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Cake Breaker Conveyor Machine Maintenance System Analysis Using the Reliability-Centered Maintenance (RCM) Method

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ABSTRACT

Machine maintenance plays a vital role in the production activities of a company, which concerns the smooth and bottleneck of production. This research was conducted in a company engaged in palm oil processing. The company often suffers from machine breakdowns and has not found a suitable solution. Reliability Maintenance is one of the methods used to determine the appropriate maintenance actions for each critical component on the Cake Breaker Conveyor (CBC) machine, based on analysis using Failure Mode and Effect Analysis (FMEA) by looking at the highest RPN value of each component, 4 critical elements are obtained from the 11 main features of the Cake Breaker Conveyor (CBC) machine, namely bearing parts, Universal Joint, Rod Clutch and Pen. Determine the maintenance schedule of critical components at the seed separation station. Taking damage, lognormal distribution, proposed replacement schedule 461.5 (hours), pen damage, normal distribution, proposed replacement schedule 587.29 (hours), universal joint damage, normal distribution, proposed replacement schedule 536.46 (hours), clutch rod damage, normal distribution, proposed replacement schedule 581.6 (hours), and axle damage, normal distribution, proposed replacement schedule 586.6 (hours).

Keywords: Machine Maintenance, Reliability Centered Maintenance, Failure Mode and Effect Analysis (FMEA)

INTRODUCTION

Maintenance machines play an essential role in the production activities of a company, which concerns the smooth and bottleneck of production, production volumes, and products so that output and consumers are received on time. There are no idle resources due to the breakdown of machines during the production process to minimize the cost of production losses, or these costs can be eliminated [1]. In addition, good maintenance will improve company performance, the investment value allocated to equipment and machinery can be minimized, and reasonable care can also improve the quality of products produced and reduce waste [2].

This research was conducted in one of the manufacturing industries engaged in palm oil processing, often experiencing high machine breakdown problems, and it is known that there is 1 machine contributes the most significant downtime, namely the Cake Breaker Conveyor machine. In the Cake Breaker Conveyor machine, changes in engine settings, along with wear and tear of other component conditions, make the rotation unbalanced so that the vibration is more robust, which results in damage to the engine components.

