MAINTENANCE TASK DESIGN AND SPARE PART INVENTORY POLICY FOR AN EVAPORATION SUB SYSTEM

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ABSTRACT

To prevent failure, it is necessary to have good maintenance activities. Currently, maintenance activities conducted at Evaporation Sub System still result in over and under maintenance. Therefore, Reliability Centered Maintenance method II (RCM II) is employed to produce functions list, malfunctions list, and Failure Mode and Effect Analysis (FMEA). Based on the information on FMEA, a maintenance policy and its technical implementation are created, as well as the historical data is used to calculate maintenance time interval. Further, spare part inventory policy is taken with respect to order lead time. By determining the maintenance policy and appropriate spare parts inventory, the cost can be minimized.

Key words: *FMEA, RCM II, maintenance interval, order lead time.*

1. INTRODUCTION

Plant 3 of PT Pupuk Kaltim has a production capacity of 330,000 tons ammonia per year (17.84% of total production) and 570,000 tons of urea per year (19.13% of total production). Production capacity can be met if the production system runs properly and in a reliable state. One stage in the process of this plant-3, which is the process whereby evaporation of urea solution recirculation processes elevated concentrations (condensed) from the concentration of 75% to 99.8%. If evaporation sub system had shut down, then the production rate decreased by 38% (equivalent to 3.015 billion dollars) to the minimum level (70%). To prevent failure in evaporation sub system, maintenance activities should be conducted. Maintenance is taken to prevent system failure and to restore the function of the system when a failure has occurred (Priyanta, 2000).

Maintenance activity at the Plant 3 PT Pupuk Kaltim indicate the occurrence of over and under maintenance that caused huge cost. Currently, the ddetermination of maintenance intervals still use the conventional method of calculation. The time required for each maintrenance period is equal. Eventhough the components that have undergone a process of improvement is not as good condition as at the time of the components are new (as good as new).

One of the factors to be considered to support the maintenance activities is spare parts (Moubray, 1997). When a system undergoes shut down due to faulty components, the value of downtime can be significantly reduced if all the spare parts needed to replace the damaged components are available (Jaarsveld et.al., 2011). Determination of spare part inventory needs that are used for this is based on operator demand in the field, not based on analysis of a particular quantity. If spare parts are not available when needed, it will lead to a higher cost of lost production. However, if the spare parts stay for too long in storage, the storage cost of spare parts is also high.

To overcome this problem, it is necessary to design maintenance policy. Maintenance policy is an activity that must be done to keep a fixed asset to function properly so that unplanned shutdown can be avoided (Moubray, 1997). Reliability Centered Maintenance method II (RCM II) is used to formulate policies for the maintenance of an engine component based Failure Mode and Effect Analysis (FMEA) and their maintenance time intervals and the executor (Moubray, 1997). Output generated from RCM method II is an activity of treatments

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tailored to the effects produced by a component when a failure happens.

To calculate the maintenance time interval, it is necessary to note a decrease reliability of the machine, especially for the repair activity. This is because the reliability of the machine will decline after PM repair activity (Zhao, 2003). A research has been conducted for modeling the scheduling maintenance activities on a decreased reliability systems (Zhou, 2004). To ensure that spare parts are always available and minimizing storage costs, it is necessary to determine the exact time of reservation by considering the use of the component time intervals and lead time. Taking into account the time interval usage and lead time, then the storage costs can be minimized.

Therefore, this study will define the function and malfunction sub evaporation system, and determined FMEA sub system. And based on the data FMEA, then a policy is determined appropriate policy decisions for maintenance program based on chart intervals RCM II and its treatment. And to determine the optimal time of order so that inventory costs can be reduced.

2. THEORETICAL BACKGROUND

Reliability can be defined as the probability that a component or system will inform a function that takes a period of time when it is used under normal operating conditions (Ebeling, 1997). Symbolized by the reliability function R (t) indicates the probability of the equipment can operate up to time t. The function is defined as follows (O'Connor, 1995):

$$R(t) = \int_x^\infty f(t)dt \quad (1)$$

Associated with the reliability of a system there are things to consider that a failure, where the system can not work properly. Mechanical condition of ready to work normally or has a very high availability expected by the company to be able to produce optimal. Then, it needsan activity for maintaining the availability of the machine or commonly called the maintenance activity. Maintenance is a combination of various measures taken to keep an item in, or fix it up, a condition that is acceptable (Corder, 1980).

