http://jurnal.yudharta.ac.id/v2/index.php/jkie
Journal Knowledge Industrial Engineering
E-ISSN: 2541-4461 | P-ISSN: 2460-0113

Analysis of Boiler Machine Maintenance using The Reliability-Centered Maintenance Method

Tiffany[a], Anita Christine Sembiring[b]
[a,b] Department of Industrial Engineering,Universitas Prima Indonesia, Medan, Indonesia
Corresponding Author: tiffany.shoen88@gmail.com

Article Info

Article history
Received : February 13, 2024
Revised : February 28, 2024
Accepted : April 02, 2024
Published : April 30, 2024

Keywords:
RCM;
Maintenance;
Machine;
FMEA.

ABSTRACT

Reliability Centered Maintenance is a structured approach to identifying maintenance needs based on the function and potential failure of a system. By conducting an in-depth analysis of the function and failure of boiler engine components, this research aims to formulate the most optimal maintenance strategy. This strategy is expected to increase the overall reliability of the boiler machine and at the same time reduce the maintenance costs required. This research begins with creating a function block diagram to map the main functions and sub-functions of the boiler machine. After that, a failure mode analysis is carried out to determine its impact using the Failure Mode and Effects Analysis method) which aims to identify potential failures in each component and the consequences they cause. So it is hoped that this research can determine appropriate maintenance actions to prevent or minimize the possibility of failure. The final result of this research is structured and effective maintenance recommendations for boiler engines. These recommendations include treatment strategies tailored to previously identified functions, failure modes, and impacts. By implementing the recommendations from this research, it is hoped that the performance and service life of the boiler machine can be improved significantly.

DOI: https://doi.org/10.35891/jkie. v11i1.5004

1. Introduction

Machine maintenance refers to the automated operation of industrial machine equipment in factories, particularly through the use of robotic automation systems. In modern manufacturing environments, these automated systems are designed to ensure that machinery operates efficiently, reducing the likelihood of unexpected breakdowns and minimizing downtime. The integration of advanced technologies such as sensors, artificial intelligence, and the Internet of Things (IoT) into maintenance processes has revolutionized the way factories operate, making predictive and preventive maintenance more effective than ever before (Lee et al., 2015).

Machines are one of the pillars of a company's sustainability, playing a crucial role in maintaining production levels and ensuring consistent product quality. Whether machines are performing tasks autonomously or with human intervention, their reliability and performance directly impact a company'operational efficiency and profitability. Proper maintenance practices not only extend the lifespan of the equipment but also enhance safety in the workplace, reducing the risk of accidents and ensuring compliance with industry standards and regulations (Mobley, 2002).

Unconsciously, we are already in the midst of an industrial revolution driven by the widespread adoption of machines and automation technologies. This transformation, often referred to as Industry 4.0, is characterized by the seamless integration of digital and physical systems, enabling smarter and more responsive manufacturing processes. The advancements in machine maintenance are a testament to this revolution, as they allow for real-time monitoring and data-driven decision-making, which are essential for optimizing production and reducing costs (Kagermann et al., 2013).

Therefore, machines are extremely crucial in today's industrial landscape. Their importance cannot be overstated, as they form the backbone of modern manufacturing operations. Companies that invest in advanced machine maintenance systems are better positioned to stay competitive in an increasingly automated and technologically advanced market. By ensuring that machines operate at peak efficiency, these companies can achieve higher productivity, improved product quality, and greater overall sustainability (Mourtzis et al., 2018).

PT Industri Karet Deli is a manufacturer that supplies rubber products and makes tires, including inner and outer tires. It is natural that this company collaborates extensively both domestically and internationally and has to produce goods in large quantities. However, the machines supporting the production process, including boiler machines, often malfunction. This has developed into a significant problem given the size of today's market. To prevent this problem from worsening and leading to more serious issues, quick action is needed to maintain the boiler machine (Smith, 2003).

For boiler machines, scheduled maintenance is very important because it can detect possible wear and tear or problems with the boiler machine before it reaches the point of failure, which could endanger the production process. This reduces the possibility of unplanned breakdowns and maintains system reliability. By preventing excessive wear and damage, preventive maintenance helps extend the life of a boiler machine and can reduce long-term costs by reducing the need for expensive equipment replacements. This also allows critical components to be repaired or replaced at a more planned time (Moubray, 1997).

