Website: https://jsiems.id/index.php/sustainability

OPEN ACCESS

Online ISSN : **2961-7324**

JOURNAL OF SUSTAINABILITY INDUSTRIAL ENGINEERING AND MANAGEMENT SYSTEM

Volume. 01, Issue. 01, 2022

Paper Type: Research Article

Machine Maintenance Planning Using the Reliability Centered Maintenance (RCM) Method at PT Perkebunan Nusantara XIV Camming Sugar Factory in Bone Regency

Sulkifli[1*], Dirgahayu Lantara[2*], Muhammad Fachry Hafid

[1,2,3] Jurusan Teknik Industri, Fakultas Teknologi Industri, Universitas Muslim Indonesia, Makassar, Indonesia.
Email Address: timahasiswaftiumi18@gmail.com[1*], dirgahayu.lantara@umi.ac.id[2*], muh.fachryhafid@umi.ac.id[3*]

*Corresponding author: dirgahayu.lantara@umi.ac.id

Received: October 15, 2022 Revised: October 29, 2022 Accepted: October 30, 2022

DOI: https://doi.org/10.56953/jsiems.v1i1.9

Abstract

Purpose: Frequent damage to the mill roll machine at the mill station and the absence of special attention to scheduling repairs, this research is expected to make scheduled maintenance intervals and maintenance strategies for mill roll machines at the mill station to reduce downtime and anticipate sudden downtime on the machine.
Design/methodology/approach: This study uses the Reliability Centered Maintenance (RCM) method approach to create the most efficient maintenance program by eliminating unnecessary maintenance activities, reducing overhaul frequency, minimizing downtime, minimizing the risk of sudden failure, focusing maintenance on critical components, and improving component reliability.
Findings: The results of this study show that there are two strategies used in mill roll machine maintenance, namely preventive maintenance, and corrective maintenance.
Research limitations/implications: This study focuses on critical components that often experience damage to the mill roll machine, namely standard milk check, feeder roll, scrapper, and chute components, and does not consider the cost aspect.
Practical implications: The results of this study provide input to the company's interval time scheduling and machine maintenance strategy.
Originality/value: This research was conducted in the production department of the milling station at PT Perkebunan Nusantara XIV Camming Sugar Factory in Bone Regency, where the production results include white crystal sugar, blotong, and molasses. Research to analyze machine reliability, minimize downtime and propose maintenance schedules and SOPs for maintaining production machinery at Camming Sugar Factory.
Keywords: Preventive Maintenance, Corrective Maintenance, Reliability Centered Maintenance (RCM).

1. Introduction

The production process of a manufacturing company is an important factor that must operate consistently to produce optimal efficiency. The continuity of the production process requires machine support to operate optimally. Planned maintenance is very important for the normal functioning of the company's production machinery because production machinery is very susceptible to damage. Damage to production machinery can cause downtime. Production activities reduce product quality and even threaten worker safety (Firmansyah & Nurhalim, 2020).

PT Perkebunan Nusantara (PTPN) XIV Camming Sugar Factory (PGC) is a company that produces sugar supported by several interrelated machines and equipment to produce products. The machines and equipment strive to work effectively and efficiently to achieve the company's target. PTPN XIV PGC requires an optimal production process to meet the high domestic sugar demand. The sugar production process, in general, consists of the process of weighing sugar cane, cutting and chopping sugar cane, milling sugar cane, weighing sugar cane juice, heating the juice, processing the pH of the juice, separating dirty and clean juice, evaporation, crystallizing sugar, separating crystals from drops, and drying and cooling sugar. Thus, the plant system arrangement of PGC production machines is serial. If one of the machines is damaged, the entire production process will stop (downtime) (Soewardi & Wulandari, 2019).

Currently, at the mill station, there are three mill roll machines ready to operate, and the one to be studied is the second mill roll machine because it often experiences downtime. Damage to production machines causes a high level of machine downtime. Data on machine downtime that occurred in the company from 2019 to 2021 can be seen in Table 1.1.

Table 1. Downtime of PGC Production Machines for the 2019-2021 Period

Year	*Downtime* (Hour)	Milling Period (Hour)	*Downtime* (%)
2019	701	3804	18,42
2020	476	4128	11,53
2021	561	3672	15,27

Source: PT Perkebunan Nusantara XIV Camming Sugar Factory

Based on the table above, the average machine downtime from 2019 to 2021 reaches 15.07% for each year. The amount of downtime value that reaches 15.07% shows that the downtime problem has become a serious problem faced by the company.

