Available online at: http://publikasi.mercubuana.ac.id/index.php/ijiem

IJIEM (Indonesian Journal of Industrial Engineering & Management)

ISSN (Print) : 2614-7327 ISSN (Online) : 2745-9063

Overall Equipment Effectiveness (OEE) Analysis: A Case Study in the PVC Compound Industry

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ARTICLE INFORMATION

Article history:

Received: 17 June 2021
Revised: 5 October 2021
Accepted: 21 December 2021

Category: Research paper

Keywords:
Availability
OEE
Performance efficiency
Quality
Six big losses

A B S T R A C T

PT. Riken Indonesia is a company engaged in PVC Compound that is specially designed to meet the needs of industrial markets such as automotive construction, household electronic toys, and high quality disposable medical devices. The sample chosen was line 5 The purpose of this study was to analyze the value of OEE including the Availability, Performance rate and quality rate. The method used is Overall Equipment Effectiveness with analysis of Six Big Losses. For the analysis of six big losses to the OEE value, namely the setup & adjustment value of 86.27%, the breakdown value of 9.06%, the idling & minor stop value of 2.67%, and the defect value of 2.01%. Set up & adjustment are the main thing from the problem of six big losses, the biggest setup and adjustment is influenced by cleaning time of 61.61%, startup/shutdown of 37.65%, and adjustment of 0.74%. Based on the analysis, the Availability rate of 76.72%, a performance rate of 84.66%, and a quality rate of 99.89%. The OEE is consists of availability rate, performance rate and quality rate, the OEE value was 64.88%, which means it was below the standard value that is 85%. So it can be said that the engine performance in line 5 PT. Riken Indonesia has not been effective and requires maintenance or continuous improvement.

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1. INTRODUCTION

In this era of globalization, there are no longer barriers between countries in the world, including competition in the industrial world. Thus, the competition is getting tougher. Many companies are starting to look for alternative advantages to increase company profits. Every company must constantly make continuous improvements to compete with competitors, especially in the production line. With improvement efforts, the company can survive and achieve the goals and objectives that have been set. To support the manufacturing system, the performance of the equipment used must be considered so that it can be used optimally in the company. In general, problems with production facilities that cause production to be interrupted or stopped can be categorized into three, namely, human, machine, and environmental factors. These three things can affect one another. One way to solve production facility problems and support increased productivity is to do an intensive evaluation and maintenance of production equipment (machines) to be used optimally.

According to (Nakajima, 1988) OEE is a method for measuring the effectiveness of using equipment or systems by including various points of view in the calculation process. OEE is a method used as a metric measurement tool in implementing the TPM program to keep equipment in ideal conditions by eliminating Six Big Losses of equipment (Gupta & Vardhan, 2016). Also, to measure the performance of a productive system (Rusman et al., 2019). Identifying the root of the problem and the factors causing it to focus on improving efforts is the main factor in this method being applied extensively by many companies in the world (Setiawan, 2021).

2. LITERATURE REVIEW

Seiichi Nakajima coins Overall Equipment Effectiveness (OEE) in 1960 to evaluate how effectively manufacturing operations are used. This is based on Harrington Emerson's way of thinking about labor efficiency (Rozak et al., 2020). Understanding OEE is a calculation carried out to determine the extent of an existing machine or equipment's effectiveness. OEE is one of the methods included in Total Productive Maintenance (TPM) (Kwaso & Telukdarie, 2018) (Sharma et al., 2018) (Purba et al., 2018) (M.Méndez & Rodriguez, 2017).

