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Analysis of Total Productive Maintenance (Tpm) Implementation Using Overall Equipment Effectiveness (Oee) And Autonomous Maintenance Methods in The Universal Pack 6 Machine

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Abstract:*The quality of products from an industry cannot be separated from one indication of the role of equipment. Equipment is one important factor that must be maintained with the implementation of maintenance and repairs. PT. XYZ is a company engaged in the manufacture of nutritional drinks. Problem that can be found at PT. XYZ is the number of breakdowns that occur on the Universal Pack 6 line 7 machine reaching 13.40% of production time. This results in a reduction in the maximum amount of production and results in a lack of effectiveness index value. One of the measurement tools to increase productivity is the measurement of Total Productive Maintenance (TPM) with the calculation of Overall Equipment Effectiveness (OEE). OEE is a systematic method to make improvements in the effectiveness level of the machine or equipment process. This study aims to calculate the OEE value of the Universal Pack 6 line 7 machine, analyzing the OEE value, and determining corrective action with the Autonomous Maintenance approach. Autonomous Maintenance is one of the pillars of TPM (Total Productive Maintenance) by using the principle of independent maintenance by machine operators to increase the knowledge, skills, and responsibilities of production operators related to the machine so that productivity will increase as a whole. The study consists of an activity of real productivity data recapitulation, determining availability rate, performance rate, and quality statistic. Based on the results of the current calculation, it obtains the availability value of 79.16%, performance of 78.26% and quality of 98.71%, while the average OEE value for Universal Pack 6 line 7 machine is 61.15%, this shows that the machine performance is still below standard and corrective action must be taken. To increase the OEE value in Universal Pack 6 line 7, the proposed improvement is to conduct Preventive Maintenance periodically to maintain machine performance, training for operators and supervising operators. After the improvement is made, the availability value of 89.82%, the performance of 78.26%, the quality of 99.35% and the average OEE value of 69.83% (there is an increase of 8.68%.)*

Kkeywords: *Productivity, Effectiveness, Autonomous Maintenance and OEE*

I. INTRODUCTION

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The success of a manufacturing industry is determined by the smooth production process. If the production process is smooth, the use of machines and production equipment is effective, it will produce quality products, the right time to complete production and low production costs [1]. Machinery and equipment are components that can support the sustainability of the production process in a company. Therefore, we need an appropriate machinery maintenance handling and handling so that machinery efficiency and productivity can be maintained.

PT. XYZ is a company engaged in the field of food by producing various types of products, one of the products produced is a type of instant powder drink. PT. XYZ has to increase the utility of machinery, one of which is the Universal Pack 6 line 7 machine. Currently, the production process is often hampered by several factors, one of which is the high number of breakdowns and lack of maintenance carried out by the company.

Improper maintenance and handling cannot only cause a decrease in the level of productivity and efficiency of the machine but can also result in other losses such as set-up and long adjustments. Machines that operate continuously are required to meet the targets that have been set with a high level of effectiveness.

This study aims to calculate the OEE value of the Universal Pack 6 line 7 machine, analyze the OEE value, and determine the corrective action with the Autonomous Maintenance approach. OEE is one of the work measurement methods used in measuring the success of TPM, besides that, according to Nakajima (1988), OEE can measure the level of effectiveness in the use of a machine/equipment or system by taking into account several viewpoints in the measurement process [2].

The use of the Overall Equipment Effectiveness method aims to determine machine performance and analyze the factors that cause the decreasing effectiveness of the machine. With the OEE approach, aspects or parameters that are improved or improved can be seen so that the productivity of the machine is better. After calculating by using this method, the repair and maintenance steps can be determined for the machine used. The results of the study become input for companies to make improvements in the future.

II. STUDY OF LITERATURE

Total Productive Maintenance (TPM). According to Corder, TPM does not only focus on how to optimize the productivity of equipment or materials supporting work activities but also pay attention to how to increase the productivity of workers or operators who will later take control of the equipment and materials [3].