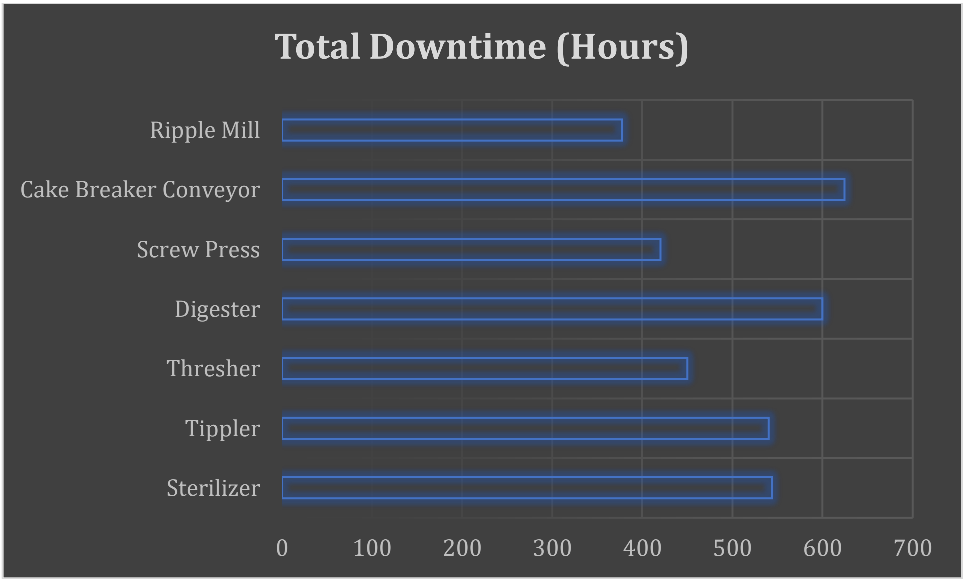

Figure 1. Engine Breakdown Downtime

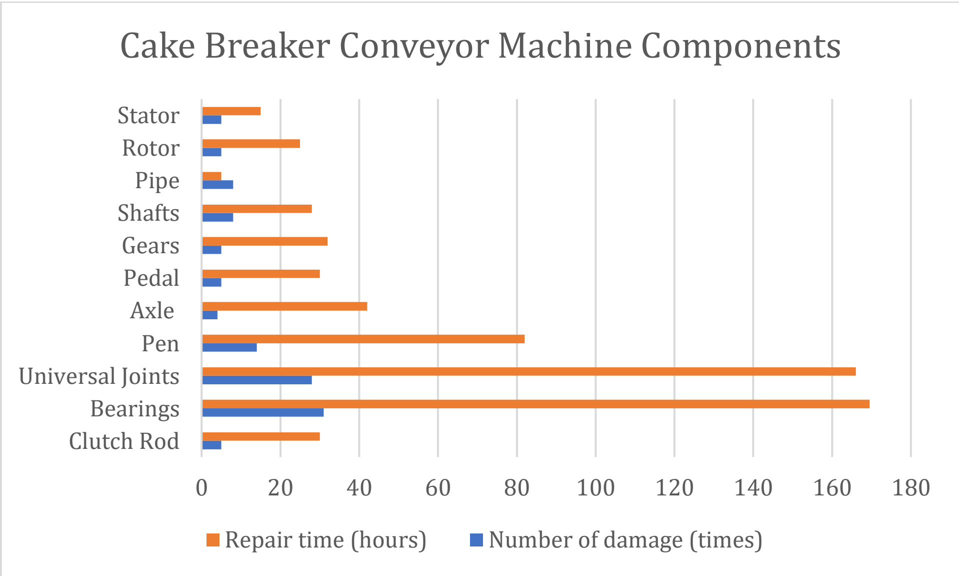

Figure 2. Frequency of Damage to Cake Breaker Conveyor Machine Components

Figure 1 and Figure 2 show that the most significant total downtime and the one that should receive special attention is the Cake Breaker Conveyor machine, with a substantial rest of 624.5 hours. Damage to the device will stop production activities for a while and impact idle work and the machine (idle time). Cake Breaker and conveyor machine components have the most significant damage and repair time, namely Bearings, with total damage 31 times the damage and 169.5 hours. The problem of damage to machines and components can harm the company. The production target that the company must achieve must decrease productivity. The longer the time to repair or replace production machine components, the longer the production process stops, affecting the company's revenue and profits.

So far, the company has implemented a corrective maintenance system, which repairs when there is damage. Other maintenance carried out by the company is assisted by planned maintenance, which is scheduled every two weeks to maintain machinery and the factory environment as a whole [3]. To reduce the impact of machine damage, it is necessary to maintain a maintenance schedule for critical components on the Cake Breaker Conveyor. This study proposes a machine maintenance system using the Reliability Centered Maintenance (RCM) method [4]. The RCM method is expected to determine the maintenance schedule and the exact maintenance activities that must be carried out on each critical component of the Cake Breaker Conveyor [5]–[8].

RCM is a maintenance method that prioritizes analyzing the reliability and importance of a component in the system to determine the most effective and efficient maintenance action [9]. This method also focuses on preventive maintenance to prevent damage or failure that can cause downtime or damage in production [10]. In the context of PDCs, RCMs can help determine appropriate treatment strategies and optimize the use of available resources [11]. Applying RCM to the PDC can analyze the reliability of PDC components, determine maintenance actions that are to the conditions and needs of the PDC, and minimize downtime and maintenance costs. Reliability-centered Maintenance (RCM) through the Failure Mode and Effect Analysis (FMEA) approach is a structural procedure to determine and prevent failures by selecting qualitative factors of critical components and calculating priority risk values (RPN) [12]. Where the key to the application of Reliability Centered Maintenance (RCM), in addition to considering in terms of reliability (ensuring assets operate according to the original design and carry out their functions as expected), is the identification of malfunctions in systems or components; it can guarantee policies or actions taken by the characteristics of damage to the facility [13].

METHOD

Action Selection Road Map

The RCM (Reliability Centered Maintenance) method systematically develops and optimizes industrial equipment maintenance programs [14]. The main goal of RCM is to improve system reliability and identify the most efficient maintenance measures [15]. The method was first developed by United Airlines in the 1960s to improve aircraft reliability and has since been widely applied in various industries, including manufacturing, energy, transportation, and others [16]–[20]. The following is a road map for selecting actions using the RCM method [21]–[24].