Generally, OEE is used as an indicator of the performance of a machine or equipment. According to (Nakajima, 1988) OEE is a method of measuring the level of effectiveness of using equipment or system by including several points of view in the calculation process. Meanwhile, according to (Sukma et al., 2021) OEE is the level of overall facility effectiveness obtained by taking into account availability, performance efficiency, and rate of a quality product. OEE is a measurement of the effectiveness of using a machine/ equipment by calculating machine availability, performance, and product quality (Fadhilah et al., 2020). OEE as a performance indicator, takes a certain time base period, such as shiftly, daily, weekly, monthly, or yearly. OEE measurement is more effectively used on production equipment (Sen et al., 2019) (Suryaprakash et al., 2020). OEE can optimize equipment performance through a systematic approach to determine performance targets through a balanced increase in process availability, performance, and quality (Winatie et al., 2018). The consistent implementation of OEE can increase the productivity and effectiveness of equipment (Sutoni et al., 2019) (Prabowo & Adesta, 2019).

The world has also recognized Overall Equipment Effectiveness (OEE) to measure the level of machine effectiveness. The assessment related to the OEE value following the global standard is 90% for the availability rate, 95% for the performance rate, and 99% for the quality rate. The excellent OEE value of the equipment is 85%. Too long setup time, breakdown, reject and rework are part of the six big losses (Tsarouhas, 2019).
Availability (A) is a ratio that describes the use of the time available for machine and equipment operating activities. Availability is the operation time ratio by eliminating equipment downtime to loading time (Hervian & Soekardi, 2016) (Patil et al., 2018). So, the Availability formula as follows:

$$A = \frac{Loading\ Time - Down\ Time}{Loading\ Time}\ x\ 100\% \quad (1)$$

Performance efficiency (PE) is a ratio that describes the ability of the equipment to produce goods. This ratio results from the operating speed and net operating rates (Fam et al., 2018). This ratio measurement formula as follows :

$$PE = \frac{Ideal\ Cycle\ Time - Process\ Amount}{Operating\ Time}\ x\ 100\% \quad (2)$$

The rate of product quality (ROPQ) is a ratio that describes equipment's ability to produce products that comply with standards (Nurprihatin et al., 2019). The formula used for measuring this ratio as follows:

$$ROQP = \frac{Processed\ Amount - Defect\ Amount}{Processed\ Amount}\ x\ 100\% \quad (3)$$

According to (Nakajima, 1988) can be calculated as follows :

$$Quality\ Rate = Availability\ x\ Performance\ x\ Quality \quad (4)$$

Benefits of Overall Equipment Effectiveness (OEE) is used OEE as a performance indicator takes a certain time base period, such as shift, daily, weekly, monthly, or yearly. OEE measurement is more effectively used in production equipment. OEE can be used at several types of levels in a company environment, including: (a) OEE can be used as a benchmark to measure the company's plan in performance, (b) The OEE value, an estimate of a production flow, can compare the company's cross-line performance, showing that the flow is not essential (Hervian & Soekardi, 2016) (Kumar et al., 2016).

According to (Denso, 2006) that the biggest factor for low OEE values such as Problems that often occur in machines are dirty machines, abandoned equipment, missing nuts and bolts, oil that has not been replaced, engine leaks, abnormal sounds, excessive engine vibration, filters that have not been replaced, and others. . This is due to the lack of involvement of production operators in machine maintenance and tend to hand over machine maintenance to maintenance. In the concept of Total Productive Maintenance (TPM), the main problem that the production team must solve is Six Big Losses. For the analysis of six big losses to the OEE value, namely the setup & adjustment value of 86.27%, The problem of Six Big Losses such as Breakdown Losses, Set-Up/ Adjustment Losses, Idling And Minor Stoppages Losses, Reduce Speed Losses, Rework losses and Reduced yield/ scrap losses. Suppose the machining process is carried out individually. In that case, OEE can identify which machines are performing poorly, even identifying the focus of TPM resources. The company must conduct training for all employees and operators and provide an understanding of the importance of work ethics and discipline in the work environment. The OEE calculation will produce a value availability, performance, and quality. These three values are used in minimizing losses. Losses are six losses that must be avoided by every company that can reduce the effectiveness of a machine (Prabowo et al., 2018) (Fam et al., 2018) (Sharma et al., 2018) (Nasir et al., 2019)**.**

3. RESEARCH METHOD

The research method carried out is represented in the research study framework, as shown in Fig. 1.