Maintenance of autonomous involvement requires proactive involvement of equipment operators to eliminate acceleration of equipment damage, through cleaning, monitoring, collecting data, and reporting equipment conditions and problems to maintenance staff. Furthermore, the operator must strive to develop a deeper understanding of the equipment so that it will improve its operational expertise. Autonomous Maintenance, which is run by an operator, or a member of a manufacturing work team, can help maintain high levels of machine reliability, low operating costs, and high-quality production components. Information collected by the equipment operator can help to measure the overall effectiveness of the equipment.

Autonomous Maintenance or Jishu Hozen provides routine maintenance responsibilities to the operator such as engine cleaning, lubrication/oil delivery, and engine inspection. Thus, the 24 operators or workers concerned have a high sense of ownership, increasing workers' knowledge of the equipment they use. With the Autonomous Maintenance Pillar, the Machine or production equipment can be ensured to be clean and well lubricated and can identify potential damage before the occurrence of more severe damage [4].

Equipment effectiveness maximization by PTT is indicated by 2 activities. The first activity is quantitative by increasing total capability and productivity in terms of the amount of operating time. Another activity is qualitative by minimizing the number of defective products and improving product quality. The overall machine effectiveness value is interpreted by the OEE (Overall Equipment Effectiveness) index which describes the percentage of machine use in real to the availability and has paid attention to the number of products produced and product defects that occur.

Overall Equipment Effectiveness (OEE) is a performance indicator that is widely used in the manufacturing industry throughout the world. The concept of Total Productive Maintenance (TPM) introduced by Nakajima has the main objective to improve and maintain equipment efficiency. This is related to maintenance, performance measurement, and productivity improvement [2]. To support the manufacturing system, the performance of the equipment used must be improved, so that it can be used properly. Efforts to improve the manufacturing industry in terms of equipment is to increase the utility of existing equipment, namely the Overall Equipment Effectiveness (OEE).

OEE aims to increase the effectiveness of production line equipment to achieve greater volumes with good results so that production costs incurred are lower. This method is chosen because the calculation is not only based on availability factors but also on Performance Efficiency and product quality factors (product quality level). By knowing the level of effectiveness of a tool or machine, a company can increase its productivity through various efforts. OEE involves the process of monitoring the availability, performance, and quality of plant equipment and/or facilities. The operating performance of the three components provides information about aspects that can be focused on increasing productivity.

The OEE approach can be carried out through the following calculations:

a. OEE = Availability Ratio x Performance efficiency x Rate of quality product x 100% (1)

b. Availability Ratio

Availability Ratio is a ratio that describes the use of the time available for the operation of a machine or equipment. The availability ratio also measures the overall time that the system is not operating due to equipment failure, production preparation, and adjustments. The formula for calculating this ratio is:

$$\frac{\text{Operation Time}}{\text{Loading Time}} \text{ x } 100\% \quad (2)$$

a. Performance Efficiency

Performance Efficiency illustrates the machine's ability to produce products. The performance efficiency ratio is also the ratio of the actual operating speed of the equipment to the ideal speed based on design capacity. The formula for calculating this ratio is

$$\frac{\text{Actual Product x Cycle Time}}{\text{Operation Time}} \text{ x } 100\% \quad (3)$$

b. Rate of Quality

Rate of Quality is a ratio that describes the quality of products produced by equipment in accordance with standards. This ratio is intended for the quality of product loss such as defects that occur related to equipment, for conversion to time with the intention of how much time the equipment is consumed to produce damaged products. The formula for calculating this ratio is:

$$\frac{\text{Good Products} - \text{Total Defect}}{\text{Gross Products}} \text{ x } 100\% \quad (4)$$

c. Six Big Losses

At this stage, the main causes of waste can be found due to the low effectiveness of the machine, categorized into six major losses.

d. Breakdown Losses

Caused by a sudden machinery failure so that the machine cannot operate. The calculation can be carried out by formula:

$$\text{Breakdown Losses} = \frac{\text{Breakdown Time}}{\text{Loading Time}} \text{x } 100\% \quad (5)$$

e. Set Up and Adjustment Losses

Losses due to installation and adjustment are all installation times and adjustment times required for activities to replace the product for the next product. Calculations can be performed by formula:

$$\text{Set Up and Adjusment} = \frac{\text{Set Up Time}}{\text{Loading Time}} \text{ x } 100\% \quad (6)$$