Company PT Industri Karet Deli can minimize risks and costs related to emergency repairs and damage while optimizing boiler machine performance by scheduling preventive maintenance, considering the short economic life of the machine. The best approach to apply to this business problem is Reliability Centered Maintenance (RCM), which provides advice on the appropriate type of maintenance for boiler machines and finding functional failures in components to provide planning for component types (Nowlan & Heap, 1978).

2. Literature Review

Heat engine or usually called _ with a boiler machine (thermal engineering) that converts chemical or automatic energy into work is a boiler or boiler (steam). The purpose of this closed vessel boiler is to produce steam. It is a steam generating device that looks like a closed vessel. Fuel is used to heat a vessel filled with water to produce steam. The purpose of a boiler is to distribute or transfer heat from a combustion source, often burning fuel (Malikussaleh, 2023).

Boilers can be broadly classified into two types: fire tube boilers and water tube boilers, depending on the fluid movement within the boiler. Any substance that can burn and turn into heat energy is considered a fuel. The boiler operates with palm oil shells and fuel.

The act of maintaining or maintaining factory equipment by carrying out any repairs or replacements necessary to ensure production operates satisfactorily and according to plans is called maintenance. Maintenance is a series of activities to keep facilities or equipment in a ready-to-use condition". After consulting with several specialists, the definition of maintenance can be summarized as follows: maintenance is the process of keeping equipment or facilities operational and in a ready-to-use condition.

All actions taken to maintain the functionally of the entire system, increase the useful life of production facilities, ensure all facilities are operationally ready, protect operator safety, support machine capacity to meet needs according to its function, and meet maintenance cost target are all considered maintenance activities, ideal (Suryana, 2021).

In industrial engineering, an approach known as reliability-centered maintenance (RCM) is used to create and execute efficient maintenance programs. The foundation of RCM is the idea that risk analysis should be used to determine what maintenance is required, with an emphasis on system availability and reliability. According to (Raharja et al., 2021) states that there are two categories of maintenance :

- Planned maintenance, or tasks related to previously scheduled maintenance which can be divided into two procedures as preventive maintenance and corrective maintenance
- Unplanned maintenance is carried out when there are signs or signals that an activity in the production process suddenly produces inappropriate results.

A maintenance technique known as reliability-centered maintenance, or RCM, utilizes data about a facility's reliability to develop maintenance methods that are effective, efficient, and easy to implement. You can find out what needs to be done to ensure that machines or equipment can continue to function properly by using RCM. Additionally, some describe reliability-centered maintenance. Utilizing operational safety requirements as a basis, reliability-centered maintenance, or RCM, is a technique for creating and selecting maintenance design alternatives (Wibowo et al., 2021). The following are the objectives of RCM (Syafei & Suhendar, 2022) :

- To create a design that is easy to maintain.
- To collect critical data to improve an initial design that was substandard.
- To create a maintenance program that can stop damage from long-term use and return equipment to its original safe and reliable condition. To achieve the above objectives at the lowest possible cost.

There are seven main principles that shape the maintenance of dependency centers (Alsakina & Momon, 2023):

- RCM maintains system functionally
- More emphasis is placed on system function by RCM than on any of its components
- The foundation of RCM is the reliability
- RCM attempts to maintain the realibilty of system functionality in line with the expected system capabilities
- RCM places a higher priority on safety than economic concerns
- According to RCM, conditions that are inadequate or fall short of expectations indicate how well the given performance standards have been implemented
- RCM must produce tangible or observable impacts; the tasks completed must be able to reduce the incidence of failure or, at least, reduce the level of damage caused by failure

3. Methodology

Here are some of the procedure used (Baihaqi & Adesta, 2023):

- Information collection and system selection.
- System function blocks, such as system history and operations, are identified using system descriptions or functional block diagrams.
- FMEA
- Logic tree analysis (LTA)
- Task Selection
- Definition of System Constraints
- Any functional failure that occurs is described in Determination of System Function and Functional

Failure

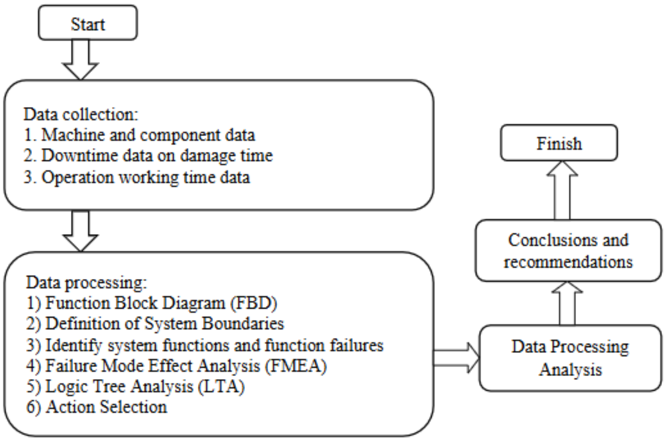

Figure 1: Research Flowchart

4. Results and Discussion

At this stage, data collection will be carried out, this data is obtained from the results of daily reports related to the boiler machine used in this research. The following is the data we obtained.