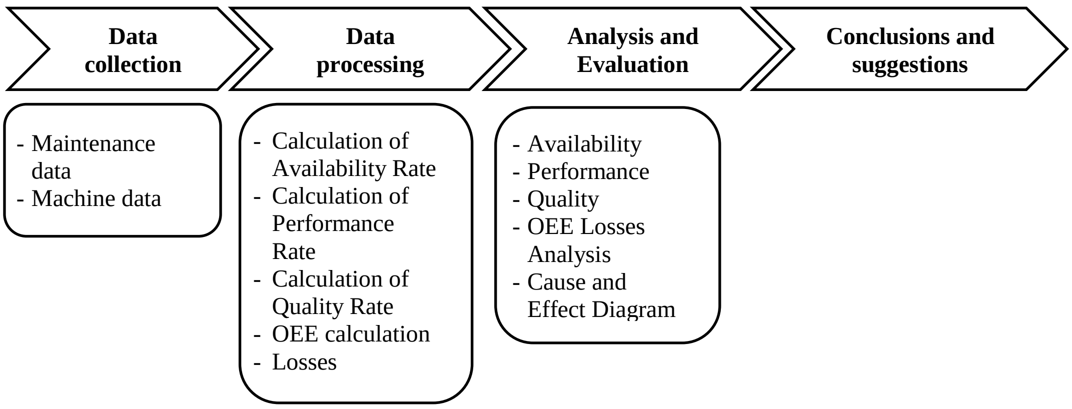

Fig. 1. Study framework

4. RESULT AND DISCUSSION

4.1 Data Collection

At Riken Indonesia, machine working hours are divided into 3, namely Effective Working Hours, Production Idle Hours, and Company Idle Hours. Effective Working Hours is the number of machine operating hours planned for an entire month (Total Machine Working Hours) minus Production Idle Hours and Company Idle Hours. Production Idle Hours is the time spent setting up or shut down, maintenance, repair, Trouble, defects, and adjustments. Company Idle Hours is the time used for company interests such as praying (Friday prayers), ceremonies, and other company activities. Data on Effective Working Hours, Production Idle Hours, and Company Idle Hours on the G5 Line from January to December 2020 are presented in Table 1.

Table 1. Data on effective working hours, production idle hours and company idle hours

Month	Working Hours	Production Idle Hours	Company Idle Hours	Effective Hours
January	550	49	23	478
February	530	41	40	450
March	481	49	54	378
April	563	49	138	376
May	567	23	229	315
June	597	42	215	341
July	720	52	124	544
August	744	70	147	527
September	696	68	4	624
October	540	72	4	464
November	525	77	4	444
December	479	51	3	424
Total	6,992	644	984	5,364
Average	583	54	82	447
Percentage	100%	9%	14%	77%

From the data above, it can be seen that the average every month in 2020 Effective hours is only 77%, Company Idle hours is 14%, and Idle production hours is 9%. Production Idle Hours and Company Idle Hours data on Line G5 from January to December 2020 are presented in Table 2.

Table 2. Data production idle hours on the G5 line in 2020

Month	CL	RP	DF	AJ	TR	MT	SU/SD	Total
January	27.8						21.7	49.4
February	30.2						10.4	40.6
March	26.6			0.7			21.4	48.7
April	21.6						27.9	49.5
May	14.0	1.7				1.0	6.6	23.3
June	24.6	1.5		1.0	0.5	1.0	12.9	41.5
July	39.8	1.0			0.5	2.5	8.5	52.3
August	31.7				27.0	3.0	8.0	69.7
September	44.7			0.3	6.3	3.0	14.1	68.3
October	28.0	0.5			14.0		29.8	72.3
November	28.4	2.0	11.8	1.1	10.1		23.8	77.2
December	25.0		1.2	1.0			24.0	51.2
Total	342.3	6.7	12.9	4.1	58.3	10.5	209.2	643.9
Average	28.5	0.7	1.6	0.5	8.3	0.9	17.4	53.7
Percentage	53%	1%	3%	1%	16%	2%	32%	100%

Based on Table 2, it is known that the cause of the biggest Production Idle Hours is due to the cleaning process by 53%, Start-Up / Shutdown by 32%, and Trouble by 16%. Meanwhile, Company Idle Hours data on Line G5 from January to December 2020 is presented in Table 3.

