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Scheduling Preventive Maintenance to Determine Maintenance Actions on Screw Press Machine

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ABSTRACT

PT. PAS is a company engaged in the manufacturing industry that manages palm oil into Crude Palm Oil (CPO) and Palm Kernel (PK) with a capacity of 30 tons/hour. The method used in this study is Reliability Centered Maintenance (RCM). This method can determine the actions of preventive maintenance activities on each component of the screw press machine. This study aims to provide proposals for scheduling preventative Maintenance of screw press machines using the Reliability Centered Maintenance (RCM) approach and determine appropriate maintenance actions in damage prevention. Based on the results of the research conducted, it can be concluded that in the Reliability Centered Maintenance (RCM) approach, it is known that five types of damage are a priority for repair. The types of damage included in the repair priority are worm screws, extension shafts, bearings, press cages, and oil seals. The proposed maintenance time for each critical component is a worm screw component maintenance time interval of 307.84 hours, and changeover schedules every 2035.3 hours. Component extension shaft maintenance time interval 279.5 hours, changeover schedule every 1824.5 hours. Bearing components have a maintenance time interval of 300.2 hours and a changeover schedule of every 1492.5 hours. Oil seal components maintenance time interval 286.1 hours, changeover schedule every 2769.9 hours. Press cage components maintenance time interval 250.72 hours, changeover schedule every 3277.8 hours. Actions are taken in the form of direct prevention of the source of component damage based on the time or age of the component.

Keywords: Machine Screw Press, Preventive Maintenance, Reliability Centered Maintenance (RCM).

INTRODUCTION

The machine is a tool with energy conversion to help facilitate human work [1]. The device must be adequately maintained to keep the production process running smoothly according to company expectations. Machine maintenance systems are generally divided into two, namely, Corrective Maintenance and Preventive Maintenance [2][3][3]. Corrective Maintenance is a maintenance activity carried out after the component is damaged or breakdown, while Preventive Maintenance is carried out before the part is impaired [4]. The impact of periodic machine maintenance includes not achieving production targets, losing production time, high repair costs, and low productivity [5]. In addition, good Maintenance can extend the machine's life and prevent damage that can cause some losses [6].

The research was conducted at PT. PAS at the press station is a company engaged in the manufacturing industry, one of the palm oil processing companies. Found problems that occurred PT. PAS is the frequent occurrence of damage to the machine that causes the production process to stop. Damage to the production machine is caused because machine maintenance scheduling is not applied regularly[7]. At the press station, there are several machines: fruit elevator machines, cake breaker conveyor machines, digester machines, screw press machines, vibrating screen machines, and others [8].

One of the machines at the press station that most often suffered damage was the screw press machine. Some of the causes why the screw press machine becomes damaged, namely: the gearbox inserts rough objects such as iron chips with a diameter exceeding the size of the screw, worn bolt heads, the installation of the gearbox shaft and worm screw shaft is not suitable so that it can cause shaft breakage, and operator negligence can also cause damage to the engine For example, when the engine has vibrated violently, it can be ascertained that the engine has been damaged and the operator still forces the machine work. Damage due to interference with the Screw Press unit includes leakage in the seal, damage to the worm screw, wear on bearings, damage to the drive shaft, damage to the press cage, and short drive shaft screw press. The purpose of this study is to propose preventive maintenance scheduling for screw press machines and determine appropriate maintenance actions to prevent damage.

The method used in this study, Reliability Centered Maintenance (RCM), is a logical engineering process for determining maintenance tasks that will ensure a reliable system design with specific operating conditions in a typical working environment [9][10]. For this reason, proper maintenance scheduling planning is carried out. Therefore, this researcher carried out machine maintenance system planning using the Reliability Centered Maintenance (RCM) method, and this method can determine the preventive maintenance activities on each component of the screw press machine [11].

METHOD

Data Collection

Primary Data

Primary data include production amount, machine maintenance system, causes of machine failure, frequency of damage, engine operating hours, last year's engine downtime data, engine repair time data, and engine change interval data [9] [10][13].

Data Processing

1. Identify critical components of the machine using the RCM method. The stages in the process of working using the RCM Method are [14]–[22]:

a. Failure Mode and Effect Analysis (FMEA)

Used to determine consequences and decide what to do to anticipate, prevent, detect, or improve them.

b. Logic Tree Analysis (LTA)

It is a qualitative measurement for classifying failure modes. Failure modes can be classified into four categories, namely [23]–[29]:

c. Task Selection

It is done to determine the policies that can be applied (practical) and select the most efficient task for each failure mode.