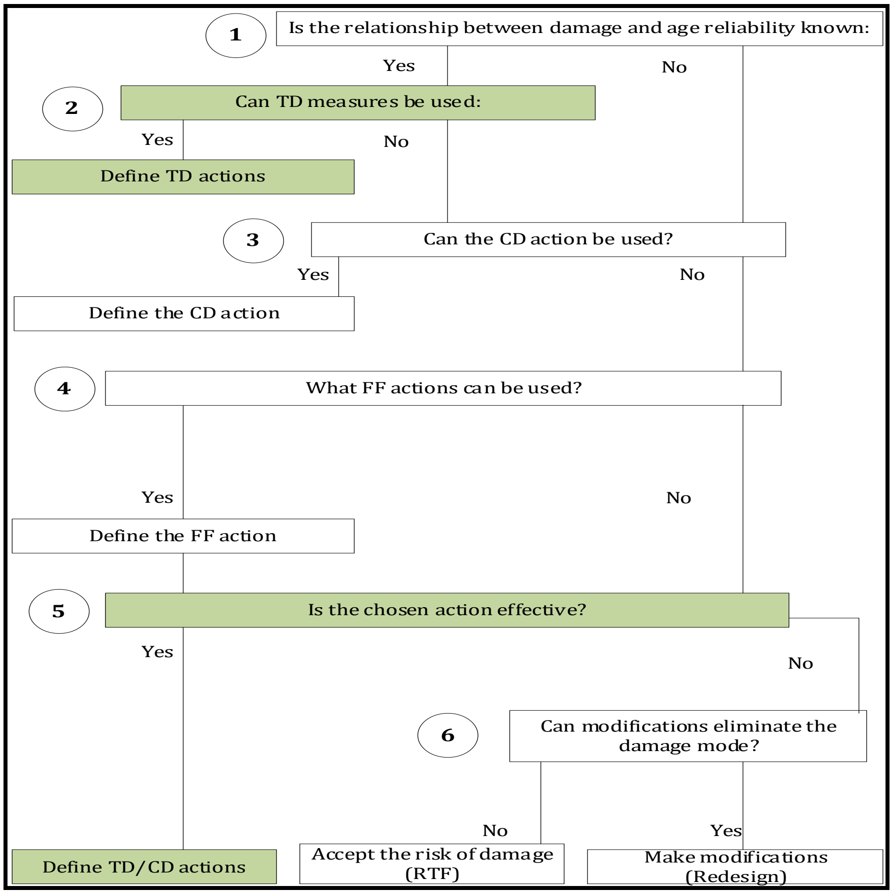

Figure 3. RCM Action Selection Road Map

System Selection and Information Collection

Each works sequentially from the beginning to the end. So, minimizing damage to the engine with the highest damage will reduce the overall breakdown [25].

a. Define System Constraints

The number of systems that support a facility varies greatly depending on the complexity of the facility itself. In the RCM analysis process, the definition of system limitations is critical because [26]–[29]:

1. Can distinguish clearly between one system and another and can make a list of components that support the system. This can prevent overlapping or overlapping.
2. Can define the input-output system of the system. With a clear distinction between what goes in and out of a system, it will be helpful in the accuracy of RCM process analysis in the next step.

System Explanation and Functional Block Diagram

A system can be described based on the function of its subsystems. The part of the Cake Breaker Conveyor station is to separate the pulp (fiber) and seeds (nut) and temporarily accommodate the beans before the following process. In addition, the input and output of the system are also described to express the inputs and outputs of each subsystem [30].

Failure Mode and Effect Analysis

Failure Mode and Effect Analysis is the process of identifying the failure of a component so that it can cause a malfunction of the system, as for the stages in the FMEA process, namely [31]–[33]:

1. Create an FMEA form containing products/systems, subsystems, subprocesses, components, design leads, FMEA builders, revisions, and revision dates. This form can be modified as needed.
2. List items or functions using an FMEA chart.
3. Identify potential failures, namely conditions where components, subsystems, systems, or processes do not conform to a predetermined design.
4. Register any technical failure for the functionality of any component or process step.
5. Describe the causal effects of each failure according to consumer perception.
6. Identify the cause of each failure.
7. Action recommendations against component failures

Action Selection

Actions are produced with a Reliability-centered Maintenance (RCM) approach as action planning for each component [24].

- Distribution Testing and Parameter Determination

The time of damage to each component is a random variable. Before calculating the probability value of the component's reliability, it is necessary to know statistically the damage distribution to the equipment. Some distributions commonly used to calculate reliability are exponential, Weibull, lognormal, and normal distributions [29].

