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Analysis of Extrusion Blow Molding Machine Maintenance Planning with Reliability Centered Maintenance and IRRO Method

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ABSTRACT

High demand for plastic products from year to year creates the need for plastic molding machines that can mass produce plastic products. An example of a plastic molding machine used at PT. X is a VK type extrusion blow molding (EBM) machine. Based on data from PT. X, the downtime of the VK type EBM machine reached 215.74 hours in 2021-2023. Therefore, improvements are needed in the machine maintenance management system. The purpose of this research is to determine the critical components, determine the reliability value of the critical components, and also establish a preventive maintenance schedule along with a cost budget plan for each critical component of the VK type extrusion blow molding machine at PT. X to increase the effectiveness of existing production activities. The method used is Reliability Centered Maintenance (RCM) with the application of RCA and FMEA methods to find critical components, then calculate the reliability of critical components as a reference for making preventive maintenance schedules. The data used are the failure data of VK type EBM machine in 2021-2023 period. The results of this study obtained 4 critical components with a reliability value of 0.5, namely the clamping unit at 210.3149 hours, the cutting unit at 79.9911 hours, the head unit at 677.5324 hours, and the hydraulic unit at 424.1550 hours. Maintenance planning is based on the IRRO (Inspection, Repair, Replace, Overhaul) method. The total maintenance cost for the period 2025 is Rp 35,093,903, which reduces the cost by 8.5% compared to 2023.

Keyword: Extrusion Blow Molding, IRRO, Machine Maintenance, Plastic, Reliability Centered Maintenance

ABSTRAK

Tingginya permintaan produk plastik dari tahun ke tahun, menyebabkan kebutuhan akan mesin cetak plastik yang dapat memproduksi produk plastik secara massal. Salah satu contoh mesin yang digunakan untuk mencetak produk plastik di PT. X adalah mesin *extrusion blow molding* (EBM) tipe VK. Berdasarkan data yang diperoleh dari PT. X, *downtime* mesin EBM tipe VK pada tahun 2021-2023 mencapai 215,74 jam. Oleh karena itu, diperlukan perbaikan dalam sistem manajemen perawatan mesin. Tujuan penelitian ini adalah untuk menentukan komponen kritis, mengetahui nilai keandalan komponen kritis, dan juga membuat jadwal *preventive maintenance* beserta rencana anggaran biaya untuk setiap komponen kritis pada mesin *extrusion blow molding* tipe VK di PT. X, sehingga dapat meningkatkan efektivitas kegiatan produksi yang ada. Metode yang digunakan adalah *Reliability Centered Maintenance* (RCM) dengan penerapan metode RCA dan FMEA untuk menemukan komponen kritis, kemudian menghitung keandalan komponen kritis sebagai acuan pembuatan jadwal perawatan *preventive*. Data yang digunakan adalah data kerusakan mesin EBM tipe VK pada periode 2021-2023. Hasil penelitian ini diperoleh 4 komponen kritis dengan nilai keandalan 0,5 yaitu *clamping unit* pada 210,3149 jam, *cutting unit* pada 79,9911 jam, *head unit* pada 677,5324 jam, dan *hydraulic unit* pada 424,1550 jam. Untuk penjadwalan perawatan dilakukan melalui metode IRRO (*inspection, repair, replace, overhaul*). Total biaya perawatan periode 2025 adalah Rp 35.093.903 yang mana memangkas biaya sebesar 8.5% dibanding 2023.

Kata Kunci: Cetakan Tiup Ekstrusi, IRRO, Perawatan Mesin, Plastik, RCM

1. Introduction

Plastic is one of the most frequently encountered materials by humans in daily activities. Global production of plastics already exceeded 367 million tonnes in 2020 [1], [2]. One example of a machine used to mass-produce plastic products is an Extrusion Blow Molding (EBM) machine. These machines work by forming parisons, then the parison is blown, compacted, and the product is ejected from molds [3], [4]. An industry must ensure that the goods they produce are reasonably priced, of good quality, and produced and delivered on time [5]. To support efficient production activities, it is necessary to carry out optimal maintenance planning activities. Based on research conducted at PT. X, which is located in Indonesia, there are obstacles that often arise in the VK type Extrusion Blow Molding (EBM) machine, which is evidenced by a total of 215 hours of failure during the 2021-2023 period.

