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Determination of Lathe Component Replacement Interval Using Age Replacment Method

Fakhrudin Ma'ruf[1], Said Salim Dahda[2*]

Universitas Muhammadiyah Gresik[1,2]
*E-mail:said_salim@umg.ac.id

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ABSTRACT

Competition between industries currently requires the industry to continue to improve in improving the industrial system. Machine flexibility is one of the programs to improve the industry's ability to increase competitiveness. In meeting consumer demand, general purpose machines have become one of the foundations for industrial systems in producing various types of products. Machine performance will decrease in line with the age of the machine / component and the length of the machine's operation. Maintenance planning / component replacement is one way to reduce downtime. A lathe is a general purpose machine, which has components that are often damaged, such as gear and control cables, which cause a lot to stop using the machine. Scheduling Replacing components is a vital process in reducing lost time and minimizing costs arising from decreased machine performance. The focus of this research is determining the component replacement schedule that can meet these two criteria. This can be achieved by applying the age replacement method. The Age Replacement method is basically looking for a balance point between the probability of component failure and component reliability to obtain the optimal probability value of total down time. By estimating the pattern of component failure with the Weibull distribution, calculations are made for the two components that are most frequently damaged on a lathe. The results obtained are the time to replace the components, the replacement period and the costs arising from the optimal replacement of these components.

Keywords : Age Replacement, Downtime, Maintenance, Reliability

INTRODUCTION

In carrying out a manufacturing process, machines have reliability, namely the chance of successful operation or performance of a system and related equipment, with a minimum risk of loss or failure of the system (Maryami et al., 2019).In any manufacturing system, the breakdown of the operating process of the machine can interfere with the smooth operation of a system, whichnegative impact on company performance such as revenue and customer service. To avoid system failure, management should pay special attention to preventive*maintenance*after regular production so that the manufacturing system can produce without interruption in the next cycle of the production process (Sana, 2012). preventive*maintenance*are activities that are applied to the system while it is still operating, which can be applied to keep the system at optimal production levels. Policy*preventivemaintenance*good will have a good impactpositive for the company, especially reducing the cost of maintaining the system in a maximum state but also increasing the productivity of the system (Park et al., 2000).

Companies engaged in construction and manufacturing services that produce Agro Industrial Equipment, in completing requests from customers using general purpose machines. With a production system in the form of a job shop like the industry, it is very dependent on the existence of machines and other supporting equipment. If the number and capacity of machines are limited, then controlling the availability of machines will determine the performance of the industry. Machines that are general purpose, have a fairly large load in supporting the completion of the final product such as a lathe, which is expected to have good availability. If the continuity of production is very dependent on operating machines, good machine maintenance activities are needed (Siswanti, 2017). The company tries to maintain the reliability of these machines by implementing a preventive maintenance system. Even though a system of preventive maintenance activities has been implemented, the company will still be unable to determine when a component is replaced so that engine reliability remains optimal (Bangun et al., 2014). The impact of engine damage from damaged components cannot be ascertained because each engine component has different reliability and damage rates.

With this damage the importance of a maintenance strategy that can minimize downtime. In reliability theory, the maintenance strategy generally consists of age-based maintenance, calendar-based maintenance, condition-based maintenance, and risk-based maintenance (Chang, 2018). One preventive replacement policy for components that is widely used is the age replacement model policy (Jiang, 2018). The Age Replacment model is a time interval replacement model for components by paying attention to a certain service life or at the time of the failure of a component (Ruchiyat et al., 2020) (Chang, 2018). The Age Replacement model aims to determine the optimal age t, where prevention of replacement of components must occur in such a way that downtime per unit time on component failure can be minimized (Ruchiyat et al., 2020). This means that this model applies if there is damage to a component in a set of machines then only one damaged component will undergo component replacement (Anshori & Imron, 2013). Besides that, it can also determine the replacement time interval for components, the Age Replacement model can also predict the length of downtime (Ruchiyat et al., 2020). In many studies, the age replacement model is widely used in industries that have a flow shop production system. In industries with flowshops, it is very easy to determine the length of time to use a machine. With relatively the same product results and the same processing time, it is easier to use the age replacement method in planning the replacement of components on a machine. In contrast to the use of age replacement in a job shop system, the length of time a machine operates is very dependent on the production scheduling of each job that has different forms and production times on the machine. In this study, the use of age replacement on machines that have many functions and the form of a job shop industrial system will be used.