Table 3. Data company idle hours on the line G5 for 2020.

Month	Order Waiting	Praying/ Company Act	T o t a l
January	16.0	7.0	23.0
February	35.5	4.0	39.5
March	50.0	4.0	54.0
April	135.0	3.0	138.0
May	228.0	1.0	229.0
June	212.5	2.0	214.5
July	120.0	4.0	124.0
August	144.0	3.0	147.0
September	-	4.0	4.0
October	-	4.0	4.0
November	-	4.0	4.0
December	-	3.0	3.0
Total	941.0	43.0	984.0
Average	78.4	3.6	82.0
Percentage	96%	4%	100%

Based on Table 3, it is known that the cause of the biggest Company Idle Hours is because of order waiting of 96%, the remaining 4% is used for friday prayers. The amount of order waiting occurred because of the Covid-19 Pandemic from January to August.

4.2 Data processing

Before calculating the OEE, we will first look for the values of the factors that make up OEE After knowing each value of the OEE forming factor, the OEE value can be calculated by multiplying the three factors, then calculating the value of losses to be more specific to determine the most significant loss affecting the low value of the OEE element. The following is data processing for the calculation of Availability, Performance, and Quality.

4.2.1 Calculation of Availability Rate

Availability Rate is a ratio that shows the use of the time available for machine operation activities. The data used in measuring the availability rate are production time and downtime. The formula used to find the availability rate is:

$$Availability\ Rate = \frac{Effective\ Hours}{Total\ Working\ Hours}\ x\ 100\%$$

Table 4. Data on the value of availability rate in line G5 in 2020

Month	Total Working Hours (Hrs)	Production Idle Hours (Hrs)	Company Idle Hours (Hrs)	Effective Hours (Hrs)	Availability Rate
January	550.00	49.42	23.00	477.58	86.83%
February	530.00	40.59	39.50	449.91	84.89%
March	481.00	48.67	54.00	378.33	78.66%
April	563.00	49.50	138.00	375.50	66.70%
May	567.00	23.25	229.00	314.75	55.51%
June	597.00	41.50	214.50	341.00	57.12%
July	720.00	52.33	124.00	543.67	75.51%
August	744.00	69.67	147.00	527.33	70.88%
September	696.00	68.33	4.00	623.67	89.61%
October	540.00	72.33	4.00	463.67	85.86%
November	525.00	77.17	4.00	443.83	84.54%
December	478.50	51.17	3.00	424.33	88.68%
Total	6,991.50	643.92	984.00	5,363.58	76.72%
Average	582.63	53.66	82.00	446.97	76.72%

4.2.2 Calculation of Performance Rate

Performance Rate is a ratio that shows the ability of the equipment to produce goods. The data used in measuring the performance rate are output, actual-ideal time, operating time and the formula used to find the performance rate is:

$$Performance\ Rate = \frac{Output\ x\ Ideal\ Cycle\ Time}{Effective\ Working\ Hours}\ x\ 100\%$$

Table 5. Data on the value of the performance rate on the G5 Line in 2020

Month	Output (Kgs)	Ideal Cycle Time	Effective Hours	Performance Rate
January	624	0.7143	527	84.69%
February	545	0.7143	450	86.45%
March	475	0.7143	378	89.76%
April	461	0.7143	376	87.70%
May	396	0.7143	315	89.89%
June	417	0.7143	341	87.43%
July	631	0.7143	544	82.95%
August	571	0.7143	527	77.38%
September	732	0.7143	624	83.80%
October	548	0.7143	464	84.49%
November	493	0.7143	444	79.39%
December	462	0.7143	424	77.81%
Total	6,357	0.7143	5,364	84.66%
Average	530	0.7143	447	84.66%