In this case, the follow-up action that needs to be taken is to improve the machine maintenance strategy to reduce the amount of downtime. Maintenance management is the management of maintenance work through a process of planning, organizing, and controlling maintenance operations to provide the best performance for industrial facilities [6]. Maintenance is an activity of maintaining an asset or facility to eliminate the causes of breakdowns, if possible before the congestion occurs, so it is in a condition that is ready to use according to needs [7], [8]. Failure occurs due to a decrease in components caused by two factors, namely natural deterioration and accelerated deterioration [6]. Accelerated deterioration occurs due to human factors such as incorrect installation, which causes a decrease in the condition of the tool faster than usual, leading to sudden failure. Sudden failure will also cause cost overruns because it allows hidden failures and waiting for spare parts, so an activity like preventive maintenance is needed to avoid damage. In this case, Reliability Centered Maintenance (RCM) is a method that can be used to maintain the reliability of a machine, so the condition of a machine can be monitored. There are four main principles of RCM, namely preserving the system function, identifying failure modes that have the potential to cause system failure, prioritizing failures based on their level of criticality, and selecting applicable and effective maintenance tasks [9].

The advantage of this method is that it focuses maintenance actions on critical components of the machine to reduce downtime while still paying attention to safety and economic factors [10], [11]. To determine the criticality of a component, the Pareto 80/20 rule can be used [12]. RCM can also be combined with the latest technologies, such as the Internet of Things (IoT), as the basis for predictive maintenance, which is a key enabling technology for smart manufacturing [13]. Predictive maintenance can predict the condition of components, so any failures will be monitored more rapidly, optimizing maintenance efforts by evaluating the state of the system using historical data [14].

The aim of this research is to determine critical components, calculate the reliability of critical components, and develop preventive maintenance schedules along with cost budget plans for each critical component on the VK type blow molding extrusion machine at PT. X, to increase the effectiveness of existing production activities.

2. Method

This research began with identifying existing problems at PT. X. The data collected is the failure data of the EBM type VK machine from 2021 to 2023, which will then be analyzed using the RCA, FMEA, and RCM methods. The results of the research are the schedule and maintenance costs of the VK type EBM machine. The research was carried out in the following stages, as shown in Figure 1.

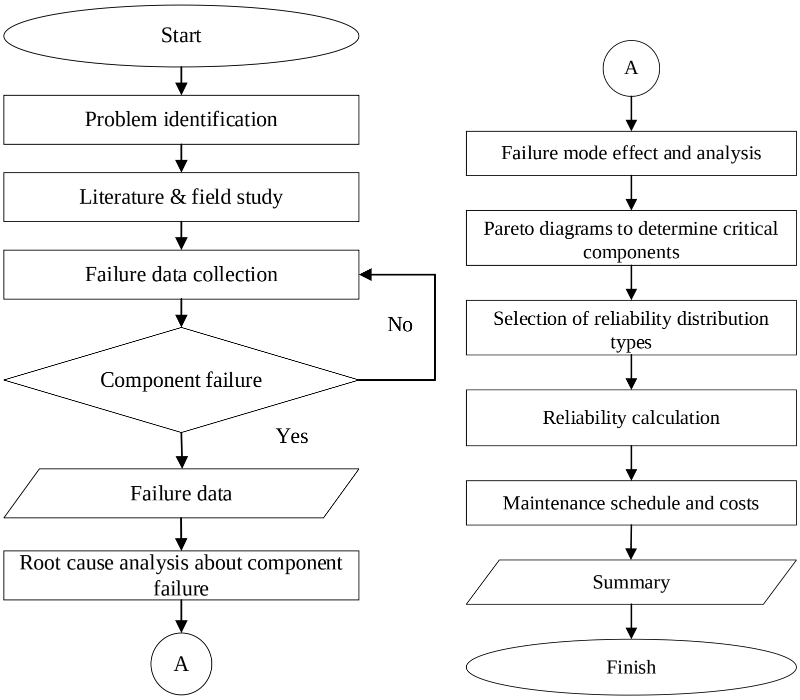

Figure 1. Flowchart of research stages

2.1. Research variable

This research focuses on three key variables. The controlled variable is the EBM machine type VK. The independent variables include data on the downtime of EBM machine type VK components and a list of critical components on this machine. The dependent variables are the reliability value of these critical components, the preventive maintenance schedule, and the associated maintenance costs.

2.2. Data Retrieval

2.2.1. Primary data

Primary data is data obtained directly during the research process, while primary data is collected by 3 ways, the first one is retrieving data of downtime and repair history of VK type EBM machine components from SAP and maintenance logbook, the second is conducting interviews with related parties (maintenance technician, supervisor, and manager), and third is retrieval of component criticality level data using the RCA and FMEA methods.

