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Analysis of Preventive Maintenance Schedule of Xym1900 Vertical Roller Mill Crusher Machine using MTBF (Mean Time Between Failures) Method Based on RCA (Root Cause Analysis)

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Abstract—The reliability and performance of heavy machinery are critical to maintaining consistent production in the cement industry. This study analyzes the preventive maintenance schedule of the XYM1900 Vertical Roller Mill crusher machine at PT XYZ, where frequent breakdowns have contributed to production inefficiencies and increased operational costs. The research employs the Mean Time Between Failures (MTBF) method to evaluate the reliability of key machine components and identify optimal maintenance intervals. Additionally, Root Cause Analysis (RCA) is used to trace the underlying causes of recurring failures. Maintenance and failure data were collected over a one-year period to calculate MTBF values for critical components, including the grinding roller, hydraulic system, and gearbox. RCA findings indicate that improper lubrication, delayed part replacements, and environmental factors such as dust contamination are the primary contributors to equipment failure. Based on the analysis, revised maintenance schedules were proposed to reduce unplanned downtime and extend component life. The results demonstrate that implementing a data-driven preventive maintenance plan can significantly enhance equipment reliability and support operational efficiency.

Keywords— Preventive Maintenance, MTBF, Root Cause Analysis, Vertical Roller Mill, Equipment Reliability, Crusher Machine

I. INTRODUCTION

The rapid development of the industrial sector demands high reliability of production equipment to ensure continuous operations. PT. XYZ, a company engaged in the magnesium processing industry, relies heavily on several critical machines to maintain production efficiency. One of the most vital machines in the production line is the Crusher type XYM1900 Vertical Roller Mill, which functions to grind raw materials to the required particle size for further processing.

During operational activities, this machine frequently experiences issues such as component wear, excessive vibration, and sudden breakdowns, leading to significant downtime and increased maintenance costs. Based on historical data from January to December 2024, the Vertical Roller Mill accounted for 74% of all recorded failures, making it the highest contributor to system unavailability at PT. XYZ.

Currently, the maintenance strategy at PT. XYZ includes preventive maintenance. However, the existing preventive maintenance schedule is not optimally designed based on actual failure patterns, often resulting in either over-maintenance or delayed servicing. This condition emphasizes the need for a data-driven preventive maintenance strategy to optimize maintenance intervals and reduce total downtime.

To address these issues, this research applies the Mean Time Between Failures (MTBF) method to determine the optimal maintenance intervals and uses Root Cause Analysis (RCA) with Fault Tree Analysis (FTA) to identify the fundamental causes of machine failure. Through this approach, it is expected that machine availability will increase, operational costs will decrease, and overall reliability of the Crusher type XYM1900 Vertical Roller Mill will be significantly improved.

II. RELATED WORKS

A. Maintenance System

Maintenance is an activity to maintain or guard factory facilities or equipment and make repairs or adjustments / replacements as needed so that there is a satisfactory state of production operation according to what is planned. Maintenance can be interpreted as an activity to maintain or guard factory facilities or equipment and make repairs or replacements as needed so that there is a satisfactory state of production operation according to what is planned [1]. According to [2], he is of the opinion that the definition of maintenance is an activity to maintain or preserve factory facilities or equipment and to carry out repairs or adjustments and replacements as necessary so that there are activities during production operations that are satisfactory according to what has been planned.

A maintenance system that does not meet standards will result in losses for the company due to frequent replacement of machine components until the machine is damaged. To maintain and maintain the optimization of a system, maintenance or care activities must be carried out. The maintenance method is an activity that aims to maintain and repair a product that is needed so that a satisfactory condition occurs. Maintenance is an activity to maintain and maintain a machine so that it is in accordance with its normal conditions and functions [3], so it is concluded that maintenance or care is a series of activities carried out to maintain goods or especially machines so that they are in their normal condition [4].

B. Maintenance Function

The function of maintenance is to extend the economic life of existing machines and production equipment and to ensure that the machines and production equipment are always in optimal condition and ready to use for the implementation of the production process. The maintenance function needs to be carried out properly to maintain the condition of production facilities, because it affects the continuity of an industry's operations. Maintenance has a major impact on the smooth running of the production process. The smooth running of the production process is often disrupted by machine damage [5].

C. Purpose of Maintenance

Maintenance is a supporting activity for commercial activities, so like other activities, maintenance must be carried out effectively, efficiently, and at low cost. With this maintenance activity, the production machine/equipment can be used according to plan and not damaged during a certain period of time that has been planned to be achieved. According to [6] in (Wati, 2009) Some of the main objectives of maintenance include:

1. Production capacity can meet the needs according to the production plan.
2. Maintain quality at the right level to meet what is needed by the product itself and uninterrupted production activities.