2. Preventive Maintenance Scheduling Planning.

Maintenance scheduling planning is usually done at planned time intervals. The level of equipment or machine and load conditions determine this interval distance. Preventive Maintenance can help extend engine life (up to 3-4 times) and reduce unexpected damage. The RCM (Reliability Centered Maintenance) method performs interval policy and machine maintenance activities. This schedule keeps the preventive maintenance program organized and neat and does not interfere with the production process or other activities.

3. Proposed Maintenance System Improvement.

It is the proper maintenance system improvement plan to be implemented by the company from the research results.

The data processing flow diagram in this study is shown in Figure 1.

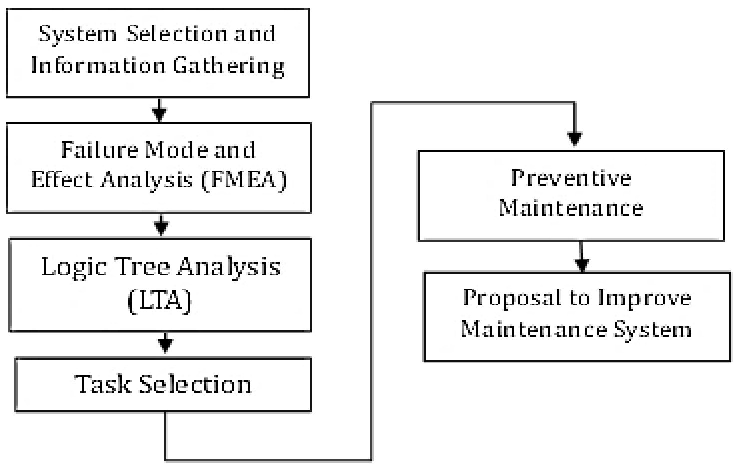

Figure 1. Data Processing Flowchart

RESULTS

Failure Mode Effect Analysis (FMEA)

FMEA determines consequences and decides what to do to anticipate, prevent, detect, or improve them. The FMEA results of the Screw Press Machine are shown in Table 1.

Table 1. FMEA Results of The Screw Press Machine

Component	Fungsi components	Failure mode	Effect failure	Causes of Failure	Actions taken	S	O	D	RPN
Worm Screw	Main components of the CPO-extracting machine	Cessation of the extraction process	Break	Inlet iron piece, too high hydraulic load	Worm screw replacement	9	6	9	**486**
Main Shaft Short	Clutch / Drive Media	The rotation of the main shaft stopped	Cracked da n Broken	Looseness on the locking peg of the worm, Empty oil	Component replacement and oil filling	8	5	5	**200**

Main Shaft Long	Clutch / Drive Media	The rotation of the main shaft stopped	Cracks and Breaks	Looseness on the locking peg of the worm, Empty oil	Component replacement and oil filling	8	5	5	**200**
Extension Shaft	Worm screw buffering/containment	Sagging bolts and nuts	Break	Hydraulic pressure power pack, iron fracture	Tightening of bolts and nuts, replacement of components	8	6	10	**480**
Oil Seal	It keeps oil from spilling	The movement of the engine is not smooth	Broken seal, Leaking oil	Delay in oil filling	Regular oil filling	9	6	6	**324**
Bearing	Main shaft drive	Rounds do not Stable	Worn, ruptured	Empty oil, Usage over capacity	Regular bearing replacement	8	6	10	**480**
V belt	Drive Liaison	Not moving	Break	Overvoltage	Belt control	10	6	1	**60**
Strainer Plate	As a filter for pressing	Ineffective screening	Wear/thinning	Long working hours	Regular check-ups	4	5	8	**160**
Press Cage	As a filter for pressing	Ineffective screening	Wear/thinning	Press cage pores are clogged	Regular check-ups	9	5	9	**405**
Ccs Connector	Stabilizer/Flashlight	No flashlight	Wear/break	Overworking hours	Component replacement	6	5	9	**270**
Bushing	Worm screw head positioning	Unstable ground	Wear Out	Overworking hours	Component replacement	4	5	9	**180**
Hidrolick Power Pack	Pressing the guide cone	Pump Performance Performance Improvement	Rupture lag	Empty hydraulic oil	Oil addition, hydraulic hose maintenance	3	3	1	**9**
Shaft Cone	Stabilizing the guide cone	Cone guide, not flashlight	Shaft wear	Overworking hours. Lack of care	Shaft conduction, lubrication	3	3	3	**27**
Cone Guide	Fiber-pressing media from worm screws	Wet fiber oil does not melt	Wear wall plate	Excessive working hours	Change of cone guide e layer plate	3	3	3	**27**