The company's downtime is caused by various failures and disruptions in production machine components that cause damage to the machine's working system. The damaged production machines are cane cutter, hummer shredder, and mil roll machine. Machine damage includes wear problems on Disc components, Scrapper Plate (wiper plate), Bearing (bearing component), jamming problems on rotor and plate components, improper installation problems on nut and bolt parts, freed handles, and Standard Mill Check (Zein et al., 2019).

Production machine breakdowns harm business activities due to delays in production progress and company production activities. Production delays can lead to a decrease in production floor productivity. Machine failure or damage can also result in the low ability or usefulness of the machine to produce products that meet established quality standards (Supriyadi et al., 2018).

The company's maintenance system so far is corrective maintenance, where the company only repairs in the event of damage by finding damaged components and replacing them with new ones. The company does not determine the steps to detect the first signs of machine failure.

The corrective maintenance system does not take into account the reliability factor of the production machine, so the company only replaces damaged components without paying attention to reliability (Firmansyah & Nurhalim, 2020). In addition, the company also does not have a clear maintenance Standard Operating Procedure (SOP), so when damage occurs, the company requires time that should be reduced to identify damage and repair it.

Therefore, research is needed to analyze machine reliability, minimize downtime and propose maintenance schedules and SOPs for maintaining production machinery at Sugar Factory Camming. The method used is the reliability-centered Maintenance (RCM) method. RCM is a method for defining maintenance tasks that will ensure reliable system design. RCM is used to fix the root cause of failure, leading to maintenance decisions focusing on preventing frequent failure types. RCM can provide a condition-based framework for planning that is effective, applicable, and potentially the best choice in tuning or developing an optimal maintenance model (Sajaradj et al., 2019).

The benefits of the RCM approach include the following (Supriyadi et al., 2018):

- Creating the most efficient maintenance program by eliminating unnecessary maintenance activities.
- Reducing overhaul frequency.
- Minimizing downtime.
- Minimizing the risk of sudden failure.
- Focusing maintenance on critical components and improving component reliability

2. Literature Review

2.1. Definition of Maintenance

Maintenance is defined as an activity carried out to maintain and maintain facilities to prevent and reduce or avoid damage from equipment to obtain a satisfactory state of equipment operation as expected. Maintenance can extend the life of equipment facilities and ensure the operational readiness of equipment to ensure its users' safety and security (Zein et al., 2019).

The implementation of machine maintenance and machine facilities is expected so that the machine can perform its function properly so that the equipment operation process can run smoothly, and the machine life is attempted to exceed its depreciation life. Maintenance can be in the form of replacing components or conducting a comprehensive examination within a certain period (Rislamy et al., 2020).

Maintenance has the main objective of maintaining the reliability of a machine so that the machine can always function properly. Machines that are used continuously will decrease the machine function (Afiva et al., 2019).

According to (Antony Corder, 1992) in (Bangun et al., 2014), The main objectives of maintenance include:

a. To extend the useful life of assets (i.e., any part of a workplace, building, and its contents).
b. To ensure optimum availability of equipment installed for production or services and get the maximum possible return on investment.
c. To ensure the operational readiness of all equipment required in case of emergency at any time, e.g., backup units, fire, and rescue units, etc.
d. To ensure the safety of people using the facility.

2.2. Maintenance Classifications

a. According to (Praharsi et al., 2015)preventive maintenance is carried out on a scheduled basis, generally periodically, where a set of maintenance tasks such as inspection and repair, replacement, cleaning, lubrication, adjustment, and equalization are carried out.
   There are four fundamental factors in deciding the application of preventive maintenance (Denur et al., 2017):
   a) Prevent the occurrence of failure.
   b) Detect failure.
   c) Uncover hidden failures.
   d) Do nothing because it is more effective than replacement.

