste

Waste is something that does not add value to the product in terms of costs, inventory, scrap, regulation and product rework [7]. There are seven kinds of waste according to [11]. The seven wastes include overproduction, defect, high inventory, transportation, motion, waiting, and over processing.

2.3. Waste Assessment Model (WAM)

Waste Assessment Model is a model developed to simplify the search and problem of waste and identify ways to reduce waste [12]. There are metrics and questionnaires used to assess waste, including the Seven Waste Relationship, Waste Relationship Matrix, and the Waste Assessment Questionnaire[3].

1. Seven Waste Relationship (SWR)

   SWR is a questionnaire that shows that basically all types of waste affect and are influenced by other wastes. In other words, all waste is related and related to each other (Rawabdeh, 2005).

2. Waste Relationship Matrix (WRM)

   According to [3] the analysis of the calculation of the criteria is summarized in a matrix called the waste relationship matrix. The answers to the SWR questionnaire are summarized and weighted in the WRM.

3. Waste Assessment Questionnaire (WAQ)

   The waste assessment questionnaire has 68 questions that were created with the aim of allocating waste. The following are the steps that need to be taken based on [3]:

   1. Grouping questions and counting the number of questions in the questionnaire based on the types of questions "from" and "to".
   2. Weighting each question based on the results of the waste relationship matrix.
   3. Divide the weighted results by the number of questions based on the type of question.

4. Calculate the total weighting score for each waste column (S_j) and calculate the total waste weighting score which is 0 (F_j).

$$Sj = \sum_{k=1}^{k} \frac{Wj.k}{Ni} = \frac{Wj.1}{N1} + \frac{Wj.2}{N2} + \cdots + \frac{Wj.68}{N68} \quad (1)$$

Where :

Sj = Score of each type of waste

Wj = Weight of linkage between types of waste

K = Number of questions on the questionnaire

Ni = Number of Questions according to waste grouping

$$Fj = N - F_0 \quad (2)$$

Where:

Fj = Total score of waste that is not worth 0

N = Total number of questions

F_0 = Total waste score which is worth

5. Entering the results of the questionnaire question weighting scores (1, 0.5, 0) into each weight, then calculating the average value of the answers from the questionnaire weighting scores and entering them into the table.
6. Calculate the total score in each column of waste type (*Sj*) and calculate the total waste weighting score which is 0 (*fj*).

$$Sj = \sum_{k=1}^{k} X_k \frac{Wj.k}{Ni} \quad (3)$$

$$= X_1 \frac{Wj.1}{N1} + X_2 \frac{Wj.2}{N2} + \cdots + X_{68} \frac{Wj.68}{N68}$$

Where:

s_j = Total for the weight value of each type of waste

X_k = Score of answers to each question

W_j = Weight of relation between types of waste

K = Number of questions on the questionnaire

N_i = Number of Questions according to waste grouping

$$f_j = N - Fo \quad (4)$$

Where:

f_j =Number of weighted scores that are not worth 0

N = Total number of questions

F_0 = Total weighted score which is 0

7. Calculate the initial indicator value for each type of waste (Y_j).

$$Y_j = \frac{sj}{Sj} \times \frac{fj}{Fj} \quad (5)$$

Where:

Y_j= Initial indicator value of each waste

sj= Total for the weight value of each type of waste

Sj= Score of each type of waste

fj = Number of weighted scores that are not worth 0

Fj = Total score of waste that is not worth 0

8. Calculate the value of the final waste factor (Final) by entering the percentage value of the relationship between waste ( ) based on the total value of "from" and "to" in the WRM table, then the Final value is converted into percentage form so that it can be seen the sequence of waste from the value largest to smallest value.

$$Y_j\ Final = Yj \times Pj \frac{sj}{Sj} \times \frac{fj}{Fj} \quad (6)$$

Where:

Y_j final = final waste factor

P_j = Percentage of the relationship between waste

2.4. Maintenance

Maintenance is a combination of all technical and managerial activities on the life cycle of an equipment that is intended to maintain or return it to a condition where a system or production equipment continues to work according to its function [13]. There are two types of maintenance which are breakdown maintenance that is fixing if it breaks" and planned maintenance that is "repair before it breaks". [14].

2.5. Total Productive Maintenance (TPM)

Total Productive Maintenance (TPM) is a system developed to maximize equipment performance, create a productive maintenance system that optimizes the life cycle of production facilities, contributes to the improvement and availability of production facilities, avoids damage to production facilities through prevention activities with a management focus [15]. Total Productive Maintenance (TPM) is based on the pillars illustrated in Fig1.