Table 1: Boiler Machine Operation Time Data

Component	Frequency	Downtime (minutes)
V-belting	13	900
Ball valves	4	1080
Bearings	5	1200
Pillow blocks	2	540
Pipe	3	2340

Table 2: Boiler Machine Downtime Data

No	Month	Operating Time	
		Day	Minute
1	22-Jan-24	23	19456
2	22-Feb-24	22	15367
3	22-Mar-24	22	14800
4	22-Apr-24	16	8678

Downtime refers to the period during which a machine or equipment is not operational due to various reasons such as breakdowns, repairs, or maintenance. In the context of boiler machines, downtime can have significant effects on operations and productivity.

System Description and Functional Block Diagram (FBD)

This phase involves system description to pinpoint design essentials, component relationships, and how these affect system performance. A functional block diagram is then created using the available data to describe the system completely.

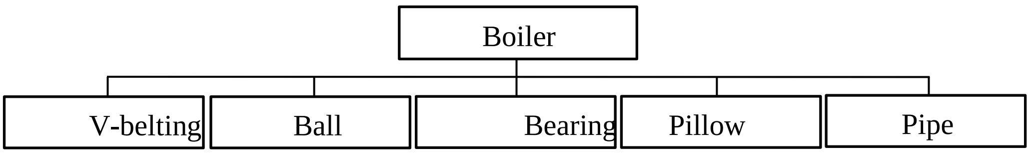

Figure 2: Function Block Diagram

Definition of System Constraints

Limitations of input, process and output of boiler machines. System boundaries must be defined so that there are boundaries, so that the recognized components are distinct, and so that they do not overlap. This is based on surveys and observations of boiler engine parts that often experience damage:

Table 3: Componen Function

No	Component type	Function
1	V-belt	Moving or connecting several components in the machine
2	Ball valves	Fluid flow control device
3	Bearings	Limiting the relative motion between two or more machine components so that they always move in the desired direction
4	Pillow blocks	The base is used to support the work of the shaft with the help of suitable and various bearings
5	Pipe	Heat absorber

Determination of System Function and System Failure

The process of describing each system, subsystem, equipment and its function and finding each functional defect is known as functional failure analysis. The largest failures in terms of total damage to downtime data occur in pipes. System function and failure must be determined by components that have a high failure rate so that appropriate action can be determined. Because components that are not functioning will hinder the operation of the machine (Finamore et al., 2021).

Determination of Failure Mode and Effect Analysis (FMEA)

The process of determining component failures that can result in system failure is known as Failure Mode and Effect Analysis or FMEA (Syafei & Suhendar, 2022). As a complementary technique for evaluating system performance, Failure Mode and Effect Analysis (FMEA) can assess and analyze system components to minimize the risk or impact of failure.

$$\text{RPN} = \text{Severity} \times \text{Occurance} \times \text{Detection}$$

Information:

- RPN (Risk Priority Number) is the combined result of three variables
- Severity (level of severity of danger)
- Occurrence (Frequency of occurrence)
- Detection (Detection level)

undamental phases in a failure mode and effects analysis (FMEA). The steps of the FMEA approach are as follows (Dwi Ramadhan & Endih Nurhidayat, 2022):

- Check or select the merchandise
- Find deficiencies or problems with the product
- Determine the origins and consequences of failure
- Calculate a severity evaluation, which indicates the extent of the impact caused by the failure.
- Establish an event assessment, indicating the likelihood of component failure.
- Find the detection assessment, which indicates the likelihood that the failure will be discovered.
- Perform RPN calculations which consist of multiplying the basic criteria for severity, occurrence, and detection.8. Create worksheets for FMEA.
- Suggestions for improvement or action
- Summary