f. Idling and Minor Stoppages

Idling and Minor Stoppage Losses are caused by a machine that stops operating, a machine that experiences a breakdown, and a waiting time from the machine because there is a breakdown. Calculations can be made with the formula:

$$\text{Idling Minor Stoppages} = \frac{\text{Non Productive Time}}{\text{Loading Time}} \text{ x } 100\% \quad (7)$$

g. Reduce Speed Losses

Speed Losses are losses because the machine is not running optimally so that the actual machinery speed is below the required optimum machine speed. The calculation can be carried out by formula:

$$Reduce\ Speed\ Losses = \frac{Operation\ Time - (Ideal\ Cycle\ Time\ x\ Total\ Product)}{Loading\ Time}\ x\ 100\% \quad (8)$$

h. Rework Losses

Rework Losses are losses caused by damaged products but rework can still be carried out. The calculation can be performed by formula:

$$Rework\ Losses = \frac{Ideal\ Cycle\ Time\ x\ Rewark}{Loading\ Time}\ x\ 100\% \quad (9)$$

i. Reject Losses

Reject Losses related to unused material or waste material. The calculation can be performed by formula:

$$Reject\ Losses = \frac{Ideal\ Cycle\ Time\ x\ Reject}{Loading\ Time}\ x\ 100\% \quad (10)$$

III. METHODOLOGY

This study consists of 2 (two) stages of data processing, i.e. the stage of calculating the effectiveness level of Universal Pack 6 line 7 machine by using the Overall Equipment Effectiveness (OEE) method, and the stage of removing the factors causing Six Big Losses of Universal Pack 6 line 7 machine.

3.1. Total Productive Maintenance (TPM)

Total Productive Maintenance is a method developed from Japan specifically to support Lean Manufacturing Systems. The purpose of TPM (Total Productive Maintenance) is to increase the productivity of the equipment used. To determine the evaluation of the successful implementation of TPM (Total Productive Maintenance) using an OEE (Overall Effectiveness Equipment) Method. Eight pillars which support the overall TPM implementation include:

a. Focussed improvement (Kobetsu Kaizen): makes continued improvements even the slightest improvement.
b. Planned Maintenance: focuses on increasing the availability of machines and equipment and reducing engine damage.
c. Education and Training: forms employee formation with skills and masters techniques for performing autonomous maintenance.
d. Autonomous Maintenance (Jishu Hozen): means to do maintenance on the machine used. There are seven steps and activities carried out at Jisshu Hozen.
e. Quality Maintenance (Hinshitsu Hozen): quality maintenance is a machine arrangement that minimizes the possibility of repeated defects. This is carried out to ensure the achievement of the target zero defect.
f. Office TPM: how to make efficient office activities and eliminate losses that might occur.
g. Safety, Hygiene & Environment (SHE): is an activity to create a safe and healthy work area, where there is very little chance of an accident. Find and repair accident-prone areas to ensure safety while maintaining environmental health.

h. Tools Management, to increase equipment availability by reducing tools resetting time to reduce equipment maintenance costs and extend service life.

3.2. Overall Equipment Effectiveness (OEE)

OEE is a comprehensive measure that identifies the level of machine/equipment productivity from performance in theory. The measurement is important to find out which areas need to be performed to increase productivity and efficiency, and also can show the bottleneck area contained in the production process [5].

The OEE component and all losses related to time, speed and bucket-capacity utilization can be seen in the Figure 3.1.

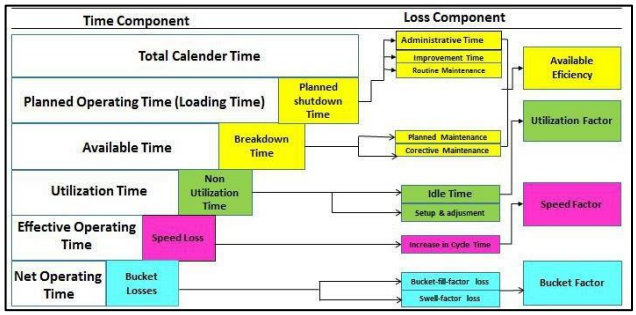

Figure 2.1 OEE Components

According to Andika (2007) some studies on OEE follows the global standard with 90% availability rate, 95% performance rate and 99% quality rate, so that the ideal OEE value of an equipment is 85%[6]