3. To help reduce use and storage that is beyond the limit and maintain the capital invested in the company for a specified time in accordance with the company's policy regarding the investment.
4. To achieve an effective and efficient overall maintenance cost level.
5. To ensure the safety of people using the facilities.
6. Maximize the availability of all production system equipment (reduce downtime).
7. To extend the service life of the machine/equipment.

D. Types Maintenance

1) Planned Maintenance

Is planned maintenance, control and recording according to a predetermined plan. Planned maintenance consists of three forms of implementation, namely:

a) Preventive maintenance is a maintenance and care activity carried out to avoid unexpected damage and to detect conditions or circumstances that can cause damage to production facilities when used in the production process.
b) Corrective maintenance is a maintenance activity carried out after damage or negligence occurs to the machine/equipment which causes the machine to not function properly.
c) Predictive maintenance is maintenance step that is carried out at a predetermined time based on predictions of the results of analysis and evaluation of operational data collected to carry out predictive maintenance, which can be in the form of vibration, temperature, vibration, flow, etc.

2) Unplanned Maintenance

Unplanned maintenance is generally in the form of emergency / breakdown maintenance. Emergency / breakdown maintenance is a maintenance action that is not carried out on machines / equipment that are still functioning, until the machine / equipment is damaged and can no longer operate. Through the implementation of this unplanned maintenance, it is hoped that the implementation of this maintenance can extend the life of the machine / equipment and can reduce the frequency of damage.

3) Autonomous Maintenance

Is an effort to increase machine productivity and efficiency through activities carried out by operators to maintain the machines they handle themselves [7]

E. Cost Maintenance

According to [8] Preventive maintenance costs consist of costs arising from equipment inspection and adjustment activities, replacement or repair of components, and loss of production time caused by these activities. Corrective maintenance costs are costs that arise when equipment is damaged or cannot operate, which include loss of production time, maintenance costs or equipment replacement costs. Good maintenance will be carried out within a certain period of time and when the production process is not running. On the other hand, if maintenance is not carried out, it will reduce the performance of the machine. Maintenance costs can be summarized into two, namely:

1. Maintenance costs due to maintenance to prevent damage to the machine or its components.
2. Repair costs incurred due to damage to critical components of the machine or equipment in addition to the cost of replacing spare parts.

There are several ways to prepare a budget for facility maintenance according to [9], including:

1. Maintenance cost planning, maintenance cost planning based on figures from the previous year.
2. Maintenance cost planning based on facility value
3. Maintenance cost planning based on facility usage
4. Maintenance cost planning based on production units
5. “Top down” budgeting and “bottom up” planning

F. MTBF

MTBF is a measure that describes the average time between one system failure and the next. This metric shows how long a system can operate normally before experiencing a disruption. MTBF is calculated by dividing the total system operational time by the number of failures that occurred during that period. The higher the MTBF value, the more reliable the system is, meaning it can operate longer without experiencing a disruption. MTBF is very useful in planning maintenance and scheduling repairs, as it helps determine optimal maintenance intervals and reduces the risk of downtime. Accurate MTBF data allows companies to analyze failure trends and make data-based decisions regarding equipment repair or replacement [10].

According to Levit (2010) in the research of Wardana and Abdulrahim [11], MTBF is an important parameter in assessing the quality of maintenance. MTBF describes the level of reliability of a system or equipment in carrying out its functions without experiencing damage. MTBF is calculated by dividing the total operational time by the number of failures that occur. The higher the MTBF value, the more reliable the system or equipment is. MTBF is also used to predict the time before the next failure and assists in preventive maintenance planning. MTBF measures the average time between equipment failures, with the following formula:

$$\mathrm{MTBF} = \frac{\text{Total Waktu Kerja (Total } \textit{Operation Time}\text{)}}{\text{Jumlah Kegagalan (}\textit{Failure Frequency}\text{)}} \quad (1)$$

G. Availability

Availability merupakan rasio dari lama waktu suatu mesin pada suatu pabrik digunakan terhadap waktu yang ingin digunakan (waktu tersedia). *Availability* merupakan ukuran sejauh mana mesin tersebut bisa berfungsi. *Availability ratio* adalah tingkat efektivitas beroperasinya suatu mesin/peralatan. Nilai *availability* yaitu dengan cara menghitung selisih *loading time* dan waktu *downtime* mesin dengan total waktu yang tersedia[12].