Table 1 shows seven types of damage that are priority repairs in the RPN Hight category. The types of damage included in the repair priority are Worm Screw, Extension Shaft, Bearing, Press Cage, Oil Seal, Ccs Connector, and Main Shaft Short.

Logic Tree Analysis (LTA)

Logic Tree Analysis (LTA) is a qualitative measurement for classifying failure modes. Determine LTA priority in the following way: **Evident**, that is, does the operator know there has been a disturbance in the system under normal conditions? **Safety**, that is, does this damage mode cause safety problems? **The outage**, i.e., does this damage mode result in all or part of the machine stopping? Category, namely the categorization obtained after answering the questions asked. The arrangement for selecting actions for critical components can be shown in Figure 2.

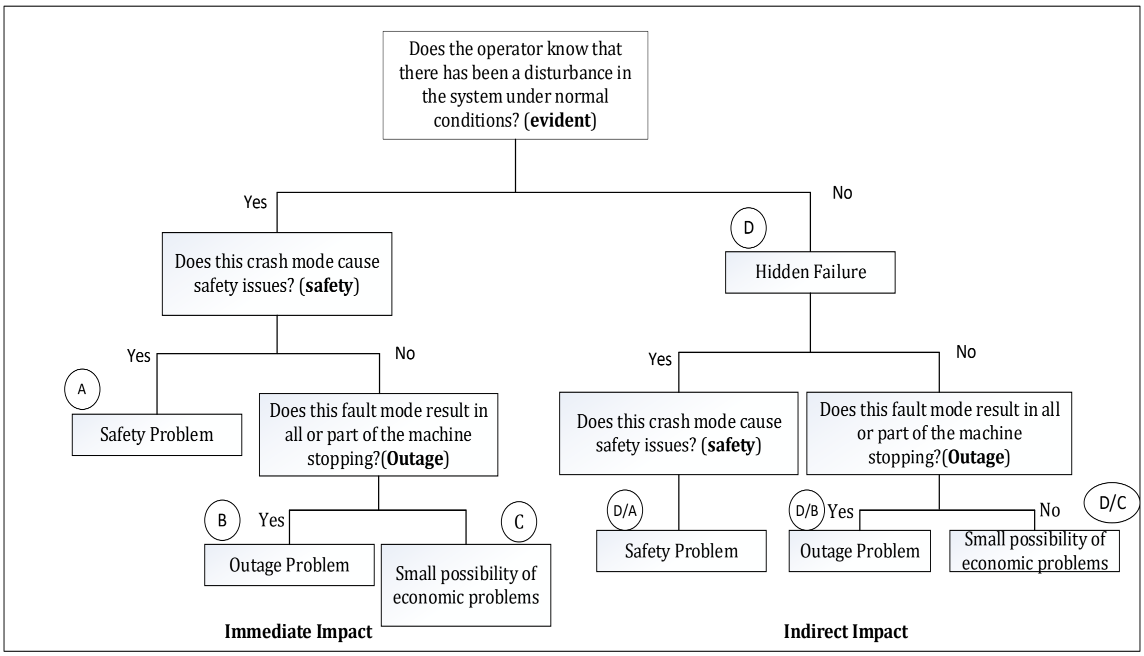

Figure 2 Structure of Logic Tree Analysis

Logic Tree Analysis (LTA) Screw Press Machine is shown in Table 2.