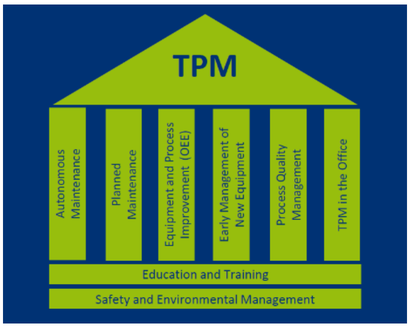

Figure 1 Pillars of TPM.

2.6. Overall Equipment Effectiveness

Overall Equipment Effectiveness (OEE) is one of the main measures of TPM that shows how effectively machines and equipment are run [2]. Although the definition implies that OEE is a specific machine measure, it can also be used to measure the efficiency of a product line, a part of a plant, or an entire plant [16]. OEE calculation is done by calculating the value of availability, performance efficiency, and Quality rate. The steps that must be taken to calculate the OEE value are:

1. Availability

$$\text{Availability} = \frac{\text{Time Less Availability Loss}}{\text{Total Production Time}} \text{x}100\% \quad (7)$$

2. Performance Rate

$$\text{Performance rate} = \frac{\text{Time Less Performance Loss}}{\text{Total Production Time}} \text{x}100\% \quad (8)$$

3. Quality Rate
   Quality Rate =

$$\frac{\text{Time less perform loss} - \text{Total Quality Loss Time}}{\text{Time Less Perform Loss}} \text{x}100\% \quad (9)$$

4. Calculation of OEE

OEE = Availability x Performance Rate x Quality Rate (10)

2.6.1. Six Big Losses

One of the main goals of TPM and OEE programs is to reduce and/or eliminate the so-called Six Big Losses which are the most common causes of efficiency loss in manufacturing [17]. Six Big Losses consist of breakdown losses, planned downtime losses, minor stoppages, reduce speed losses, reject on startup losses and reject in process losses. Here's the formula for calculating six big losses:

1. Breakdowntime Losses

$$\text{Breakdowntime} = \frac{\text{Breakdown time}}{\text{Total Production Time}} \text{x}100\% \quad (11)$$

2. Planned Downtime (kerugian karena waktu downtime yang ditentukan)

$$\text{Planned downtime} = \frac{\text{Planned downtime}}{\text{Total Production time}} \text{x}100\% \quad (12)$$

3. Reduce Speed Losses

$$\text{Reduced Speed} = \frac{\text{Good Product}}{\text{Actual Output}} - \frac{\text{Good Product}}{\text{Max Output}} \text{x}100\% \quad (13)$$

4. Minor Stoppages Losses

$$\text{Minor Stoppages} = \frac{\text{Minor Stoppage}}{\text{Total Production Time}} \text{x}100\% \quad (14)$$

5. Rejects in Process Losses

$$\text{Rejects in Process} = \frac{\frac{\text{Rejects}}{\text{Actual output per menit}}}{\text{Total Production time}} \text{x}100\% \quad (15)$$

6. Rejects on Startup Losses

$$\text{Rejects on Startup} = \frac{\frac{\text{Rejects on Startup}}{\text{Actual output per menit}}}{\text{Total Production time}} \text{x}100\% \quad (16)$$

2.7. Whys's Analysis

The 5 Why technique is done by asking "why" repeatedly 5 times so that the root of the problem can be found and the solution to the problem is clearer and more precise. The advantage of the 5 Why (5 Why) technique is that asking 5 Whys can help uncover the root of the problem so it is easier to fix it [11].

2.8. Diagram Pareto

A Pareto chart is a bar graph that displays a graph of a problem sequentially according to the number of events [18]. The highest bar on the far left shows the problem with the highest value, then sequentially until the rightmost bar shows the problem with the lowest value [19].

3. METHODS

This research was conducted for 4 months at the SMEs which is a company that produces plastic straws and cups. The data taken for this research is primary data. The primary data taken are time data related to machine working time and data for the WAM questionnaire. The main purpose of this study was to determine the effectiveness of the production equipment with OEE calculations and Six Big Losses as a TPM measurement tool and to find out the most dominant waste in the production process using the WAM method. Respondents used in WAM data collection were all operators and heads of production. While the data used for the calculation of OEE is data for 2 work shifts for 4 months.

4. RESULT AND ANALYSIS

After observing the plastic straw production process, the data needed for processing OEE, Six Big Losses, and WAM have been obtained. For data processing using WAM, two questionnaires, namely the Waste Analysis Seven (SWR) and the Waste Assessment Questionnaire

(WAQ) were filled in together with the six operators and the head of production.

4.1. Calculation of Six Big Losses

To be able to calculate the effectiveness of production equipment with OEE, the value of each loss must be known first. The data used in calculation are shown in table 1 until table 3.

Table 1. Machine Working Time and Breakdown Time.