2.2.2. Secondary data

Secondary data is data obtained from machine manual book, literature on maintenance and RCM, as well as previous research. Secondary data functions as a complement to primary data.

2.3. Data Processing

2.3.1. Qualitative data

The qualitative data is obtained in the form of interview data which was entered into Root Cause Analysis (RCA) and Failure Mode Effect and Analysis (FMEA). RCA is a logical, proven and mutually binding analysis process to obtain the fundamental cause of a problem[15]. One example of an analysis method using RCA is a cause effect diagram. Meanwhile, FMEA is an analysis method that aims to determine potential failures that may occur and their impact[16]. By creating a cause effect diagram for each main component, and conducting FMEA interview, the potential failure, failure effects, causes of failure, control processes, and recommendations for action due to VK type EBM machine components failure will be obtained which will then be entered into the FMEA table.

2.3.2. Quantitative data

The quantitative data is obtained based on calculations such as: (1) FMEA parameter (severity, occurrence, detection), (2) Pareto diagrams to determine critical components, (3) Selection of reliability distribution types, (4) Reliability calculations, and (5) Maintenance scheduling and costs with IRRO methods.

Severity is the numerical rating of the impact of failures on a system, occurrence is the estimated frequency of failures in a system, and detection is the numerical rating of a system that can detect and find the cause of certain failures[17]. Multiplication of these three parameters will produce the RPN value, where the higher the value, the higher the criticality of a component.

Pareto diagrams is a diagram that can determine the priority of an event, so that the most dominant value can be known by looking at the cumulative value, selection of critical components in pareto diagrams using the 80/20 rules [12].

By knowing the type of distribution, the reliability distribution will be calculated. Reliability distribution types depend on time to failure data. This process carried out by using statistical software. Reliability is a probability that a machine will be able to function properly within the expected period of time[18] Reliability calculated by using statistical software.

IRRO (inspection, repair, replace, overhaul) is a maintenance strategy of tools or machines, with this method, preventive maintenance activities can be arranged more clearly by classifying inspection, repair, replace, overhaul activities. Maintenance schedule determined based on the calculation of reliability values and estimated component life. Maintenance cost depends from the maintenance activities, it is obtained from the spare parts costs and labor costs [5].

2.4. Specification of Extrusion *Blow Molding (EBM) Machine VK*

EBM machines work by forming parisons, then the parison is blown, the parts are compacted, and the product is ejected from the molds [3], [4]. This machine has seven main components: the extruder, clamping unit, blowing unit, cutting unit, head unit, punching unit, and hydraulic unit. Below are the specifications of the machine.

Table 1. EBM VK Machine Specifications

Voltage	: 380 V
Control	: PLC
Number of Head	: 2
Number of Stations	: 1
Center Head Distance	: 100 mm
Machine Dimension	: 4.5 m x 1.3 m x 2.63 m

3. Result and Discussion

3.1. Downtime Data of EBM Machine VK

Downtime data is obtained from the maintenance logbook and daily production data collection held by PT. X for 2021-2023. From this data, a list of component failures, failure times, repair times, and total downtime for the VK type EBM machine can be compiled. The following is a summary of the failure data from 2021-2023.

Based on Table 2, it can be seen that the VK type EBM machine suffered a total of 219 failures with a cumulative total of 215.74 hours of downtime during the period from 2021 to 2023. With the downtime data, further analysis can be carried out to determine the root cause of the failures.

Table 2. Downtime Data of EBM Machine VK 2021-2023

Components	Failure Frequency	Total Downtime (Hours)
Extruder	9	14.28
Clamping Unit	39	76.36
Blowing Unit	2	2.7
Cutting Unit	134	80.65
Head Unit	18	13.85
Punching Unit	4	3.8
Hydraulic Unit	13	24.1
Total	219	215.74

3.2. Root Cause Analysis of EBM Machine VK Failure

By carrying out RCA through a cause effect diagram, it can be found the root cause of the problem in each component, so we can determine the solution to the root problem. The following is a summary of the cause effect diagram that created.