Maintenance

*Maintenance*is the concept of all activities needed to maintain the quality of a facility or system so that it can function optimally at the initial engine condition (Kurniawan, 2013). Maintenance broadly aims to focus on preventive or anticipatory steps to minimize the occurrence of damage to facilities and systems and ensure the level of reliability and readiness as well as minimize maintenance costs on facilities and systems in the company.

In general, care management has the following objectives (Kurniawan, 2013):

a. Extend the operating life of a facility or system in the industrial world
b. Minimize maintenance costs and the cost of stopping the production flow due to reliability problems
c. Can estimate preventive maintenance planning. So that it can facilitate the process of scheduling component replacement on the machine
d. Minimize the occurrence of downtime.

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Distribution Test (Weibull)

To apply Age replacment, it takes data on the average time the components do not function normally. The time pattern of the damage is described in the form of a Weibull distribution. The Weibull distribution is one of the most popular probability functions used to describe the lifetime of a system failure event and this distribution can be used to estimate optimal maintenance time intervals and relative costs (Sgarbossa et al., 2019). The Weibull distribution is the most widely used distribution in determining the time of damage, because this distribution is either used for the increasing rate of damage or decreasing the rate of damage (Pamungkas, 2014).

Damage Rate

According to (Ebeling, 1997) the rate of damage is always changing and difficult to predict in accordance with the increasing age of the machine. From the results of the analysis can show the rate of damage of a component will follow a basic pattern Bathtub curve as shown in Figure 1. Following:

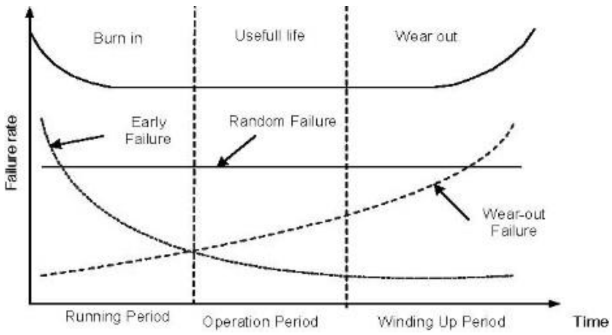

Figure 1. Damage rate curve (Bathtub curve)

According to (Ebeling, 1997) there are 3 phases of damage, namely as

follows

1. *Burn In Phase*, which is a phase that describes the rate of breakdown that continues to decrease with the length of time a machine operates.
2. *Useful Life Phase*, which is a phase that describes the rate of breakdown that is constant with the length of time a machine operates.
3. *Wear Out Phase*,namely the phase that describes the rate of damage that continues to increase sharply with the length of time the operation of a machine.

Age replacment method

One of the most common and popular component replacement policies is the age replacment model which was developed in the early 1960s. Under this replacement policy, a unit or facility will be replaced at its age or at the time of failure. The age replacment method is a replacement policy when there is damage to components due to wear and tear on the system which is characterized by periodic component replacement (Sgarbossa et al., 2019). The Age replacment method is a method that performs preventive replacement on the age of the component of the facility or system that is being used and if there is damage to the component it will be reset to zero or to the beginning of the component's life (Ramadhan et al., 2016).

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However, in this method, replacingWhen a component has reached the specified time and can be seen in Figure 2. In the first interval there is no damage to the component, after doing so, the first preventive replacement of the component is damaged before the specified age. Then rescheduled for replacement on the next component .