Month	Number of days	Machine Working Time (minutes)	Break down Time per *Shift* (minutes)		Minor Stoppages per *Shift* (minutes)	
			1	2	1	2
1	26	24960	103	82	54	40
2	24	23040	76	36	63	25
3	26	24960	595	95	63	31
4	25	24000	68	70	37	38

Table 2. Machine Cycle Time and Production Time.

Actual Cycle Time (minutes)	Ideal Cycle Time (minutes)	Planned Down Time (minutes)	Load-ing Time (minutes)	Total Pro-duction Time (minutes)
0,001	0,0009	240	24720	24441
0,0009	0,0009	240	22800	22600
0,001	0,0009	240	24720	23936
0,0009	0,0009	240	23760	23547

Table 3. The Amount Output.

Month	Output (unit)	Defect (unit)	Good Product (unit)
Maret	25632000	115532	24441
April	25164000	240	22600
May	24372000	240	23936
June	2509200	240	23547

The data that shown above is used to calculating the equipment effectiveness using OEE and Six Big Losses. After calculating the six losses with equations 12 to 17, the results are obtained as in Fig 2.

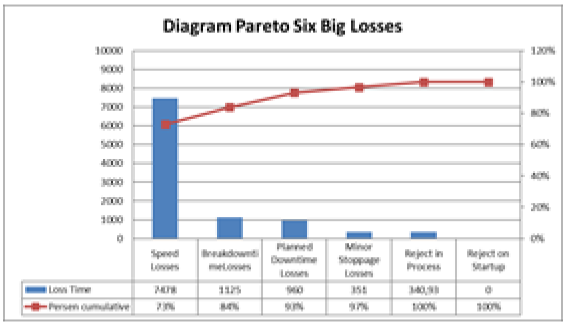

Figure 2. Pareto Chart of Six Big Losses

It can be seen from Fig. 2, the losses that get the highest percentage value are reduce speed losses with 73%. So this loss will be analyzed using 5 why's analysis to find the most basic root cause. The waste that related to this loss is waiting and defect. Thus, the speed of the machine to produce a unit of straw is decreasing and defect causes the company can't reach the target amount of total product. Therefore, the percentage of machine speed losses is so high.

After being analyzed using 5 why's analysis, 5 root problems were found. Based on the results of the analysis, the proposed improvement is given to the company. The root of the problem and proposed improvements are as follows:

1. There is a policy of only 3 operators/shift. Companies are advised to increase the number of operators for one shift.
2. There is no SOP of machine maintenance. Companies are advised to make SOPs regarding maintenance or change their type of maintenance to preventive or periodic maintenance. In addition, it is recommended to implement the pillars of TPM in the form of autonomous maintenance and planned maintenance.
3. The door to the production room is always open. Companies are advised to implementing the TPM pillar in and implementing 5S in the form of seiketsu and seiso.
4. There is no SOP regarding material composition. Companies are advised to implement the 5S (seiketsu) program by developing SOPs regarding the standard composition of appropriate material mixing.
5. Production room and warehouse are combined into one. Companies are advised to apply the 5S (Seiso) principle so that the production room environment remains neat, safe and clean. Companies should implement TPM Pillars in the form of safety, health, and environment.

4.2. Calculation of Overall Equipment Effectiveness (OEE)

Based on existing data, the OEE calculation is carried out using the formula in equations. The results of the calculation of the three elements of OEE namely availability, performance rate and quality rate are then entered into the histogram as shown in Figures 2 to 5.

Figure 3. Histogram of Availability

It can be seen in Fig3, the availability value of four months has reached the ideal standard set by the Japan Institute of Plant Maintenance (JIPM), which is more than 90%. The highest availability value is in April, which is 98.44%. This is because the comparison between machine downtime and total production time in April can be said to be the highest compared to other months.

Figure 4. Histogram of Performance rate

The average of performance rate for four months is ideal based on standard of JIPM. The performance rate value on May which is still below the standard indicates that the machine is still not optimal in producing a product in the production process. The low value of the performance rate is caused by the low number of products produced per day.

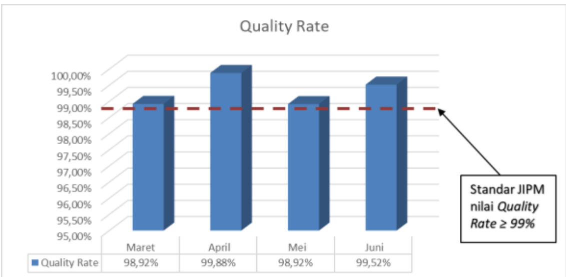

Figure 5 Histogram of Quality rate

The quality rate value for the BNL50 engine in April and June is included in the ideal criteria in the JIPM standard. This shows that the machine has a fairly optimal ability to produce products that are not defective or according to standards. However, for March and May, the quality rate value is still below the standard. This is due to the total production results in March which were far from the ideal total production, while the defect products produced by the machine were quite high**.**