4.2.3 Calculation of Quality Rate

Quality Rate is a ratio that shows the ability of the equipment to produce products that comply with standards. The data used in measuring the quality rate is output data in good, reject and rework products. The formula used to find the quality rate is:

$$Quality\ Rate = \frac{Output - Reject}{Output}\ x\ 100\%$$

Table 6. Quality rate value data on the G5 Line 2020

Month	Total Product (Ton)	Defect Product (Ton)	Good Product (Ton)	Quality Rate
January	624.4	-	624.4	100.00%
February	544.6	-	544.6	100.00%
March	475.4	-	475.4	100.00%
April	461.0	-	461.0	100.00%
May	396.1	-	396.1	100.00%
June	417.4	-	417.4	100.00%
July	631.3	-	631.3	100.00%
August	571.2	-	571.2	100.00%
September	731.7	-	731.7	100.00%
October	548.4	-	548.4	100.00%
November	493.3	6.5	486.8	98.68%
December	462.3	0.5	461.8	99.89%
Total	6,357.2	7.0	6,350.2	99.89%
Average	529.8	0.6	529.2	99.89%

4.2.4 Calculation of OEE

OEE is the result of multiplying the Availability, Performance, and Quality elements, so the formula used to calculate the OEE value is:

$$Quality\ Rate = Availability\ x\ Performance\ x\ Quality$$

Table 7. Overall equipment effectiveness (OEE) value data in the G5 Line 2020

Month	Availability Rate	Performance Rate	Quality Rate	OEE
January	86.83%	84.69%	100.00%	73.54%
February	84.89%	86.45%	100.00%	73.39%
March	78.66%	89.76%	100.00%	70.60%
April	66.70%	87.70%	100.00%	58.49%
May	55.51%	89.89%	100.00%	49.90%
June	57.12%	87.43%	100.00%	49.94%
July	75.51%	82.95%	100.00%	62.63%
August	70.88%	77.38%	100.00%	54.84%
September	89.61%	83.80%	100.00%	75.09%
October	85.86%	84.49%	100.00%	72.55%
November	84.54%	79.39%	98.68%	66.23%
December	88.68%	77.81%	99.89%	68.93%
Total	76.72%	84.66%	99.89%	64.88%
Average	76.72%	84.66%	99.89%	64.88%

4.3 Discussion and Analysis of Overall Equipment Effectiveness (OEE) Values

Overall Equipment Effectiveness (OEE) is a method that can be used to measure machine effectiveness based on measuring three main ratios, namely: availability, performance efficiency, and rate of quality. By knowing the value of the effectiveness of the machine, it can be seen how much the loss affects the effectiveness of the machine, known as six big losses in equipment .

Availability is an indicator that shows machine reliability, how long the machine has downtime and how long it takes for setup and adjustments. As seen in table 4, the availability rate value of the G5 machine is between 55.51% to 89.61%, with an average of 76.72%, and overall is still below the ideal availability value (90%). The low availability rate, especially from April to August, was due to the stop machines waiting for orders. Apart from this, the low value of availability rate is also influenced by the value of Downtime losses and the value of Speed Losses which is almost the same every month.

To increase the value of the availability rate, the value of downtime and the value of speed losses must be controlled. The company, idle hour value will decrease by itself when the Covid-19 pandemic ends.

Performance is an indicator of how well the equipment is working at its standard speed. The performance rate value of the G5 engine is as shown in Table 5. It is between 77.38% to 89.89%, with an average of 84.66%, and overall it is still below the ideal performance efficiency value (95%). From the distribution of these values, it can be seen that the G5 engine has not worked at the speed set by the company. To increase the value of the performance rate, it is necessary to improve the value of Speed Losses, namely by reducing the idling factor & minor stoppage losses and reduced speed losses.

Quality rate is an indicator of how much scrap or rework is in a process. The value of the product quality rate in the G5 machine is between the value of 98.68% to 100.00%, with an average of 99.89%. Overall is above the ideal rate of quality products value (99%). In this case, the G5 machine produces products according to predetermined specifications. Even all data shows that every month the G5 engine has Quality Rate values above the specified standards.

