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Risk Analysis of Critical Axial Pump 2000LPS Hydraulic Components Using the Risk Based Inspection Method (RBI)

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***Abstract* - A pump is a machine or mechanical equipment that is used to raise fluid from lowland to highland or to increase fluid pressure from low pressure fluid to high pressure fluid and also as a flow rate amplifier in a transfer network system. In order to ensure that the performance of a pump can operate well and optimally, it is necessary to have a good maintenance system because the smoothness of the production process is influenced by the maintenance applied. Maintenance or what is usually referred to as maintenance is an activity carried out to maintain the condition of a facility (machinery, equipment and a system) in a condition where the system can operate/function properly, which is done by limiting and eliminating damage to the system. In order for the maintenance system to be more scheduled, it is necessary to know the reliability of each critical component in the pump. Reliability is obtained by using the risk based inspection method to determine the cause of damage to critical components. The results obtained from this analysis are six critical components that have MTTF and reliability values, namely at an interval of 600 HM hours, o-ring - AP.850.76 is 56.84% at 1826.57 hours, o-ring - AP.850.80 is 56.84% at 1826.57 hours, out ring – AP.850.43 is 56.84% at 1826.57 hours, wear ring – AP.850.44 is 56.84% at 1826.57 hours, bellmouth – AP.850.42 is 55.02% at 2204.11 hours, bearing – AP.850.20 is 54.88% at 2626.83 hours.**

Keywords: Risk based inspection, hydraulic axial pump, mttf, periodic maintenance, reliability.

1. Introduction

Pump is a machine or mechanical equipment that is used to raise fluid from lowland to highland or to increase fluid pressure from low pressure fluid to high pressure fluid and also as a flow rate amplifier in a transfer network system. [1]. In order to ensure that the performance of a pump can operate well and optimally, it is necessary to have a good maintenance system because the smoothness of the production process is influenced by the maintenance applied. Maintenance or what is usually referred to as maintenance is an activity carried out to maintain the condition of a facility (machinery, equipment and a system) in a condition where the system can operate/function properly, which is done by limiting and eliminating damage to the system [2].

Failure Analysis is a step to check failure or damage to a component which includes the situation and conditions of the failure or damage, so that the cause of the failure/damage that occurs to the component can be determined. [3]. Risk Based Inspection (RBI) is a method for determining an inspection program or plan based on the risk of failure and the consequences of failure of equipment. RBI risk is defined as the result of a combination of probability of failure and consequence of failure. RBI can classify those as high, medium and low risk, and then focus inspections on high risks [4].

Maintenance is an activity that aims to maintain a facility (machinery, equipment and system) in good condition so that it remains in such a condition that the system can function/operate well, which is done by limiting and eliminating damage to the system. In general, maintenance is a combination of various activities carried out to preserve and maintain a machine and repair it to an acceptable condition [5]. Risk-Based Inspection (RBI) is a risk-based control method where hazards are the basis for determining priorities and managing control programs. In operational installations, a relatively large percentage is associated with equipment group risks. RBI allows the transfer of inspection and maintenance resources to ensure a higher level of protection for high-risk locations and thoughtful efforts to reduce the risk of such threats. Possible benefits from the RBI program include increased equipment availability and the use of industrial plants with long processes to minimize failures or at least maintain the same level of risk [6].

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2. Research Materials and Methods

2.1 Data collection

The Object studied is Hydraulic Driven Axial Pump berkapasitas 2000 LPS as many as 2 units which play a vital role in the smooth running of the machining process at the Pasar Waru Pump House, Semarang City, Central Java. The reason for choosing a hydraulic driven axial pump is because this unit has a big role, this can be seen from the function of the hydraulic driven axial pump which is a vital unit for removing floods and puddles in the Semarang City area, especially in the East Semarang area, if this unit experiences breakdown will really disrupt the machining process and be very detrimental to the company, the people of Semarang City, and the Semarang City government.

The data obtained from the test results of the hydraulic driven axial pump with a capacity of 2000 liters per second will then be made into graphical form. This data shows the performance that a hydraulic driven axial pump with a capacity of 2000 liters per second must be able to achieve when working under normal conditions. Data collection can be done by direct observation in the field and through interviews. Basically data sources are divided into two types, namely primary data, in the form of flow rates that can be produced by a hydraulic driven axial pump when given a certain amount of power using an ultrasonic flow meter as well as interviews with company management, available field supervisors, and operators and secondary data, in the form of technical drawings and specifications.

