

Reliability Centred Maintenance (RCM) Analysis of Laser Machine in Filling Lithos at PT X

M A E Suryono¹ and C N Rosyidi²

Department of Industrial Engineering, Universitas Sebelas Maret, Indonesia

angelein22@student.uns.ac.id¹ and cucuk@uns.ac.id²

Abstract. PT. X used automated machines which work for sixteen hours per day. Therefore, the machines should be maintained to keep the availability of the machines. The aim of this research is to determine maintenance tasks according to the cause of component's failure using Reliability Centred Maintenance (RCM) and determine the amount of optimal inspection frequency which must be performed to the machine at filling lithos process. In this research, RCM is used as an analysis tool to determine the critical component and find optimal inspection frequencies to maximize machine's reliability. From the analysis, we found that the critical machine in filling lithos process is laser machine in Line 2. Then we proceed to determine the cause of machine's failure. Lastube component has the highest Risk Priority Number (RPN) among other components such as power supply, lens, chiller, laser siren, encoder, conveyor, and mirror galvo. Most of the components have operational consequences and the others have hidden failure consequences and safety consequences. Time-directed life-renewal task, failure finding task, and servicing task can be used to overcome these consequences. The results of data analysis show that the inspection must be performed once a month for laser machine in the form of preventive maintenance to lowering the downtime.

1. Introduction

PT X is one of Lube Oil Blending Plant (LOBP) under PT X Indonesia. PT X uses automated machines in oil production process from blending until filling. The automated machine is used to keep and improve the product efficiency so the company is able to result competitive products in the market. LOBP works for 16 hours per day and five days per week. Therefore, machines maintenance is important to keep the machines always in good condition to reach the target both in term of quantity and quality.

Maintenance is all actions necessary for retaining an item or equipment in or restoring it to, a specified condition [1] Maintenance clearly impacts on component and system reliability; too little maintenance may result in an excessive number of costly failures and poor system performance, and therefore, reliability decrease; excessive maintenance may improve reliability, but the maintenance cost will be sharply increased [2]. Therefore, a maintenance policy is necessary to a process production. One kind of maintenance policy is Reliability Centred Maintenance (RCM). Dehghanian et al [3] explore a comprehensive RCM framework tailored to power distribution systems. Riyanto et al [4] studied about optimization of maintenance interval with RCM that can provide savings for company. Wilmeth et al applied RCM to improve battery maintenance program at SPSS [5]. Therefore, many companies conducted RCM method.



There are two kinds of maintenance activity, namely corrective maintenance and preventive maintenance. In plant operation, PT. X perform corrective maintenance. Corrective maintenance is a maintenance activity do after machine or production facility were failure or interference so it can't function properly [6]. The drawback of corrective maintenance is this kind of maintenance can bring out many economic impacts like repair or replacement cost without any preparation from the company. Besides that, by corrective maintenance, unpredicted failure on the machine will give impact to the whole production process in the form of stopped the whole production lines. On the other side, preventive maintenance is a maintenance that performed on a schedule basic, generally periodic where a number of activities such as inspection and repair, replacement, cleaning, lubrication, adjustment, and equalization are done [7]. Also, the benefits of preventive maintenance are reducing the probability of equipment breakdowns and extension of equipment life [8].

The aim of this research is to determine maintenance tasks according to the cause of component's failure using RCM and determine the amount of optimal inspection frequency that can be done to the machine at filling lithos process. There are 3 kind of filling process: filling lithos, filling drum, and filling Intermediate Bulk Container (IBC). We choose filling lithos process to be the concern of this research is because filling lithos is the most complicated filling line with 11 machines in the line. There are labelling, filling, capering, volume censor, heater, induction seal, laser, robotic, carton sealer, carton erector, and palletizing.