Reliability-Centered Maintenance (RCM) II method is a process used to determine what should be done so that any physical asset continues to do what is desired by the users in the context of operations (Moubray, 1997).

In this RCM II method, there are seven key questions about the system being observed, namely (Moubray, 1997):
1. What is the function of assets and performance standards associated with that function in the context of current operations?
2. How these assets may fail to meet its function?
3. What is the mode or the cause of any failure of the function?
4. What happens if the mode or the failure occur?
5. How is the affect of these failures?
6. What actions can be done to predict or prevent each failure?
7. What if the appropriate proactive measures are not found?

Techniques to handle failures are divided into two categories, namely:

1. ***Proactive task***, the work done before the failure, to prevent equipment into the failed state. RCM proactive task split into the following three groups:
• Scheduled restoration tasks, including activities to restore the ability of the origin of a component or an assembly overhaul on or before the specified age limits regardless of the condition of components or equipment at the time of repair.
• Scheduled discard tasks, including activities to replace components or equipment on or before the specified age limits regardless of the condition of components or equipment at the time of replacement.
• Scheduled on-condition tasks, including checking the activities of potential failure so to do an action to reduce or eliminate the consequences that occur when failure left a malfunction. This includes all forms of condition-based monitoring, predictive maintenance and condition monitoring.

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2. ***Default action***, the activities undertaken at the time the equipment is entered into a failed state, and selected when not found an effective proactive task. RCM divided into three major categories for the default function, as follows:

• Failure-finding, including checking hidden functions to determine whether the function has failed.

• Redesign, including the ability to change from a system. These include modifications to equipment or procedures work.

• Non scheduled maintenance, do nothing to anticipate or prevent the failure mode, and failure ensues newly repaired left. This condition is also called run-to-failure.

For the probability distribution of reliability, some common distributions are used to calculate the level of reliability of the equipment. These are Exponential distribution, Weibull distribution, and Lognormal distribution with different equation or estimation function for the reliability, probability density function, the rate of decay, and Mean Time to Failure (MTTF).

For the maintenance interval time maintenance, the calculation of is generated based on maintenance policy. Here is the calculation of the time interval for each maintenance policy.

• On condition task

The rules for determining the on-condition task interval is half the PF interval. PF interval is defined as the interval between the occurrence of potential failure and functional failure of equipment condition (Moubray, 1997). Here is a picture illustrating the PF interval of the equipment.

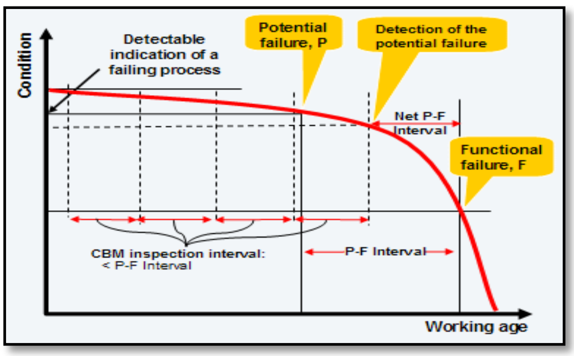

Figure 1. P-F interval (Moubray, 1997)

• Discard Scheduled Task

The time interval used for the maintenance task is scheduled discard half of the Mean Time to Failure (MTTF) of a component. MTTF of components obtained from historical data component damage.

• Restoration Scheduled Task

If a component has undergone a rebuild or overhaul activities, the reliability of these components can not be as good as new components (as good as new). This is what is called the imperfect maintenance (Pham et.al, 1996).