Then after calculating the three elements above, the OEE value can be known. As in Fig. 6, the average of OEE value is ideal, which is 87.40%. The low value of the performance rate on May greatly affects the low value of the OEE. The value of the performance rate is caused by high reduced speed losses, so the length of time for the production of straws on the machine per minute or the cycle time of the machine is very slow. Thus, the number of straw products produced is still low when compared to the ideal number of products according to the company

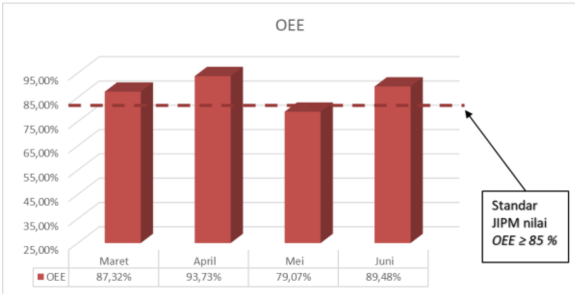

Figure 6. Histogram of OEE

4.3. Identification of waste using the Waste Assessment Model

Data from SWR is used to calculate the weight of the Waste Relationship Matrix (WRM) which will then be used as the basis for the weighting of WAQ. The results of the weighting of the SWR questionnaire data filled into the WRM matrix are shown in the Table IV.

Table 4. Waste Weight Result With RWM

F/T	O	I	D	M	T	P	W	*Score*	%
O	10	2	4	4	4	0	4	28	13
I	4	10	2	2	4	0	0	22	10
D	2	4	10	2	4	0	6	28	13
M	0	2	6	10	0	10	10	38	17
T	4	2	2	6	10	0	10	34	15
P	6	6	4	10	0	10	10	46	21
W	6	8	2	0	0	0	10	26	12
Score	32	34	30	34	22	20	50	222	
%	14	15	14	15	10	9	23		

From the results of the WRM calculation, it is found that the highest value of waste from is From Process with a value of 21%. So it can be said that the waste that has the most influence on the emergence of other wastes in the production process is process waste.. While the highest value for waste is To Waiting with a value of 23%. That way, it can be said that waste waiting is the biggest waste that arises from the straw production process.

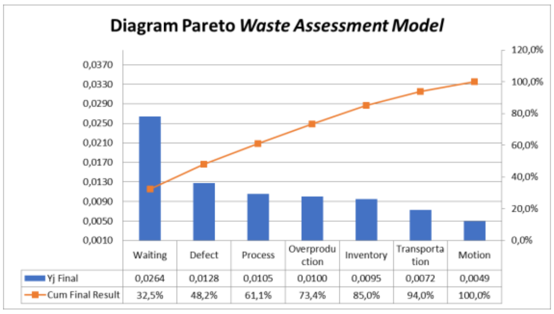

Figure 7 Pareto Chart of Final Result Waste Based on WAQ

After weighting the WAQ questionnaire to the final result calculation in the form of a percentage of each waste. Thereafter the results were analyzed using a Pareto chart to found the most critical waste. Based on pareto chart, waiting is the most critical waste with 73% final percentage. To provide suggestions for improvement, the highest waste is analyzed with 5 why's analysis and then proposed improvements are made. The proposed improvements given to companies related to the highest waste are the application of the TPM pillar in the form of autonomous maintenance and planned maintenance as well as implementing 5S in the form of seiketsu and seiso.

5. CONCLUTION

The application of TPM is expected to reduce losses in the production process and reduce constraints on the production equipment used. Basically, the purpose of implementing TPM is to reduce losses associated with the manufacturing system to increase overall production effectiveness. Based on the calculation results of OEE, Six Big Losses and Waste Assessment Model, it can be concluded that the pillars of TPM have not been implemented properly so that the effectiveness of production equipment is still below the ideal standard. This is indicated by the presence of losses with a high percentage such as reduce speed losses. In addition, the waste that has been discussed previously also shows that the application of TPM needs to be considered properly. if the company implements TPM properly, then the machine will not experience breakdowns and minor stoppages which result in slower total production that indicates a reduced machine speed. As well as many defective products, it also indicates that machine parts need to be given maintenance to produce more good products.

To increase the effectiveness of production equipment and reduce the level of waste in the production process, the company can consider an improvement program, namely by implementing the Pillars of TPM in the form of safety, health, and environment, Auntonomous and Planned Maintenance or implementing 5S in the form of Seiketsu, Seiso, and Seiton to control the condition of the machine and keep the production room always neat and clean to avoid engine trouble. Repair activities are expected to be implemented continuously with the help and support of all parties within the company so that the repair activities carried out run smoothly. This research is only a recommendation to the company so that it is hoped that further research can implement the research results and provide follow-up on the developments obtained by the company in order to complete the shortcomings of this research

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