Thus the formula used to measure the availability ratio is as follows:

$$Availability = \frac{\text{Total time availability} - \text{Downtime}}{\text{Total time availability}} \times 100 \quad (2)$$

H. Root Cause Analysis (RCA)

Root Cause Analysis (RCA) is a method for solving problems, trying to identify the causal factors of a problem or unwanted event. Root Cause Analysis is a method that helps answer the questions 'what happened? ', 'how did it happen? ', and 'why did it happen? '. The main purpose of this method is to identify factors expressed in natural form, size, location, and time due to certain habits, actions, and conditions that need to be changed to avoid unnecessary errors. The Root Cause Analysis method is often used in carrying out various types of business activities, including building construction projects and the like. Identifying the main factors causing material waste using the Root Cause Analysis Method can produce accurate and systematic results [13].

Metode diagram tulang ikan (*fishbone diagram*) juga dapat digunakan untuk mengidentifikasi dan mengelompokkan faktor penyebab cacat. Pendekatan ini membantu memvisualisasikan masalah secara terstruktur dan mendalam . Dalam konteks produksi tinta di PT Epson Batam, analisis RCA, FTA, dan *fishbone diagram* sangat relevan untuk mengidentifikasi faktor penyebab cacat utama. Kombinasi metode ini memungkinkan perusahaan untuk fokus pada perbaikan yang memberikan dampak paling signifikan terhadap kualitas produk [18]

Fault Tree Analysis (FTA) or also called Fault Tree is a method to analyze the root cause. The process begins by analyzing the system that has an undesired event, FTA is in the form of a tree-like diagram consisting of symbols (fault tree symbols) that are interrelated in a structure, the diagram is connected by event symbols and logic gate symbols to facilitate the Analysis process [14].

I. Machine Crusher Vertical Roller Mill

Vertical Roller Mill is the most common component as a raw material grinding unit that is widely used in cement companies. Vertical Roller Mill itself has a table diameter of 2 to 6 meters depending on the size of the Vertical Roller Mill itself. The final product of the Vertical Roller Mill itself is smaller than the original size of around 90 microns. With centrifugal force, the Vertical Roller Mill operates normally at 20-40 RPM depending on the size of the Vertical Roller Mill itself and has a maximum tangential speed of 7 m / s [15].

The material milling itself has an important role in the process of energy production, mining and cement production. Efficiency and Quality in the milling process have a direct impact on the milled product. In recent years, Vertical Roller Mill has been widely used in the mining industry. Vertical Roller Mill itself has many advantages such as high drying efficiency, low noise and has a large input size, low wear and low energy consumption [16].

Vertical roller mill is a combination of the system on the millstone and rocker arm, in the process the millstone is driven by a motor so that it can rotate and the material enters through the center of the millstone. with the centrifugal force the material above the millstone is ground by a roller that is given pressure by the hydraulic cylinder bears so that the material can be eroded [17].

III. METHOD

A. Data Collection Methods

To support the research being conducted, some data is needed which will later be used to analyze the problems that occur and this data is obtained from:

1) Primary Data

Primary data is data measured during field research by researchers on research objects. There are 2 methods used in data collection, namely:

- Observation is involves direct observation and recording of company documents related to the information needed.
- Interview are a method of direct communication with employees or operators relevant to the research object.

2) Secondary data

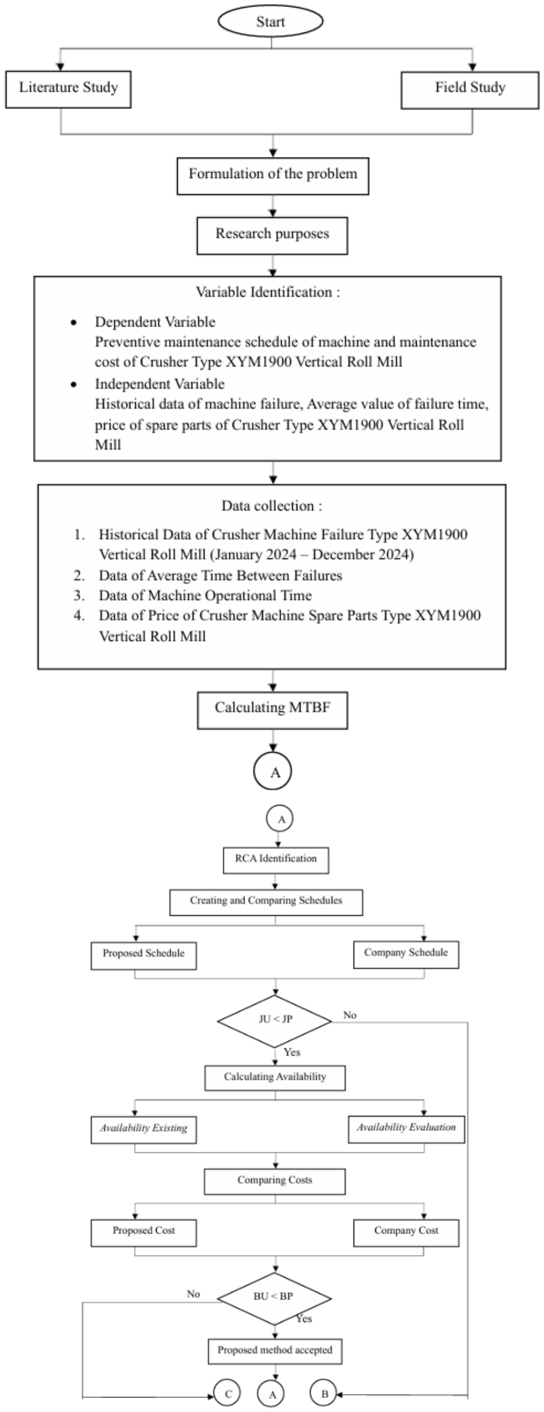
Secondary data is data obtained by researchers by collecting existing data in the company (company documents).