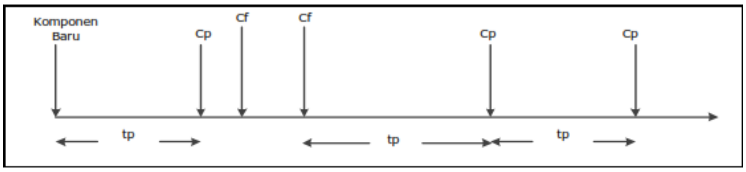

Figure 2. Age replacment method

Information:
Cp = total cost of prevention when damage
Cf = total replacement cost in case of damage Tp = preventive replacement interval when damage occurs
The following variables relate to the age replacement method:

a. MTTF (Mean Time to Failure) and MTTR (Mean Time to Repair)
b. Preventive replacement time interval (tp)
c. *Downtime*which occurs due to replacement of damage (Tf)
d. *Downtime*which occurs due to preventive replacement (Tp)
e. Component reliability or probability of a reliable component (R(tp))
f. R(tp) = ( ) $dt = (\,)$ □ □
g. Probability of component failure (F(tp))
F(tp) = 1 – R(tp)
h. Total downtime probability value per unit time (D(tp))

$$(tp) = \frac{(Tp\ (tp))+(Tf\ [1-R(tp)])}{((tp+Tp)\ (tp))+((M(tp)+Tf)\ [1-R(tp)])}$$

D(tp) = Total value*downtime*unit time R(tp)
= Level of reliability at the time tp
Tf =Timeto replace the damage Tp =
Time to carry out preventive replacement tp = Preventive replacement time interval
M(tp) = Damage rate value

i. Maintenability value (M(tp))

$$(tp) = \frac{\square}{(tp)}$$

METHOD

The research method used to solve the problem with the following steps:

a. Data collection
At the initial stage is to collect primary and secondary data used as research:
- Lathe component datawhich is frequently damaged
- Data on the frequency of time of occurrence of damage to damaged components
- Machine maintenance cost data which includes: labor costs, component prices, lost opportunity costs when production machines are downtime, etc.

b. Estimated failure distribution.

At this stage, the parameters of the Weibull distribution are tested, using the Weibull distribution, the damage to the components can be determined. In the failure rate, consider the Weibull distribution with the shape parameter (β) describing the shape of the distribution in the Weibull distribution, for the scale parameter (η) describing the data distribution in the Weibull distribution.

c. Parameter calculation
In this calculation, based on the distribution used, namely the Weibull distribution, the data used is the component downtime time and the distance between damage. This parameter is used in the calculation of the goodness of fit test and the calculation of MTTF and MTTR.

d. Calculation *mean Time to Failure* (MTTF) and *mean Time to* Repair (MTTR)Then calculate the MTTR and MTTF obtained from the results of the Weibull distribution in accordance with the pattern of damage to the engine components. MTTF states the service life of a tool which is expressed as the average time interval for the occurrence of damage, while MTTR is the average time used for maintenance of a component.

e. Calculation of the component replacement scheduler using the Age Replacement Method The Age Replacement method is a method that can determine the replacement scheduler for machine components experiencing downtime and aims to determine the optimal time for replacement of components. perform preventive maintenance. Determination component replacement scheduler based on machine downtime.

f. Calculation of estimated replacement costs on components
This calculation aims to determine the amount of maintenance costs by applying the age replacement method for proposed preventive maintenance improvements.

RESULTS AND DISCUSSION

Time data between Lathe Damage

Before processing the data, the first step that needs to be done is to collect data related to the object of research, namely lathe data on historical data on the occurrence of damage for one year on lathe components and data on the time of damage which includes:

Table 1. Data on Damage and Repair of Lathe Machine Components

No.	Downtime/Hours	Component
1.	13 hours	*Bros tell*motorcycle
2.	5 hours	Control Cable
3.	9 hours	Gear
4.	10 hours	Gear
5.	7 hours	Control cable
6.	9 hours	Foundation bolt
7.	12 hours	Gear
8.	15 hours	Gear
9.	6 hours	Control Cable
10.	10 hours	Gear
11.	10 hours	*Bust thread drill*
12.	5 hours	Control Cable
13.	7 hours	*Bust thread drill*
14	10 hours	Drive Motor
15.	8 hours	Control Cable
16..	4 hours	*Bed Machine*
17.	4 hours	Control Cable

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For time data between damage and repair can be seen in table 1 and in more detail the components that often experience damage will be made the object of research and can be seen in Figure 3 below:

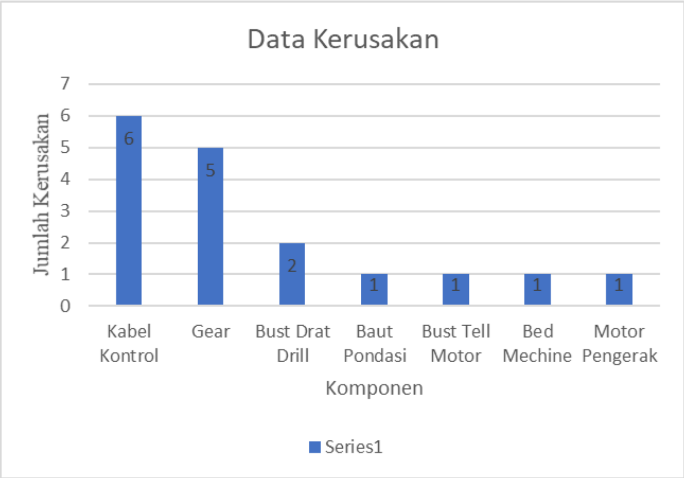

Figure 3. Graph of the Most Critical Components

Figure 2 shows the most critical components or components that often experience damage and downtime data with the greatest frequency. In determining the greatest frequency between one component and another, it is found in the control cable and gear components. Therefore, this research focuses on 2 critical components, namely the control cable component and the Gear.

Data Distribution Test

Table 2. Distribution Test Results on Gear Box and Control Cable

No.	Component	Information	Distribution Type	Parameter (Shapes)	Parameter (Scale)
1	Gear	Distribution 1	*Weibull*	5,65821	12,0110
		Distribution 2	*Weibull*	1.22165	34.0944
2	Control Cable	Distribution 1	*Weibull*	4.30328	6,38130
		Distribution 2	*Weibull*	3.88111	86.1467

Based on the results of the distribution test processing, it can be determined the suitability of the data distribution on component damage. Distribution 1 describes the distribution of downtime time distribution for components, while distribution 2 describes the distribution of time distribution tests for component damage. Parameter values can be obtained by looking at the estimated value in the distribution test.

MTTR and MTTF Calculation

After obtaining the distribution and parameters of each distribution, the next step can be calculated Mean Time To Repair (MTTR) and Mean Time To Failure (MTTF) using the formula MTTR/MTTF = $(1 + \frac{1}{\square})$.

MTTR calculations on Gear components are:

MTTR= $(1 + 1)\frac{}{\square}$

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$12{,}0110\Gamma(1 + \frac{1}{5{,}65821})$

= 11.13 Hours

MTTF calculations on Gear components are:

MTTF = $(1 + 1)\frac{}{□}$

= $34.0944\Gamma(1 + \frac{1}{1.22165})$

= 31.75 Days

MTTR calculation on Control Cable components, namely:

MTTR= $(1 + 1)\frac{}{□}$

= $6.38130\Gamma(1 + \frac{1}{4.30328})$

= 5.81 hours

MTTF calculation on the Control Cable component, namely:

MTTF = $(1 + 1)\frac{}{□}$

= $86.1467\Gamma(1 + \frac{1}{3.88111})$

= 78.083 Days

Determination of Maintenance Using the Age Replacement Method

In determining the optimal component replacement time interval, using the age replacement model approach with the criteria of minimizing downtime. The steps that will be used to determine the optimal replacement time for components are as follows:

Table 3. Calculation of Age Replacement Gear Components

tp	R(tp)	F(tp)	M(tp)	D(tp)
20	0.5938099	0.4062	78.1654	0.20326466
21	0.5751030	0.4249	74.7240	0.20252137
22	0.5567962	0.4432	71.6375	0,20188822
23	0.5388955	0.4611	68.8564	0,20135832
24	0.5214053	0.4786	66.3401	0.20092528
25	0.5043283	0.4957	64.0545	0.2058316
26	0.4876659	0.5123	61.9713	0.20032645
27	0.4714183	0.5286	60.0664	0.20150000 0
28	0.4555848	0.5444	58.3195	0.20004898
29	0.4401635	0.5598	56,7130	0.20001890
30	0.4251519	0.5748	55,2320	0.20005552
31	0.4105466	0.5895	53.8635	0.20015486
32	0.3963435	0.6037	52.5961	0,20031319