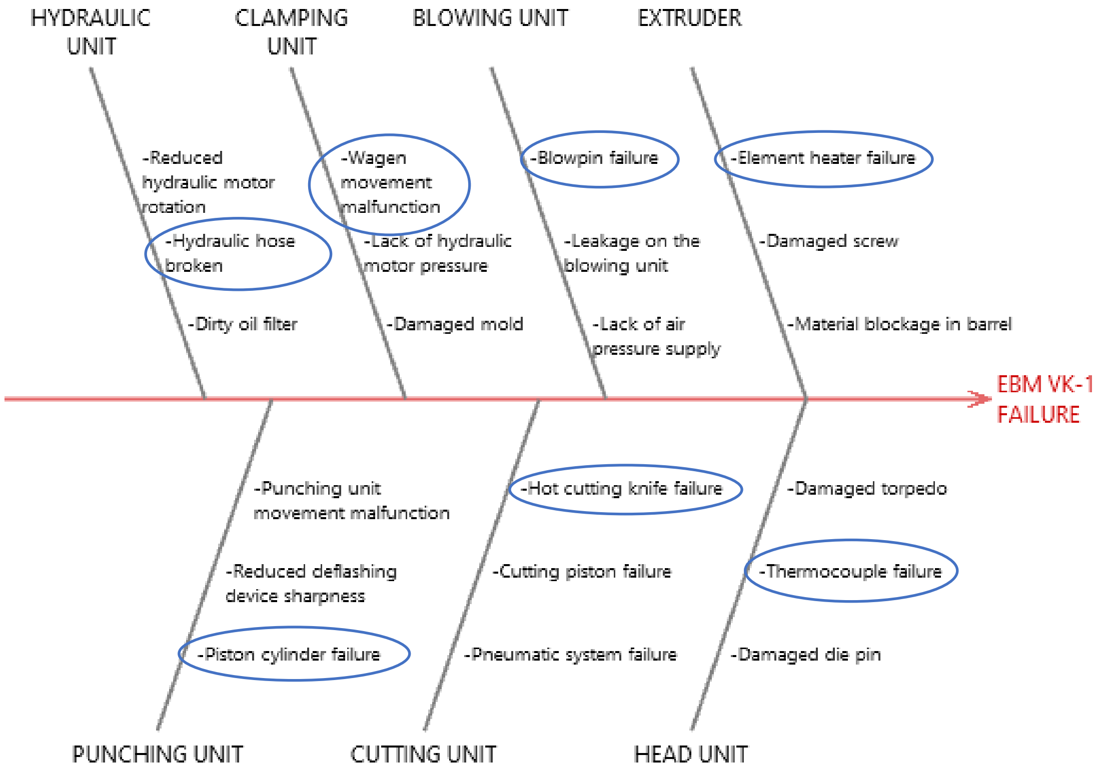

Figure 2. Root Cause Analysis of EBM VK-1 Machine Failure

Based on Figure 2, it is known that there are 7 main components in the EBM VK machine along with the root cause of the problem of each component damage (according to the circled texts). This data is obtained from EBM VK failure data in 2021-2023 and also interviews with related parties. With this root cause analysis, it will make it easier to create FMEA tables.

3.3. Failure Mode Effect and Analysis to Find Out Critical Components

FMEA was used to analyze the criticality level of components on VK type EBM machines. Based on data collection activities carried out at PT. X, the results obtained from the FMEA analysis are shown in Table 3.

Table 3. FMEA of EBM VK Machine Components

Machine type	: Extrusion Blow Molding (EBM)
Prepared by	: Mohammad Bintang Rizqi Pratama
Machine name	: EBM VK-1
FMEA FORM	

Item & Functions	Potential Failure Mode	Potential Effect of Failure	Severity	Potential Cause of Failure	Occurrence	Current Control	Detection	RPN	Recommended Action
Extruder (for heat plastic pellets and distribute them to the head unit)	Element Heater turns off in one or more zones	1.Causing results defective product 2.Causing material blockage in the screw barrel	7	Element Heater has exceeded age limit for use	4	Visually by looking at the zone heater temperature on the monitor	4	112	Scheduling maintenance activities (periodic inspection and replacement)