The data or information obtained includes:

- Historical data on the failure of the Crusher Type XYM1900 Vertical Roll Mill machine for the last 1 year (January 2024 - December 2024).
- Data on the average time between failures.
- Machine Operational Time Data
- Price Data for Spare Parts of the Crusher Type XYM1900 Vertical Roll Mill Machine.

B. Data Processing Method

Data processing will be done when the required data has been collected. Data processing aims to resolve and discuss the problems being analyzed. Steps taken data processing are:


Start
Literature Study
Field Study
Formulation of the problem
Research purposes
Variable Identification :
Dependent Variable
Preventive maintenance schedule of machine and maintenance cost of Crusher Type XYM1900 Vertical Roll Mill
Independent Variable
Historical data of machine failure, Average value of failure time, price of spare parts of Crusher Type XYM1900 Vertical Roll Mill
Data collection :
1. Historical Data of Crusher Machine Failure Type XYM1900 Vertical Roll Mill (January 2024 – December 2024)
2. Data of Average Time Between Failures
3. Data of Machine Operational Time
4. Data of Price of Crusher Machine Spare Parts Type XYM1900 Vertical Roll Mill
Calculating MTBF
A
A
RCA Identification
Creating and Comparing Schedules
Proposed Schedule
Company Schedule
JU < JP
No
Yes
Calculating Availability
Availability Existing
Availability Evaluation
Comparing Costs
Proposed Cost
Company Cost
BU < BP
No
Yes
Proposed method accepted
C
A
B

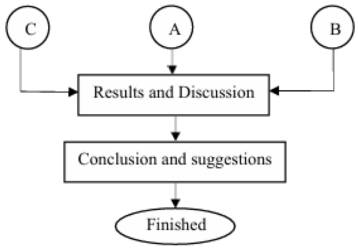


Fig 1. Flowchart

IV. RESULT AND DISCUSSION

A. Data Collection

Before do data processing , especially formerly done collection of related data with object study that is machine *Crusher Type* XYM1900 *Vertical Roll Mill* (VRM) at PT XYZ. Historical data maintenance the machine used in study This is data from January 2024 to with December 2024. The data includes :

1) Data Historical Failure Machine *Crusher Type* XYM1900 VRM

The following data is Company Preventive Maintenance schedule on machines Crusher VRM :

Tabel 1. Machine Preventive Maintenance Schedule *Crusher Type XYM1900 Vertical Roll Mill* Company

PREVENTIVE MAINTENANCE SCHEDULE														
Equipment	**Component**	**P/R**	**Month**											
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Vertical Roll Mill	Rotary Valve	P	8	8	8	8	8	8	8	8	8	8	8	8
		R	8	8	8	8	8	8	8	8	8	8	8	8
	Bucket Elevator	P	8	8	8	8	8	8	8	8	8	8	8	8
		R	8	8	8	8	8	8	8	8	8	8	8	8
	Vertical Roll Mill	P	8	8	8	8	8	8	8	8	8	8	8	8
		R	8	8	8	8	8	8	8	8	8	8	8	8
	Hydraulic	P	8	8	8	8	8	8	8	8	8	8	8	8
		R	8	8	8	8	8	8	8	8	8	8	8	8

The following data is historical data failure machine *Crusher* VRM in 2024 (January – December) with total *downtime* as many as 1037 hours, 62220 minutes and the total frequency as many as 60 incidents , data as following :

Tabel 2. Frequency Data failure machine in January 2024 – December 2024 at PT. XYZ