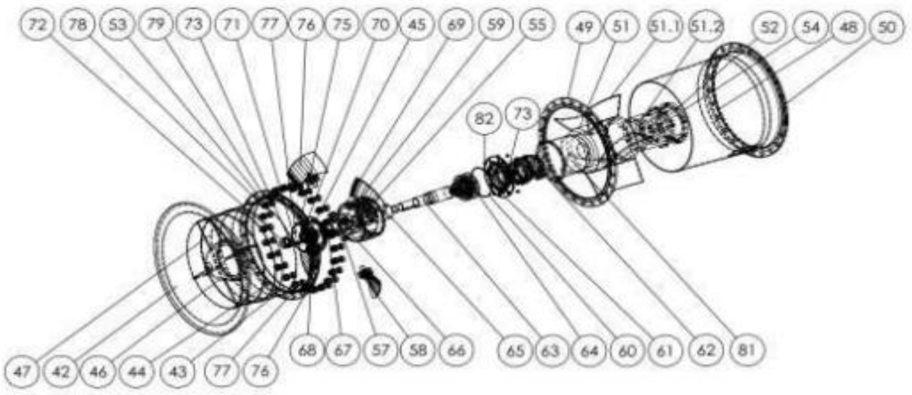

Figure 1: Technical Drawings of Hydraulic Driven Axial Pump 2000 LPS

2.2 Selection of Critical Components using the Critical Analysis Method

Critical analysis is a method used to determine the criticality value of a component so that the results of the assessment can be used as input for machine maintenance. The step in determining critical components begins by first determining the criteria in the critical component assessment standards. There are four criteria in the critical analysis method and each criterion is then given a weighting factor with a different value according to the priority of each criterion regarding the criticality of the component [7]. Grade or component assessment is the level of how well a component meets the existing critical criteria. Component grade categories and the weighting of each criterion can be seen in Table 1.

Table 1: Critical Component Assessment Standards

No	Assessment Criteria	Rating Scale				
		1	2	3	4	5
1	Damage Frequency (Weight 4)	Damage Frequency 1 time	Damage Frequency 2 times	Damage Frequency 3 times	Damage Frequency 4 times	Damage Frequency ≥5 times
2	Impact (Weight 3)	Pump still can operate There isn't any propagation damage	-	Pump still can operate There is propagation damage	-	Pump Can't operate

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3	Proses Repair (Weight 2)	Repairing Process<24 hours	Repairing Process 1 day	Repairing Process 2 days	Repairing Process 3 days	Repairing Process 4 days
4	Harga (Weight t 1)	<250 USD	250-499USD	500-749 USD	750-999 USD	≥1000 USD

Determining the critical components of a hydraulic driven axial pump with a capacity of 2000 liters per second is carried out by multiplying the component grade by the weight of each critical criterion to determine the criticality value of the machine. After the machine criticality value is obtained, the critical components can be determined

2.3 Determination of Damage Distribution Used

Four types of probability plots or damage distributions are used to process the selected critical component data. The probability plot chosen to find out which type of distribution is most suitable for processing critical component data is the Weibull Distribution, Normal Distribution, Lognormal Distribution, and Exponential Distribution. [8].

2.4 Distribution Testing Using Goodness of Fit Test

The probability plot or damage distribution selected is then tested using the goodness of fit test in Minitab 19 software. The purpose of this test is to make it easier to determine the distribution that best suits the existing data. This test will produce correlation coefficient values and Anderson-Darling values from time data based on each distribution.

The Anderson-Darling (AD) value is the value used as a Goodness of Fit Test for distribution plots. Goodness of Fit Test based on Anderson-Darling values and graphical analysis shows that each distribution offers a superlative fit to the failure time data [9]. Meanwhile, the general form of static testing is as follows:

$$A^2 = -n - S$$

with,

$$S = \sum_{i=1}^{n} \frac{2i-1}{n}\left[\ln F(Y_i) + \ln(1 - F(Y_{n+1-i}))\right]$$

in this case n is the number data, i = 1, 2, …., n, and $F(Y_i)$ is the cumulative distribution function for the data Y_i, with $Y_i \in \{Y_1, Y_2, \dots, Y_n\}$ and $Y_1 \le Y_2 \le \cdots \le Y_n$.

