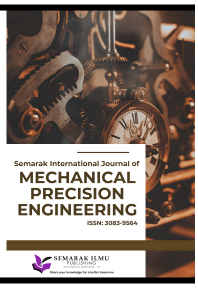
Semarak International Journal of Mechanical Precision Engineering

Journal homepage: https://semarakilmu.my/index.php/sijmpe/index
ISSN: 3083-9564



Determination of Control Valve Maintenance Interval using RCM Method at Pertamina Refinery Unit V Balikpapan

Irwan Setiawan[1,*], Muhammad Ilhamsyah Arifin[1], Hasnida Ab Samat[2], Sapta Asmal[1], Saiful[1]

[1] Department of Industrial Engineering, Hasanuddin University, Makassar – South Sulawesi, Indonesia
[2] School of Mechanical Engineering, Universiti Sains Malaysia, Penang, Malaysia

ARTICLE INFO

Article history:
Received 18 December 2024
Received in revised form 17 January2025
Accepted 24 February 2025
Available online 15 March 2025

Keywords:
Control valve; maintenance interval; Reliability Centered Maintenance; FMEA; mean time to failure; mean time to repair

ABSTRACT

The Pertamina Oil Refinery Unit V in Balikpapan is a crucial infrastructure in Indonesia's oil and gas industry. One of the critical components in this refinery is the control valve, specifically the control valve with tag number 02-LCV-084, which has experienced frequent malfunctions. This study aims to determine the optimal maintenance intervals for the control valve using the Reliability Centered Maintenance (RCM) methodology. The research involves analyzing two years of failure data and applying techniques such as Failure Mode and Effect Analysis (FMEA), Time to Failure (TTF), and Time to Repair (TTR) calculations. The results indicate that the seat ring requires maintenance every 757 hours (32 days), the plug every 874 hours (37 days), and the stem every 1694 hours (70 days). These maintenance intervals provide important insights for improving the operational efficiency of the refinery's equipment by preventing unscheduled downtime and reducing repair costs. The implementation of RCM in determining maintenance intervals can enhance the reliability and longevity of critical equipment in industrial environments.

1. Introduction

The oil and gas industry in Indonesia, as one of the main sectors of the national economy, has experienced rapid growth over the past few decades. Sudrajat [1] studied that PT Pertamina (Persero) Refinery Unit V Balikpapan, as one of the largest refineries in Indonesia, plays a crucial role in providing energy for domestic society and industry. This refinery produces various petroleum products, ranging from fuels to derivative products such as LPG and petrochemicals.

However, in refinery operations, Tangkuman [2] mention, there are significant challenges in maintaining the reliability of equipment, especially the control valve, which functions to control fluid flow in the production system. One of the control valves that frequently encounters issues is the control valve with tag number 02-LCV-084. Over the past two years, this valve has experienced 14 failures, which can impact operational efficiency and lead to unplanned downtime. This condition can result in high repair costs and significant production losses as Suyitno [3].

* *Corresponding author.*
E-mail address: irwansmuthalib@unhas.ac.id

https://doi.org/10.37934/sijmpe.2.1.110a

To address this issue, the Reliability Centered Maintenance (RCM) method was implemented, designed to identify critical components and determine the optimal maintenance intervals. RCM allows for the reduction of maintenance costs and the improvement of equipment reliability by focusing on components most prone to failure [4,5]. Noviansyah [6] studied that reactive maintenance were less efficient because its most of times fail and high cost, but contras to lessen cost [7]. This approach is considered the best solution for extending equipment life and minimizing unplanned downtime at Pertamina Refinery Unit V Balikpapan.

This research aims to analyze the components that frequently experience failure on the control valve 02-LCV-084 and determine the most efficient maintenance intervals based on the RCM and RAM approach. Where the realibility centered maintenance (RCM) and the reliability availability maintainability as like Fahrurroji *et al.,* mention [8,9]. The results of this study are expected to provide better maintenance recommendations to ensure the continuity of refinery operations.