Historical Data			
Month	**Frequency**	***Downtime* (hours)**	***Downtime* (Minutes)**
January	5	90	5400
February	4	78	4680
March	5	93	5580
April	7	108	6480
May	4	72	4320
June	3	57	3420
July	4	80	4800
August	5	88	5280
September	3	63	3780
October	8	115	6900
November	7	104	6240
December	5	89	5340
Total	60	1037	62220

2) Average time value data between failure

Average time value data between failure Machine Crusher VRM on on 2024 (January – December) includes as following :

Tabel 3 Average time value data between failure in January 2024 – December 2024 at PT. XYZ

No	Date	Equipment	Component	Sub-Components	Downtime (Minutes)
1	01/01/2024	Vertical Roll Mill	Bucket Elevator	Buckets	1062
2	01/09/2024	Vertical Roll Mill	Vertical Roll Mill	Roller Assembly	525
3	01/13/2024	Vertical Roll Mill	Rotary Valve	Bearing	2187
4	01/17/2024	Vertical Roll Mill	Bucket Elevator	Buckets	860
5	01/27/2024	Vertical Roll Mill	Vertical Roll Mill	Grinding Table	724
6	02/03/2024	Vertical Roll Mill	Rotary Valve	Blade	951
7	02/08/2024	Vertical Roll Mill	Bucket Elevator	Electric motor	630
8	11/02/2024	Vertical Roll Mill	Bucket Elevator	Buckets	1194
9	02/18/2024	Vertical Roll Mill	Hydraulic	Cylinder	954
10	02/03/2024	Vertical Roll Mill	Bucket Elevator	Chain/Belt Conveyor	781
11	03/04/2024	Vertical Roll Mill	Rotary Valve	Drive Motor	586
12	03/20/2024	Vertical Roll Mill	Bucket Elevator	Buckets	1001
13	03/26/2024	Vertical Roll Mill	Vertical Roll Mill	Roller Assembly	563
14	03/26/2024	Vertical Roll Mill	Bucket Elevator	Buckets	968
15	04/07/2024	Vertical Roll Mill	Hydraulic	Hydraulic Pipe	588
16	04/08/2024	Vertical Roll Mill	Bucket Elevator	Electric motor	507
17	10/04/2024	Vertical Roll Mill	Vertical Roll Mill	Grinding Table	829
18	11/04/2024	Vertical Roll Mill	Vertical Roll Mill	Roller Assembly	612
19	04/16/2024	Vertical Roll Mill	Vertical Roll Mill	Grinding Table	987
20	04/19/2024	Vertical Roll Mill	Vertical Roll Mill	Separator	2400
21	04/22/2024	Vertical Roll Mill	Bucket Elevator	Buckets	921
22	03/05/2024	Vertical Roll Mill	Hydraulic	Motorbike Play	546
23	12/05/2024	Vertical Roll Mill	Rotary Valve	Blade	978
24	05/13/2024	Vertical Roll Mill	Hydraulic	Motorbike Play	440
25	05/13/2024	Vertical Roll Mill	Hydraulic	Cylinder	585
26	04/06/2024	Vertical Roll Mill	Bucket Elevator	Buckets	1204
27	06/17/2024	Vertical Roll Mill	Bucket Elevator	Chain/Belt Conveyor	431
28	06/19/2024	Vertical Roll Mill	Rotary Valve	Blade	515
29	02/07/2024	Vertical Roll Mill	Bucket Elevator	Buckets	1183
30	02/07/2024	Vertical Roll Mill	Rotary Valve	Drive Motor	936
31	07/15/2024	Vertical Roll Mill	Vertical Roll Mill	Separator	1896