2.5 Determination (MTTF) and Reliability of Each Critical Component

This distribution is used to formulate the form of the damage rate of a component. The appropriate distribution is used in determining the level of reliability which has the concept of damage rate in its application. Each selected distribution certainly has several parameters needed to determine the mean time to failure (MTTF) value of each critical component based on the formula for each distribution.

2.6 Preparation of Periodic Maintenance Times

After the lifetime prediction values have been analyzed, a periodic maintenance table for critical components can be prepared to reduce unit downtime. The periodic maintenance table is adjusted to the scheduled maintenance schedule, namely PS (Periodical Service) every HM (Hour Meter). By compiling a periodic maintenance table, it is hoped that it will be able to increase production results because unit downtime can be reduced.

3. Results and Discussion

3.1 Determining Critical Components Using Critical Analysis

Determining the critical components contained in a hydraulic driven axial pump with a capacity of 2000 liters per second is carried out using the critical analysis method to determine the criticality value of components that are damaged in accordance

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with critical component assessment standards. The criticality values for the hydraulic driven axial pump components with a capacity of 2000 liters per second can be seen in Table 2.

Table 2: Critical Component Weighting Matrix

No	Part Number	Part	Criteria 1 (Weight 4)		Criteria 2 (Weight 3)		Criteria 3 (Weight 2)		Criteria 4 (Weight 1)		Total (Grade x Weight)
			Grade	Grade x Weight	Grade	Grade x Weight	Grade	Grade x Weight	Grade	Grade x Weight	
1	AP.850.85	Hose	5	20	3	9	4	8	2	2	39
2	AP.850.86	Hose	5	20	3	9	4	8	2	2	39
3	AP.850.84	Hose	5	20	3	9	4	8	2	2	39
4	AP.850.87	Hose	5	20	3	9	4	8	2	2	39
5	AP.850.83	Hose	5	20	3	9	4	8	1	1	38
6	AP.850.88	Hose	5	20	3	9	4	8	1	1	38
7	AP.850.70	Oil Seal	3	12	3	9	4	8	1	1	30
8	AP.850.6	Seal Ring	3	12	3	9	4	8	1	1	30
9	AP.850.33	Seal Ring	3	12	3	9	4	8	1	1	30
10	AP.850.38	Carbon Brush	3	12	3	9	4	8	1	1	30
11	AP.850.42	Bellmouth	2	8	3	9	4	8	4	4	29
12	AP.850.20	Bearing	2	8	3	9	4	8	4	4	29
13	AP.850.60	O - Ring	2	8	3	9	3	6	1	1	24
14	AP.850.75	O - Ring	2	8	3	9	3	6	1	1	24
15	AP.850.76	O - Ring	2	8	3	9	3	6	1	1	24
16	AP.850.80	O - Ring	2	8	3	9	3	6	1	1	24
17	AP.850.43	Out Ring	2	8	3	9	3	6	1	1	24
18	AP.850.44	Wear Ring	2	8	3	9	3	6	1	1	24

3.2 Risk Based Inspection for Damage to Critical Components

After knowing and analyzing any damage to the hydraulic driven axial pump with a capacity of 2000 liters per second, critical components were obtained. After obtaining critical components, the Risk Based Inspection table is used to find out what factors cause damage to these components. [10].

Table 4: Risk Based Inspection Critical Components

No	Components	Damage Type	Impact
1	Hose	Rift	Leakage
		Corrosion	
		Blockage	Disrupts fluid flow

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		Overpressure	Environmental and Operator Damage
2	Oil Seal	Tearing	Leakage
		The Wear and Tear	
		Dimensional Change	
3	Seal Ring	Rift	Leakage
		Aging	
4	Carbon Brush	Rift	Electrical contact failure
		The Wear and Tear	Decreased pump performance
5	Bellmouth	Corrosion	Structural Damage
		The Wear and Tear	Decreased pump performance
		Rift	Leakage
6	Bearing	The Wear and Tear	Decreased pump performance
		Vibration	
		Overheat	
7	O-Ring	Overpressure	Leakage
		The Wear and Tear	
		Deformation	Decreased pump performance
8	Out Ring	Overpressure	Leakage
		The Wear and Tear	
		Deformation	Decreased pump performance
9	Wear Ring	Overpressure	Decreased pump performance
		The Wear and Tear	
		Rift	Leakage