2. Methodology

This research uses the Reliability Centered Maintenance (RCM) method to determine the optimal maintenance interval for the control valve as like Pranoto [10]. The study focuses on the analysis of component failures within the control valve, as well as the use of the FMEA approach and the calculation of MTTF (Mean Time to Failure) and MTTR (Mean Time to Repair). The stages in this research are explained at Figure 1, as follows:

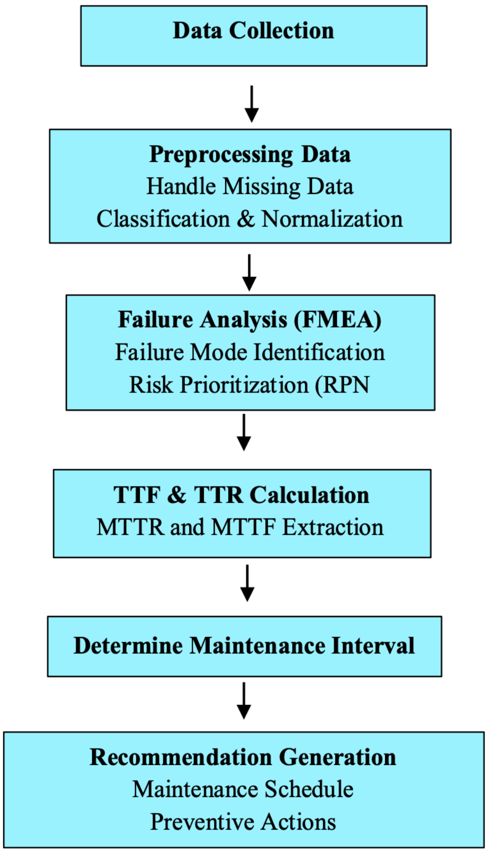


Fig. 1. Maintenance interval determination process

2.1 Data Collection

Collecting failure data related to control valve 02-LCV-084 at Pertamina RU V Balikpapan Refinery from January 2022 to December 2023. The data includes the time of failure and repair time for each valve component. Toruan [11,12] refers that control valves are important components in process control systems and are used in a variety of industries, including petrochemical, chemical, power generation, water treatment, and manufacturing.

2.2 Data Preprocessing

The data preprocessing process is carried out to ensure that the data to be analyzed has good quality and is suitable for further processing. The preprocessing techniques applied include:

i) Null Value Handling: Handling missing or incomplete values in the dataset by removing incomplete data to ensure accurate analysis.
ii) Data Classification: Classifying the failure data based on the control valve components that failed, such as seat ring, plug, stem, and others.
iii) Data Normalization: Normalizing the data to equalize the scale or range of values in the dataset, making it easier for further calculations and analysis

2.3 Failure Analysis Using FMEA

This process involves using Failure Mode and Effect Analysis (FMEA) to identify failure modes in the control valve components, analyze the impact of the failures, and classify the risks based on the Risk Priority Number (RPN) [13,14]. Each component, such as seat ring, plug, and stem, is analyzed to determine the failure frequency and its impact on operations.

i) Failure Mode Identification: Identifying various types of failures in the control valve components.
ii) Effect and Cause Analysis: Analyzing the causes and effects of each failure mode.
iii) Risk Prioritization (RPN): Calculating and prioritizing the risk based on severity, frequency, and detection capability of the failure modes.

2.4 Time to Failure (TTF) and Time to Repair (TTR) Calculation

Time to Failure (TTF) and Time to Repair (TTR) are calculated based on historical failure data. Mean Time to Failure (MTTF) and Mean Time to Repair (MTTR) are calculated to determine the optimal maintenance interval for each control valve component.

i) TTF Calculation: Calculating the time between two failure events
ii) TTR Calculation: Calculating the time required to repair a component after failure.

2.5 Distribution and Parameter Analysis

The distribution patterns of failure time and repair time are analyzed using Minitab software to determine the most suitable distribution for the failure data. This distribution pattern is used to help predict when components are likely to fail again and to determine the most efficient maintenance intervals.

2.6 Determining Maintenance Financial

Based on the analysis of MTTF, MTTR, and failure distribution, the optimal preventive maintenance interval for each control valve component is determined same studied by Widiasih [15]. For example, the seat ring requires maintenance every 757 hours (32 days), the plug every 874 hours (37 days), and the stem every 1694 hours (70 days).