RESULTS

Failure Mode and Effect Analysis (FMEA)

Determination of critical components directly does not provide too much information about CBC machines, so a process is needed to assess the seriousness of the effects caused (severity), frequency of failure (occurrence), and failure control (detection). The FMEA process is used in this problem to identify errors or failures in the manufacturing process because FMEA is used as a planning tool to identify and eliminate potential failures or breakdowns.

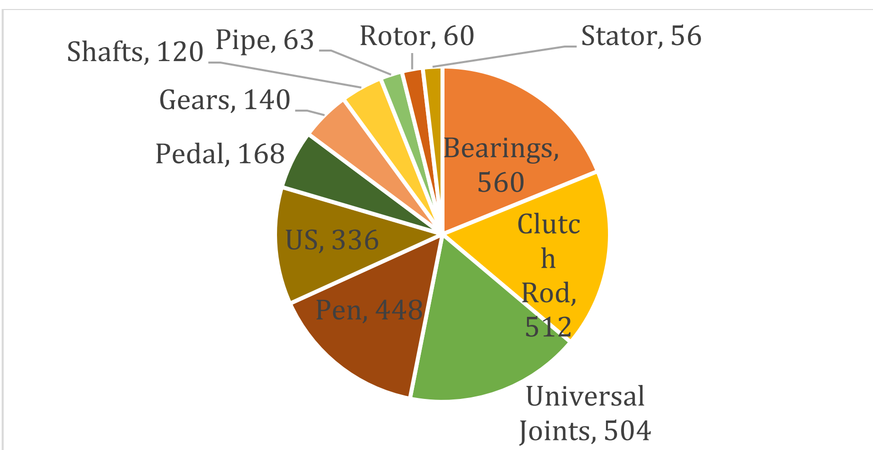

Figure 4. Risk Priority Number Value of Each CBC Engine Component

Figure 4 shows four critical components in the CBC engine: the Bearing, Clutch Bar, Universal Joint, and Pen. The Risk Priority Number value of the four components has the most significant value of the other components. The RPN value is 560, 512, 504, and 448, respectively. The four elements are interrelated. If one of these components malfunctions or is damaged, it can cease the production process because the machine is damaged so that it cannot operate. The four components are challenging to detect because the symptoms caused by harm are almost similar, so identifying the damaged component takes a long time.

Task Selection Analysis

Recapitulation of the types of damage that occurred to critical components of CBC machines by category and selection of part handling actions.

Table 1. CBC Machine Maintenance Action Selection

Number	Parts	Failure Mode	Selection Task
1	Bearing	Damaged bearings	**T.D**
2	Clutch Rod	Ruptured/cracked clutch	C.D
3	Universal Joint	Universal joint fracture	**T.D**
4	Pen	CBC pen bolt break	**T.D**

The selection of preventive measures based on the results of the analysis of FMEA is as follows:

1. Time Directed (T.D) is an action that focuses more on turnover activities carried out periodically. The components included in the selection of this action are:

a. Bearing

b. Pen

c. Universal Joint

2. Condition Directed (C.D) refers to actions taken that aim to detect damage using visual inspection, inspecting tools, and monitoring several existing data. The components included in the selection of this action are Clutch Rod

Damage Distribution of Critical Components Cake Breaker Conveyor Machine

The distribution of damage to this Cake Breake Conveyor machine's critical components used TTF (Time to Failure) values and TTR (Time to Repair) values of each crucial element of the Cake Breake Conveyor machine. Time To Failure is the time interval between damage calculated from the difference between the time the device or part has been repaired until the time of damage to the next machine or part. Time To Repair is the time needed to fix the device or damaged component until the device can operate correctly.

1. Bearing Damage

In scheduling maintenance of Cake Brake Conveyor machine-bearing components, TTF and TTR values are needed to test the determination of component damage distribution patterns.

Table 2. Bearing Breakdown Time (TTF) and Repair Time (TTR) Intervals

Component	Breakdown Interval (Hours) (TTF)	F	Repair (Hours) (TTR)
Bearing Damage	529, 577, 505, 457, 433, 433, 385, 361, 361, 409, 313, 361, 313, 624, 529, 409, 384, 361, 409, 409, 625, 433, 601, 625, 601, 313, 529, 433, 313, 673, 601	31	3

To detect distribution patterns that match the damage data of the Cake Breaker Conveyor machine bearing components can be seen in the probability density function figure (PDF).