3.3 TTF Test Results Using Goodness of Fit Test

In selecting the drive components used on the conveyor, it is necessary to calculate the variable values related to the drive unit with the following calculations. According to the test results that have been carried out using Minitab 19 software, the requirements must be met, namely the data must have the smallest Anderson-Darling value, Correlation value The largest coefficient, and the P-Value value is ≥ 0.05, the selected distribution results for each component of damage to the hydraulic driven axial pump with a capacity of 2000 liters per second can be seen in Table 5.

Table 5: Results of TTF

No	Part Number	Part	AD	CC	P-Value	Distribution
1	AP.850.83	Hose	2,005	0,95	0,124	Weibull

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2	AP.850.85	Hose	2,005	0,95	0,124	Weibull
3	AP.850.86	Hose	2,005	0,95	0,124	Weibull
4	AP.850.84	Hose	2,36	0,978	>0,250	Weibull
5	AP.850.87	Hose	2,36	0,978	>0,250	Weibull
6	AP.850.88	Hose	2,36	0,978	>0,250	Weibull
7	AP.850.70	Oil Seal	3,482	0,955	0,302	Lognormal
8	AP.850.6	Seal Ring	3,482	0,955	0,302	Lognormal
9	AP.850.33	Seal Ring	3,482	0,955	0,302	Lognormal
10	AP.850.38	Carbon Brush	3,482	0,979	>0,250	Weibull
11	AP.850.60	O - Ring	4,569	1	>0,250	Weibull
12	AP.850.75	O - Ring	4,569	1	>0,250	Weibull
13	AP.850.76	O - Ring	4,569	1	>0,250	Weibull
14	AP.850.80	O - Ring	4,569	1	>0,250	Weibull
15	AP.850.43	Out Ring	4,569	1	>0,250	Weibull
16	AP.850.44	Wear Ring	4,569	1	>0,250	Weibull
17	AP.850.42	Bellmouth	4,569	1	>0,250	Weibull
18	AP.850.20	Bearing	4,569	1	>0,250	Weibull

3.4 Analysis of MTTF (Mean Time to Failure) Values for Each Component

In analyzing and considering the shafts used in conveyors, it is necessary to calculate the related variables based on the free body diagram that occurs on the shaft as in Figure 7 with the following calculations. After the probability plot for each component has been determined, the next step is to calculate the MTTF of each component that is damaged to determine the average value of damage time from the damage distribution. MTTF calculations were carried out using the Minitab 19 software with two selected distributions, namely the Weibull Distribution and Lognormal Distribution. MTTF calculations for damage component data using the Weibull Distribution as the selected distribution can be seen in Table 6.

Table 6: Analysis Results MTTF

No	Part Number	Part	β	θ	$\left(1+\frac{1}{\beta}\right)$	$\Gamma\left(1+\frac{1}{\beta}\right)$	MTTF
1	AP.850.83	Hose	882,821	832,065	1,11	0,946134	787,244
2	AP.850.85	Hose	882,821	832,065	1,11	0,946134	787,244
3	AP.850.86	Hose	882,821	832,065	1,11	0,946134	787,244
4	AP.850.84	Hose	378,272	1065,39	1,26	0,903558	962,637
5	AP.850.87	Hose	378,272	1065,39	1,26	0,903558	962,637
6	AP.850.88	Hose	378,272	1065,39	1,26	0,903558	962,637
7	AP.850.38	Carbon Brush	790,837	1515,1	1,13	0,941214	1426,03
8	AP.850.60	O - Ring	136,968	1834,2	1,01	0,995838	1826,57