Machine type	: Extrusion Blow Molding (EBM)								
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FMEA FORM									
Item & Functions	Potential Failure Mode	Potential Effect of Failure	Severity	Potential Cause of Failure	Occurrence	Current Control	Detection	RPN	Recommended Action
Head unit (to convert the movement of the plastic melt from horizontal to vertical while changing the shape of the plastic melt into a hollow cylinder/parison)	Thermocouple is no longer able to read the heater temperature according to the original temperature	1.Temperature setting on the heater will be inappropriate, it can cause a material blockage at the die head	6	Thermocouple use has exceeded the standard usage limit	7	Visual inspection and also checking the heater temperature with a thermal imaging camera. The deviation tolerance allowed is 5-15 degrees Celsius	4	168	Schedule maintenance activities (periodic inspection and replacement of components, ensuring that the temperature deviation of the head unit is in the range of 0-15 degrees Celsius)
Blowing unit (to circulate air for the parison blowing process)	Malfunction in blowpin movement	1.The blowing on the parison/plastic will not be perfect	6	Wrong setting parameters on blowpin limit switch Damaged blowpin limit switch	2	Visual inspection of the blowpin movement to see whether it is appropriate and can blow the parison according to the recommended air pressure	4	48	Schedule maintenance activities (inspection and replacement of components, making adjustments to limit switches)
Cutting unit (for cutting parisons)	Damaged hot cutting knife / hot cutting system	1.The production process stopped temporarily because hot cutting could not cut the parison	8	Cable connections or skunks break due to deformation that occurs during hot cutting (curving) due to repeated mechanical movements	10	Visual inspection, by looking at the flare and also the shape of the hot cutting	4	320	Schedule maintenance activities (periodic inspection and replacement of components)
Clamping unit (to capture and move the parison to the blowing unit and the finished product to the punching unit)	Movement malfunction wagen	1.Production activities stopped temporarily Causes damage to other components such as mold, blow pin 2.Causing defective product	8	Damaged limit switch	10	Testing the limit switch directly (NO & NC) Visual inspection of wagen movement	4	320	Schedule maintenance activities (inspection and replacement of components periodically)
Punching unit (to cut aval or remaining material on the bottle)	Piston cylinder broke	1.Cannot cut aval (residual material)	4	The absence of regular checks causes the piston axle bolts to loosen and repeated mechanical movements cause the piston axle to break	2	Visual observation	4	32	Scheduling maintenance activities (inspections, regular component replacement, tightening piston cylinder bolts)
Hydraulic unit (distributes fluid/oil to move components	Hydraulic hose broken/leaking	1.Oil will splatter around the machine area	7	The hose has exceeded its useful life limit	5	Visual inspection, whether there are any leaks in the machine	4	140	Schedule maintenance activities (inspection and replacement of

Machine type	: Extrusion Blow Molding (EBM)
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Machine name	: EBM VK-1
FMEA FORM	

Item & Functions	Potential Failure Mode	Potential Effect of Failure	Severity	Potential Cause of Failure	Occurrence	Current Control	Detection	RPN	Recommended Action
such as head unit, extruder)		2.Hydraulic pressure will decrease, so it will not be strong enough to move the hydraulic system				lubrication lines/area around the machine, visual inspection, whether a pressure drop occurs from the hydraulic system			components periodically)

Based on the results of the FMEA analysis that has been carried out, it can be concluded that the higher the RPN value, the higher the criticality of a component. To make it easier to see the order of component criticality, refer to the Pareto diagrams shown in Figure 3.