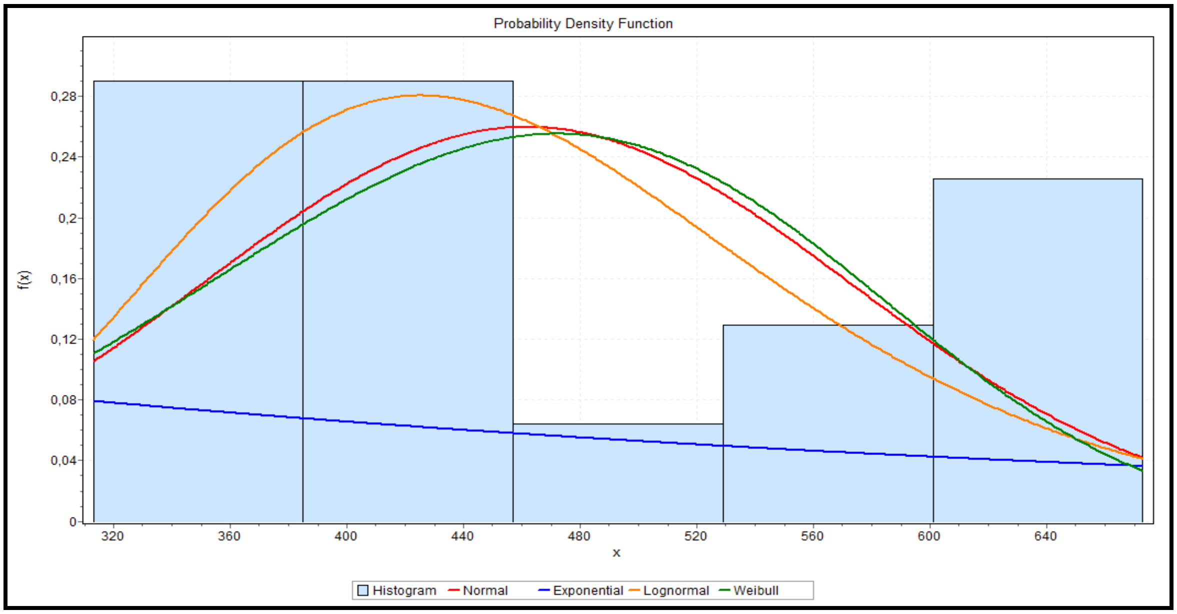

Figure 4. Probability Density Function TTF Bearing Component Damage

2. Clutch Rod Damage

Testing distribution patterns and determining parameters on Clutch Bar components requires TTF and TTR values in testing component damage distribution patterns. Tests are performed with a tendency for damaged data to follow a specific distribution pattern.

Table 3. Breakdown Time Interval (TTF) and Repair Time (TTF) of Clutch Rod

Component	Breakdown Interval (Hours) (TTF)	F	Repair (Hours) (TTR)
Clutch Rod Damage	577, 505,648, 649, 529	5	3

The clutch rod cake breaker conveyor machine can be seen in the probability density function picture (PDF) to detect distribution patterns that match component damage data.

