Implementation of Total Productive Maintenance (TPM) to Improve Sheeter Machine Performance

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Abstract. This paper purpose is an evaluation of TPM implementation, as a case study at sheeter machine cut size line 5 finishing department, PT RAPP, Indonesia. Research methodology collected the Overall Equipment Effectiveness (OEE) data of sheeter machine and computed its scores. Then, OEE analysis big losses, statistical analysis using SPSS 20 and focused maintenance evaluation of TPM were performed. The data collected to machine sheeter's production for 10 months (January-October 2016). The data analyses was resulted the OEE average score of 82.75%. This score was still below the world class OEE (85%) and the company target (90%). Based the big losses of OEE analysis was obtained the reduce speed losses, which most significant losses of OEE scores. The reduce speed losses value was 44.79% of total losses during the research period. The high score of these losses due to decreasing of machine production speed by operators, which intended to improve the quality of resulting products. The OEE scores statistical analysis was found breakdown losses and reduces speed losses, which significantly affected to OEE scores. Implementations of focused maintenance of TPM in the case study may need to improve because there were still occurred un-expecting losses during the research period.

1 Introduction

Companies have implemented the TPM for their production activities, which minimize losses incurred in the company. The losses incurred in the company usually originate from the production floor caused by the operator, personal care, the process, the tooling problem and the unavailability of components [1]. Other forms of losses that occur in the production floor is the idle machine condition due to the absence of operators, broken machines, rejected parts and so forth [1]. Waste is very necessary to be eliminated because it involves the sustainability of the company and the profits earned by the company. The concept of zero tolerance for waste, defect, breakdown, and zero accident is a prerequisite in the company. To implement this concept, many companies in the world adopted Total Productive Maintenance (TPM) method as their equipment management method [1]. TPM

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is an equipment management method from Japan that has been developed based on the concept of productive maintenance. TPM is an innovative approach for equipment maintenance to improve equipment effectiveness, eliminate equipment damage and promote autonomous activities for operators to maintain daily machines that involve employees. Characteristic of the TPM is autonomous maintenance that operator understands how to care on the equipment so as to reduce the breakdown on the equipment [2]. The objective of TPM is to maximize the value of Overall Equipment Effectiveness (OEE) on the equipment by eliminating the equipment failures, defects on product and accident. Improvements in the quality, productivity and creation of a more positive atmosphere in the work area are critical to implementation of the TPM concept. This improvement would affect the effectiveness of a production activity [3]. To achieve the objectives of the TPM program that can be included in 5 main areas: 1) raising awareness for all employees ranging from top management to production line workers to jointly engage in TPM implementation to improve effectiveness in the work area, 2) carry out all activities based on teamwork, 3) introducing 5S activities in the work area, 4) creating an impartial assessment system and comparison of the assessment results for each work area, 5) develop and implement sustainable management awareness of the health and safety system for employees [4].

The OEE can be defined as a measurement of the effectiveness value of equipments in term of availability equipments to be used, the performance efficiency of equipments and the ability the equipments to produce the quality products. According Ahuja & Khamba [2] stated the OEE measurement can help the production teams to improve equipment performance on actual activities of the production processes. The OEE measurement is focused on the analysis of six big losses that contribute to decreasing the effectiveness of the equipment. The six big losses are equipment failure or breakdown losses, setup and adjustment losses, idling and minor stoppage, reduce speed, defect in process and reduce yield. Therefore, based on the OEE measurement can provide information to all management and workers to determine the critical losses that may be occurred in the production process activities and take action to remove the most critical losses [2].

The OEE is one of the many benchmarks of TPM success. The OEE is the most effective measurement to encourage improvement in the work environment by continues to focus on the concept of zero waste [3]. Besides, the OEE measurement can be benchmarks of TPM success's program to improve productivity, quality, cost, delivery, safety and morale [2].

The purpose of this paper is to analyze implementation of TPM on sheeter machine cut size line 5 finishing department PT Riau Andalan Pulp and Paper. The implementation of TPM was analyzed from OEE measurement on the sheeter machine in term of availability, performance efficiency and capability to produce quality products. Furthermore, the OEE scores of the sheeter machine were computed and determined the big losses factors. The causes of the big losses can be identified by using a fishbone diagram, then, determination of action to minimize the critical losses. Finally, from the history of the monthly losses in company's case study can be analyzed the benchmarking of the TPM implementation of focused maintenance that achieved the company's target or not.