2.7 Recommendation Generation

Maintenance recommendations are generated based on the analysis of maintenance intervals for each control valve component. These recommendations include preventive maintenance schedules that the company should follow to reduce downtime and ensure the continuity of refinery operations.

3. Result

3.1 Failure Data in Control Valve

Damage data refers to repair records for the components of the control valve. The damage data collected spans from January 2022 to December 2023. This data can be found in the Table 1.

Table 1
Control valve failure data

No	Date	Start	End	Machine repair time (minutes)
1	20 May 2022	08.17	14.33	256
2	10 June 2022	08.01	15.37	396
3	8 September 2022	08.07	15.20	373
4	7 October 2022	08.01	16.00	419
5	21 November 2022	08.01	10.02	121
6	22 December 2022	13.01	15.27	146
7	21 January 2023	08.00	15.40	330
8	22 March 2023	08.56	16.19	383
9	30 April 2023	08.10	10.11	121
10	17 May 2023	08.00	14.59	299
11	14 Agustus 2023	10.10	13.31	131
12	25 September 2023	09.00	13.35	155
13	21 October 2023	10.00	15.01	241
14	13 November 2023	09.22	13.30	128

3.2 Failure Mode Effect Analysis (FMEA)

To analyze the failure data, the Failure Mode and Effect Analysis (FMEA) method was used to identify failure modes and analyze the impact of each failure. The results of the FMEA analysis provide a Risk Priority Number (RPN), as shown in Table 2, which measures the risk of each component based on failure frequency, impact, and detection capability.

Table 2
FMEA Analysis

FMEA Worksheet			SYSTEM: Control valve operation SUBSYSTEM: Control valve Tag Number: 02-LCV-084						
Part/process	Function	Potential failure mode	Potential effect of failure	Sev (1-10)	Potential cause of failure	Occ (1-10)	Current controls	Det (1-10)	RPN
Seat Ring	Regulates fluid flow	Leakage in seat ring	Fluid leakage	9	Seat ring wear	1	Regular monitoring of seat ring	5	45
		Seat ring shrinkage	Loss of sealing capability	6	Material degradation	3	Regular monitoring and replacement of seat ring	7	126
TOTAL RPN									171
Plug	Regulates flow rate and quantity	Fluid leakage	Reduced mechanical performance	8	Corrosion	2	Monitoring the spiral case	7	112
TOTAL RPN									112
Stem	Connects actuator/driver to disc/plug	Corrosion	Risk of leakage	9	Exposure to corrosive environment	2	Selecting corrosion-resistant stem material	6	108
TOTAL RPN									108

The FMEA analysis yields the RPN (Risk Priority Number) for the control valve components, which is calculated by multiplying severity, occurrence, and detection. The RPN value is used to determine the risk level as follows: high risk with an RPN value ≥ 100, medium risk with an RPN value of 50-99, and low risk with an RPN value < 50. Components with a high-risk RPN value will undergo maintenance. Anthony [16] ranked the value of severity, occurrence and detection from the Failure Modes and Effect Analysis (FMEA) table, the total RPN values that fall into the high-risk category include the seat ring with an RPN of 171, the plug with 112, and the stem with 108.

3.3 Time to Repair (TTR) and Time to Failure (TTF) Calculation

Time to Repair (TTR) data represents as shown at Table 3, Table 4, and Table 5 the time required to repair a maintainable item, while Time to Failure (TTF) data indicates the time until failure occurs. Damage data, including the date and time of failure and downtime during repairs, is used to determine TTR and TTF distribution parameters. TTF is calculated with the machine operating 24 hours a day, 7 days a week. TTR is measured from the moment of failure until the machine is repaired, while TTF is the time between repairs. The following table presents the data for these components:

Table 3
Seat Ring

No	Date	Start	End	Machine Repair Time (minutes)	TTR (Hours)	TTF (Hours)
1.	10 June 2022	08.01	09.53	112	1,866	0
2.	8 September 2022	08.07	10.21	134	2,233	2158,2
3.	21 November 2022	08.15	10.02	107	1,783	1773,9
4.	21 January 2023	08.15	10.30	135	2,25	1462,2
5.	22 March 2023	14.21	16.19	118	1,966	1443,8
6.	17 May 2023	13.02	14.59	117	1,95	1340,7
7.	14 August 2023	10.10	11.59	109	1,816	2131,1
8.	13 November 2023	09.22	11.18	116	1,933	2181,3

Table 4
Plug

No	Date	Start	End	Machine repair time (minutes)	TTR (Hours)	TTF (Hours)
1.	20 May 2022	08.17	10.05	108	1,8	0
2.	7 October 2022	14.01	16.00	119	1,983	3363,9
3.	22 December 2022	13.30	15.27	117	1,95	1821,5
4.	30 April 2023	08.10	10.11	121	2,016	3088,7
5.	25 September 2023	10.00	11.59	119	1,983	3551,8
6.	21 October 2023	13.00	15.01	121	2,01	625,1

Table 5
Stem

No	Date	Start	End	Machine repair time (minutes)	TTR (Hours)	TTF (Hours)
1.	8 September 2022	09.30	10.03	33	0,55	0
2.	7 October 2022	08.21	09.00	39	0,65	1774,3
3.	22 December 2022	13.01	13.29	28	0,466	748,01
4.	22 March 2023	14.44	15.10	26	0,433	2161,2
5.	25 September 2023	09.00	09.30	30	0,5	1337,83
6.	21 October 2023	10.00	10.31	31	0,516	3144,5

3.4 Identification of Distribution Patterns and TTR and TTF Parameters

The next step is to identify the distribution pattern and parameters for the time to repair of the three components, aiming to find the most suitable distribution. Four distributions will be calculated can be seen at Table 6 and Table 7: Weibull, exponential, normal, and lognormal. To support the selection of the distribution, a Goodness of Fit test will be conducted, with the smallest Anderson-Darling (AD) value being chosen.

Table 6
Identification of TTR

No	Components	Distribution	AD Value	Coefficient
1	Seat Ring	Normal	1,910	0,934
		Lognormal	1,854	0,943
		Weibul	2,562	0,943
		Eksponensial	6,286	*
2	Plug	Normal	2,540	0,858
		Lognormal	2,569	0,852
		Eksponensial	5,620	*
		Weibul	2,324	0,910
3	Stem	Normal	2,078	0,966
		Lognormal	2,031	0,980
		Eksponensial	4,754	*
		Weibul	2,339	0,951

Table 7
Identification of TTF

No	Components	Distribution	AD Value	Coefficient
1	Seat Ring	Normal	2,059	0,933
		Lognormal	2,047	0,936
		Weibul	2,138	0,932
		Eksponensial	4,745	*
2	Plug	Normal	2,506	0,938
		Lognormal	2,674	0,890
		Eksponensial	3,255	*
		Weibul	2,536	0,939
3	Stem	Normal	2,316	0,991
		Lognormal	2,337	0,989
		Eksponensial	3,051	*
		Weibul	2,308	0,997

Based on the software calculations, the TTF distribution pattern for the seat ring is lognormal with an AD value of 2.047. The TTF distribution pattern for the plug is normal with an AD value of 2.506, while the TTF distribution pattern for the stem is Weibull with an AD value of 2.308.

After determining the appropriate distribution, the next step is to find the distribution parameters for each component using Minitab 19 and the result shown at Table 8 and Table 9.

Table 8
TTR Parameters Distribution

No	Component	Distribution	Parameter
1	Seat Ring	Log Normal	Median (tmed) = 1,968 Scale (s) = 0,091
2	Plug	Weibul	Shape(β) = 27,196 Scale (s) = 1,993
3	Stem	Lognormal	Median (tmed) = 0,515 Scale (s) = 0,156

Table 9
TTF parameters distribution

No	Component	Distribution	Parameter
1	Seat ring	Lognormal	Median (tmed) = 1750,5 Scale (s) = 0,19
2	Plug	Normal	Mean = 2490,20 StDev = 1111,28
3	Stem	Weibul	Shape(β) = 2,466 Scale (s) = 2073,79