2. Methodology

For the first step plant observation was done to find the problem that affect the production process. PT. X has a critical problem that affect the production process, that is the line production stop caused of machine downtime. In second step, we perform literature study to find out more about theories related to the issues that will be solved. In this research, RCM method is used to find the maintenance task that suitable to each component to minimize machine downtime. In the third step, data collection and processing were conducted. In this step, downtime data were collected to find critical machine. We collect downtime data of all machine we recapped all of the downtime data so we can find a machine that has the longest downtime and the highest downtime frequency. Afterwards, Fault Tree Analysis (FTA) was used to breakdown the cause of machine downtime. FTA was then followed by creating Failure Mode and Effect Analysis (FMEA) to find the detail potential failure mode, failure effect, and cause of failure. The Risk Priority Number (RPN) of each failure mode can be determined. In the last step, maintenance and the optimal frequency for the whole critical machine can be developed.

2.1. *Collecting and processing data*

The data used in this study is limited only downtime data filling lithos process from August 2015 until July 2016. The assumptions used are every machine work for two shifts starting at 07.00 till 23.00, average inspection time assumed for 2 hours and the average repair time is assumed for 4 hours, and the reliability of the machine after maintenance activities amounted to 85% according to the world standards that have been set.

2.2. *Theoretical probability distribution used in this research*

There are several probability distributions that used in research are Weibull distribution and exponential distribution. The Weibull distribution equation used to calculate MTBF and reliability of the critical machine based on the TBF data. The exponential distribution used to determine the optimal frequency of inspection of critical machine based on the downtime data.

- Weibull Distribution

The reliability equation is [7]:

$$R(t) = e^{-\left(\frac{t}{\theta}\right)^\beta} \quad (1)$$

With average value as follow [7]:

$$mean = \theta \Gamma \left(1 + \frac{1}{\beta}\right) \quad (2)$$

Where Γ is gamma function [9] with equation:

$$\Gamma(s) = \int_0^{\infty} x^{s-1} e^{-x} dx \quad (3)$$

- Exponential Distribution

The reliability equation is [7]:

$$R(t) = e^{-\lambda t} \quad (4)$$

With average value as follow [7]:

$$mean = \frac{1}{\lambda} \quad (5)$$

2.3. Reliability centred maintenance (RCM)

RCM is a method to determine maintenance task to ensure the reliability of a system. RCM serves to overcome the dominant cause of failure which will bring on maintenance decisions that focus on the prevention of these types of failures that occur often. The application of RCM method can provide some advantages such as the safety and integrity of environment which will be becoming more preferably, increasing operational achievements, higher effectiveness of operating and lowering maintenance cost, increasing the availability and reliability of the equipment, giving longer component life, more comprehensive data base, greater individual motivation, and able to improve cooperation among operators of installation [10]. The steps for implementing RCM are as follow [11]:

- Determine the cause of failure using Fault Tree Analysis (FTA) aimed to obtain the probability of failure and determine the critical components that are prone to failure.
- Develop analytical work with Failure Mode Effect Analysis (FMEA), such as determining the priority of equipment that needs to be maintained.
- Classify the level of consequences of failure.
- Make RCM decisions to classify the levels of maintenance needs.
- Implement maintenance decision based on the RCM.
- Conduct an evaluation based on the results of the proposed maintenance.

RCM classify the failure consequences in four groups:

- Hidden failure consequence is a failure that has many impact on the failure of another component and more serious because of hidden or unknown to the operator.
- Safety consequences is a failure that may causes hazards, injured or even killing someone.
- Operational consequence is a failure that have any impact in operating process such as product, output, operating cost, repair cost and also can cause the stopped of production process.
- Non-operational consequence is a failure that have no impact on safety of production, but can impact directly to the cost with relatively small impact.

Several maintenance tasks are exist in RCM [12]:

- Condition-Directed Task
This type of maintenance task aims to determine the potential failure which can be prevented before the actual failure occurs and detect the potential failure by checking the component. This maintenance task leads to a regular basis diagnostic test or conduct inspections which can compare the condition of pre-maintain components to their standard.
- Time-Directed Life-Renewal Task
Time-directed life-renewal task is an action that aims to prevent component failure directly to the source which is based on the life time of the component. Time-directed life-renewal task duty is to replace or repair component before it reaches a time in which the probability of failure becomes greater. In this maintenance task, there are two kinds of task. Replacement which an item must be replaced with new item when it has reached the level of wear-out, while restoration which an item can still be repaired so that it can be used again.
- Failure Finding Task
Failure finding task aims to find hidden failure to the component by implementing the periodic inspection and evaluate the state of equipment or components.