No	Date	Equipment	Component	Sub-Components	Downtime (Minutes)
32	07/23/2024	Vertical Roll Mill	Bucket Elevator	Chain/Belt Conveyor	771
33	01/08/2024	Vertical Roll Mill	Hydraulic	Motorbike Play	465
34	01/08/2024	Vertical Roll Mill	Hydraulic	Hydraulic Pipe	488
35	06/08/2024	Vertical Roll Mill	Vertical Roll Mill	Separator	2437
36	06/08/2024	Vertical Roll Mill	Vertical Roll Mill	Roller Assembly	626
37	08/13/2024	Vertical Roll Mill	Rotary Valve	Drive Motor	524
38	07/09/2024	Vertical Roll Mill	Vertical Roll Mill	Grinding Table	711
39	10/09/2024	Vertical Roll Mill	Vertical Roll Mill	Separator	2017
40	12/09/2024	Vertical Roll Mill	Hydraulic	Hydraulic Pump	447
41	10/03/2024	Vertical Roll Mill	Bucket Elevator	Electric motor	498
42	10/03/2024	Vertical Roll Mill	Vertical Roll Mill	Separator	1838
43	10/03/2024	Vertical Roll Mill	Bucket Elevator	Electric motor	860
44	10/05/2024	Vertical Roll Mill	Vertical Roll Mill	Separator	1973
45	10/06/2024	Vertical Roll Mill	Vertical Roll Mill	Separator	2228
46	10/06/2024	Vertical Roll Mill	Hydraulic	Cylinder	609
47	10/28/2024	Vertical Roll Mill	Bucket Elevator	Chain/Belt Conveyor	525
48	10/28/2024	Vertical Roll Mill	Rotary Valve	Drive Motor	903
49	11/01/2024	Vertical Roll Mill	Vertical Roll Mill	Separator	2309
50	11/09/2024	Vertical Roll Mill	Bucket Elevator	Electric motor	680
51	11/15/2024	Vertical Roll Mill	Rotary Valve	Drive Motor	636
52	11/18/2024	Vertical Roll Mill	Vertical Roll Mill	Separator	2196
53	11/21/2024	Vertical Roll Mill	Rotary Valve	Bearing	1738
54	11/25/2024	Vertical Roll Mill	Hydraulic	Cylinder	609
55	11/29/2024	Vertical Roll Mill	Vertical Roll Mill	Roller Assembly	983
56	12/05/2024	Vertical Roll Mill	Rotary Valve	Blade	575
57	12/12/2024	Vertical Roll Mill	Hydraulic	Hydraulic Pump	745
58	12/16/2024	Vertical Roll Mill	Vertical Roll Mill	Separator	2449
59	12/17/2024	Vertical Roll Mill	Bucket Elevator	Buckets	1129
60	12/19/2024	Vertical Roll Mill	Rotary Valve	Bearing	1707

3) Operational Time Data Machine in 1 year

Operational hours machine counted based on difference between total time walk machine (Running Hour) with time used For maintenance planned maintenance . From the calculations carried out , the total time operational machine obtained amounting to 6456 hours, which comes from from reduction of 8760 hours of time walk with 2304 hours of time maintenance planned . This value used as base calculation Mean Time Between Failures (MTBF) for determine the optimal Preventive Maintenance (PM) strategy . The calculation as following :

- Running Hours = 365 x 24
  = 8760 hours
- Planned Maintenance = 96 x 24
  = 2304 hours
- Operational Hours Machine = *Running Hour – Planned Maintenance*
  = 8760 – 2304
  = 6456 hours

4) Price data spare parts Machine

Purchase price for , spare parts machine Crusher VRM can seen in the table under This :

Tabel 4 . Spare Part Price Data Machine Crusher VRM at PT. XYZ

No	Equipment	Component	Price
1	VRM	Rotary Valve	Rp. 8,500,000
2		Bucket Elevator	Rp14,700,000
3		Vertical Roll Mill	Rp18,800,000
4		Hydraulic	Rp22,300,000

B. Data Processing

1) Calculating MTBF

Tabel 5. Calculation Data *Mean Time Between Failure* Machine *Crusher* VRM

Sub- Components	Operational Hours	Amount Failure	MTBF Calculation	MTBF (Hours)
Blade	6456	4	6456 ÷ 4	1614
Bearing	6456	3	6456 ÷ 3	2152
Drive Motor	6456	5	6456 ÷ 5	1291.2
Buckets	6456	9	6456 ÷ 9	717,3333333
Chain/Belt Conveyor	6456	4	6456 ÷ 4	1614
Electric motor	6456	5	6456 ÷ 5	1291.2
Grinding Table	6456	4	6456 ÷ 4	1614
Roller Assembly	6456	5	6456 ÷ 5	1291.2
Separator	6456	10	6456 ÷ 10	645.6
Motorbike Play	6456	3	6456 ÷ 3	2152
Cylinder	6456	4	6456 ÷ 4	1614
Hydraulic Pump	6456	2	6456 ÷ 2	3228
Hydraulic Pipe	6456	2	6456 ÷ 2	3228

Formula :

$$\text{MTBF Blade} = \frac{\text{Total Waktu Kerja (Total } \mathit{Operation\ Time})}{\text{Jumlah Kegagalan (}\mathit{Failure\ Frequency})} = \frac{6456}{4} = 1614$$

