Developing Maintenance Policy for Solna Printing Machine with Reliability Centered Maintenance (RCM II)

Nariska Purbandari Riyanto, Wakhid Ahmad Jauhari, Azizah Aisyati, Cucuk Nur Rosyidi

***Abstract*— This research aims to prioritize preventive maintenance actions for Solna D300B printing machine in PT. Macanan Jaya Cemerlang by evaluating the risk associated with failure modes by using Reliability Centered Maintenance (RCM II). The other aim is to determine maintenance interval based on the reliability of equipments to minimize the maintenance cost. RCM II analysis produces several critical components such as; plastic gear, pneumatic dancing roll, blade, etc. Also, the result of this research shows that plastic gear has the highest risk value that equals to IDR 56,817,342 per year. Whereas, bearing has the lowest risk value that equals to IDR 9,869 per year. Based on RCM II Decision diagram, preventive maintenance action for Solna D300B Printing Machine can be in form of Scheduled On-Condition Task, Scheduled Restoration Task, Scheduled Discard Task and No Scheduled Maintenance. Maintenance interval recomendation only given to those component that classified into Scheduled Discard Task and Scheduled Restoration Task.**

***Index Terms*—RCM II, Reliability, Failure Modes, Maintenance Interval.**

I. Introduction

RCM II method was first introduced by Mounbray [1] and published in 1991. RCM concepts (or models, or philosophies) are the fundamental and most developed maintenance models [2]. In order to optimize maintenance service, based on those concept in recent years other models are being implemented by some researchers. Shanmuganathan et al. [3] try to implement lean or six sigma principles that based on RCM to optimize of maintenance cost and increase the availability of aircraft and its components. Sudradjat [4] studied about risk assesment application on the non-static equipment. Sudradjat [4] studied about risk assesment application on the non-static equipment. The result of this study shows the potential objects have a risk of damage due to the failure of its component. Furthermore, Azis et al. [5] developed RCM web-based with software free open source Software.

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This paper results a computer program that help and support the maintenance management in the cooling sistem of GA. Siwabessy reactor.

Some researchers focused on optimizising preventive maintenance interval based on minimize service cost. Matias et al. [6] used appropriate maintenance model and policies to reduce significantly the maintenance cost as well as to optimize the useful key performance indicators-failure rates, reliability, mean time between failures, and mean time to repair. Another case study on preventive maintenance which tries to improve existing battery maintenance program at SPS by applying RCM has already done by Wilmeth et al. [7]. This research results optimal maintenance interval that can provide savings for company. Giatman [8] also proved that total cost of replacement of the company has decreased by using opportunity based-age repalcement model.

This research analyzes maintenance policy for Solna D300B Printing Machine that is applied in PT. Macanan Jaya Cemerlang Indoenesia-Central Java by using RCM II (Reliability Centered Maintenance II) method, risk management method and reliability theory. RCM II is used to prioritize and determine the type of maintenance activities by analyzing the impact and the causes of failure in Solna D300B Printing Machine by using FMEA analysis first and then finally choosing the appropriate proposed task for every component through RCM II decision diagram. The long-run variance model of the cost suggested by Chen [9] is used in this paper to define the optimal preventive maintenance interval based on the minimum cost. By using an age replacement policy, the critical component is replaced either at the time in which the component has an failure, or at a proposed maintenance interval, whichever occurs first.

II. Research Methodology

The company has a critical problems that affect the production productivity, that is the length of machine downtime. There are many potential factors that lead to downtime of the machine. Therefore, we use cause and effect diagram to identify any potential factor that contribute to downtime of the machine. Then, we find that machine failure is the most contribute factor. Especially on replacement of machine that requires the longest time. So this research proposes a policy to determine an interval of components replacement based on the economic life of the component. In this study, we only involve one of the most critical machines in production line. This critical unit is selected based on the certain criteria. From the criteria analysis based on historic company data, we find that Solna

D300B printing machine is classified into the most critical unit in production system.

In the next step will be described about the main component of the machine and its function. Solna D300B printing machine has 3 main components namely feeder, printing unit, and folder. From this 3 main components, there are 40 components that construct this machine. Then, 41 components will be analyzed in FMEA Worksheet. RCM II Decision Worksheet is used to analyze the consequences of each of the effects of failure and also to find the type of treatment (proposed task). Proposed task determination is analyzed through RCM II decision diagram, refers to the 4 main aspects namely safety, enviroment, hidden failure, and operational consequences. Maintenance interval recomendation only given to those component that classified into scheduled discard task and scheduled restoration task [1].