Table 4: FMEA

Component	Function failure	The effects of potential failure	S	Potential cause	O	Control	D	RPN
V-belt	The machine stops and components are not connected	Damage to the machine	2	The components are old	7	Carry out periodic checks	3	42
Ball valves	Steam still comes out even though it is closed	Uneven temperature	6	Dirty	5	Clean and service ball valves	7	210
Bearings	The machine does not move as desired	The machine stops	3	Layout error	4	Check again after installation	9	108
Pillow blocks	The shaft rotation is not correct	The machine is damaged	8	Product error	3	Check the product before installing	4	96
Pipe	Overheating and porous	The water continues to flow	5	Dirty	9	Clean and service pipes	2	90

Logic Tree Analysis (LTA)

In this step, errors are handled through the use of logic tree analysis (LTA), which classifies failures into classes. In criticality analysis, there are several important things that need to be considered, especially the following (Hakim et al., 2020):

- Evidence
- Safety
- Outages
- Category A (failure affects safety) and Category B (failure affects production).

Table 5: LTA

Function failure	The effects of potential failure	Potential cause	Critically Analyze			
			E	S	O	C
The machine stops and components are not connected	Damage to the machine	The components are old	NO	YES	NO	A
Steam still comes out even though it is closed	Uneven temperature	Dirty	YES	NO	NO	B
The machine does not move as desired	The machine stops	Layout error	NO	NO	YES	B
The shaft rotation is not correct	The machine is damaged	Product error	NO	YES	NO	B
Overheating and porous	The water continues to flow	Dirty	YES	NO	NO	B

Table 6: Task Selection

No	Component type	Function failure	RPN	LTA	Action Plan
1	V-belt	The machine stops and the components are not connected	42	A	Condition Directed

2	Ball valves	Steam still comes out even though it is closed	210	B	Time Directed
3	Bearings	The machine does not move as desired	108	B	Finding Failure
4	Pillow blocks	The shaft rotation is not correct	96	B	Condition Directed
5	Pipe	Overheating and porous	90	B	Time Directed

Task Selection

Using the task selection values in the previous table as a guide, the following Reliability Centered Maintenance (RCM) operations are selected :

- Time-directed cleaning (TD) is the process of concentrating on a repetitive cleaning task. Of the five components currently available, two of them require this step so that they have reached 40%.
- Condition Directed (CD) refers to the process that recognizes possible equipment damage and decides whether to replace or repair components. Of the five components currently available, two of them require this step so that they have reached 40%.
- Failure Finding (FF) is the process of identifying machine or equipment damage that is hidden from routine inspection. Of the five components that currently exist, there is one that requires this action to reach 20%.

5. Conclusion

The ball valve which has an RPN level of 210 is the most important part. So the following maintenance plan must be implemented for these components: Preventive maintenance will be performed on Time Directed (TD) components, ball valves and pipes. If failure (FF) is found, the bearing components will be treated with proactive maintenance. Component failures found were the machine stopped and the components were not connected, steam still came out even though it was closed, the machine did not move as desired, the shaft rotation did not match and overheating.

References

Alsakina, A., & Momon, A. (2023). Analisis Perawatan Mesin Injection dengan Metode RCM pada Perusahaan Manufaktur. *STRING (Satuan Tulisan Riset Dan Inovasi Teknologi)*, *8*(1), 20. https://doi.org/10.30998/string.v8i1.16089

Armanda, D. D., Jufriyanto, M., & Rizqi, A. W. (2023). Perencanaan Perawatan Mesin dengan Metode Reliability Centered Maintenance (RCM) Pada PT. XYZ. *G-Tech: Jurnal Teknologi Terapan*, *7*(4), 1588–1595. https://doi.org/10.33379/gtech.v7i4.3298

Baihaqi, W. K., & Adesta, D. (2023). Analisa Perawatan Mesin Pembentuk Papan Fiber Semen Dengan Menggunakan Metode RCM Di PT. XYZ. *Jurnal Serambi Engineering*, *8*(4), 7139–7147. https://doi.org/10.32672/jse.v8i4.6779

Dwi Ramadhan, W., & Endih Nurhidayat, A. (2022). Analisis Perawatan Mesin dengan Menggunakan Metode Reability Centered Maintenance dan Fuzzy Fuzzy Failure Mode and Effect Analysis.*Jurnal Indonesia Sosial Teknologi*, *3*(08), 867–878. https://doi.org/10.36418/jist.v3i8.474