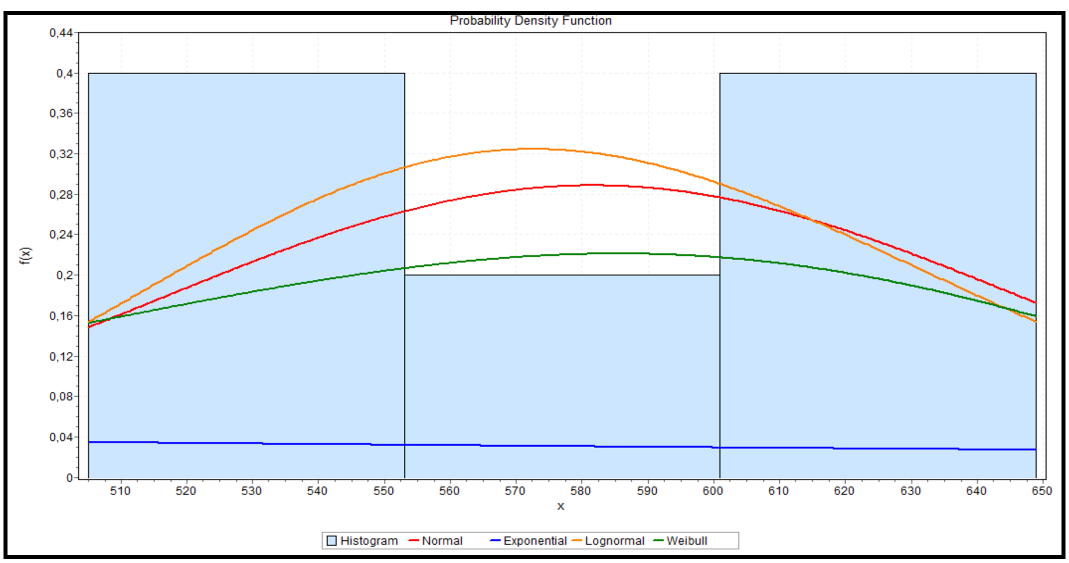

Figure 5. Probability Density Function TTF Damage to Coupling Rod Components

MTTF is the average time of damage to engine components that are often damaged and must be replaced with new or good features. Features At the same time, MTTR is the average time to repair engine components. The following is the Mean Time To Failure (MTTF) of the critical component data of the Cake Breaker Conveyor machine through output calculations.

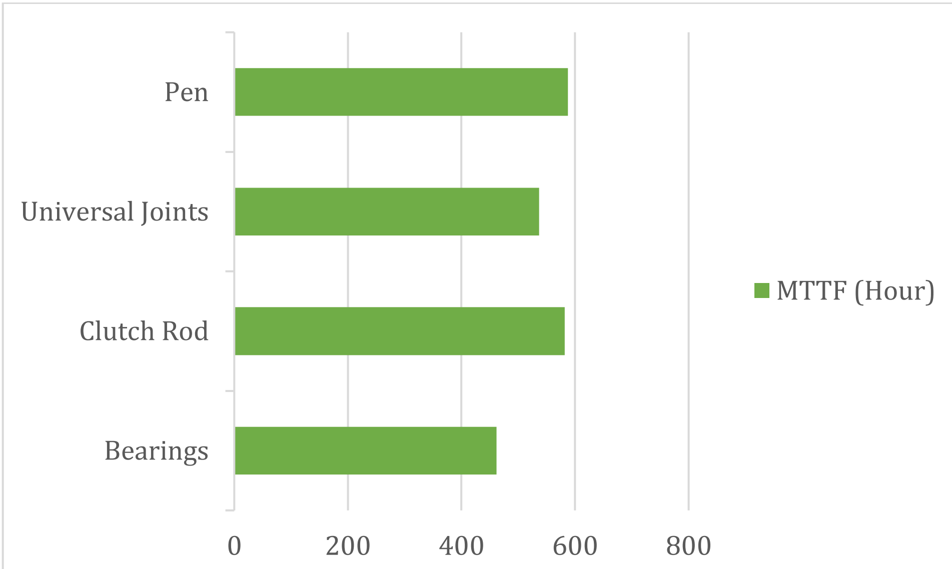

Figure 6. Average Time to Breakdown of Critical Engine Components

DISCUSSION

Analysis of the application of the maintenance system using the Reliability Centered Maintenance (RCM) method through the Failure Mode and Effect Analysis (FMEA) approach, a structural procedure to determine and prevent failures by selecting the qualitative factors of critical components and calculating the priority risk value (RPN) [34]. Picking essential elements of this study uses a direct approach method and the Failure Mode and Effect Analysis (FMEA). Based on the results of data processing with FMEA analysis, 4 critical components with the highest RPN value were obtained, namely the Bearing component with an RPN value of 560 at a very high level, because it can cause disruptions to the production line, for example when the production process is running. Suddenly, the bearing components are damaged, and the production process on the Cake Breaker Conveyor machine will stop, which can be detrimental [2]. The coupling rod has a value of RPN 512, meaning that it is at a very high level because it can cause disruption to the production line and damage the bearing. It can interfere with the production process; 100% of the product must be disassembled, cannot be operated, and loses its primary function of connecting between two shafts at both ends. [35] the determination of the value of severity, occurrence, and detection of each component of the discussion and conclusion explained using the FMEA method is 683 RPN, so regular machine maintenance must be carried out. From the proposed Reliability Centered Maintenance planning accompanied by a comparative analysis, it was found that the proposed improvement could reduce the average downtime by 39% on the problem of each component accompanied by an MTBF of 2,412 hours. Other studies using RCM The results of the checks showed a decrease in the value of the Risk Priority Number (RPN) from 540 to 126, indicating the success of corrective actions and replacement of components in significantly reducing the risk of failure. With a lower RPN value, Distribution Control panel maintenance can be focused on scheduled preventive care and more intensive supervision of components that still carry a higher level of risk [6].