3.5 Mean Time to Repair (MTTR) and Mean Time ti Failure (MTTF)

After calculating the parameters, the next step is to determine the Mean Time to Repair (MTTR) and Mean Time to Failure (MTTF) for the seat ring, plug, and stem components. The following are the results of the MTTR and MTTF calculations and be shown in Table 10, aligned with each component's respective distribution, using Minitab software:

Table 10
MTTR and MTTF

No	Component	MTTR (Hours)	MTTF (Hours)
1.	Seat ring	1,976	1784,88
2.	Plug	1,953	2490,20
3.	Stem	0,521	1839,41

3. 6 Determination of Component Maintenance Interval

Based on the calculations, we can determine the maintenance interval for the machine.

Table 11
Recommendation of maintenance time

No	Component	Maintenance time company	Recommended maintenance time
1	Seat Ring	+ 90 days	32 days
2	Plug	+ 90 days	37 days
3	Stem	+ 90 days	70 days

The analysis of control valve failure times shows varying failure intervals for the main components in Table 11, namely the seat ring, plug, and stem. The failure interval for the seat ring is 32 days, while the plug has a failure interval of 37 days. The stem has the longest failure interval at 70 days.

At PT Pertamina RU V Balikpapan, control valve 02-084-LCV has been identified as the most frequently failing component, based on historical data from January 2022 to December 2023. Using the Failure Mode and Effect Analysis (FMEA), the seat ring, plug, and stem were determined to have the highest Risk Priority Numbers (RPN), indicating a need for prioritized maintenance. The seat ring had an RPN of 171, followed by the plug with 112, and the stem with 108, highlighting them as key areas for focus. Following the FMEA, distribution patterns were identified for each component using Minitab software. The seat ring was found to follow a lognormal distribution, the plug a Weibull distribution, and the stem also a lognormal distribution. Based on these patterns, the Mean Time to Repair (MTTR) and Mean Time to Failure (MTTF) were calculated. Maintenance intervals were set at 32 days for the seat ring, 37 days for the plug, and 70 days for the stem, ensuring timely preventive maintenance to avoid unexpected failures as like studied by Taufiq [17]. This study emphasizes the importance of preventive maintenance in reducing operational disruptions and extending the lifespan of control valves. By implementing these calculated maintenance intervals, the company can optimize maintenance schedules, reduce downtime, and enhance equipment availability, thereby improving overall productivity and efficiency at the Pertamina RU V refinery. Preventive maintenance proves to be a critical investment for long-term operational sustainability.

4. Conclusions

The developed maintenance recommendation system successfully provides optimal preventive maintenance intervals for the critical components of the control valve 02-LCV-084 based on failure data analysis. The system identifies the Seat Ring, Plug, and Stem as the most frequently failing components. For example, the recommended preventive maintenance interval for the Seat Ring is 32 days, with a Mean Time to Failure (MTTF) of 1,784.88 hours, while the Plug is recommended for a 37-day interval with an MTTF of 2,490.20 hours. This demonstrates the system's capability to accurately determine more efficient maintenance intervals, allowing the company to prevent unexpected failures and enhance overall operational efficiency.

Acknowledgement
This research was not funded by any grant.