Table 2 Logic Tree Analysis (LTA) Screw Press Machine

Component	Effect of component failure	Causes of Failure	Evident	Safety	Outage	Category
Worm Screw	Break	Inlet iron piece, too high hydraulic load	Y	N	Y	**B**
Extension Shaft	Break	Hydraulic pressure power pack, iron fracture	Y	N	Y	**B**
Bearing	Worn, ruptured	Empty oil, Usage over capacity	Y	N	Y	**B**
Press Cage	Wear/thinning	Press cage	N	N	Y	**D/B**

		pores are clogged				
Oil Seal	Broken seal, Leaking oil	Delay in oil filling	N	N	Y	**D/B**
Ccs Connector	Wear/break	Overworking hours	N	N	Y	**D/B**
Main Shaft Short	Cracked and Broken	Looseness on the locking peg of the worm, Empty oil	Y	N	Y	**B**

Based on Table 2 of the Logic Tree Analysis (LTA) of the Screw Press Machine, it can be seen that: Worm Screw components, Extension Shafts, bearings, and Main Shaft Short are included in category B (Outage problem) in failure mode can shut down the system. While the Oil Seal Component, Press Cage, and Ccs Connector are included in the D/B (hidden Failure) category, namely, the failure mode that occurs cannot be known by the operator and can interfere with production.

Task Selection

Action selection is the final stage of the RCM process. A list of practical actions from each damage mode is created. The Screw Press, Machine Selection Task, is shown in the table3

Table 3. The Screw Press Machine Selection Task

Component	**Effect of Component Failure**	**Causes of Failure**	**Selection Guide**							
			1	**2**	**3**	**4**	**5**	**6**	**7**	**Task Selection**
Worm Screw	Break	Inlet iron piece, too high hydraulic load	Y	Y	N	N	N	N	N	**TD**
Extension Shaft	Break	Hydraulic pressure power pack, iron fracture	Y	Y	N	N	N	N	N	**TD**
Bearing	Worn, ruptured	Empty oil, Usage over capacity	Y	Y	N	N	N	N	N	**TD**
Press Cage	Wear/thinning	Press cage pores are clogged	N	N	N	N	N	Y	Y	**TD**
Oil Seal	Broken seal, Leaking oil	Delay in oil filling	Y	Y	N	N	N	N	N	**TD**
Ccs Connector	Wear/break	Overworking hours	Y	N	N	Y	Y	N	N	**FF**
Main Shaft Short	Cracked and Broken	Looseness on the locking peg of the worm, Empty oil	Y	N	Y	N	N	N	N	**CD**

Based on Table 3, Selection of actions from damage to Screw Press Machine components, it can be seen that Worm Screw Components, Extension Shafts, Bearings, Oil Seals, and Press Cages are components included in the selection of Time Directed (TD) actions. Actions are taken in the form of direct prevention of the source of component damage based on the time or age of the component. The Ccs Connector component is included in selecting Failure Finding (FF) actions. The action taken is to find hidden component damage with periodic inspections. The Main Shaft Short component determines Condition Directed (CD) actions. The action taken is in the form of detecting damage by inspecting components.

Preventive Maintenance Scheduling Planning Reliability

Based on the results of RCM analysis, reliability calculations are carried out on components included in the selection of Time Directed (TD) actions. These components include Worm Screw, Extension Shaft, Bearing, Oil Seal, and Press Cage. Each component's time to repair (TTR) and Time To Failure (TTF) calculations are carried out to determine the appropriate distribution for damage. These distribution identifiers include the Exponential, Normal, Lognormal, and Weibull distributions. To determine the distribution pattern by damage data, 5 Components of Worm Screw, Extension Shaft, Bearing, Press Cage, and Oil Seal are shown in Figure 3 to Figure 7.