The selection of actions is based on grouping the type of damage in the Cake Breaker Conveyor machine into the appropriate category of precautions. After data processing, results are obtained for bearing components, and selecting selected maintenance actions is time-directed (TD) because the actions taken are in the form of direct prevention of running parts based on the time or age of the details. After inspection, whether the element is still suitable for use can be determined. If not, it will be immediately replaced with a new one, but if it can still be repaired, then corrective actions can be taken; for the clutch rod component, the selected maintenance action is condition-directed (CD), which is the action of detecting damage to the clutch rod component that has been damaged such as the broken/cracked Clutch Rod component [9]. This action can be done by looking around the surrounding parts of the Clutch Bar component to prevent damage to the element [19].

The MTTF value of bearing components is 461.56 hours, the average life of taking parts will be damaged for the first time is approximately 461.56 hours, and if it is related to the selection of actions, it means that for delivering parts every 461.56 hours, Time Directed (TD) must be carried out in the form of direct prevention of taking positions based on the time or life of the details. After inspection, whether the element is still suitable for use can be determined. If not, it will be immediately replaced with a new one, but if it can still be repaired, corrective actions can be taken, with the reliability of engine components of 64.64%. The value of dependability or reliability is influenced by time, which means that the longer the use time of the element, the more the reliability value will decrease. Therefore, actions taken after the component life of 461.56 hours must be repaired, and bearing components must be replaced. The MTTF value of the clutch rod component is 581.6 hours. The average life of the Clutch Rod component will be damaged for the first time around 581.6 hours, with the reliability of the engine component of 58.12%. The value of dependability or reliability is influenced by time, which means that the longer the use time of the element, the more the reliability value will decrease. Therefore, actions taken after the component life of 581.6 hours must be repaired and replaced by the Clutch Rod component [36]. Another study using calculations using the Reliability Centered Maintenance (RCM) method and Maintenance Value Stream Map obtained maintenance time intervals, namely in unit 1 for 82.24 hours, unit 2 for 29.72 hours, and unit 3 for 2.82 hours. The action that must be taken in machine maintenance with the Reliability Centered Maintenance (RCM) method is that 1 (once) a month, the company must provide time for maintenance on the machine with time on unit 1 for 82.24 hours, unit 2 for 29.72 hours and unit 3 for 2.82 hours. Research [37] produced a maintenance schedule that must be done before experiencing damage, namely wear sprockets = 4384.7720 hours, broken hydraulic shafts = 724.6993 hours, bent billet pusher hydraulic shafts = 663.6685 hours, replacing PGN safety valves = 551.7647 hours, perforated ducting pipes = 995.4881 hours, and bent arms = 725.0752 hours

CONCLUSION

Critical component maintenance schedule on Bearing Damage, Lognormal distribution, Proposed Replacement Schedule 461.5 (Hours), Pen Damage, Normal distribution, Proposed Replacement Schedule 587.29 (Hours), Universal Joint Damage, Normal distribution, Proposed Replacement Schedule 536.46 (Hours), Clutch Rod Damage, Normal distribution, Proposed Replacement Schedule 581.6 (Hours). Selection of maintenance actions carried out on component damage Bearings selected Time Directed (TD) action is by replacing bearings directly based on component life. The choice of actions taken on the Clutch Rod component is condition-directed (CD), which is detecting damage to the Clutch Rod component that has been damaged, such as broken Clutch Rod components. This action can be done by looking around the surrounding parts of the Clutch Bar component. The selection of action on Universal Joint components is time-directed (TD), where the action taken directly prevents the source of damage to Universal Joint components, namely by replacing the Universal Joint now based on the component's life. This action is carried out so that there is no damage to other machine components and does not interfere with the production process. The selection of action on Pen components is time directed (TD), where the action taken is direct prevention of the source of damage to Pen components, namely by replacing the Pen directly based on the age of the element.

This action is carried out so that there is no damage to other machine components and does not interfere with the production process.

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