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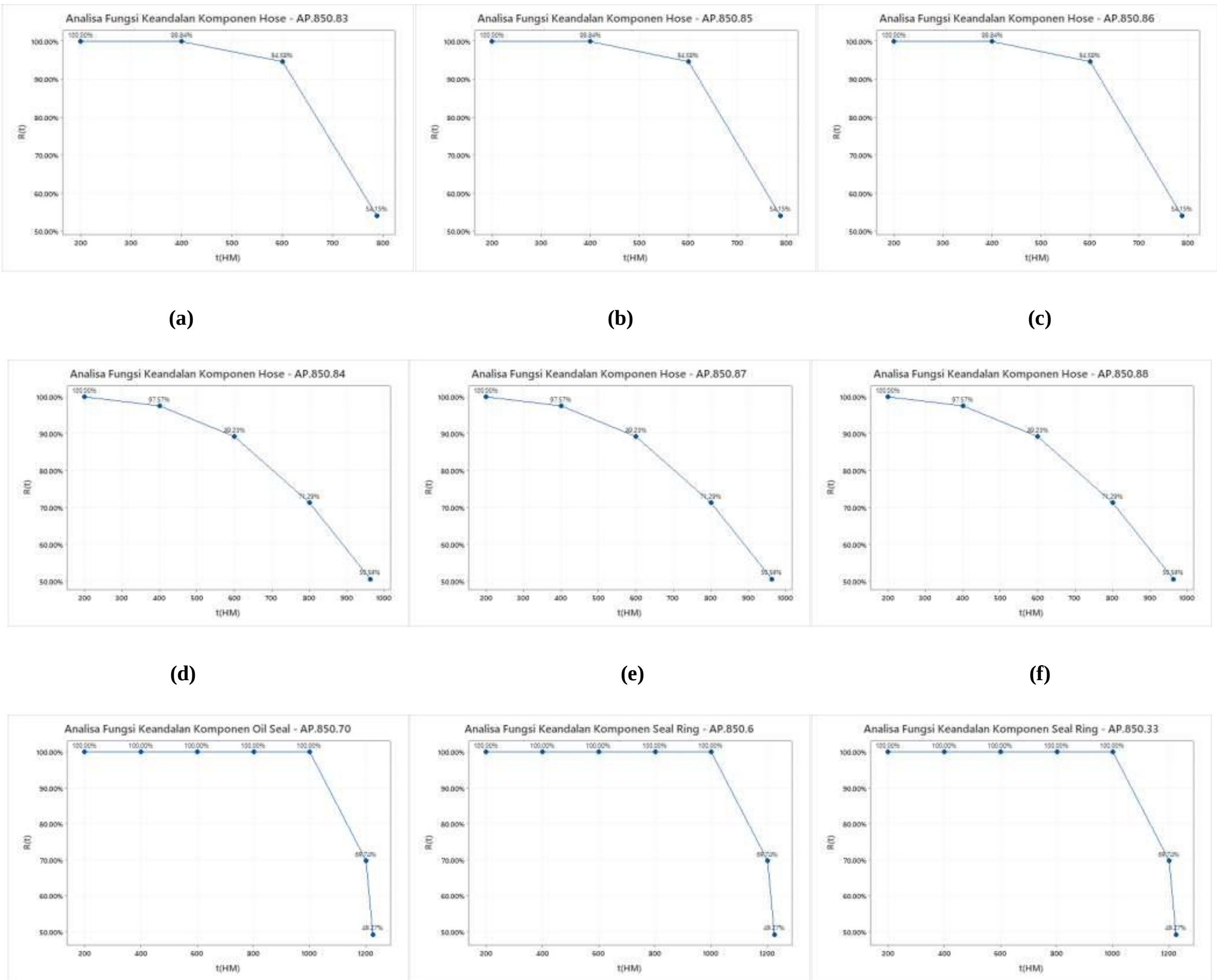
9	AP.850.75	O - Ring	136,968	1834,2	1,01	0,995838	1826,57
10	AP.850.76	O - Ring	136,968	1834,2	1,01	0,995838	1826,57
11	AP.850.80	O - Ring	136,968	1834,2	1,01	0,995838	1826,57
12	AP.850.43	Out Ring	136,968	1834,2	1,01	0,995838	1826,57
13	AP.850.44	Wear Ring	136,968	1834,2	1,01	0,995838	1826,57
14	AP.850.42	Bellmouth	127,352	2295,07	1,08	0,960369	2204,11
15	AP.850.20	Bearing	118,665	2742,33	1,08	0,957884	2626,83

3.5 Component Damage Reliability Function Analysis

In the previous discussion, MTTF calculations were carried out for each critical component and components that experienced damage to the hydraulic driven axial pump with a capacity of 2000 liters per second, then a reliability function analysis was carried out to determine the reliability value of each component. Based on previous tests (goodness of fit), two probability plots were obtained that best suited the existing damage data, namely the Weibull Distribution and the Lognormal Distribution. In Figure 2 you can see a graph of the reliability function for critical components as follows.