   According to (Prihastono & Prakoso, 2017), preventive maintenance activities carried out by the company are divided into two, namely:
   a) Routine Maintenance
   b) Periodic Maintenance
b. Predictive Maintenance is defined as a measurement that can detect system degradation so that the cause can be eliminated or controlled depending on the physical condition of the component. Predictive maintenance differs from preventive maintenance by being based on maintenance needs on the actual condition of the machine rather than on a predetermined schedule (Hadi et al., 2020).
c. Corrective maintenance is also defined as maintenance that consists of actions to restore the condition of a system or product that is damaged or fails to operate back to operating conditions. The action is usually in the form of repair of damaged components or replacement of damaged components. Repair maintenance is usually carried out in the event of a sudden and usually unplanned failure (Rambuna, 2019).

   Corrective maintenance must be done so that the machine can be used again immediately. Problems arise when only certain maintenance operators can perform corrective maintenance on specific machines. Thus, a best practice document for corrective maintenance activities is needed based on the knowledge possessed by maintenance operators. This is useful to speed up the corrective maintenance process so that it does not only depend on certain operators and prevent the loss of knowledge as a company asset (Atma et al., 2017).
d. Schedule Maintenance This maintenance is carried out within a certain time frame according to a predetermined schedule. This treatment is based on experience or recommendations from the manufacturer of the machine or equipment concerned (Zein et al., 2019).
e. Breakdown Maintenance can be interpreted as a maintenance policy using machines/equipment operated until damaged, then only repaired or replaced. This policy is a very rough and unfavorable

strategy because it can lead to high costs, loss of opportunities to take advantage of the company due to the stoppage of the machine, work safety is not guaranteed, the condition of this machine is unknown, and there is no good time, labor, or cost planning (Iqbal, 2017).

2.3. Reliability Centered Maintenance

Reliability Centered Maintenance (RCM) is a logical engineering process for determining maintenance tasks that will ensure a system design reliability with specific operating conditions in a specific operating environment (Ebeling, 2019). 5 The biggest emphasis in RCM is to realize that the consequences or risks of failure are far more important than the engineering characteristics themselves. RCM can be defined as a process used to determine what must be done to ensure that some physical assets can normally run to perform the functions they are intended to use in the context of current operations (Rambuna, 2019).

Fundamentally, the RCM methodology recognizes that all equipment in a facility does not have the same priority level. RCM realizes that the design and operation of the equipment are different, so it has additional chances of failure as well (Silva et al., 2020).

The steps required in RCM are described in the following section (Hasan et al., 2019).

a) System Selection and Information Gathering
b) Defining System Limitations
c) System Description and Function Block Diagram
d) System Functions and Failure Functions
e) Action Selection

2.4. Distribution Pattern

The damage distribution pattern of a machine or its components is usually

Exponential, Lognormal, and Weibull distributions. The following patterns are common patterns that describe the distribution of machine component damage (Sunaryo et al., 2021).

a. The exponential distribution is used to calculate the reliability of a damage distribution with a constant damage rate. This distribution has a fixed rate of damage over time; in other words, the probability of damage is independent of the age of the equipment. This distribution is the easiest distribution to analyze.
b. The lognormal distribution uses two parameters, which are the shape parameter and timed as the location parameter, which is the center value of a damage distribution. This distribution can have various shapes, so it is often found that data that fits the Weibull distribution also fits the lognormal distribution.
c. The Weibull distribution is the most widely used empirical distribution. It appears in almost all failure characteristics of products because it covers all three possible damage phrases in the distribution. In general, this distribution is used on mechanical components or machining equipment.

2.5. Techniques in Maintenance System Analysis

According to (Hermanto et al., 2017), there are several techniques for analyzing maintenance systems, among others:

a. The Pareto diagram was first introduced by an economist, Alfredo Pareto (1848-1923). This diagram is an image that sorts data classification from left to right according to the highest to lowest ranking order. This can help find the most important problems to be resolved immediately (highest ranking) and problems that do not have to be resolved immediately (lowest ranking). Pareto diagrams can also identify the most important problems affecting quality improvement efforts and guide in allocating limited resources to solve problems.
b. Check sheet, the purpose of making this check sheet is to ensure that data is collected thoroughly and accurately by the user for process control and problem-solving. The data in the check sheet will later be used and analyzed quickly and easily.

3. Research Methodology

3.1. Time and Place of Research.

This research was conducted at PT Perkebunan Nusantara XIV Camming Sugar Factory located in Wanuawaru village, Libureng sub-district, Bone Regency.