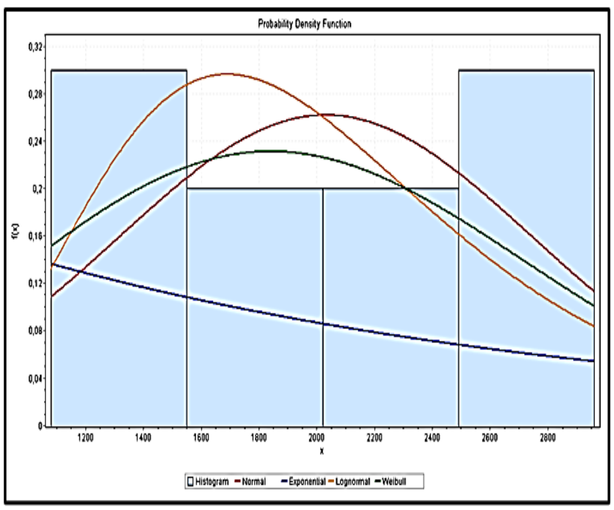

Figure 3. PDF Diagram of Worm Screw Component Damage

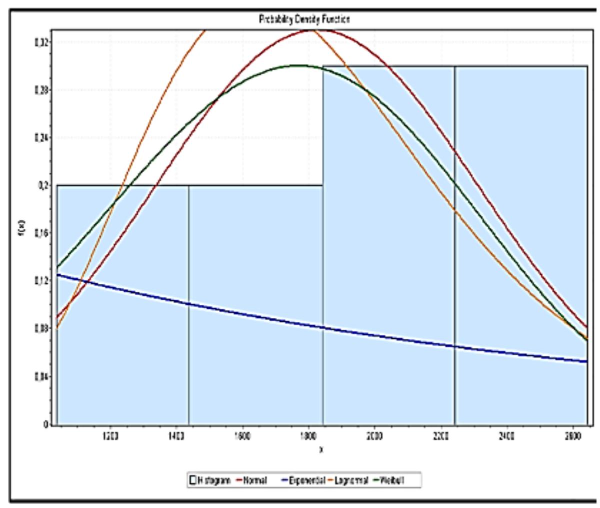

Figure 4. PDF Diagram of Extension Shaft Component Damage

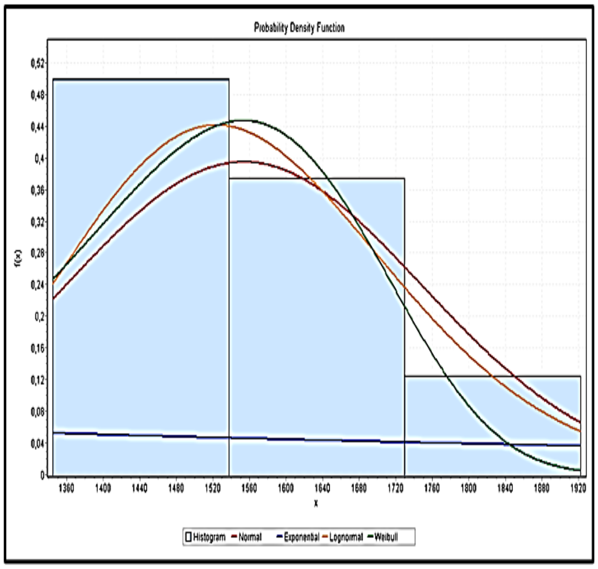

Figure 5. PDF Diagram of Bearing Component Damage

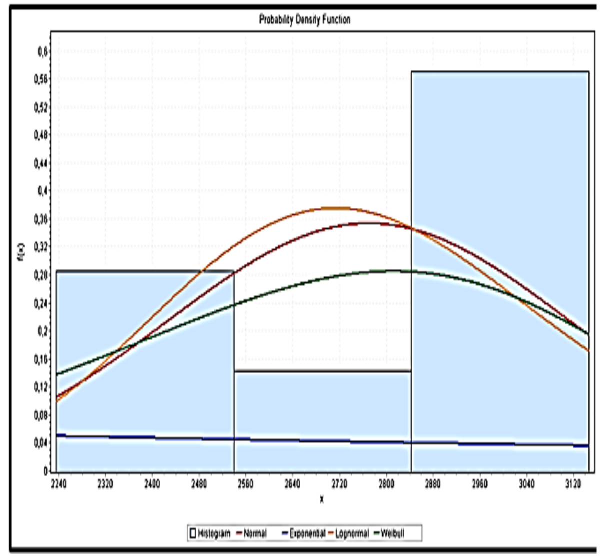

Figure 6. Oil Seal Component Damage PDF Diagram

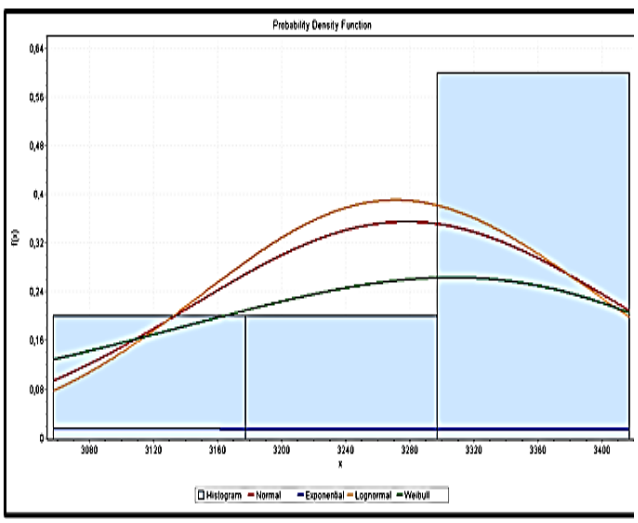

Figure 7. Press Cage Component Damage PDF Diagram

Figures 3 through 7 determine the distribution pattern corresponding to the data. The Probability Density Function (PDF) closest to the downward shifting line is the most appropriate to the data, and it can be said that the data has followed that distribution pattern. To see the corresponding distribution can use the information from the text output, which can be seen in Table 4.

Table 4. Distribution and Parameter Test Summary

Component	Distribution Patterns	Statistics	Parameters
Worm Screw	Lognormal	0.17795	$\sigma = 0.35273$ $\mu = 7.5562$
Extension Shaft	Usual	0.16367	$\sigma = 486.45$ $\mu = 1824.5$
Bearing	Weibull	0.19798	$\alpha = 9.8472$ $\beta = 1569.9$

Oil Seal	Usual	0.22667	σ = 343.27 μ = 2769.9
Press Cage	Usual	0.28583	σ = 135.13 μ = 3277.8

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

Mean Time to Failure (MTTF) is the average time of component damage used only on frequently damaged components and must be replaced with new or good components. At the same time, the Mean Time to Repair (MTTR) is the average time to repair these engine components. The following is the Mean Time to Failure (MTTF) and Mean Time to Repair (MTTR) from the critical component data of the Screw press machine.

The following Mean Time To Failure (MTTF) of critical component data of the Screw press machine through output calculations from easyfit 5.6 professional software is shown in Figure 8 to Figure 12.