Tabel 6. Calculation Data *Mean Time Between Failure* Machine *Crusher* VRM

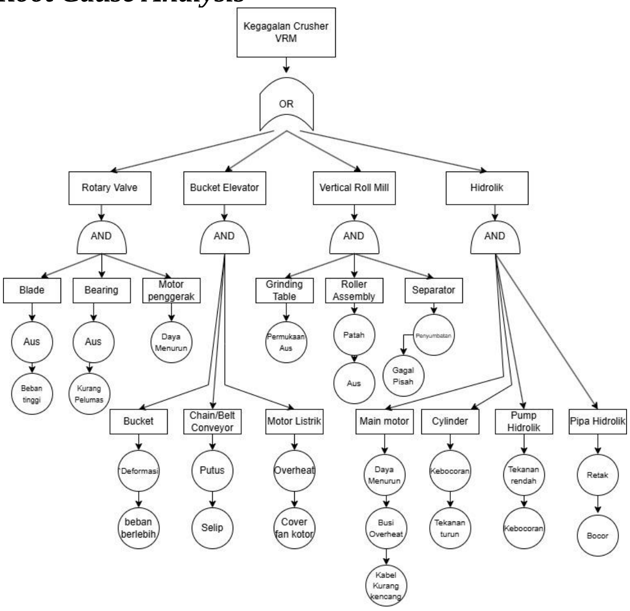
Sub- Components	MTBF (Hours)	MTBF (Days)	Frequency (per year)
Blade	1614	67.25	5
Bearing	2152	89.66666667	4
Drive Motor	1291.2	53.8	7
Buckets	717,3333333	29,88888889	12
Chain/Belt Conveyor	1614	67.25	5
Electric motor	1291.2	53.8	6
Grinding Table	1614	67.25	5
Roller Assembly	1291.2	53.8	6
Separator	645.6	26.9	14
Motorbike Play	2152	89.66666667	4
Cylinder	1614	67.25	5
Hydraulic Pump	3228	134.5	3
Hydraulic Pipe	3228	134.5	3

Formula :

$$\text{MTBF (Hari) Blade} = \frac{\text{MTBF}}{24} = \frac{1614}{24} = 67{,}25$$

$$\text{Frekuensi PM Blade} = \frac{365}{\text{PM Interval}} = \frac{365}{67{,}25} = 5{,}43 \approx 5$$

2) Identification Root Cause Analysis



1. *Rotary Valve*

Rotary Valve Failure happen consequence three sub- components Main : *Blade, Bearing,* and Drive Motor .

- *Blade* experience wear and tear consequence burden high , which can reduce efficiency system material cutting .
- *Bearing* experience worn out consequence lack of lubrication , causing improvement friction and heat excessive .
- Drive motor experience decline power , which can influence performance system in a way overall .

2. *Bucket Elevator*

Failure *Bucket Elevator* caused by disturbances in three sub- components main , namely *Bucket, Chain/Belt Conveyor* , and Electric Motor.

- *Buckets* experience deformation consequence burden excess , which can cause decline capacity transport materials.
- *Chain/Belt Conveyor* experience separated or slip , which can happen Because suboptimal tension .
- Electric motor experienced overheating due to a dirty fan cover , so lower efficiency cooling .

3. *Vertical Roll Mill*

In *Vertical Roll Mill* , failure can triggered by *the Grinding Table, Roller Assembly* , and Separator.

- *Grinding Table* experience wear on the surface , which can reduce effectiveness material grinding .
- *Roller Assembly* experience broken or wear , which has the potential hinder the work process .
- The separator experiences blockage or fail in separation of materials, which can result in suboptimal distribution of materials .

4. Hydraulic System

Failure in the Hydraulic System is related with disturbances in *the Main Motor, Cylinder, Hydraulic Pump* , and Hydraulic Pipe.

- *Playing motorbike* experience decline Power due to overheating of the spark plugs and insufficient cables tight .
- *Cylinder* experience leaks and pressure decreased hydraulics , which impacts performance actuator .
- *Hydraulic pump* experience pressure low consequence leaks , which reduces ability system in transfer Power .
- Hydraulic pipe experience cracks and leaks , which can cause lost fluid and failure system hydraulic in a way overall .

3) Make New Scehdule

Tabel 7. New schedule Machine Crusher VRM

PROPOSED PREVENTIVE MAINTENANCE SCHEDULE													
Equipment	**Component**	**Month**											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
VRM	Rotary Valve	3	1	2	1	1	2	1	1	3		1	
	Bucket Elevator	4	2	2	2	2	2	2	2	3	1	1	
	Vertical Roll Mill	4	2	2	2	2	2	3	2	3	1	1	1
	Hydraulic	4		2		3	1	1		4			

4) Calculating & Comparing Availability

Tabel 8. Presentation mark Availability Machine Crusher VRM

Availability

Company Schedule	Proposed Schedule
73.69%	94.58%

Availability value that is obtained with method count difference *loading time* and *downtime* machine with the total time available . Machine *Crusher* VRM is used in 3 shifts with a total time of operational for 6456 hours in 1 year .

$$Availability = \frac{Running\ Hour - Planned\ Maintenance}{Running\ Hour} \times 100\%$$

Historical data company For old schedule for 1 year , machine The VRM *crusher* experienced PM 96 times with a total time of *downtime* machine *Crusher* VRM is of 2304 hours. So that availability value *The crusher* on the old schedule was by 73.69%.