3.2. Data Collection.

The data is secondary data obtained from the company:

- Production machine downtime data
- Historical data on damage to mill roll machine components
- Working hour data
- Machine component repair data

3.3. Data Processing

The data processing used in this study uses the Reliability Centered Maintenance (RCM) method, namely:

a. Component Damage Downtime Calculation.
b. Calculation of damage time and repair time (TTF and TTR)
c. Calculation of Index Of Fit TTF and TTR
d. Goodness of Fit Test for Time to Failure (TTF) and Time to Repair (TTR)
e. Calculation of Time to Failure (TTF) and Time to Repair (TTR) parameters.
f. Calculation of MTTF and MTTR values.
g. Component Maintenance Interval Calculation.

4. Result And Discussion

Based on the identification of data collection that has been carried out at PTPN XIV PG. Camming in Bone Regency, it is known that the actual maintenance system that needs to pay attention to the concept of reliability has resulted in the function of production machines not being properly maintained. Damage to production machines causes a high level of machine downtime, so production goals are not achieved.

4.1. Engine Component Damage Downtime Calculation

At the stage of calculating the downtime of machine damage, the total downtime of each component from August to December 2021 can be seen in table 1.

Table 2. Results of Component Damage *Downtime* Percentage

No	Component Name	*Downtime* (Hours)	% *Downtime*	%Downtime Cumulative
1	*Standart Milk Check*	8,5	20,36	20,36
2	*Feeder roll*	5,25	12,57	32,93
3	*Scrapper*	15,25	36,53	70,29
4	*Chute*	12,75	30,54	100
Jumlah		41,75	100	

4.2. Calculation of Damage Time Interval (TTF) and Calculation of Repair Time Interval (TTR)

Table 3. TTF and TTR Calculation Results *Standard Milk Check* Components

No	Date	Initial breakdown schedule	Final breakdown schedule	TTR (Hours)	Previous damage end time - End time of working hours	Current damage end time - Start time of working hours	Day (minute)	TFF (Hour)
1	10-08-21	20.00	21.00	1				
2	12-08-21	03.30	05.00	1,50	960	1170	47880	77,5
3	09-09-21	09,30	10.30	1	690	750	25200	612
4	30-09-21	02.00	03.00	1	1080	1260	8820	480
5	05-10-21	15.00	16.30	1,50	330	360	*8820*	116,5
6	11-11-21	13.00	14.15	1,25	465	540	46620	793,75
7	17-12-21	14.15	15.30	1,25	390	465	45360	770,25

Table 4. Calculation Results of TTF and TTR of Feeder Roll Components

No	Date	Initial breakdown schedule	Final breakdown schedule	TTR (Hours)	Previous damage end time - End time of working hours	Current damage end time - Start time of working hours	Day (minute)	TFF (Hour)
1	13-09-21	19.00	20.15	1,25				
2	21-10-21	16.00	17.00	1	360	300	47880	809
3	10-11-21	08.30	09.30	1	750	810	25200	446
4	17-11-21	10.00	11.00	1	660	720	8820	170
5	24-11-21	20.00	21.00	1	120	60	*8820*	150

Table 5. Results of TTF and TTR Calculations for Scrapper Components

No	Date	Initial breakdown schedule	Final breakdown schedule	TTR (Hours)	Previous damage end time - End time of working hours	Current damage end time - Start time of working hours	Day (minute)	TFF (Hour)
1	09-08-21	02.15	04.15	1				0
2	20-08-21	14.45	16.00	1,25	420	435	13860	245,25
3	21-08-21	13.30	14.30	1	450	510	1260	37
4	29-09-21	19.00	21.00	2	120	120	49140	823
5	06-10-21	10.45	11.45	1	615	675	*8820*	168,5
6	08-10-21	10.30	11.30	1	630	690	*2520*	64
7	12-10-21	13.45	14.45	1	435	495	5040	99,5
8	18-10-21	16.00	17.00	1	360	300	*7560*	137
9	06-11-21	06.00	07.30	1,50	870	1020	*23940*	430,5
10	09-12-21	03.25	04.55	1,50	966	1179	41580	728,75
11	14-12-21	23.00	02.00	3	1140	0	6300	124