Formulas used are as follows:

a. OEE = Availability Ratio x Performance efficiency x Rate of quality product x 100% (11)

b. Availability Ratio

$$\frac{Operation\ Time}{Loading\ Time} \text{ x } 100\% \qquad (12)$$

c. Performance Efficiency

$$\frac{Actual\ Product\ x\ Cycle\ Time}{Operation\ Time} \text{ x } 100\% \qquad (13)$$

d. Rate of Quality

$$\frac{Good\ Products - Total\ Defect}{Gross\ Products} \text{ x } 100\% \qquad (14)$$

3.3. Six Big Losses

Losses are activities that consume inputs and resources without providing valuable results in terms of monetary values. Seiichi Nakajima categorizes this loss in six frameworks. The disadvantages identified in this case study are shown below:

Table 3.1 Identification of Losses

S.No	Big Losses	Reason For Losses	Category
1	Breakdown	Machien Failure	Downtime Losses
		Tool Breakage	
		Machine Program Issue	
		Electric Power Trip	
		Unplanned Maintenance	
		General Breakdown	
		Heavy Vibration Occurs Due to Uneven	
		Tool Unavailabilty	
2	Set-Up Adjustment	Operator Unavailabilty	Downtime Losses
		Crane Unavailability	
		Fixture are not Up to Mark	
		Helper Inefficient	
3	Small Stops	Obstructed Product Flow	Speed Losses
		Drill Jam	
		Component Jam	
		Coolant Stop	
		Misfed	
		Housekeeping of Machine	
		Confidence and Documetation	
4	Reduced Speed	Low Grade of Tools Used	Speed Losses
		Low Maintenance of Equipment	
		Operator Procrastinates Job	
		Level f Machine Operator Training	
5	Production Start-up Reject	Casted / Fabricated Job Damage During Set-up	Quality
6	Production Reject	In Process Damage	Quality
		Scrap	
		Rework	
		In Correct Dimension Due to Wrong	

The table above is the identification of losses that are grouped by Seiichi Nakajima, these losses will affect the value of availability, performance, and quality.

IV. RESULT

Data are obtained through continuous observation for one month in December 2019.

4.1 Data Collection

Data from observations of downtime in December 2019 are as follows:

Table 4.1 Recapitulation of Downtime Data in December 2019

Downtime Data Recapitulation Desember 2019				
No	Day	Date	Duration (Minutes)	Causes
1	Tuesday	3	85	Humidity not good
			25	Cange teflon
2	Thursday	5	60	Printer machine constrained
			25	Printer machine constrained
			50	Printer machine constrained
3	Friday	6	90	Auger motor constrained
			20	Change teflon
4	Tuesday	10	45	Printer machine constrained
5	Wednesday	11	20	Change teflon
6	Thrusday	12	85	Printer machine constrained
			35	Printer machine constrained
			10	Printer machine constrained
7	Friday	13	30	Printer machine constrained
8	Monday	16	100	Waiting ingredients
			100	Printer machine constrained
9	Tuesday	17	20	Printer machine constrained
10	Wednesday	18	10	Setting
			60	Waiting ingredients
11	Thrusday	19	415	Following company activitie
			105	Waiting ingredients
12	Friday	20	10	Humidity not good
			15	Waiting ingredients
13	Monday	23	125	Machine Cleaning
			100	Humidity not good
			45	Sealing jaw constrained
14	Wednesday	25	15	Waiting ingredients
15	Thrusday	26	185	Sealing roller constrained
			20	Printer machine constrained
16	Friday	27	25	Printer machine constrained
Total			1930	

Table 4.1 shows a recapitulation of downtime data that occurred during December 2019. The most common cause of downtime is the constrained printer machine followed by waiting for products and poor RH quality.