The Overall Equipment Effectiveness value of the G5 engine is between the values of 49.90% to 75.09%, with an average of 64.88%. This OEE value is obtained from the multiplication of 3 factors, namely the availability rate of 76.72%, the performance rate of 84.66% and the quality rate of 99.89%. Meanwhile, the minimum standard value for Overall Equipment Effectiveness set by the Japan Institute of Plant Maintenance is 85%. Each factor, namely availability of 90%, performance of 95% and quality rate of 99%. Based on the OEE value of the G5 engine and the minimum OEE value standard that the

Japan Institute of Plant Maintenance has implemented, it can be seen that the OEE factor value that has passed the standard is a quality rate of 99.89%. Meanwhile, the availability rate and performance rate do not meet the standard. So it is necessary to evaluate the factors that cause the low OEE value on availability and performance by reducing the idling factor and minor stoppage losses and speed losses.

Based on the research above, shows the level of availability of results is 76.72%, the performance level of 84.66%, the quality level is 99.89% and the OEE value is 64.88%. Based on the three variables, only the value availability and value performance are still below global standards so that they greatly affect the OEE value. To increase the OEE value, an evaluation of the availability rate and performance rate must be carried out. The solution for the availability rate, namely the value of downtime and the value of speed losses, must be controlled and the idle hour value of the company will decrease by itself when the Covid-19 pandemic ends. The solution for this level of performance is that it is necessary to improve the value of the speed loss, namely by reducing the idling factor & minor stopping losses and reducing the speed loss. The following are improvements that can be made by Pt. Riken Indonesia

4.3.1 Determining Standard Cleaning Time

The standard must determine the cleaning process at each product change, what is the maximum time used for the cleaning process. Legal determination can be made based on the physical and chemical properties of the product to be made.

4.3.2 Determine the sequence of the production process

The sequence of the production process will determine the amount of cleaning time performed. Products with the same physical, chemical, and color characteristics certainly do not require a long cleaning time.

4.3.3 Production with a minimum batch

The greater the quantity of product produced, the less cleaning process is carried out. It is recommended to make in large amounts. This is concerned with planning a production schedule based on orders from customers and delivery times.

4.3.4 Use of oil heater to replace steam

Start-up for heating the engine using steam requires a relatively short time, which is about 2 hours compared to heating using oil. However, at the time of product changeover, heating using steam takes a long time to stabilize according to the conditions specified. In total, a start-up with steam heating takes a long time compared to heating using oil. However, this replacement requires a large amount of money.

4.3.5 Production schedule setting

Production planning based on stock orders is needed to avoid repeated production with the production quantity according to the estimated order from the customer. It is recommended to get an estimated order from the customer at least one month ahead.

4.4 Discussion and Analysis of Six Big Losses

Six Big Losses can be considered as common factors that cause ineffectiveness on machines. The six factors are breakdown loss, setup and adjustment loss, idling and minor, stoppage loss, reduced speed loss, rework loss, and scrap loss. Based on the OEE value, it is necessary to evaluate the factors that cause the low OEE value, especially on availability and performance. Therefore, an analysis of Six Big Losses is carried out, so we will find out what factors influence the low value of the OEE. The following Six Big Losses can be seen in Fig. 2.

.**Table 8.** Six big losses data from January to December 2020

Month	Breakdown	Set-Up & Adjustment	Idling & minor stop	Defect	Total
January	-	49.42	-	-	49.42
February	-	40.59	-	-	40.59
March	-	48.67	-	-	48.67
April	-	49.50	-	-	49.50
May	-	20.58	2.67	-	23.25
June	0.50	38.50	2.50	-	41.50
July	0.50	48.33	3.50	-	52.33
August	27.00	39.67	3.00	-	69.67
September	6.25	59.08	3.00	-	68.33
October	14.00	57.83	0.50	-	72.33
November	10.08	53.33	2.00	11.75	77.17
December	-	50.00	-	1.17	51.17
Total	58.33	555.50	17.17	12.92	643.92
Average	4.86	46.29	1.43	1.08	53.66
Percentage	9.06%	86.27%	2.67%	2.01%	100.00%