Based on the age replacement calculation, it can be seenthat the value of tp 29 is obtained because the value of Dt decreases and at tp 30 the value of Dt increases, therefore at Tp 29 it is optimal and is the optimal component replacement time while the value of R (tp) which is 0.4401635 is the value of machine reliability in the range time tp and the value of F(tp) of 0.5598 is the probability of damage that occurs in the time span tp. Then the value of M(tp) which is 56.7130 is the average time of occurrence of damage if preventive replacement is carried out at tp. While the value of D(tp) which is 0.20001890 is the lowest probability of downtime in the tp time range.

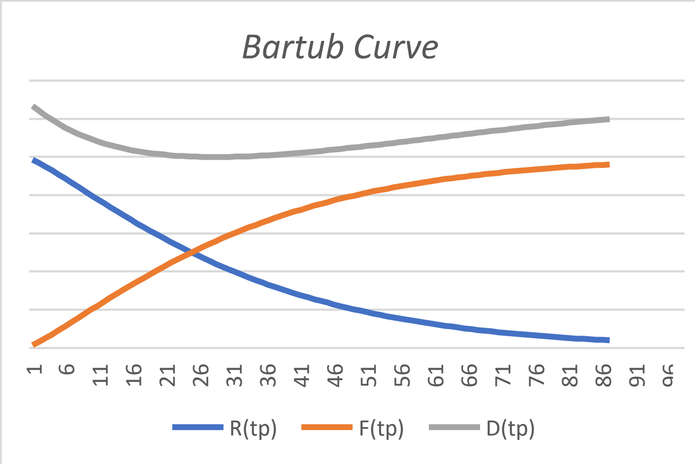

Figure 4. Barhtub Curve Gear

The R(tp) curve depicts the decreasing failure rate that occurs at the beginning of the operation of a component which is marked with a decreasing rate of damage. Meanwhile, the F(tp) curve depicts failures that occur at the useful life of the component which is characterized by an increasing rate of damage that demands immediate replacement of the component. The curve D(tp) shows that the curve is decreasing and is in a constant condition, so the failure occurs in the component and at 29 days the component is replaced.

Table 3. Age Replacement Calculation of Control Cable Components

tp	R(tp)	F(tp)	M(tp)	D(tp)
50	0.8859772	0.1140	684,8014	0.03396831
51	0.8774498	0.1226	637,1512	0.03384779
52	0.8685162	0.1315	593.8603	0.03373822
53	0.8591726	0.1408	554.4587	0.03363976
54	0.8494160	0.1506	518.5345	0.03355260
55	0.8392448	0.1608	485,7262	0.03347690
56	0.8286584	0.1713	455,7154	0.03341285
57	0.8176574	0.1823	428,2213	0.03336063
58	0.8062436	0.1938	402.9957	0.03332043
59	0.7944202	0.2056	379.8184	0.03329242
60	0.7821916	0.2178	358,4940	0.03327679
61	0.7695639	0.2304	338,8488	0.03327372
62	0.7565443	0.2435	320,7277	0.03328341
63	0.7431415	0.2569	303.9923	0.0333604

Based on the age replacement calculation, it can be seenthat the value of tp 61 is obtained because the value of Dt decreases and at tp 62 the value of Dt increases, therefore at tp 61 it is optimal and is the most optimal component replacement time while the value of R (tp) which is 0.7695639 is the value of machine reliability at the time span of tp and the value of F(tp) of 0.2304 is the probability of damage that occurs in the time span of tp. Then the value of M(tp) which is 338.8488 is the average time of occurrence of damage if preventive replacement is carried out at tp. While the value of D(tp) which is 0.03327372 is the lowest probability of downtime in the tp time range.