4.2 OEE Calculation Formula

Current OEE (Overall Equipment Effectiveness) Calculation based on downtime data for December 2019 is presented in Table 4.1. and comparison between OEE international and current OEE is currently presented in Figure 4.1

Table 4.2 OEE Calculation of December 2019

OVERALL EQUIPMENT EFFECTIVENESS WORKSHEET								
Job Tittle : Filling								OEE
Machine : Universal Pack 6 Line 7								
Date : December 2019								
OEE DATA								
Number of shifts	:	40						
Shift Duration	:	8 hours / Shift						
Shift lengsth	:	480	Minutes / day					
Short Breaks	:	80	Breaks	10	Min Each	800	Minute	
Meal Break	:	40	Breaks	30	Min Each	1200	Minute	
Down Time	:	1585	Minute		Sheduled maintenance	0	Minute	
Change Over Time	:	2000	Minute		House keeping of m/c	0	Minute	
Rework Time Duration	:	240	Minute		Total time	2000	Minute	
Planned Production Time	:	17200	Minute					
Operation Time	:	19200	Minute					
Actual Completion Time	:	18400	Minute					
Budgeted time for job	:	14400	Minute					
Actual operating Time	:	13615	Minute					

OEE CALCULATIONS				
OEE FACTORS		CALCULATION	OEE	OEE %
Availability	:	Actual Operating time / Planned Production time	0,7916	79,16%
Performance	:	Budget time / actual completion time of job	0,7826	78,26%
Quality	:	Actual Min / (Rework Min + Actual Min)	0,9871	98,71%
Overall OEE	:	Availability x Performance x Quality	0,6115	61,15%

WORLD CLASS OEE			
OEE Factors		World Class Oee	My OEE
Availability	:	90%	79,16%
Performance	:	95%	78,26%
Quality	:	99,90%	98,71%
Overall OEE	:	85%	61,15%

FORMULA
Actual Operating Time = Planned Production Time - Total Down Time
Planned Production Time = Plant Operating Time - Planned Down Time
Plant Operating Time = Shift Lengh x No of Shift
Total Down Time = Down Time + Change Over Time

The table above explains that the OEE calculation is carried out for 20 working days with 2 shifts/day. The time spent in 1 shift is 8 hours of work or 480 minutes. Short Breaks are temporary stops that are usually less than 10 minutes, while Meal Break is a break that is needed by workers.

Total downtime is the sum of downtime and changes over time, change over time includes several things, including clean-up, set-up, and start-up. Rework time duration is the time needed to rework caused by a problem during the production process.

Based on the calculations in Table 4.2, some results are still far from world standard, the results of machinery availability still reach 79.16%, the performance of 78.26%, quality of 98.71% and the OEE value obtained is 61.15%.

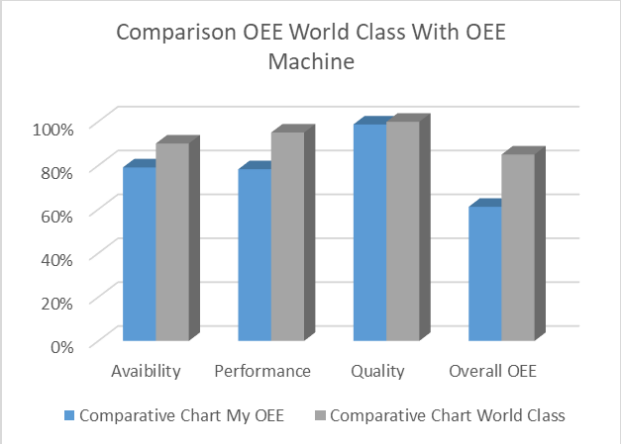

Figure 4.1 Comparative Bar Chart of the World Class OEE and OEE

The bar chart above is a comparison between the current OEE results at PT.XYZ and the OEE results which are the world standard.

V. DISCUSSION

Analysis of the current situation on Universal Pack 6 line 7 machine, the result of OEE is still far adrift with the standards set in the world. This condition is caused by several findings that cause delays in the production process, but this can be a proposal for improvement in the future.

5.1 Findings and Discussions

Findings obtained in this case study are:

1. Short break often occurs and makes the machine stops operating for several minutes
2. A high level of downtime is caused by machinery damage and other unexpected events.
3. High changeover times are caused by too long clean-up, set-up, and start-up times.