Based on Table 8, it can be seen that only four losses occurred from six big losses, namely Breakdown, Set Up & Adjustment, Idling & minor stoppage and Defect. The breakdown loss value was 9.06%, the setup and adjustment loss value was 86.27%, the idling and minor stoppage value was 2.67%. The defect loss value was 2.01%. From this value, it can be seen that the setup and adjustment loss factor is the factor with the largest value.

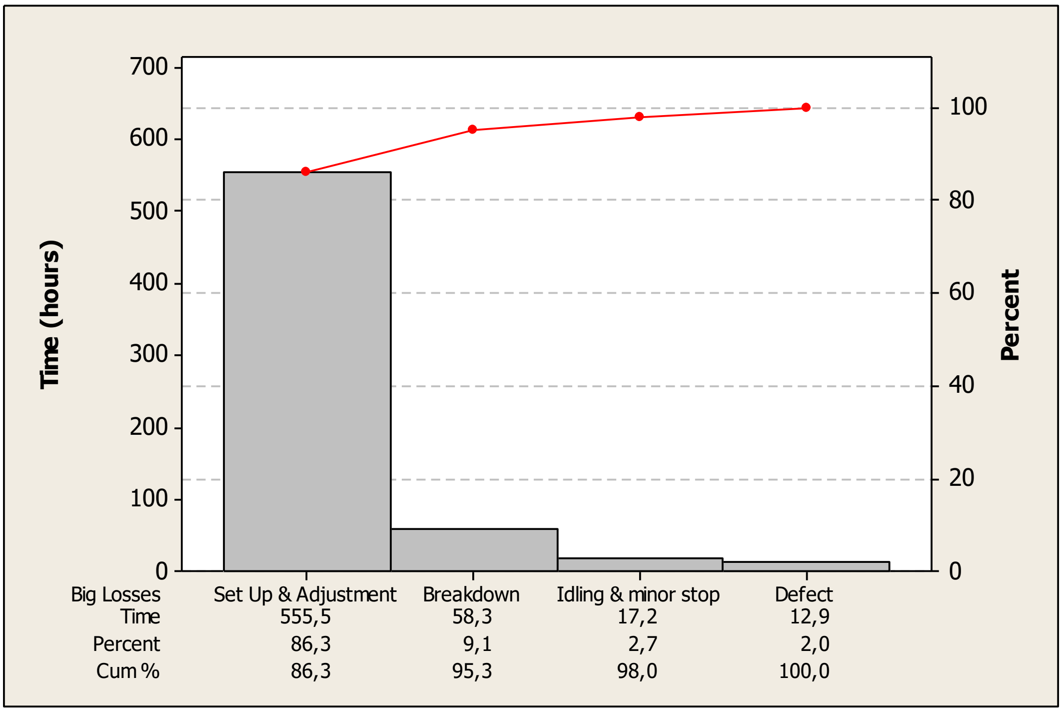

Fig.2. Pareto chart six big losses

Data processing using Pareto diagrams can help determine the causes of the biggest losses. Based on the Pareto chart, the biggest value of six big losses is Set Up & Adjustment loss, 86.27%. The setup & adjustment loss itself is a combination of 3 losses in the G5 engine: cleaning time, startup & shutdown, and adjustment.

Based on Table 9, it can be seen that the cleaning process is the biggest loss for Set-Up & Adjustments, which is 61.61%, then Start-Up/ Shutdown is 37.65%, and Adjustments is 0.74%. For the analysis of six major losses to the OEE value, namely the setup & adjustment value of 86.27%, the breakdown value of 9.06%, the idling & minor stop value of 2.67%, and the defect value 2.01%. Set up & adjustment is the main thing from the problem of six big losses, the biggest setup and adjustment, by cleaning time of 61.61%, startup/shutdown 37.65%, and adjustment of 0.74%. The following Pareto chart Set Up & Adjustment Losses can be seen in Fig. 3.