2 Literature review

2.1 Total Productive Maintenance

The TPM represents a new culture, philosophy and attitude toward for equipment or machine maintenance. Concept of TPM is a maintenance, which involves all employees,

ranging from top management to production line personnel [4]. According [5] the TPM includes participation of all sections in planning and maintaining of equipments. Based on [2] stated that the TPM encompass eight pillar i.e. autonomous maintenance, focused maintenance, planned maintenance, quality maintenance, education and training, TPM office, development management, safety, health and environment. Autonomous maintenance activities of TPM give an awareness of operators and workers to maintain the equipments or machines in respectable manner. The essence of this activity is to keep machine work and prevent equipment or machine failure during production activities. By applying TPM system, the machine on each production line can keep running which no failure occurs during the production process activities [4].

2.2 Overall Equipment Effectiveness

The Overall Equipment Effectiveness (OEE) is a method to measure the effectiveness of the use of equipment. The OEE is one of key success parameters of TPM implementation. The OEE measurement is required for continuous improvement in TPM implementation. Based on the OEE measurement is revealed the OEE scores that is used for performance measurement activities of TPM pillar implementation such as focused maintenance [5]. The OEE scores indicate whether equipment that is optimally work or not to produce a quality product by reducing losses during the production process [6]. World class standard of OEE score is 85%, which availability score rate of 90%, performance efficiency score rate of 95% and rate of quality score of 99.9% [5]. The formula of OEE is [2]:

$$OEE = Availability \times Performance\ efficiency \times Rate\ of\ quality \quad (1)$$

2.3 Big Losses

The key to success of TPM implementation is focus in minimizing losses which occur in production activities thus increasing overall production effectiveness. TPM focus to minimize six big losses that is equipment failures or breakdown losses, setup and adjustment losses, idling and minor stoppage losses, reduce speed losses, defect in process losses and reduce yield losses [2]. With focus to minimize big losses in production process, the company will get high availability of the equipment used, the equipment is able to achieve the ideal performance and product of production activities will be good [5].

2.4 Correlation and Regression

Correlation test is as statistical methods to test the strength of relation of two variables interval or ratio scales. The relation between two variables was usually denoted r , or called r Pearson. According Lind et al [7], the reason was called r Pearson, because this method was introduced Karl Pearson in 1900. The coefficient correlation has a range values between -1.0 to 1.0. Two variables have perfect correlation when the values of coefficient correlation of -1.0 or 1.0. Positive and negative symbols represent the relation between two variables has tested. And regression test as statistical method that aims to reveal the linear relation between dependent variable and independent variables. From the regression test obtained coefficient regression then can be formed into linear equation. The regression equation function is to estimate change of dependent variable value in the future to affect on the independent variables [7].

The general form of multiple regression equation is [7]:

$$Y = a + b_1X_1 + b_2X_2 + \dots + b_kX_k \quad (2)$$

Where: “a” is the intersection of Y value or Y value when all X values equal to zero. And “b” is the slope of line or average change of Y value for one unit change of X values. This regression test can be done using SPSS software.

3 Research Methods

A quantitative research method was adopted to evaluate the implementation TPM in the case study company. The OEE data was collected in sheeter machine cut size line 5 finishing department PT RAPP Indonesia, from January 2016 to October 2016. The stages of research conducted to analyze the OEE and evaluate focused maintenance of TPM that can be seen in Figure 1. Research begins by collecting data that is in the form of primary data and secondary data. The primary data was obtained from direct observation of TPM implementation in the company. The secondary data was obtained from the collection production data on sheeter machine such as time availability, plan shutdown, external shutdown, un-plan shutdown, no roll or no pack, operation speed, average speed, net production and roll used. After all the data was obtained, then the next performed processing data that was calculation of availability, performance efficiency, rate of quality, OEE scores, big losses identification, then correlation and regression test of OEE scores and big losses were performed. The problem solving of this research conducted some analysis that was analysis of OEE scores, analysis of big losses, analysis of correlation and regression of OEE scores with big losses, cause-effect analysis to identify the causing of losses from the using of sheeter machine, and evaluation of implementation of focused maintenance pillar of TPM.

The calculation of OEE used the formula (1). The availability, performance efficiency and rate of quality used formula (3), (4) and (5) below. The availability is a parameter to measure the equipment to be used in production activities in accordance with the schedule that has been planned [8]. The formula to compute the availability is [2]:

$$\text{Availability (\%)} = \frac{\text{Loading Time} - \text{Downtime}}{\text{Loading time}} \times 100 \quad (3)$$

The performance efficiency is the ratio of actual production speed of the equipment to ideal speed based on design capacity. Thus, performance efficiency will be good if the production speed can be maintained in accordance with the ideal speed of equipment [8]. Based on the calculation of performance efficiency can be seen the percentage of wasting time, which contribute to decrease the production speed on equipment [9]. The formula to compute the performance efficiency is [2]:

$$\text{Performance efficiency (\%)} = \frac{\text{Processed amount} \times \text{Ideal cycle time}}{\text{Operating time}} \times 100 \quad (4)$$

The rate of quality is a parameter of ability equipment to produce product in accordance with the standards [8]. Reworking of a reject product is considered to be one of the quality parameters. If more reject product was produced that will waste time and resource to produce the product [9]. The formula to compute the rate of quality of sheeter machine is:

$$\text{Rate of quality (\%)} = \frac{\text{Net Production}}{\text{Rollused}} \times 100 \quad (5)$$

Fig. 1. The Stages of Research Method

4 Results and Discussion

4.1 Result

4.1.1 Production data

The production data of sheeter machine cut size line 5 from January 2016 to October 2016 is as depicted in Table 1.