Based on the concept of imperfect maintenance, it can be said that the hazard rate will increase after maintenance activities. Value hazard rate after maintenance activities can be expressed as (Zhou, 2004):

$$h_{i+1}(t) = b_i h_i(t + a_i T_i)\ untuk\ t \in (0, T_{i+1}) \quad (2)$$

Description:

$h_{i+1}(t)$: Function hazard rate after a treatment component of i-th

b_i : Factors that increase the hazard rate (> 1)

a_i: Factors leading to reduced component life (0 << 1)

T_i : Period of treatment time interval i-th

Here is the relationship between the hazard rate before and after maintenance activities.

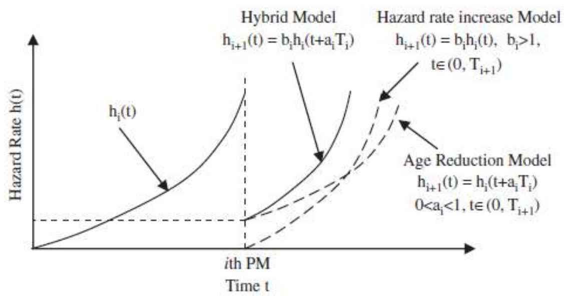

Figure 2. Evolution hybrid model for the hazard rate of a system (Zhou, 2004)

In the model, maintenance activities performed at the time of component reliability reaches R. Here is the formula reliability R

$$R = \exp\left[-\int_0^{T_1} h_1(t)dt\right] = \exp\left[-\int_0^{T_2} h_2(t)dt\right] = \cdots = \exp\left[-\int_0^{T_N} h_N(t)dt\right] \quad (3)$$

Based on the above equation, it is obtained

$$-\ln R = \int_0^{T_1} h_1(t)dt = \int_0^{T_2} h_2(t)dt = \dots = \int_0^{T_N} h_N(t)dt \quad (4)$$

The equation used to find the value of Ti To find the optimal value of the number of treatments (N) and reliability at the time of treatment (R), the simulated value of CER and look for the smallest value of CERs. Here is the formula used to find the CER (Zhou, et al., 2004):

$$C_{Er} = \frac{N\left(C_{up}(-\ln R)+C_{sp}(1+\ln R)\right)\tau_p+Cost_r}{\sum_{i=1}^{N}(T_i)+N\tau_p} \quad (5)$$

Description:
C_{ER}: expected cost per unit time
C_{up}: expected costs for unscheduled PM
C_{SP}: expected costs for scheduled PM
$Cost_r$: additional replacement costs
τ_p: duration PM

• Failure Finding Task

According to Mobray (1997), the time interval to treatment failure-finding task was calculated using the following formula:

$$FFI = 2 \times U_{tive} \times M_{tive} \quad (6)$$

Description:
FFI: failure finding interval
U_{tive}: desired unavailability of the protective device
M_{tive}: MTBF of protective device

Spare parts inventory is stored for future use (Silver, 1998). Designing for spare parts logistics is different from other material. Inventory of spare parts usually have a very small value of the request. The main purpose of determining the need for spare parts inventory is to achieve better service levels with inventory investment and administration costs as small as possible (Huiskonen, 2001).

The relationship between spare parts and maintenance activities depend on the time required to supply spare parts from a supplier which is called the lead time (Moubray, 1997). If spare parts are not available in the warehouse, lead time shows how long it takes to repair the damage. On the other hand, also store spare part costs. So, it takes a balance between storage cost and total cost of spare parts are not kept.

3. RESEARCH METHOD

This research is focused on maintenance task design and spare part inventory management. The observation is taken ini PT Pupuk Kaltim at Kalimantan Timur. First, there are system breakdown determination, main function system identification, and boundary system design for makin a clear research boundary. Then, several steps of data collection were taken to draw Functional Block Diagram (FBD), define function and malfunction list, and determine Failure Mode and Effect Analysis (FMEA). Based on FMEA, the maintenance task for each component is design to achieve the expected reliability performance. Combining with the order time interval and storage policy, a quantity storage of the required spare parts is calculated to meet the determined maintenance time interval.