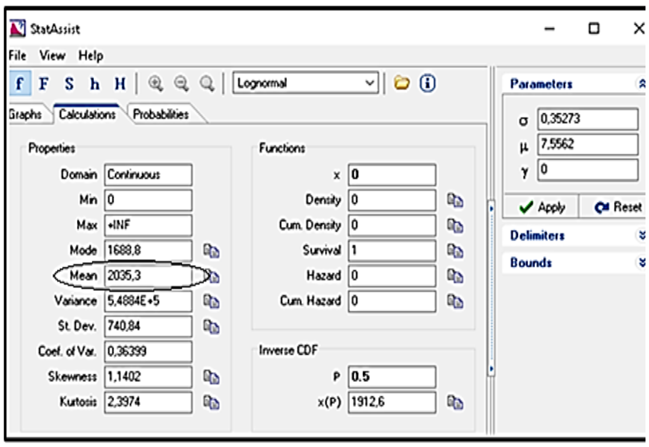

Figure 8. Worm Screw Components

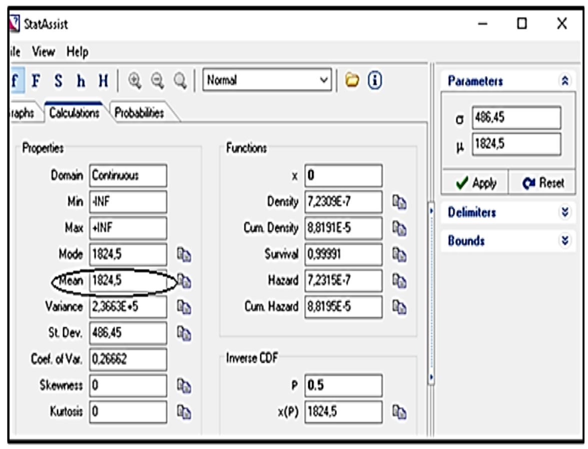

Figure 9. MTTF Component Extension Shaft

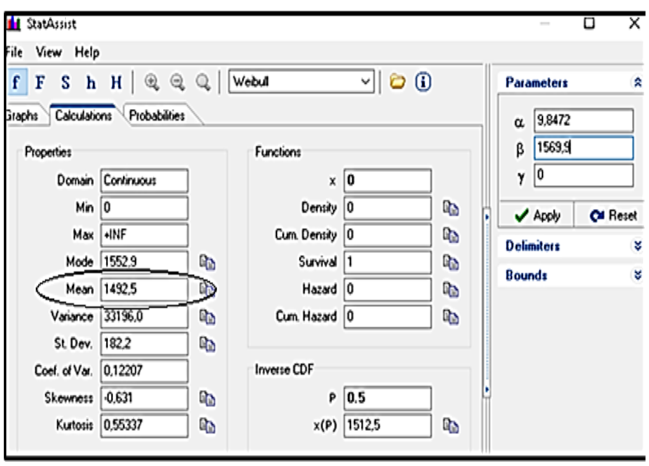

Figure 10. MTTF Bearing Components

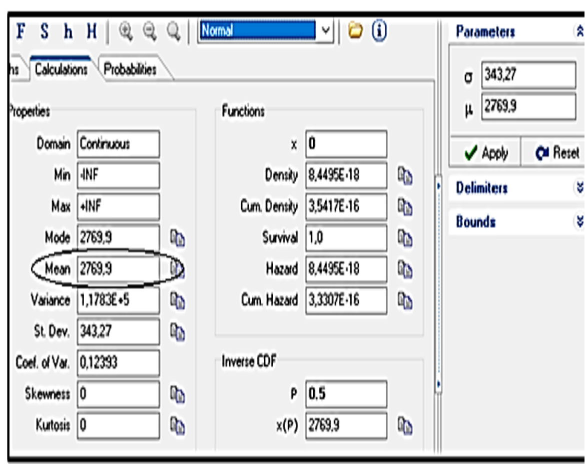

Figure 11. MTTF Oil Seal Components

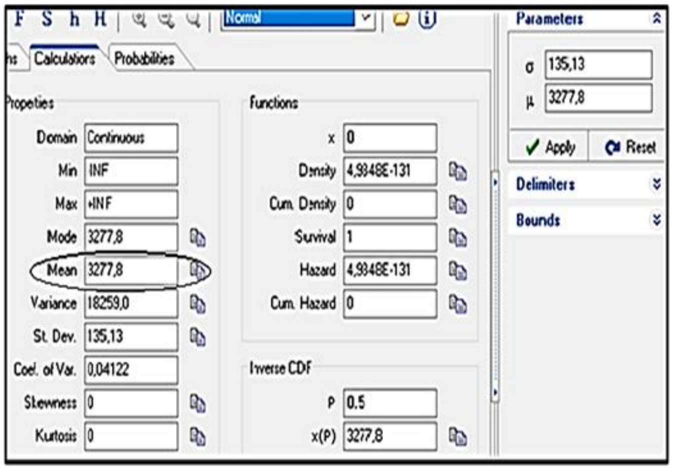

Figure 12. MTTF Component Press Cage

Based on Figure 8 to Figure 12, it can be seen that the Mean Time to Failure (MTTF) damage to the Worm Screw Component is 2035.3 hours, the Extension Shaft Component damage is 1824.5 hours, the Bearing Component damage is 1492.5 hours, Oil Seal Component damage is 2769.9 hours, Press Cage Component damage is 3277.8 hours.

Determination of treatment time intervals

The determination of the maintenance time interval is aimed at finding out the optimal Time for the Maintenance of components, the calculation of which is as follows:

1. Component Worm Screw

Average production hours per month = 486.4 Hours
The amount of damage in 1 year = 10 Times
Average repair time (MTTR) = 9 hours
The average inspection time = 3 hours

a. Average time to repair

$$\frac{1}{\mu} = \frac{\text{MTTR}}{\text{Average production hours per month}} = \frac{9\text{ hours}}{486.4\text{ hours}} = 0.019\text{ hours}$$

$$\mu = \frac{1}{1/\mu} = \frac{1}{0{,}019} = 54.04\text{ hours}$$

b. Average inspection time

$$\frac{1}{i} = \frac{\text{Average one-time inspection}}{\text{Average production hours per month}} = \frac{3\text{ hours}}{486.4\text{ hours}} = 0.006\text{ hours}$$

$$\text{i} = \frac{1}{1/i} = \frac{1}{0{,}006} = 162.1\text{ hours}$$

c. Average damage

$$k = \frac{\text{Total damage in 1 year}}{12} = \frac{10}{12} = 0.83$$

d. Optimal inspection frequency

$$n = \sqrt{\frac{k\ x\ i}{\mu}} = \sqrt{\frac{0.83\ x\ 162{,}1}{54.04}} = 1.58$$

e. Maintenance time interval

$$ti = \frac{\text{Average production hours per month}}{n} = \frac{486.4 \text{ hours}}{1.58} = 307.84 \text{ hours}$$

Recapitulation of maintenance time intervals of Screw Press Machine components can be seen in Table 5.