(a) **(b)** **(c)**

(d) **(e)** **(f)**

(g) **(h)** **(i)**

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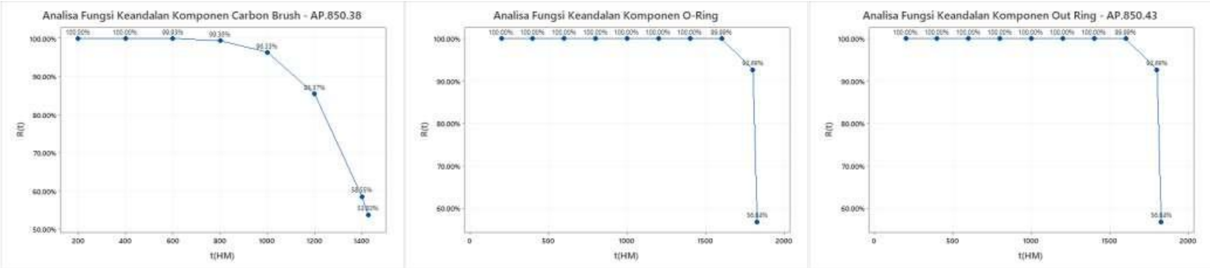
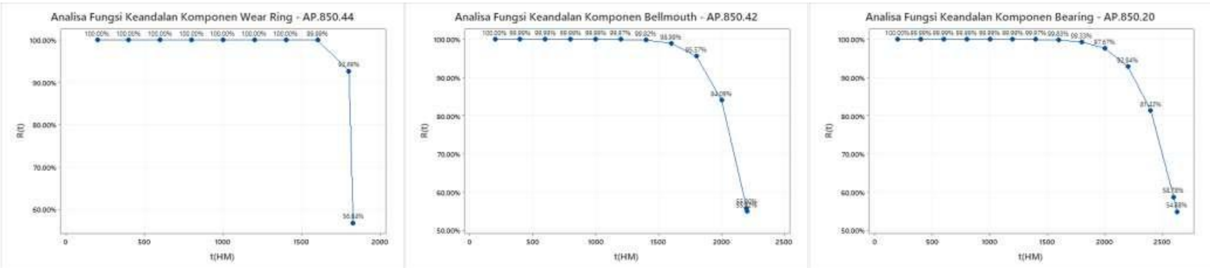


(j) (k) (l)



(m) (n) (o)

Figure 2: Critical Component Reliability Function Graph

3.6 Preparation of Periodic Maintenance of Critical Components

One of the main objectives of maintenance activities is to maintain the readiness of a tool so that it can continue to carry out its function optimally to avoid sudden damage. A periodic maintenance schedule is created to determine maintenance activities to be carried out periodically within a certain period of time on each critical component and other components that are damaged based on the MTTF value of each component. Determining the periodic maintenance period can be done based on the time interval and length of working hours of the pump machine. The periodic maintenance schedule for each component of the hydraulic driven axial pump with a capacity of 2000 liters per second takes into account several factors regarding the need for consumable goods when replacing parts and there are also parts that are still in one assembly, but the intervals for replacing the parts are close together. It can be seen in Table 7.