The FBD, FMEA and maintenance time interval design are the base activities for this research. After understanding the process flow through the FBD, the next step is to define the FMEA, which consists of the function, failure, failure mode, and failure effect. Information from FMEA analysis will then be used to determine the appropriate treatment policy for each component. Followed by the calculations to get the treatment time interval for each component. Calculation of maintenance time interval was based maintenance policy that has been produced before.

4. RESULT AND DISCUSSION

The time interval for component maintenance task on condition determined from the half-interval PF. Here are the results of the calculation.

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Table 1 Maintenance interval time for components on condition task

No.	Component	P-F interval (year)	Time interval (year)
1	Tube 2-E-401	4	2 (1xTA)
2	Spray condensat 2-S-401	10	5(2xTA)
3	Bubble cap (topi cina) 2-S-401	10	5(2xTA)
4	Strainer element separator 2-S-401	10	5(2xTA)
5	Tube 2-E-402	4	2(1xTA)
6	Nozzle booster 2-J-703	10	5(2xTA)
7	Spray condensat 2-S-402	10	5(2xTA)
8	Bubble cap (topi cina) 2-S-402	10	5(2xTA)
9	Strainer element separator 2-S-402	10	5(2xTA)
10	Seat plug valve FV 401	20	10(5xTA)
11	Positioner valve FV 401	20	10(5xTA)
12	Stem valve FV 401	20	10(5xTA)

The time interval for component maintenance tasks scheduled discard half of the value obtained through the MTTF. Here are the results of the calculation.

Table 2 Maintenance interval time for components scheduled discard task

Component	MTTF	Time interval (year)
Gasket tube 2-E-401 A/B	6709.62	8
Gasket tube 2-E-402	-	10
Mechanical Seal 2-P-303 A	-	5
Line Suction 2-P-303 A	-	10
Strainer 2-P-303 A	1371.579	2
Shaft 2-P-401 A	1263.982	2
Impeller 2-P-401 A	1044.152	2
3 Way Valve 2-P-401	1800.708	2

MTTF values obtained from the calculations using the formulations based on the data distribution time to failure of each component.

Calculation of maintenance time interval for scheduled restoration task components using the concept of imperfect maintenance. This research used iε (1.6) and Rε (0.5,0.38) for bearing components 2-P-303 A. Here is the calculation for the value of Ti.

Table 3 The results of calculation of Ti

R/Ti/i	1	2	3	4	5	6
0.5	2008.842	1886.582	1868.448	1845.785	1823.696	1801.922
0.49	2047.389	1924.903	1911.5	2189.43	1851.636	1844.98
0.48	2086.731	1961.697	1949.334	1930.039	1909.7	1887.448
0.47	2126.902	1999.265	1987.964	1969.456	1948.467	1927.926
0.46	2167.936	2037.642	2027.425	2009.721	1988.068	1966.945
0.45	2209.872	2076.862	2067.753	2050.872	2028.539	2006.822
0.44	2252.751	2116.963	2108.988	2092.947	2069.92	2047.595
0.43	2296.616	2157.986	2151.17	2135.989	2112.252	2089.305
0.42	2341.513	2199.975	2194.346	2180.044	2155.58	2131.997
0.41	2387.491	2242.975	2238.561	2225.67	2198.514	2175.789
0.4	2434.606	2287.038	2283.869	2272.567	2237.927	2216.759
0.39	2482.913	2332.215	2321.796	2308.741	2278.932	2256.891
0.38	2021.085	2402.909	2359.623	2342.928	2318.262	2297.137

With a note that τ_p = 1 hour, C_{up} = Rp 9,187,500, -, C_{SP} = Rp 946,250, -, and $Cost_r$ = Rp 10,000,000, -, then the value of c_{er} is 1,692,800,000,000.