Table 1. Production Data of Sheeter Machine Cut Size line 5

Month	Time availability (%)	Plan shutdown (%)	External shutdown (%)	Un plan shutdown (%)	No roll or no pack (%)	Operation speed (ream/min)	Average speed (ream/min)	Net production (tons)	Roll used (tons)
January	100	2.02	0	5.11	4.17	170	156	8528	8864
February	100	2.16	0	4.45	0	170	152	8492	8740
March	100	2.02	0	4.44	0.13	170	161	9839	10188
April	100	2.08	0	8.32	0.13	170	158	9022	9378
May	100	1.48	0	2.82	0.27	170	159	10172	10550
June	100	12.36	0	5.83	0.14	170	146	7780	8075
July	100	2.02	0	8.33	0	170	155	8038	8433
August	100	2.02	0	3.23	4.17	170	161	9220	9622
September	100	1.94	0	5.69	1.39	170	156	8770	9107
October	100	2.42	0	1.48	0.13	170	155	9466	9886

4.1.2 OEE Scores

From processing data production of sheeter machine cut size line 5 was obtained the OEE scores of the machine from January 2016 to October 2016 that can be seen in Table 2.

Table 2. The OEE Scores of Sheeter Machine Cut Size Line 5 from January 2016 to October 2016

Month	Availability (%)	Performance Efficiency (%)	Quality (%)	OEE (%)
January	90.53	91.76	96.21	79.92
February	95.45	89.41	97.16	82.92
March	95.34	94.71	96.57	87.20
April	91.37	92.94	96.20	81.70
May	96.86	93.53	96.42	87.35
June	93.19	85.88	96.35	77.11
July	91.50	91.18	95.32	79.52
August	92.45	94.71	95.82	83.90
September	92.78	91.76	96.30	81.99
October	98.35	91.18	95.75	85.86

4.1.3 Big Losses Scores

Total big losses in the sheeter machine during the period of January 2016 to October 2016 can be seen in Table 3.

Table 3. The Big Losses in Sheeter Machine Cut Size Line 5 From January 2016 to October 2016

Number	Factors Losses	Total Time Loss (minutes)	Percentage (%)
1	Reduce Speed Losses	32756.68	44.79
2	Breakdown Losses	21774.88	29.78
3	Quality Losses	13920.01	19.04
4	Setup and Adjustment Losses	4675.84	6.39
Total		73127.41	100

4.1.4 Correlation and Regression

The OEE data correlation test results and big losses sheeter machine cut size line 5 is shown in Table 4. Whilst, the results of regression test of OEE data and big losses of sheeter machine cut size line 5 is shown in Table 5.

Table 4. Results of Correlation Test Using SPSS 20

		Breakdown losses	Setup and adjustment losses	Reduce speed losses	Quality losses	OEE
Breakdown losses	Pearson correlation	1	-.198	.201	-.071	-.715*
	Sig. (2-tailed)		.584	.578	.846	.020
	N	10	10	10	10	10
Setup and adjustment losses	Pearson correlation	-.198	1	-.358	.158	-.133
	Sig. (2-tailed)	.584		.309	.663	.714
	N	10	10	10	10	10
Reduce speed losses	Pearson correlation	.201	-.358	1	-.373	-.635*
	Sig. (2-tailed)	.578	.309		.289	.049
	N	10	10	10	10	10
Quality losses	Pearson correlation	-.071	.158	-.373	1	.110
	Sig. (2-tailed)	.846	.663	.289		.762
	N	10	10	10	10	10
OEE	Pearson correlation	-.715*	-.133	-.635*	.110	1
	Sig. (2-tailed)	.020	.714	.049	.762	
	N	10	10	10	10	10

Table 5. Results of regression test using SPSS 20

Model	<i>Coefficients unstandardized</i>		<i>Standardized coefficients</i>	T	Sig.
	B	Std. error	Beta		
(Constant)	99.973	.026		3895.709	.000
Breakdown losses	-1.000	.001	-.678	-876.567	.000
Setup and adjustment losses	-.998	.002	-.508	-625.230	.000
Reduce speed losses	-.999	.001	-.729	-843.728	.000
Quality losses	-.994	.006	-.129	-159.926	.000

4.2 Discussion

4.2.1 OEE Scores

From OEE calculation was obtained the average score of OEE from January 2016 to October 2016 on sheeter machine cut size line 5 of 82.75% with average score of availability was 93.78%, average score of performance efficiency was 91.71% and average score of quality product was 96.21%. The OEE score was still below the world class OEE (85%) and the company target (90%). However, the OEE scores in March, May and October obtained the higher score than word class OEE, that was 87.20%, 87.53% and 85.86% respectively. This is indicated the company has an opportunity to achieve more than word class OEE along time in the future.