References
[1] Sudrajat, Nandang. *Teori dan praktik pertambangan Indonesia*. Media Pressindo, 2013.
[2] Tangkuman, Kevin, Bernhard Tewal, and Irvan Trang. "Penilaian kinerja, reward, dan punishment terhadap kinerja karyawan pada PT. Pertamina (persero) cabang pemasaran suluttenggo." *Jurnal EMBA: Jurnal Riset Ekonomi, Manajemen, Bisnis Dan Akuntansi* 3, no. 2 (2015).
[3] Suyitno, Budhi M. "Rekayasa Sistem Energi Nasional." (2022).
[4] Setio, Herlien D., Dono Ari Bawono, and Sangriyadi Setio. "Studi Perawatan Jaringan Jalan Rel Kereta Api Berbasis Kehandalan (Rcm) Study of Reliability-Centered Maintenance (RCM) On Railway Network." *Dinamika Teknik Sipil* 9, no. 2 (2009): 163-173.
[5] Sarah, Andina Nur, Ambar Harsono, and Fifi Herni Mustofa. "Usulan kebijakan perawatan lokomotif jenis CC201 dengan menggunakan metode reliability centered maintenance Di PT. kereta api Indonesia DIPO Bandung." *REKA INTEGRA* 2, no. 2 (2014).
[6] Noviansyah, Luky, Erlina Purnamawati, and Dira Ernawati. "Analisis Performance Mesin Residual Oil Main Burner Pada Unit Pltu 3/4 Dengan Metode Reliability Availability Maintainability (Ram) Di Pt Pembangkit Jawa Bali Unit Pembangkit Gresik." *JUMINTEN* 1, no. 2 (2020): 12-23. https://doi.org/10.33005/juminten.v1i2.12
[7] Budianto, Dimas Arief, Waspada Tedja Bhirawa, and Basuki Arianto. "Analisis Optimalisasi Penjadwalan Inspeksi C Check Main Landing Gear Retractable Pada Pesawat Atr 42–300 Dengan Metode Reliability Centered Maintenance (RCM)." *Jurnal Teknik Industri* 11, no. 1 (2022): 30-41.
[8] Hanifa, Putri Etrif, Endang Budiasih, and Aji Pamoso. "Usulan Kebijakan Perawatan Berdasarkan Analisis Performansi Pada Mesin Raw Mill Menggunakan Metode Reliability, Availability, Maintainability (ram) Analysis Di Pt. Xyz." *eProceedings of Engineering* 7, no. 2 (2020). https://doi.org/10.33005/juminten.v2i4.240

[9] Fahrurroji, Muhamad, Dene Herwanto, and Asep Erik Nugraha. "Usulan Perencanaan Perawatan Dengan Menggunakan Metode Reliability Centred Maintenance (RCM) di PT. Djabesmen." *Jurnal Industry Xplore* 6, no. 2 (2021). https://doi.org/10.36805/teknikindustri.v6i2.1458
[10] Pranoto, H. *Reliability centered maintenance*. Mitra Wacana Media. 2015.
[11] Lumbantoruan, Parmin. "Aplikasi Sistem Kontrol Valve di PT. Pupuk Sriwidjadja Palembang." *Jurnal Penelitian Fisika dan Terapannya (JUPITER)* 3, no. 1 (2021): 5-10. https://doi.org/10.31851/jupiter.v2i1.4164
[12] Damayanti, Rissa, Puji Santoso, and Budi Santoso. "Penentuan Ukuran Control Valve Pada Unit Pengolahan Air Bebas Mineral Iradiator Gamma PRFN." *PRIMA-Aplikasi dan Rekayasa dalam Bidang Iptek Nuklir* 12, no. 1 (2017): 9-19.
[13] Rekayasa, J. *Jurnal Rekavasi*. *3*(1). 2015.
[14] Enim, Kab Muara, and Hendro Asisco. "Usulan Perencanaan Perawatan Mesin Dengan Metode Reliability Centered Maintenance (RCM) Di Pt. Perkebunan Nusantara Vii (Persero) Unit Usaha Sungai Niru."
[15] Widiasih, Wiwin. "Perhitungan Biaya Penggantian Komponen dengan Mempertimbangkan Penjadwalan Perawatan pada Mesin Bucket Raw Material." *Tekmapro: Journal of Industrial Engineering and Management* 14, no. 2 (2019): 68-76. https://doi.org/10.33005/tekmapro.v14i2.90
[16] Anthony, Muhamad Bob. "Analisis penyebab kerusakan hot rooler table dengan menggunakan metode failure mode and effect analysis (FMEA)." *Jurnal INTECH Teknik Industri Universitas Serang Raya* 4, no. 1 (2016): 1-8. https://doi.org/10.30656/intech.v4i1.851
[17] Septyani, Selly. "Penentuan interval waktu perawatan komponen kritis pada mesin turbin di PT PLN (Persero) Sektor Pembangkit Ombilin." *jurnal optimasi sistem industri* 14, no. 2 (2015): 238-258. https://doi.org/10.25077/josi.v14.n2.p238-258.2015