Table 5. Recapitulation of Maintenance Time Intervals of Screw Press Machine

Component	Amount of damage (times)	MTTF (Hours)	MTTR (Hours)	Maintenance time interval (Hours)
Worm Screw	10	2035.3	9	307.84
Extension Shaft	10	1824.5	11	279.5
Bearing	8	1492.5	8	300.2
Oil Seal	7	2769.9	5	286.1
Press Cage	5	3277.8	9	250.72

Preventive Maintenance

To avoid downtime on the machine, the proposal is in the form of preventive maintenance component maintenance using the Average Time To Failure as the maintenance schedule. At the same time, the Maintenance of components with the proposed actions is shown in Table 6.

Table 6. Maintenance of components with proposed actions

Component	Fungsi components	Actions taken
Worm Screw	main components of the CPO extracting machine	Direct prevention of sources of component damage based on the time or life of the component by replacing the defective part with a new one.
Extension Shaft	Worm screw buffering/containment	Tightening of bolts and nuts: when the bolts are loose and worn, do bolt tightening or bolt replacement, and damaged components are replaced.
Bearing	Main shaft drive	Regular bearing replacement is on schedule and does not exceed component life.
Oil Seal	It keeps oil from spilling.	Regular oil filling, following a maintenance schedule, and frequent periodic checks.
Press Cage	As a filter for pressing	Check regularly and change components according to the maintenance schedule so that the pores of the press cage are not clogged and no damage can interfere with the filtering poses.

DISCUSSION

The Mean Time to Repair (MTTR) of the worm screw component was obtained from the data on the machine repairs carried out, which was 9 hours, and the maintenance time interval for the Worm Screw component was every 307.84 hours. Preventive maintenance measures for the worm screw component can be carried out by directly preventing the source of component damage by replacing the damaged component with a new component. This action aligns with [30] research, where his research on replacing actions reduces downtime from 7.29 hours/month to 7.08 hours/month, or by 0.21 hours/month (2.85%). Meanwhile, the decrease in machine maintenance costs with preventive Maintenance was from IDR 14,469,590.00 to IDR 8,908,230.00, or a savings of 38%. The MTTR of the extension shaft is 11 hours, and the maintenance time interval for the extension shaft component is every 279.5 hours. Preventive Maintenance of the extension shaft component can be done by tightening the bolts and nuts. If the bolts are loose and worn out, tighten the bolts or replace the bolts, replace the damaged components. According to [31] research, optimal inspection frequency is two times in one month, and availability is 98.87%. There are two results of suitable maintenance activities: time-directed life-renewal task and time-directed life-renewal task & Failure finding task. The Mean Time to Failure (MTTF) for bearing component damage is 1492.5 hours. The maintenance time interval for bearing components is every 300.2 hours. Preventive Maintenance of bearing components can be carried out by replacing bearings regularly according to a schedule and not exceeding the service life of the components. These results are reinforced by [32] research results, namely maintenance time intervals and optimal replacement of Spring Carbon Brush components on Callender machines that have a value of the highest reliability of 85% and occur in 35 days. The most optimal replacement time interval is 18 days, and 16 component repairs occur in 1 year. • Savings on downtime and costs incurred when carrying out preventive Maintenance for 35 days with 16 treatments of IDR. 2,880,000,-. Compared to before using the Age Replacement method, the company paid a fee of IDR. 4,590,000

CONCLUSION

Five types of damage are priority repairs. The types of damage included in the repair priori are worm screws, extension shafts, bearings, press cages, and oil seals. The proposed maintenance time for each critical component is a worm screw component maintenance time interval of 307.84 hours; changeover schedule every 2035.3 hours. Component extension shaft maintenance time interval 279.5 hours, changeover schedule every 1824.5 hours. Bearing components maintenance time interval 300.2 hours, changeover schedule every 1492.5 hours. Oil seal components maintenance time interval 286.1 hours, changeover schedule every 2769.9 hours. Press cage components maintenance time interval 250.72 hours, changeover schedule every 3277.8 hours. Actions are taken in the form of direct prevention of the source of component damage based on the time or age of the component.

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