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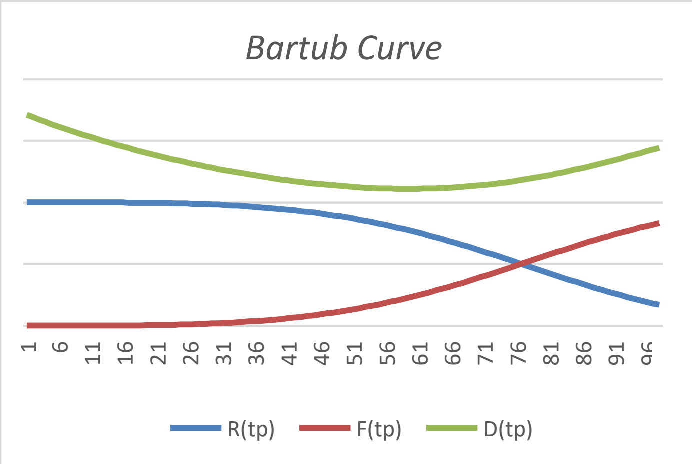

Figure 5. Barhtub Curve Control Cable

The R(tp) curve depicts the decreasing failure rate that occurs at the beginning of the operation of a component which is marked with a decreasing rate of damage. While the F(tp) curve depicts failures that occur at the useful life of the component which is characterized by an increasing rate of damage that demands immediate replacement of the component. The curve D(tp) shows that the curve is decreasing and is in a constant condition, so the failure occurs in the component and at 61 days the component is replaced.

Calculation of Downtime Costs and Labor Costs

The costs of downtime and labor can be seen in the calculation below.

- Lost Profit
  Lost Profit = (Product Selling Price – Production Cost) x Output per day
  = (Rp 515,900,000 – Rp 374,690,495) x 1 4/day
  = IDR 141,209,505,- per day
- Cost Calculation of Downtime Machine Losses
  a. Gear component loss calculation
  $= \frac{\text{Component Downtime}}{\text{Hourly Conversion}}$ ~~x Cost~~ per hour
  = 11.13 Hours x IDR 141,209,505 per hour
  60 Minutes
  = IDR 25,888,409

  b. Calculation of the cost of control cable component losses
  $= \frac{\text{Component Downtime}}{\text{Hourly Conversion}}$ ~~x cost~~ per Hour
  = 5.81 IDR 141,209,505 per hour
  60
  = IDR 13,673,787
- Mechanical Cost
  Based on the data, it is known that the hourly mechanical costs are:
  $= \frac{\text{Salary/month (Rp)}}{\text{Working Hours/month (Hours)}}$
  $= \frac{\text{IDR}}{8{,}500{,}000-/\text{month } 180 \text{ hours/month}}$
  = IDR 47,222,-/hour
- Cost of 2 Mechanics
  = Cost of one mechanic per hour x Number of mechanics
  = IDR 47,222,-/hour x 2 people

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= IDR 94,444,-/hour

- Operator Fee

  Then it can be seen that the hourly operator costs are:

  $= \frac{\text{Salary/month (Rp)}}{\text{Working Hours/month (Hours)}}$

  $= \frac{\text{IDR}}{\text{3,800,000−/month 180 hours/month}}$

  = IDR 21,111,-/hour

Cost of component replacement due to maintenance (Cp)

These costs include operator labor, maintenance or mechanical labor costs, and component prices.The formula used to calculate the replacement cost due to maintenance is:
Cp = [(Operator fee + Mechanical fee) x MTTR] + Component price

a. the calculation of replacement costs due to maintenance on Gear components is:
   Cp = [(Operator costs + Mechanical costs) x MTTR] + Component prices
   = [(Rp 21,111 + Rp 94,444) x (11,13/60)] + Rp 10,300,000
   = IDR 10,321,435
b. the calculation of replacement costs due to maintenance on Control Cable components is: Cp = [(Operator costs + Mechanical costs) x MTTR] + Component prices
   = [(Rp 21,111 + Rp 94,444) x (5,81/60)] + Rp 4,100,000
   = IDR 4,111,185

Cost of component replacement due to damage (Cf)