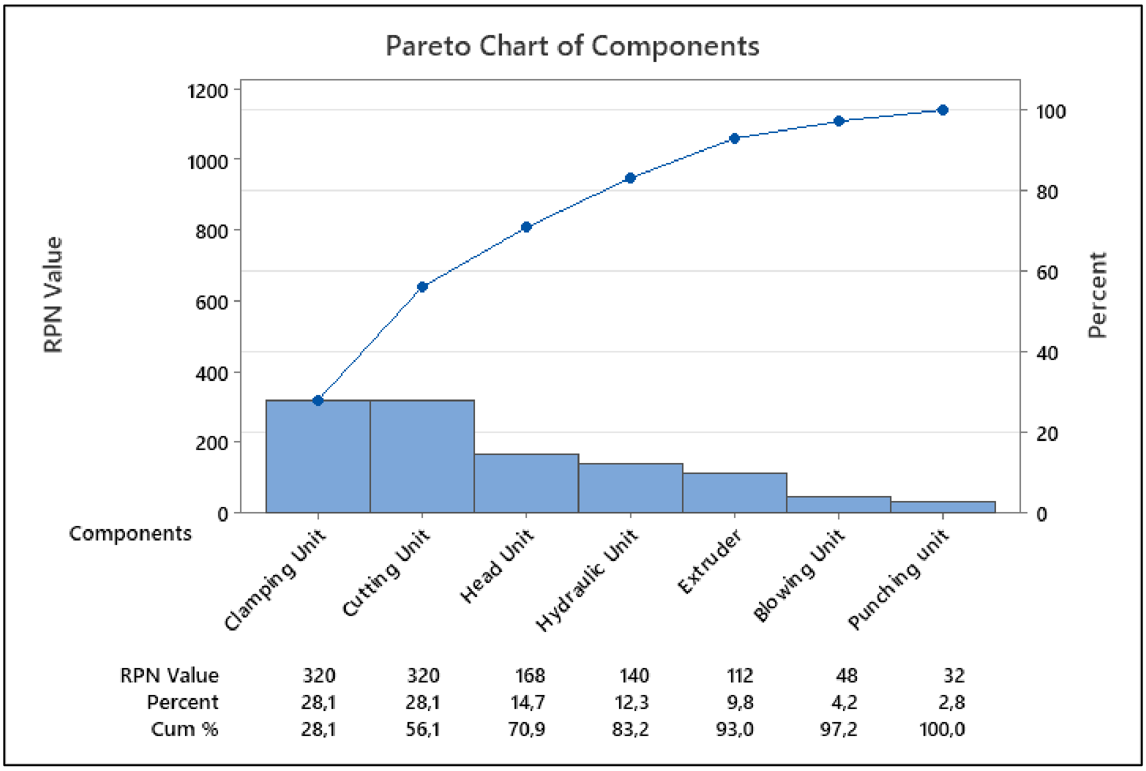

Figure 3. Pareto Diagrams for Critical Components of EBM VK Machine

Based on the Pareto diagrams in Figure 3, critical components are selected through failure types that achieve a cumulative defect percentage closest to 80%[12]. Therefore, the critical components of the VK type EBM machine are the clamping unit, cutting unit, head unit, and hydraulic unit.

3.4. Reliability Distribution Selection and Reliability Calculations

Based on Table 4, it is known that clamping units and hydraulic units use Weibull reliability distribution 3 parameters, while head units and cutting units use lognormal reliability distribution. The determination of this distribution is obtained through time to failure data (the interval between one failure and the next) on each component, then processing through statistical software. Based on the distribution selection that has been made, the reliability value can be calculated using the statistical software. Below is a graph of the reliability values obtained for each critical component.

Table 4. Selected Reliability Distribution Types

Components	Selected Reliability Distribution
Clamping Unit	Weibull 3 Parameter
Cutting Unit	Lognormal
Head Unit	Lognormal
Hydraulic Unit	Weibull 3 Parameter

Based on Figure 4. It shows that reliability value of components will decrease over time. When calculating the reliability value, a multiple of 24 hours is used to determine the shape of reliability chart for each critical component. After knowing the reliability value, the next step is to find out the expected time for determining the maintenance schedule. The following are the results of calculations carried out in statistical software.