Operational Hours Machine = *Running Hour – Planned Maintenance*
= 8760 – 2304
= 6456 hours

$$Availability = \frac{6456}{8760} \times 100\% = 73{,}69\%$$

On the proposed Schedule For machine *Crusher* VRM based results calculation time *downtime* that has been obtained is activity maintenance as many as 79 times with duration *downtime* per maintenance for 6 hours obtained time *downtime* as many as 474 hours. So that machine availability value *Crusher* VRM of 94.58%.

Operational Hours Machine = *Running Hour – Planned Maintenance*
= 8760 – 474
= 8 286 hours

$$Availability = \frac{8286}{8760} \times 100\% = 94{,}58\%$$

5) Calculating & Comparing cos Spare parts

Tabel 9. PM Cost Schedule of Machine Company Crusher VRM

No	Equipment	Component	Frequency Maintenance	Price	Total
1	VRM	Rotary Valve	48	Rp. 8,500,000	Rp408,000,000
2		Bucket Elevator	48	Rp14,700,000	Rp705,600,000
3		Vertical Roll Mill	48	Rp18,800,000	Rp902,400,000
4		Hydraulic	48	Rp22,300,000	Rp1,070,400,000
Total					Rp3,086,400,000

Wages (per hour)	Estimate Cost (IDR)
Helper (Rp. 11,000)	Rp. 25,344,000.00
Mechanic (Rp. 25,000)	Rp. 57,600,000.00
Total	**Rp. 82,944,000.00**

Tabel 10. PM Costs Proposed schedule Machine *Crusher* VRM

No	Equipmen t	Component	Frequency Maintenance	Price	Total
1	VRM	Rotary Valve	16	Rp. 8,500,000	Rp136,000,000
2		Bucket Elevator	23	Rp14,700,00 0	Rp338,100,000

No	Equipment	Component	Frequency Maintenance	Price	Total
3		Vertical Roll Mill	25	Rp18,800,000	Rp470,000,000
4		Hydraulic	15	Rp22,300,000	Rp. 334,500,000
Total					Rp1,278,600,000

Wages (per hour)	Estimate Cost (IDR)
Helper (Rp. 11,000)	Rp. 3,476,000.00
Mechanic (Rp. 25,000)	Rp. 7,900,000.00
Total	**Rp. 11,376,000.00**

In the table calculation estimate cost on happen subtraction very significant costs from old schedule and schedule proposal , with total cost the old PM schedule was Rp. 3,169,344,000.00 , while in the proposed timetable new amounting to Rp.1,289,976,000.00, This proves that that timetable proposal new more economical amounting to Rp. 1,879,368,000.00.

V. CONCLUSION

Based on the results of the research conducted, the following conclusions can be drawn. First, the analysis of Mean Time Between Failures (MTBF) and Root Cause Analysis (RCA) was used to develop a proposed maintenance schedule that takes into account the frequency of failures, optimal maintenance intervals, and the main causes of damage to each component. MTBF calculations enable more accurate determination of preventive maintenance intervals. In the previous schedule, 96 preventive maintenance actions were carried out within a 24-hour period due to the scheduling of all components. However, in the proposed schedule, only 79 preventive actions are required, with an average interval of 6 hours per component, making the scheduling more effective. The implementation of the proposed Preventive Maintenance (PM) schedule showed an improvement in machine availability from 73.69% to 94.58%, indicating a significant reduction in downtime and an increase in operational efficiency. Second, the analysis using RCA and the Fault Tree Analysis (FTA) tool successfully identified critical components that frequently experience failures in the Vertical Roll Mill machine. Based on failure data analysis, the Bucket Elevator, Rotary Valve, and Separator were identified as the components with the highest failure rates. The primary causes of these failures include component wear and tear, lack of specialized maintenance, deformation due to excessive loads, and blockages in the separator system. Overall, the main causes of failure in each component are generally due to suboptimal maintenance practices, inappropriate operating procedures, and a lack of operator understanding regarding machine conditions. Third, the implementation of the preventive maintenance schedule based on MTBF results is estimated to incur a total cost of Rp.1,289,976,000.00.

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