Table 7: Periodic Component Maintenance Schedule

No	Part Number	Part	MTTF	Changeover Interval
1	AP.850.83	Hose	787.244	600
2	AP.850.85	Hose	787.244	600
3	AP.850.86	Hose	787.244	600
4	AP.850.84	Hose	962.637	900
5	AP.850.87	Hose	962.637	900
6	AP.850.88	Hose	962.637	900
7	AP.850.70	Oil Seal	1224.09	1200
8	AP.850.6	Seal Ring	1224.09	1200
9	AP.850.33	Seal Ring	1224.09	1200
10	AP.850.38	Carbon Brush	1426.03	1200

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11	AP.850.60	O - Ring	1826.57	1800
12	AP.850.75	O - Ring	1826.57	1800
13	AP.850.76	O - Ring	1826.57	1800
14	AP.850.80	O - Ring	1826.57	1800
15	AP.850.43	Out Ring	1826.57	1800
16	AP.850.44	Wear Ring	1826.57	1800
17	AP.850.42	Bellmouth	2204.11	1800
18	AP.850.20	Bearing	2626.83	2400

4. Conclusion

Based on research on the Risk Analysis of Critical Components of the Hydraulic Axial Pump 2000LPS using the Risk Based Inspection (RBI) Method which has been carried out, several conclusions can be drawn, namely:

1) Selection of critical components using the critical analysis method through weighting factors resulted in 6 critical components out of a total of 18 components that were damaged. The 6 critical components are: • Hose – AP.850.84 with total value39 • Hose – AP.850.85 with total value39 • Hose – AP.850.86 with total value39 • Hose – AP.850.87 with total value39 • Hose – AP.850.83 with total value38 • Hose – AP.850.88 with total value38.
2) Based on Risk Based Inspection, there are factors that cause critical components, namely machine, material, method and human factors.
3) There are two damage distributions used in this research, namely Weibull and Lognormal. By using two distributions, the damage lifetime prediction is obtained for each component by calculating MTTF (Mean Time to Failure). The following are the MTTF values for each component, namely:• hose – AP.850.83 is 787,244 hours • hose – AP.850.84 is 962,637 hours • hose – AP.850.85 is 787,244 hours • hose – AP.850.86 is 787,244 hours • hose – AP.850.87 is 962,637 hours • hose – AP.850.88 is 962,637 hours • oil seal – AP.850.70 is 1224,09 hours • seal ring – AP.850.6 is 1224,09 hours • seal ring – AP.850.33 is 1224,09 hours • carbon brush – AP.850.70 is 1426,03 hours • o-ring – AP.850.60 is 1826,57 hours • o-ring – AP.850.75 is 1826,57 hours • o-ring – AP.850.76 is 1826,57 hours • oring – AP.850.80 is 1826,57 hours • out ring – AP.850.43 is 1826,57 hours • wear ring – AP.850.44 is 1826,57 hours • bellmouth – AP,850.42 is 2204,11 hours • bearing – AP.850.20 is 2626,83 hours.
4) Based on the reliability calculation analysis, the reliability function value is obtained based on the MTTF value of each component, namely: • hose – AP.850.83 is 54,15% at 787,244 hours • hose – AP.850.84 is 50,59% at 962,637 hours • hose – AP.850.85 is 54,15% at 787,244 hours • hose – AP.850.86 is 54,15% at 787,244 hours • hose – AP.850.87 is 50,59% at 962,637 hours • hose – AP.850.88 is 50,59% at 962,637 hours • oil seal – AP.850.70 is 49,27% at 1224,09 hours • seal ring – AP.850.6 is 49,27% at 1224,09 hours • seal ring – AP.850.33 is 49,27% at 1224,09 hours • carbon brush – AP.850.70 is 53,83% at 1426,03 hours • o-ring – AP.850.60 is 56,84% at 1826,57 hours • o-ring – AP.850.75 is 56,84% at 1826,57 hours • o-ring – AP.850.76 is 56,84% at 1826,57 hours • o-ring – AP.850.80 is 56,84% at 1826,57 hours • out ring – AP.850.43 is 56,84% at 1826,57 hours • wear ring – AP.850.44 is 56,84% at 1826,57 hours • bellmouth – AP,850.42 is 55,02% at 2204,11 hours • bearing – AP.850.20 is 54,88% at 2626,83 hours.
5) Based on the MTTF value of each component, a periodic maintenance schedule for each component is obtained, namely at intervals 600 HM, o-ring – AP.850.76 is 56,84% at 1826,57 hours, o-ring – AP.850.80 is 56,84% at 1826,57 hours, out ring – AP.850.43 is 56,84% at 1826,57 hours, wear ring – AP.850.44 is 56,84% at 1826,57 hours, bellmouth – AP,850.42 is 55,02% at 2204,11 hours, bearing – AP.850.20 is 54,88% at 2626,83 hours.

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