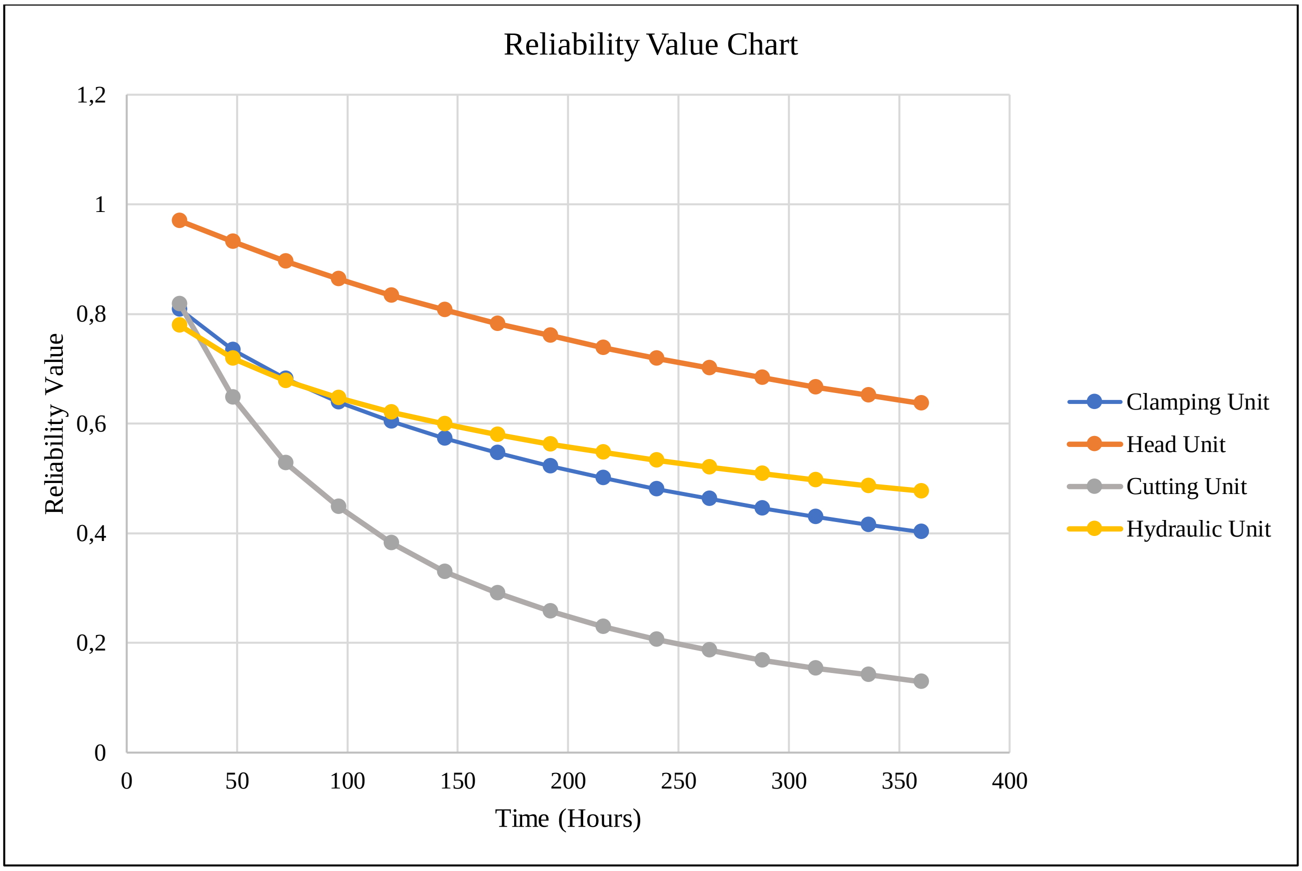

Figure 4. Reliability Value Chart on Critical Components

Based on Table 5, the expected time of each critical component is known. Reliability value expectations are kept constant at 0.5, which means that the critical components are under the condition of 50% reliability value. It is necessary to be able to know the expected time, so as to make a maintenance schedule (maximum inspection) when the component reliability value is at 50%, With the expectation that the reliability value of critical components will increase after maintenance.

Table 5. Critical Components Reliability Calculations Result

Components	Reliability Value Expectations	Expected Time (Hours)
Clamping Unit	0.5	210.3149
Cutting Unit	0.5	79.9911
Head Unit	0.5	677.5324
Hydraulic Unit	0.5	424.155

3.5. Maintenance Schedule and Cost

Table 6. Maintenance Schedule EBM VK Machine in 2025

Month	Maintenance time																														
	Date																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
JAN		1	1	2C	1	1	2C	1	2A	2C	1	1	4C	1	1	2C	2A	2D	2C	1	1	2C	1	1	2A 4C	1		1		2C	4B
FEB	1	2C	1	2A	2C	2D	1	4C	1	1	2C	2A	1	2C	1	1	2C	1	1	2A 4C	1	1	2C 2D	1	1	2C	1	2A 4B			
MAR	2C	1	1	4C	1	1	2C	2A	1	2C	1	2D	2C	1	1	2A 4C	1	1	2C	1	1	2C	1	2A	2C	1	1	4B 4C		2D	
APR		1	2C	2A	1	2C	1	1	2C	1	1	2A 4C	1	1	2C	1	1		2C 2D	1	2A	2C	1	1	4C	1	1	2C	2A 4B	1	
MAY		2C	1	1	2C	1	2D	2A 4C	1	1	2C		1	1	2C	1	4A	2C	1	1	4C	1	1	2C	2A 2D	1	2C	1		4B	2C
JUN		1	1	2A 4C	1	1		2C	1	1	2C	1	2A	2C 2D	1	1	4C	1	1	2C	2A	1	2C	1	1	2C		1	1	5	
JUL	1	2 D	2C	1	1	2C	1	2A	2C	1	1	4C	1	1	2C	2A	1	2C	2D	1	2C	1	1	2A 4C	1	1	2C	4B	1	2C	1
AUG	2A	2C	1	1	4C 2D	1	1	2C	2A	1	2C	1	1	2C	1	1		2A 4C	1	1	2C	1	2D	2C	1	2A 4B	2C	1	1	4C	1
SEP	1	2C	2A	1		2C	1	1	2C	2D	1	2A 4C	1	1	2C	1	1	2C	1	2A	2C	1	1	4B 4C	1	1	2C 2D	2A	1	2C	
OCT	1	1	2C	1	1	2A 4C	1	1	2C	1	1	2C	1	2A 2D	2C	1	1	4C	1	1	2C	2A 4B	1	2C	1	1	2C	1	1	2A 4C	2D
NOV	1	2C	1	1	2C	1	4A	2C	1	1	4C	1	1	2C	2A	1	2C 2D	1	4B	2C	1	1	2A 4C	1	1	2C	1	1	2C	1	
DEC	2A	2C	1	2D	4C	1	1	2C	2A	1	2C	1	1	2C	1	1	2A 4B 4C	1	1	2C	1	1	2C	1		2A	2C	1	1	4C	1