Distribution test is conducted to determine the distribution pattern of distribution in accordance with each data plot of critical machine components. This test is conducted on time between failures (TTF) and time of data repair (TTR). We use easyfit 5.5 software to test the distribution of both data. Furthermore, TTF and TTR calculation that matches with the distribution pattern, will be used in the next stage, namely for optimal replacement interval and risk priority determination. The purpose of determining the optimal interval between preventive replacement is to minimize the total cost each unit time [9]. The mathematical model which is used in this research is showed in equation (1).

$$\Phi(a) = \left(\left(C1xF(a)\right) + \left(C2x\bar{F}(a)\right)\right) / S(a) \quad (1)$$

Where:

$$S(a) = \left(-\sigma * G(x)\right) + \left(\alpha * F(x)\right) + a(R(a)) \quad (2)$$

Thus, we could formulate total cost each unit time (3) by considering (1) and (2) :

The notations used in the model are described as follows:

MTTF : mean time to failure (day)
MTTR : mean time to repair (hour)
σ : standard deviation (day)
μ : average value (day)
a : optimal replacement interval (day)
C1 : corrective repalcement cost (IDR)

C2 : preventive replacement cost (IDR)
S(a) : average length of the replacement cycle (day)
Φ(a) : the total cost with the replacement interval batch a (IDR)
F(a) : the possibility of damage prior to the time a
$\bar{F}(a)$: the possibility reliability of a system prior to the time a
CO : cost of losses due to lost production (IDR/hour)
TC : inventory total cost (IDR)
Q : ordering number (unit)
D : number of demand (unit)
S : ordering cost (IDR/order)
H : storage cost (Rp/unit)
x : number of actual usage (unit)
$\bar{x}$: number of usage forecast (unit)
SD : standard deviation of demand (unit)
N : number of data (unit)
Z : safety factor that is determined based on the ability of the company
SS : safety stock
d : level of need (%)
L : lead time
ROP : re-order point

To determine the optimal replacement interval, we used the basic idea of algorithm from (1) and (2). The algorithm to determine the optimal interval is as follows:

Step 0 : Set MTTF, μ, and σ

Step 1 : To determine a value using enumeration by trying some value replacement time interval that have value of a<MTTF<a.

Step 2 : Determine value $z = (a - z)/\sigma$ for normal distribution and z = (1/s x ln a/tmed) for lognormal distribution

Step 3 : Value of G(z) is the standard normal curve ordinate points which can be seen in Table ordinate normal curve.

Step 4 : Value of F(z) is normsdistfunction from z value.

Step 5 : Determine value $\int_0^a x\, f(x)dx$ = (-σ * G(x)) + (μ * F(x))

Step 6 : For the calculation of other a values and calculating the most minimal total cost.

The next step is risk priority calculation. Risk calculation is a combination of likelihood and consequence. Likelihood is probability within a time period of these risks will arise. Likelihood is obtained by the division of an operational span of the equipment within one year with MTTF. The formulation of likelihood is given as follows :

Likelihood : 5,280 hours / MTTF (4)

Then we calculate the consequence. The consequence value is determined by corrective repair costs that can be obtained from equation (5):

Consequence(C1)=C2+(COxMTTR) (5)

Where operational cost (CO) is defined as production profit lost for the company. The value can be obtained from equation (6):

CO = company profit for each sheet of paper x production capacity (6)

= IDR 25 / sheet of paper x 31,000 sheets / hour

= IDR 775,000 / hour

The determination of likelihood and consequences criteria is obtained by considering the company opinion and policy. Then we use risk-matrix to help the determination of each risk level. Risk-matrix is shown in table 1. The calculation of the risk value can be obtained by multiplying likelihood and consequence.

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TABLE I: RISK MATRIX

Level	Likelihood	Consequences				
		Low	Minor	Moderate	Major	Critical
A	Almost Certain	H	H	E	E	E
B	Likely	M	H	H	E	E
C	Moderate	L	M	H	E	E
D	Unlikely	L	L	M	H	E
E	Rare	L	L	M	H	H
	Level	A	B	C	D	E

TABLE 2: RECAPITULATION FOR RISK PRIRITY

No	Komponen	Likelihood	Level	Consequences	Level	Risk	Risk Level
1	Plastic gear	9.81	Almost certain	5.790.250	Critical	56.817.343	Extreme Risk
2	Plate cylinder	5.6	Almost certain	4.396.133	Critical	24.618.163	Extreme Risk
3	Blade	7.5	Almost certain	1.669.253	Minor	12.520.817	High Risk
4	Brake	9.64	Almost certain	1.192.418	Minor	11.489.161	High Risk
5	Impresi	6.57	Almost certain	1.276.600	Minor	8.383.642	High Risk
6	Pneumatic dancing roll	4.13	Likely	1.630.955	Minor	6.728.110	High Risk
7	Roll pen	0.44	Rare	4.312.752	Critical	1.899.352	High Risk
8	Plate Jaw	0.03	Rare	3.073.748	Major	99.623	High Risk
9	Streng	1.5	Rare	1.516.425	Minor	2.280.325	Low Risk
10	Water Motor	0.26	Rare	1.104.553	Minor	282.327	Low Risk
11	Stacker	0.16	Rare	1.289.003	Minor	203.911	Low Risk
12	Gear Box	0.2	Rare	913.308	Low	180.157	Low Risk
13	Roll clamp build	0.08	Rare	791.249	Low	63.632	Low Risk
14	Bearing	0.01	Rare	1.044.028	Minor	9.868	Low Risk

III. RESEARCH AND DISCUSSION

3.1 FMEA (FAILURE MODES AND EFFECT ANALYSIS)

After function and functional failure are being defined, FMEA is used to identify the incidents that are most likely causing a form of failures (failure modes) as well as identify the effects that occur when each failure mode occured. In composing FMEA, it requires a series of engine damage data contained in the historical data of the company. From 3 main parts of Solna D300B printing machine, there are 41 failure modes that can lead the machine into failure.