These replacement costs include operator costs, mechanical costs, production loss costs, and component prices where the entire cost is a loss due to component damage. The formula used to calculate the replacement cost due to damage is:

a. the calculation of replacement costs due to maintenance on Gear components is:
   Cf = [(Operator cost + Mechanical cost + Production loss per day) x MTTR] + Component price
   = [(Rp 21,111 + Rp 94,444 + Rp 25,888,409) x (11,13/60)] + Rp 10,300,000
   = Rp. 15,123,735
b. the calculation of replacement costs due to maintenance on Control Cable components is:
   Cf = [(Operator costs + Mechanical costs + Production loss costs per day) x MTTR] + Component price
   = [(Rp 21,111 + Rp 94,444 + Rp 13,673,787) x (5,81/60)] + Rp 4,100,000
   = Rp. 5,434,808

Calculation of Total Maintenance Costs Using the Age Replacement Method

The calculation of the total maintenance cost is calculated based on the optimal replacement frequency. To calculate the TC per unit time or TC (tp) on the Gear sub-components are as follows:

$$(tp) = \frac{(C(tp))+(C|1-R(tp)|)}{(tpxR(tp))+(M(tp)x|1-R(tp)|)}$$

$$= \frac{(Rp\ 10{,}321{,}435\ 0.44016)+(Rp\ 15{,}123{,}735\ 0.559)}{(29\ 0.44016+(56.71300.559)}$$

= IDR 292.288

Based on the optimal replacement frequency. To calculate TC per unit of time or TC (tp) on the Control Cable sub-component is as follows:

$$TC(tp) = \frac{(C(tp))+(C|1-R(tp)|)}{(tpxR(tp))+(M(tp)x|1-R(tp)|)}$$

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$$= \frac{(Rp\ 4{,}111{,}185x\ 0.7695)+(Rp\ 5{,}434{,}808\ 0.2304)}{(61\ 0.7695)+(338.8488\ 0.2304)}$$

= IDR 35,322

Furthermore, the total maintenance costs for the Gear and Control Cable sub components can be calculated. The total maintenance costs for Gear components can be calculated as follows:

TC* = ((312 days x 24 hours x 60 minutes) / tp) x MTTR x TC) + Component price
= ((449,280/29) x 11.13 x IDR 292,288) + IDR 10,300,000
= Rp 15,267,247,-

The calculation of the total maintenance costs for Control Cable components can be seen as follows: TC* = (((312 days x 24 hours x 60 minutes) / tp) x MTTR x TC) + Price of components
= ((449,280/61) x 5.81 x Rp 35,322) + Rp 4,100,000
= IDR 5,611,501,-

Analysis

From the data analysis of the calculation of component replacement scheduling on the lathe by applying the age replacement method, the optimal preventive replacement results are obtained at the time of component replacement at the 29th interval on the Gear component. The machine reliability value is 0.4401635, the probability of damage that occurs is 0.5598 for the average damage if preventive replacement is carried out, which is 56.7130, for the lowest downtime probability value, which is 0.20001890. Furthermore, for maintenance costs (Cp) of Rp. 10,321,435. While the cost in the calculation (Cf) the total replacement cost is Rp. 15,123,735, for the calculation of the total maintenance cost (TC*) of Rp. 15,267,247. Meanwhile, for preventive replacement of Gear components which has been calculated using the age replacement method, the interval is 29 days with 12 replacements within a year with a total cost of replacing preventive components for one year, which is Rp. 183,206,964

Meanwhile, preventive replacement of control cable components that have been calculated by applying the age replacement method obtained an interval of 61 days with 6 replacements within a period of one year with a total cost of preventive replacement for one year, which is Rp. 33,669,006 So that it can be used as a reference in making preventive replacements on lathe components.

CONCLUSION

Based on the calculation, it can be concluded that the high frequency of damage to the control cable and gear components on the lathe can be caused by improper maintenance planning. Therefore, the calculation of determining the time interval for replacing the most critical components by applying the age replacement method is expected to be a solution or input for replacement of lathe components in order to minimize downtime. So the optimal replacement time interval for replacing Gear components is at the 29-day interval, while the control cable component results in the most optimal preventive replacement for replacing components, which is at the 61-day interval. Prevention for one year is Rp. 183,206,964. Meanwhile, for the replacement cost of the control cable components, the replacement time interval is 6 times within one year with a total preventive replacement cost of Rp. 33,669,006. Based on the results of the analysis and calculation of the total cost savings, it was found that the company should do better to replace it by applying the proposed system of the age replacment method.

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