Based on some of the findings above, the suggestion that can be performed is by carrying out autonomous maintenance activities. Autonomous Maintenance is a machine maintenance concept that involves the production operator as the user to perform basic maintenance. The principle is that the maintenance and repairs are carried out independently by the machine operator, who has special knowledge about the machine. Its implementation is carried out with a structured approach to increase employee skill levels so that they are able to understand, manage and improve the processes and machines that are in their area of responsibility. This implementation aims to increase the knowledge, skills, and responsibilities of production operators related to the machine so that productivity will increase as a whole. Autonomous Maintenance uses a structured and documented system so that the program can run consistently. This application is expected to reduce downtime of 50%.

5.2 OEE Calculation after the Improvement

After performing Autonomous Maintenance, the latest results from OEE calculation are as follows:

Table 5.1 OEE Calculation after the Improvement

OVERALL EQUIPMENT EFFECTIVENESS WORKSHEET								
Job Tittle : Filling Machine : Universal Pack6 Line 7 Date : December 2019								OEE
OEE DATA								
Number of shifts	:	40						
Shift Duration	:	8 hours / Shift						
Shift lengsth	:	480	Minutes / day					
Short Breaks	:	80	Breaks	10	Min Each	800	Minute	
Meal Break	:	40	Breaks	30	Min Each	1200	Minute	
Down Time	:	1585	Minute		Sheduled maintenance	0	Minute	
Change Over Time	:	2000	Minute		House keeping of m/c	0	Minute	
Rework Time Duration	:	240	Minute		Total time	2000	Minute	
Planned Production Time	:	17200	Minute					
Operation Time	:	19200	Minute					
Actual Completion Time	:	18400	Minute					
Budgeted time for job	:	14400	Minute					
Actual operating Time	:	13615	Minute					
OEE CALCULATIONS								
OEE FACTORS		**CALCULATION**				**OEE**	**OEE %**	
Availability	:	Actual Operating time / Planned Production time				0,7916	79,16%	
Performance	:	Budget time / actual completion time of job				0,7826	78,26%	
Quality	:	Actual Min / (Rework Min + Actual Min)				0,9871	98,71%	
Overall OEE	:	Availability x Performance x Quality				0,6115	61,15%	
WORLD CLASS OEE								
OEE Factors		World Class Oee				My OEE		
Availability	:	90%				79,16%		
Performance	:	95%				78,26%		
Quality	:	99,90%				98,71%		
Overall OEE	:	85%				61,15%		
FORMULA								
Actual Operating Time = Planned Production Time - Total Down Time								
Planned Production Time = Plant Operating Time - Planned Down Time								
Plant Operating Time = Shift Lengh x No of Shift								
Total Down Time = Down Time + Change Over Time								

The calculation above is performed after applying the Autonomous Maintenance concept, with a more well-maintained machine condition and operator responsibility for the machine that is increasingly changing in change over time, downtime and Shortbreak.

5.3 Result

After implementing the recommendations, it is found that the overall Equipment Effectiveness of Universal Pack 6 line 7 machine is increased from 61.1% to 69.8%. The results are still below the world-class OEE, this means that there is still further scope for increased machine utilization. The following is a comparative graph:

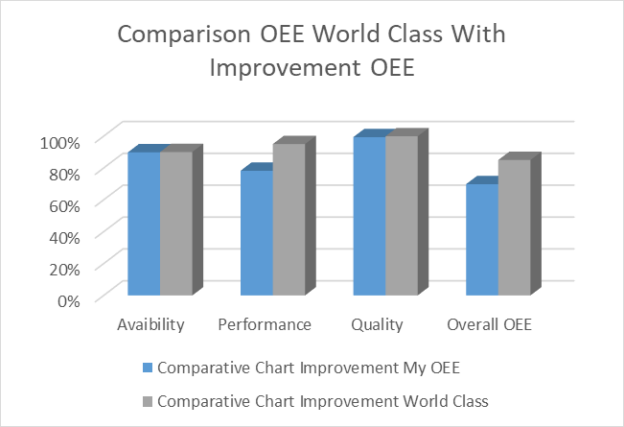

Figure 5.1 Comparative Bar Chart of World Class OEE and OEE Improvement

VI. CONCLUSION

Universal Pack 6 line 7 machine runs for 2 shifts/day or equivalent to 960 minutes. A high level of downtime is caused by damage to the engine and a high change over time. Performance measurement is very important, because it can identify any significant differences between current performance and expected output. Besides, by using OEE, we can provide solutions to minimize the differences of results to a certain level.

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