Table 6. Calculation Results of TTF and TTR of Chute Components

No	Date	Initial breakdown schedule	Final breakdown schedule	TTR (Hours)	Previous damage end time - End time of working hours	Current damage end time - Start time of working hours	Day (minute)	TFF (Hour)
1	21-08-21	23.30	02.00	2,50				
2	18-09-21	03.00	04.00	1	1020	1200	35280	625
3	08-10-21	13.00	14.00	1	480	540	25200	437
4	12-10-21	17.00	18.00	1	300	240	5040	93
5	14-10-21	19.30	20.30	1	150	90	2520	46
6	14-10-21	20.45	21.45	1	75	15	*2520*	43,5
7	18-10-21	14.00	15.00	1	480	480	*5040*	100
8	26-10-21	19.00	21.00	2	120	120	*10080*	172
9	25-12-21	21.00	22.00	1	60	0	*75600*	1261
10	29-12-21	09.15	10.30	1,25	690	765	*5040*	108,25

4.3. Calculation of Index of Fit Time to Failure (TTF)

After that, the distribution test for the time to failure interval. In the distribution test for the time to failure interval, the results of the index of fit (r) on the Lognormal distribution for the Standard Milk Check component were 0.91, the Feeder Roll component was 0.83, the Scrapper component was 0.99, and the Chute component was 0.97.

4.4. Goodness of Fit Test for Time to Failure (TTF)

The results of the calculation of the goodness of fit test for the Standart Milk Check the component in the Lognormal distribution obtained the results Dn (0.228) < Derit (0.521), it can be concluded that the data is lognormal distributed, these results can then be seen in table 4.20. The results of the calculation of the goodness of fit test for the Feeder Roll component in the Lognormal distribution obtained the results Dn (0.329) < Derit (0.624), it can be concluded that the data is lognormal distributed, these results can then be seen in table 4.21. The results of the calculation of the goodness of fit test for the Scrapper component in the Lognormal distribution obtained the results Dn (0.317) < Derit (0.410), it can be concluded that the data is lognormal distributed, these results can then be seen in table 4.22. The results of the calculation of the goodness of fit test for the Chute component in the Lognormal distribution obtained the results Dn (0.389) < Derit (0.391), it can be concluded that the data is lognormal distributed.

4.5. Calculation of Index of Fit Time to Repair (TTR)

Next, in the same stage for time to repair (TTR), namely at the distribution test stage for the time to repair interval, the results of the index of fit (r) on the Lognormal distribution for the Standard Milk Check component are 0.46, the Feeder Roll component is -0.72, the Scrapper component is 0.57, and the Chute component is -0.18.

4.6. Goodness of Fit Test for Time to Repair (TTR)

The results of the calculation of the goodness of fit test for the Standart Milk Check the component in the Lognormal distribution obtained the results Dn (0.433) < Derit (0.486), it can be concluded that the data is lognormal distributed, these results can then be seen in table 4.29. The results of the calculation of the goodness of fit test for the Feeder Roll component in the Lognormal distribution obtained the results Dn (0.544) < Derit (0.565), it can be concluded that the data is lognormal distributed, these results can then be seen in table 4.30. The results of the calculation of the goodness of fit test for the Scrapper component in the Lognormal distribution obtained the results Dn (0.388) < Derit (0.391), it can be concluded that the data is lognormal distributed, these results can then be seen in table 4.31. The results of the calculation of the goodness of fit test for the Chute component in the Lognormal distribution obtained the results Dn (0.409) < Derit (0.410), it can be concluded that the data is lognormal distributed.

4.7. Parameter Calculation for Time to Failure (TTF)

The next calculation is the calculation of parameters for time to failure on the Standart Milk Check component, which results in 336.76 hours, Feeder Roll 272.98 hours, Scrapper 168.93 hours, and Chute 159.90 hours.