4.2.2 Big Losses

From big losses calculation that most contributed to the low achievement of OEE scores was reduce speed loss, which time losses of 32576.68 minutes or 44.79 % of total time losses (73127.41 minutes), from January 2016 to October 2016. The percentage of losses contribution to OEE is shown in Pareto Diagram at Figure 2.

Fig. 2. Pareto Diagram Big Losses Sheeter Machine Cut Size Line 5

4.2.3 Correlation and Regression Analysis

From the correlation test was found the losses factors that closely affects the low scores of OEE of reduce speed losses (Pearson correlation = -0.635) and breakdown losses (Pearson correlation = -0.715). And to predict the change of OEE scores in the future, in this paper has developed a regression equation as follow:

$$Y = 99.973 - 1.000X1 - 0.998X2 - 0.999X3 - 0.994X4 \tag{6}$$

As the dependent variable is OEE (Y) and the independent variables are breakdown losses (X1), setup and adjustment losses (X2), reduce speed losses (X3) and quality losses (X4).

4.2.4 Fishbone Diagram

The critical losses on the sheeter machine during research period were “reduce speed losses”. For future improvement, based a cause-effect analysis can help to minimize the “reduce speed losses” during the research period, it is shown in Figure 3. The fishbone diagram is known effect of several factors influences to take action such as man, machine, method, environment and material. From man factor, “reduce speed losses” influenced by (1) lack of operator concentration on the production activities and (2) achieving production targets. From machines factor, “reduce speed losses” influenced by (1) damage the slitter and cross cutter, (2) resulting products were not according to quality products standard of company. From method factor, “reduce speed losses” influenced by decreasing the speed that was intended by operators to reduce the number of products reject. From environment factor, “reduce speed losses” was influenced by (1) the dust contained in the raw material and (2) wear on engine components. And from material factor, “reduce speed losses” was caused by perishable materials.

Fig. 3. Fishbone Diagram of Reduce Speed Losses

4.2.5 Evaluation of Implementation Focused Maintenance

Implementation of focused maintenance of TPM on the sheeter machine during the research period can be analyzed from the OEE scores. The OEE average score of 82.75% was less than the world class OEE (85%) and the company target (90%). This is indicated that the TPM implementations in the case study company may need to improve due to still occurred un-expecting losses during the research period. This can be seen in Figure 4, based the calculation of big losses of each month during the period of research indicated frequency occurring losses. Reduce speed losses awarded the highest losses value and followed by breakdown losses for almost each month of research period.

Fig. 4. Percentage of Big Losses of the Sheeter Machine

5 Conclusions and Recommendations

5.1 Conclusion

From the results of research on the sheeter machine cut size line 5 during the period January to October 2016 was obtained the following conclusions:

- The average of OEE score during research period was 82.75%, the OEE score still below world class OEE (85%) and the company target (90%).
- The most significant losses decreasing the OEE scores during research period was reduce speed losses with a percentage of 44.79% of the total losses and a total losses time was 32756.68 minutes.
- Statistical test results from OEE scores show significant losses was the breakdown losses and reduce speed losses. The result of the regression test was constant on 99.973 and the regression coefficient of each independent variables of breakdown losses ($X_1 = -1,000$), setup and adjustment losses ($X_2 = -0.998$), reduce speed losses ($X_3 = -0.999$) and quality losses ($X_4 = -0.994$).
- From the history of losses data each month during research period was known that implementation of focused maintenance of TPM on sheeter machine may need to improve, because there were still losses occurred during research period.

5.2 Recommendations

From this case study results, it would be recommended that company pay attention the method of decreasing speed of sheeter machine to get a good product quality in optimize manner. An optimization decision making alternative between ‘reduce speed losses’ and ‘quality losses’ needs to be analyzed breakeven point of this alternative whether it is feasible to be implemented. Decrease sheeter machine speed will be able to reduce the quality losses and otherwise. This is related to the role of the operator in operating the machine and implementation autonomous maintenance of TPM.

Finally, recommending for the company may focus more on machine maintenance such as implementation of autonomous maintenance and conduct multi-skill training for operators to improve the ability and expertise of them to tackle the existing problems to reduce OEE losses value on the machine for the future.

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