Table 9. Data set-up & adjustment losses from January to December 2020

Month	Cleaning Time	Start Up / Shutdown	Adjustment	Total
January	27.8	21.7		49.42
February	30.2	10.4		40.59
March	26.6	21.4	0.7	48.67
April	21.6	27.9		49.50
May	14.0	6.6		20.58
June	24.6	12.9	1.0	38.50
July	39.8	8.5	-	48.33
August	31.7	8.0	-	39.67
September	44.7	14.1	0.3	59.08
October	28.0	29.8	-	57.83
November	28.4	23.8	1.1	53.33
December	25.0	24.0	1.0	50.00
Total	342.25	209.17	4.08	555.50
Average	28.52	17.43	0.51	46.29
Percentage	61.61%	37.65%	0.74%	100.00%

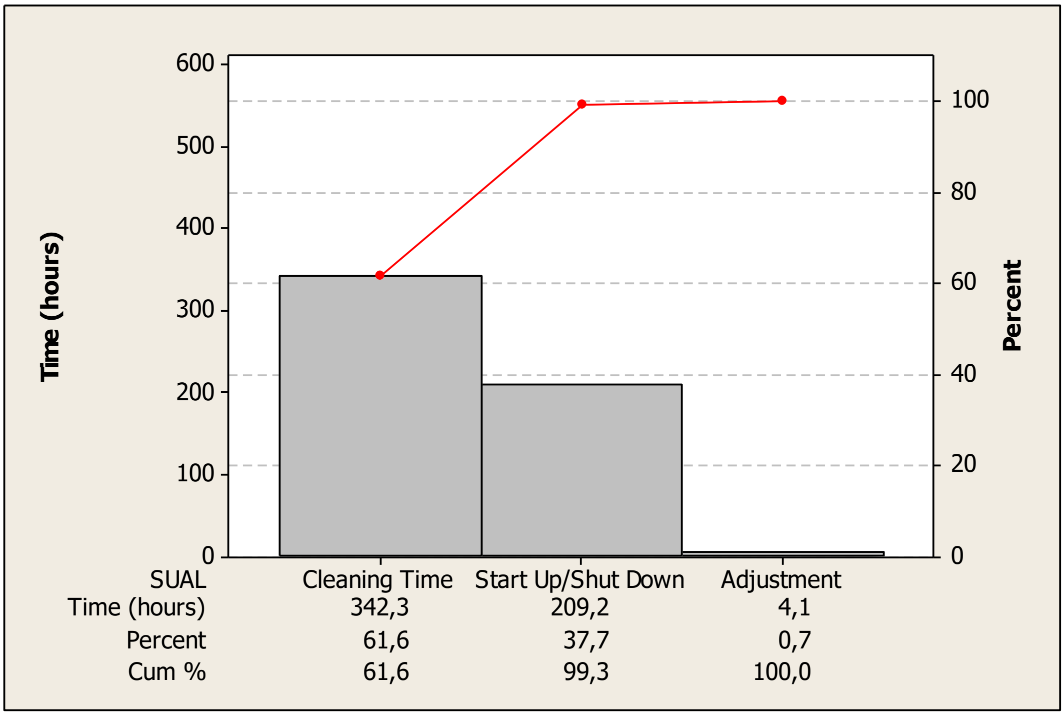

Fig. 3. Pareto chart set up & adjustment losses

5. CONCLUSION

This study has analyzed the OEE value on line 5. Based on the calculation, the company's OEE value was 64.88%, which means it was below the standard value that is 85%. So it can be said that the engine performance in line 5 PT. Riken Indonesia has not been effective and requires maintenance or continuous improvement. Based on the analysis of Six Big Losses, ss is the biggest factor that affects the low OEE value. In future research, it is possible to increase the value of OEE by implementing eight pillars of Total Productive Maintenance.

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