4.8. Parameter Calculation for Time to Repair (TTR)

The next calculation is the calculation of parameters for time to repair on the Standart Milk Check component, which results in 1.19 hours, Feeder Roll 1.04 hours, Scrapper 1.25 hours, and Chute 1.15 hours

4.9. Calculation of Mean Time to Failure (MTTF) and Mean Time to Repair (MTTR)

The next stage analyzes Mean Time to Failure (MTTF) calculation results, Mean Time to Repair (MTTR), and machine maintenance time intervals. The MTTF value obtained for the Standard Milk Check component for 783.90 hours, the Feeder Roll component is for 499.86 hours, the Scrapper component is for 338.85 hours, and the Chute component is for 412.22 hours. Furthermore, in the Mean Time to Repair (MTTR) calculation, the MTTR value of the Standart Milk Check component is 1.47 hours, the Feeder Roll component is 1.05 hours, and the Scrapper component is 1.61 hours, and the Chute component is 12.92 hours. Henceforth, the company can consider this time to determine the standard maintenance time for future components.

4.10. Determination of Component Maintenance Intervals

The next stage is determining the maintenance interval. Maintenance is carried out to prevent machine damage that can interfere with the operational process, resulting in losses. The results of the calculation of the maintenance time interval for the Standart Milk Check component are 370.58 hours or 18 days, the Feeder Roll component is 450 hours or 21 days, the Scrapper component is 95.5 hours or four days, and the Chute component is 100 hours or five days during operational hours.

5. Conclusion

Maintenance intervals for critical components that have potential failures include Standard Milk Check components with preventive maintenance intervals every 18 days a month or 8 times in 5 months, Feeder Roll components with preventive maintenance intervals every 21 days a month or 7 times in 5 months, Scrapper components with preventive maintenance intervals every 4 days a month or 38 times in 5 months and Chute components with preventive maintenance intervals every 5 days a month or 30 times in 5 months during machine operating hours.

The strategy to reduce the occurrence of damage to the Mill Roll machine maintenance uses a preventive maintenance strategy with a combination of corrective maintenance where preventive maintenance is carried out following a predetermined maintenance interval schedule, and corrective maintenance is carried out by preparing spare parts that must be replaced during preventive maintenance checks.

References

Afiva, W. H., Atmaji, F. T. D., & Alhilman, D. J. (2019). Penerapan Metode Reliability Centered Maintenance (RCM) pada Perencanaan Interval Preventive Maintenance dan Estimasi Biaya Pemeliharaan Menggunakan Analisis FMECA (Studi Kasus : PT. XYZ). *Jurnal PASTI (Penelitian Dan Aplikasi SIstem Dan Teknik Industri)*, *XIII*(3), 298–310. http://dx.doi.org/10.22441/pasti.2019.v13i3.007

Atma, S., Soesanto, R. P., Kurniawati, A., & Hediyanto, U. Y. K. S. (2017). Best Practice Kegiatan Corrective Maintenance untuk Kerusakan Bearing pada Mesin Millac 5H 6P Berdasarkan Knowledge Conversion. *Prosiding Seminar Nasional Teknik Industri (SNTI) Dan Seminar Nasional Terpadu Keilmuan Teknik Industri (SATELIT)*, C1–C7. http://industri.ub.ac.id

Bangun, I. H., Rahman, A., & Darmawan, Z. (2014). Perencanaan Pemeliharaan Mesin Produksi dengan Menggunakanan Metode Reliability Centered Maintenance (RCM) II pada Mesin Blowing Om (Studi Kasus: PT Industri Sandang Nusantara Unit Patal Lawang). *Jurnal Rekayasa Dan Manajemen Sistem Industri*, *2*(5), 997–1008.

Denur, Hakim, L., Hasan, I., & Rahmad, S. (2017). Penerapan Reliability Centered Maintenance (RCM) pada Mesin Ripple Mill. *JISI : Jurnal Integrasi Sistem Industri*, *4*(1), 27–34. https://doi.org/10.24853/jisi.4.1.27-34

Ebeling, C. E. (2019). *An Introduction to Reliability and Maintainability Engineering* (3rd Edition). Waveland Press, Inc.