In feeder, 9 failure modes are identified. Then, 23 failure modes are identified in printing unit. And finally, 9 failure modes are identified in folder. In this machine, performance for each subcomponent influences each other. This is because each subcomponent is installed in serial position. So we need to know which components that have direct effect to the machine failure or machine downtime.

3.2 RCM II DECISION WORKSHEET

The effect of each subcomponent which is defined in Failure Modes and Effect Analysis. This is quite important because this informations are needed to be considered in the next step namely, RCM II worksheet. The result from RCM II Decision Worksheet, 7 components classified in restororation schedule task and 7 other component classified in discard schedule task.

3.3 DETERMINATION OF OPTIMAL REPLACEMENT INTERVAL AND RISK LEVEL

In this step, we try to define the optimal replacement time (a). The result from the calculation also shows that proposed replacement interval can minimize the total cost of the maintence. Mapping of risk assesment is needed as a follow-up of risk analysis. The calculation for all components is described in Table 2. From the risk analysis, it shows that the component that has the highest risk is plastic gear. Plastic gear is classified into the top level of risk, namely extreme risk with the risk value is about IDR 56,817,343 each year. The components which are identified at extreme risk level should be countermeasured as soon as possible. Table 2 shows the recapitulation of total cost and risk level determination for all the critical components.

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TABLE 3: THE PROPOSED POLICY AND RISK LEVEL

No	Component	Company policy			Proposed policy		
		a (day)	φ(a) (Rp/day)		a (day)	φ(a) (Rp/day)	
1	Plastic Gear	4	Rp	4.038.563	2	Rp	2.461.532
2	Rem (brake)	22	Rp	577.574	4	Rp	209.791
3	Pneumatic Dancing Roll	53	Rp	820.639	11	Rp	309.892
4	Impresi	33	Rp	648.366	11	Rp	405.647
5	Blade	29	Rp	832.713	6	Rp	379.360
6	Roll Clamp Build	20	Rp	547.490	10	Rp	401.784
7	Cylinder Plate	39	Rp	2.226.206	11	Rp	579.974
8	Roll Pen	8	Rp	3.154.848	4	Rp	2.184.420
9	Gear Box	16	Rp	570.907	10	Rp	407.026
10	Streng	10	Rp	994.741	5	Rp	683.300
11	Bearing	29	Rp	1.030.172	2	Rp	741.672
12	Stacker	18	Rp	912.754	8	Rp	590.994
13	Plate Jaw	39	Rp	1.847.271	33	Rp	1.526.268
14	Water Motor	14	Rp	736.079	7	Rp	510.369

3.3 DETERMINATION OF OPTIMAL REPLACEMENT INTERVAL AND RISK LEVEL

Mapping of risk assesment is needed as a follow-up of risk analysis. The calculation for all components is described in table 6. From the risk analysis, it shows that the component that has the highest risk is plastic gear. Plastic gear is classified into the top level of risk namely extreme risk with the risk value is about Rp 56.817.343,00 each year. The component which are identified at extreme risk level should be countermeasured as soon as possible.

Otherwise, from all of the components bearing has the lowest risk with the risk value is about IDR 9,868. It means that the company is only recommended to monitor the component regularly. Other components are classified in high risk, require the attention from the company. The components involve blade, brake, impresi, penumatic dancing roll, and roll pen. The result of risk level determination for solna D300B printing machine through both quantitative and qualitative analysis are used as a guidelines to prioritixe the handling of critical compoennt properly. The risk management context defines that part of the organisation (goals, objectives, or project) to which the risk management process is to be applied. One of the objective of risk management is minimize of losses and increase the chance or oppurtunity.

IV. CONCLUSION AND FUTURE WORK

This proposed methodology is to re-evaluate the maintenance policy for Solna D300B Printing Machine in PT. Macanan Jaya Cemerlang. Based on the result, all maintenance tasks can be planned well in advance. This will enhance the possibility of implementing maintenance based on reliability through RCM II method. Through this kind of maintenance model which is integrated with risk priority calculation, critical machine can be continously monitored so that the company can focus on critical machine and the components that are more susceptible to failure. Next, this study can be extended by adding the study about the inventory system for managing the need of the component during replacement activity by considering optimal replacement interval obtained in this research. The model from Panda [10] and Wang [11] can be used to integrate the inventory and maintenance decisions. Another extension can be done by employing the model from Hadidi et al. [13] which integrates scheduling decisions into the proposed maintenance policy.

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