Finamore, P. da S., Kós, R. S., Corrêa, J. C. F., Collange Grecco, L. A., De Freitas, T. B., Satie, J., Bagne, E., Oliveira, C. S. C. S., De Souza, D. R., Rezende, F. L., Duarte, N. de A. C., Grecco, L. A. C., Oliveira, C. S. C. S., Batista, K. G., Lopes, P. de O. B., Serradilha, S. M., Souza, G. A. F. de, Bella, G. P., & Dodson, J. (2021). [No title]. *Journal of Chemical Information and Modeling*, *53*(2). https://doi.org/10.1080/09638288.2019.1595750

Hakim, A., Pratiwi, A. I., & Prasetyo, A. (2020). Usulan Preventive Maintenance Dengan Metode Reliability Centered Maintenance Untuk Meminimalkan Biaya Perawatan Mesin. *Industry Xplore*, *5*(1), 26–33. https://doi.org/10.36805/teknikindustri.v5i1.901

Kagermann, H., Wahlster, W., & Helbig, J. (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry. Final report of the Industrie 4.0 Working Group.

Lee, J., Bagheri, B., & Kao, H. A. (2015). A cyber-physical systems architecture for Industry 4.0-based manufacturing systems. *Manufacturing Letters*, *3*, 18-23.

Malikussaleh, U. (2023). *Analisis Perawatan Mesin Boiler Dengan Menggunakan Metode Reliability Centered Maintenance Di Pt . X*. *5*, 1–8.

Mobley, R. K. (2002). *An Introduction to Predictive Maintenance*. Butterworth-Heinemann.

Moubray, J. (1997). *Reliability-centered maintenance*. Industrial Press In Mourtzis, D., Vlachou, E., & Milas, N. (2018). Industrial big data as a result of IoT adoption in manufacturing. *Procedia CIRP*, *55*, 290-295.

Mohammad Amarrudin Firmansyah, & Nurhalim. (2020). 3 Rcm. *J-Proteksion: Jurnal Kajian Ilmiah Dan Teknologi Teknik Mesin*, *4*(2), 19–23.

Nowlan, F. S., & Heap, H. F. (1978). *Reliability-centered maintenance*. United Airlines.

Raharja, I. P., Suardika, I. B., & Galuh W, H. (2021). Perencanaan Perawatan Mesin Produksi Roller Mill Unit 1 Tuban Dengan Metode Reliability Centered Maintenance (RCM) Di Pt Semen Indonesia (Persero) Tbk. *Industri Inovatif : Jurnal Teknik Industri*, *11*(1), 39–48.

Sispranta, R. M. (2022). *Analisis Perancangan Perawatan Mesin Boiler Dengan Menggunakan Metode Reability Centered Maintернance (Rcm) Dan Life Cycle …. Lcc*. http://repository.upnjatim.ac.id/10136/%0Ahttp://repository.upnjatim.ac.id/10136/1/18032010152_Cover.pdf

Smith, R. (2003). *Rules of thumb for maintenance and reliability engineers*. Elsevier.

Sultan, A. Z., Suyuti, M. A., Naim, T. Bin, & Amiruddin, A. A. (2020). Peningkatan Ketersediaan Waktu Operasi Pada Mesin Boiler Berdasarkan Down Time Dengan Pendekatan Metode Reliability Centered Maintenance (RCM) (Studi Kasus PT. Dian Swastika Sentosa, Tbk. *Jurnal Teknik Mesin Sinergi*, *18*(2), 189. https://doi.org/10.31963/sinergi.v18i2.2630

Suryana, W. (2021). Analisis Pemeliharaan Mesin Produksi dengan Metode RCM (Reliability Centered Maintenace) Pada PT. Eluan Mahkota Kabupaten Rokan Hulu. *Jurnal Teknik Industri*, 1–48.

Syafei, M. I., & Suhendar, E. (2022). Analisis Perawatan Mesin dengan Pendekatan Metode Reliability Centered Maintenance (RCM) dan Maintenance Value Stream Map (MVSM) (Studi Kasus di PT. Nusa Indah Jaya Utama). *Integrasi : Jurnal Ilmiah Teknik Industri*, *7*(2), 67. https://doi.org/10.32502/js.v7i2.4783

Wibowo, T. J., Hidayatullah, T. S., & Nalhadi, A. (2021). Analisa Perawatan pada Mesin Bubut dengan

Pendekatan Reliability Centered Maintenance (RCM). *Jurnal Rekayasa Industri (Jri)*, *3*(2), 110–120. https://doi.org/10.37631/jri.v3i2.