Columns colored red (Table 6) mean national holidays/public leave.

And the following is a description of the maintenance schedule in the Table 6.

Table 7. Description of Machine Maintenance Schedule

No	Activities	No	Components Name
1	Inspection	A	Clamping Unit
2	Maximum Inspection	B	Head Unit
3	Repair	C	Cutting Unit
4	Replace	D	Hydraulic Unit
5	Overhaul		

Table 7 is an instruction on how to read the maintenance schedule in table 6, number means the activity to be carried out, while the letter means the name of the component to be maintained. And if only the number is written, then maintenance activities are carried out on all critical components. For example, on January 4, 2025, 2C is written, which means that the maintenance activities to be carried out are maximum inspections for cutting unit components. On January 2, 2025, the number 1 is written which means maintenance activities that will be carried out is an inspection for all critical components.

Maximum inspection maintenance activities are carried out every time the reliability value of critical machine components reaches 0.5. Replacement activities are carried out based on the age of components obtained through catalogs and interviews with related employees. If the schedule shows a buildup of more than three activities, then overhaul activities need to be carried out. Inspection activities are carried out if on one day there is no schedule for maximum inspection, replacement, or overhaul activities.

Table 8. Maintenance Costs of EBM Machine VK in 2025

Week	Costs 2023	Planned costs on 2025
1-5	IDR 1.356.000	IDR 1,604,500
6-10	IDR 3,150,000	IDR 2,327,750
11-15	IDR 2,320,000	IDR 2,000,750
16-20	IDR 14,123,000	IDR 2,194,250
21-25	IDR 1,074,000	IDR 1,947,500
26-30	IDR 4,668,000	IDR 12,382,500
31-35	IDR 1,496,000	IDR 2,258,250
36-40	IDR 1,588,000	IDR 1,873,500
41-45	IDR 2,734,000	IDR 2,563,250
46-52	IDR 5,846,000	IDR 3,064,250
Additional costs	-	IDR 892,653
Total	IDR 38,355,000	IDR 35,093,903

Table 8 is Comparison between maintenance costs in 2023 (without implementing RCM) and planned maintenance costs in 2025 by implementing RCM. From this comparison, it is known that applying the RCM method to this machine can save costs of IDR 3,261,097 or around 8.5%. In this research, the cost of maintenance was calculated based on the maintenance activities (table 6). Additional costs are costs that are used as reserve funds, just in case they are needed in necessary conditions. The amount of this additional cost refers to Indonesian Coordinating Ministry for Economic Affairs, the amount of inflation in 2023 is 2.61%. The total maintenance costs required for 2025 is IDR 35,093,903. Maintenance costs are determined based on the cost of spare parts and labor costs[5].

4. Conclusion

The results of this research obtained 4 critical components with a reliability value of 0.5, namely the clamping unit at 210.3149 hours, the cutting unit at 79.9911 hours, the head unit at 677.5324 hours, and the hydraulic unit at 424.1550 hours. For maintenance scheduling carried out through the IRRO method (inspection, repair, replace, overhaul). Preventive maintenance schedule is made based on IRRO method with the following conditions such as maximum inspection maintenance activities are carried out every time the reliability value of critical machine components has been at 0.5, replace activities are carried out based on the age of components obtained through catalogs and interviews with related employees. If the schedule shows a buildup of more than 3 activities, then overhaul activities need to be carried out. And inspection activities are carried out if on one day there is no schedule for maximum inspection, replace, or overhaul activities. Total maintenance cost for 2025 period is IDR 35,093,903. Future work that can be done for this research is by implementing the RCM method at PT. X And evaluate the RCM activities that have been planned. For future researchers who have the topic of RCM, they can do the following; conducting a comparative analysis of Condition Based Maintenance (CBM) and Total Productive Maintenance (TPM) compared to RCM; or conducting research related to the integration of the latest technologies such as Internet of Things (IOT) with RCM.

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