Firmansyah, M. A., & Nurhalim. (2020). Reliability Centered Maintenance (RCM) Analysis of 1000 Ton Hydraulic Press Plate Machine (Case StudyPT. X). *J-Proteksion: Jurnal Kajian Ilmiah Dan Teknologi Teknik Mesin*, *4*(2), 19–23. https://doi.org/10.32528/jp.v4i2.3144

Hadi, S., Gustopo, D., & Indra, D. (2020). Predictive Maintenance Analysis Overhead Crane Machine in PT Bromo Steel Indonesia. *Journal of Physics: Conference Series*, *1569*(2). https://doi.org/10.1088/1742-6596/1569/2/022093

Hasan, I., Denur, & Hakim, L. (2019). Penerapan Reliability Centered Maintenance (RCM) pada Mesin Ripple Mill. *Jurnal Surya Teknika*, *6*(1), 43–48. https://doi.org/10.37859/jst.v6i1.1866

Hermanto, Irvan, M., & Wiratmani, E. (2017). Analysis of Maintenance System on KMF 250 A Machine Using Overall Equipment Effectiveness (OEE) Method at PT TSG. *Prosiding SEMNASTEK*, 1–10. https://jurnal.umj.ac.id/index.php/semnastek/article/view/2023

Iqbal, M. (2017). Pengaruh Preventive Maintenance dan Breakdown Maintenance terhadap Kelancaran Proses Produksi di PT. Quarryndo Bukit Barokah. *Jurnal Manajemen Dan Bisnis (ALMANA)*, *1*(3), 33–46. https://doi.org/10.36555/almana.v1i3.394

Praharsi, Y., Kumala Sriwana, I., & Sari, D. M. (2015). Perancangan Penjadwalan Preventive Maintenance pada PT. Artha Prima SUkses Makmur. *Jurnal Ilmiah Teknik Industri (JITI)*, *14*(1), 59–65. https://doi.org/10.23917/jiti.v14i1.624

Prihastono, E., & Prakoso, B. (2017). Perawatan Preventif untuk Mempertahankan Utilitas Performance pada Mesin Cooling Tower di CV. Arhu Tapselindo Bandung. *Dinamika Teknik*, *10*(2), 17–27.

Rambuna, O. (2019). Penerapan Metode Realibility Centered Maintenance (RCM) pada Mesin Produksi Obat-Obatan (XYZ). *Jurnal Valtech*, *2*(2), 117–123. https://ejournal.itn.ac.id/index.php/valtech/article/view/1498

Rislamy, A. F., Mahbubah, N. A., & Widyaningrum, D. (2020). Analisis Risiko Kerusakan pada Alat Berat Grab dengan Metode Failure Mode and Effect Analysis (Study Kasus: PT Siam Maspion Terminal

Gresik). *Profisiensi : Jurnal Program Studi Teknik Industri*, *8*(1), 36–43. https://doi.org/10.33373/profis.v8i1.2553

Sajaradj, Z., Huda, L. N., & Sinulingga, S. (2019). The Application of Reliability Centered Maintenance (RCM) Methods to Design Maintenance System in Manufacturing (Journal Review). *IOP Conference Series: Materials Science and Engineering*, *505*(1). https://doi.org/10.1088/1757-899X/505/1/012058

Silva, E. T. da, Achcar, J. alberto, & Piratelli, C. L. (2020). Strategic formulation of industrial maintenance based on equipment reliability in a sugar and ethanol production plant. *Independent Journal of Management & Production*, *11*(7), 2592–2612. https://doi.org/10.14807/ijmp.v11i7.1145

Soewardi, H., & Wulandari, S. A. (2019). Analysis of Machine Maintenance Processes by using FMEA Method in the Sugar Industry. *IOP Conference Series: Materials Science and Engineering*, *528*(1). https://doi.org/10.1088/1757-899X/528/1/012023

Sunaryo, Japri, Yuhelson, & Hakim, L. (2021). Implementasi RCM pada Mesin Diesel Deutz 20 kVA. *TURBO : Jurnal Program Studi Teknik Mesin*, *10*(1), 42–52. http://dx.doi.org/10.24127/trb.v10i1.1451

Supriyadi, S., Jannah, R. M., & Syarifuddin, R. (2018). Perencanaan Pemeliharaan Mesin Centrifugal dengan Menggunakan Metode Realibility Centered Maintenance pada Perusajaan Gula Rafinasi. *JISI: Jurnal Integrasi Sistem Industri*, *5*(2), 141–147. https://doi.org/10.24853/jisi.5.2.139-147

Zein, I., Mulyati, D., & Saputra, I. (2019). Perencanaan Perawatan Mesin Kompresor Pada PT. Es Muda Perkasa Dengan Metode Reliability Centered Maintenance (RCM). *Jurnal Serambi Engineering*, *IV*(1), 383–391. https://doi.org/10.32672/jse.v4i1.848