Table 4 The results of calculation of C_{ER}

R/Cer/N	1	2	3	4	5	6
0.5	5.0784E+11	5.23769E+11	5.30968E+11	5.36234E+11	5.40706E+11	5.44783E+11
0.49	4.9736E+11	5.12684E+11	5.19185E+11	5.04519E+11	5.12988E+11	5.19086E+11
0.48	4.8706E+11	5.02092E+11	5.08357E+11	5.12793E+11	5.16558E+11	5.20083E+11
0.47	4.7693E+11	4.9168E+11	4.97718E+11	5.01938E+11	5.05561E+11	5.08876E+11
0.46	4.6698E+11	4.81441E+11	4.87259E+11	4.91273E+11	4.94759E+11	4.9797E+11
0.45	4.5719E+11	4.71368E+11	4.76974E+11	4.80791E+11	4.84144E+11	4.87254E+11
0.44	4.4755E+11	4.61456E+11	4.66858E+11	4.70484E+11	4.7371E+11	4.76722E+11
0.43	4.3807E+11	4.51698E+11	4.56902E+11	4.60346E+11	4.63449E+11	4.66366E+11
0.42	4.2873E+11	4.42088E+11	4.471E+11	4.5037E+11	4.53354E+11	4.56178E+11
0.41	4.1953E+11	4.3262E+11	4.37447E+11	4.40524E+11	4.43455E+11	4.46181E+11
0.4	4.1047E+11	4.23288E+11	4.27936E+11	4.30822E+11	4.33873E+11	4.36603E+11
0.39	4.0153E+11	4.14087E+11	4.19061E+11	4.22176E+11	4.25145E+11	4.2782E+11
0.38	4.9203E+11	4.49579E+11	4.398E+11	4.35863E+11	4.34469E+11	4.34211E+11

According to the Table 4, it can be seen that the reliability of 0.39 cycles N = 1, the smallest obtained value of C_{ER}. So, for the component bearing 2-P-303 A, the time interval of treatment used is 2482.913 days.

While treatment time interval for component failure finding task formulation obtained through FFI. Here are the results of the calculation (Table 5).

Table 5 Interval Time Maintenance for component failure finding task

No.	Component name	U_{tive}	MTBF (year)	FFI (year)
1	By pass PV 401	0.8	10	16
2	By pass PV 403	0.8	10	16
3	By pass PV 712	0.85	10	17
4	Bearing pompa 2-P-401 stand by	0.5	5	5
5	Shaft pompa 2-P-401 stand by	0.5	5	5
6	Impeller pompa 2-P-401 stand by	0.5	5	5

Validation is conducted to determine the most appropriate maintenance policy to be used. Validation maintenance policy compared the results generated by the calculation and adjustments to FY results and existing conditions. Parameters were compared in this validation is the total cost of maintenance per year incurred by each maintenance policy.

Sensitivity analysis conducted to determine the impact of changes to variables defined subjectively, ie the factors that cause a reduction in the age of the components (a), factors that increase the failure rate (b), and the additional replacement cost ($Cost_r$) the calculation of the time interval for the component scheduled maintenance restoration and the unavailability of the desired task (U_{tive}) the calculation of treatment time intervals for component failure-finding task.

Spare parts inventory is counted only for the components requiring replacement component maintenance activities. The use of this spare part is based on the time interval treatments that have been calculated in the previous stage. In order to supply spare parts does not pose a high cost, then do not do spare part storage to avoid storage costs. So, it should be taken into account when booking the right to avoid storage costs. When ordering can be determined from the period when the components necessary to use reduced the lead time. This is done to reduce the retention time of which raises the cost of storage.

5. CONCLUSION

The conclusions obtained from this research include the main function of the sub-system of evaporation is to increase the urea concentration from 75% to 99.8%. The results of the FMEA analysis will be the basis in determining treatment. The time interval is calculated based on each maintenance policies that are used.

The time interval of treatment used is mainly a result of adjustment intervals with Turn Arround treatment. However, there are 3 components that maintenance intervals resulting from the calculation, the bearing 2-P-303 A, mechanical seal 2-P-303 A, and bearing 2-P-401 A. This is because these three components do not cause the shut down in the event of failure so that performed maintenance will be taken on the condition of normal production shut down unnecessary sub-systems.

Calculation of inventory of spare parts only for the components requiring replacement component maintenance activities and their use is based on the time interval for maintenance. Thus, ordering can be determined from the period when the components necessary to use reduced the lead time.

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