- **Run to Failure**
Run to failure is a task in which the component is used until it is broken, because no economical action can be conducted to prevent the failure.
- **Servicing Task**
Servicing task is a task of maintenance for additional products or material before it is used during the normal operation,
- **Lubrication Task**
Lubricating is a type of maintenance task in terms of doing lubrication on a regular basis.

2.4. The optimal frequency of inspections

The time to failure of the machine can be determine using the downtime data of critical machine. The total downtime per unit time can be constructed as a function of inspection frequency with the construction of the model as follows [13]:

- Equipment failures occur according to the exponential distribution with mean time to failure (MTTF) = $1/\lambda$, where λ is the mean arrival rate of failures. For example, if the MTTF = 0,5 years, then the mean number of failures per year = 2, i.e. $\lambda = 2$.
- Repair times are exponentially distributed with mean time $1/\mu$.
- The inspection policy is to perform n times per unit time. Inspection times are exponentially distributed with mean time $1/i$.
- The objective is to choose n to minimize total downtime per unit time. The function can be written as follows:

$$D(n) = \frac{\lambda(n)}{\mu} + \frac{n}{i} \quad (6)$$

By changing the value of $\lambda(n) = k/n$ and deriving equation (6) to determine the optimal number n , the equation become as follows:

$$D'(n) = -\frac{k}{n^2\mu} + \frac{1}{i} = 0 \quad (7)$$

Therefore,

$$n = \left(\frac{ki}{\mu}\right)^{1/2} \quad (8)$$

3. Result and Discussion

Based on data shown in Table 1 the filling lithos line 2 has the longest downtime. From Table 2 the laser machine on line 2 is the critical machine in filling lithos process at PT. X. After determining the probability distribution function of laser machine's Mean Time Between Failure (MTBF) data, it was found that the data followed Weibull distribution. Based on the MTBF of that probability distribution, then the machine reliability is calculated and found to be 24.54%, and it can be concluded that the machine is under condition of low reliability so it needs to be analyzed further.

Table 1. Downtime machine in filling lithos

Line	1	2	3	4
Downtime (minutes)	16325	24630	18535	17465

Table 2. Downtime machine in filling lithos line 2

Machine	Labelling	Filling	Capering	Sensor Volume	Heater	Induction Seal	Laser	Robotic	Carton Sealer	Carton Erector	Palletizing
Downtime (minutes)	3730	2325	3165	240	0	30	6115	5765	1020	665	1650

The RCM is started by constructing the FTA (Fig.1), the FMEA (Table 3), and then determining the maintenance task (Table 4). The optimal inspection frequency for laser machine is then can be calculated using equation (8). From the FTA (Fig.1), it can be seen that the failures which might be occurred can be classified into two categories based on the effect of the failure: the effect of machine stops from operating and error marking. The effect of machine stops from operating was caused by lens error. The lens error occurred because of the lens is broken or cracked, and the broken lens was caused by human

error. From FMEA in Table 3, marking trouble were caused by inappropriate marking result and machine does not perform marking. FMEA for lastube, the potential failure mode is CO gas cylinder's error because of CO gas is discharge. The error of lastube can produce an error in marking of the product. From Table 4 the cause of the failure of laser machine includes the failure of power supply component, lens, chiller, laser siren, lastube, encoder, conveyor, and mirror galvo. The consequences of such failures are hidden failure consequences, operational consequences, and safety consequences. Maintenance task that are suitable for component laser machine is time-directed life-renewal task, while the other components such as power supply, encoder, and laser siren must use failure finding task and lastube and chiller must use servicing task.

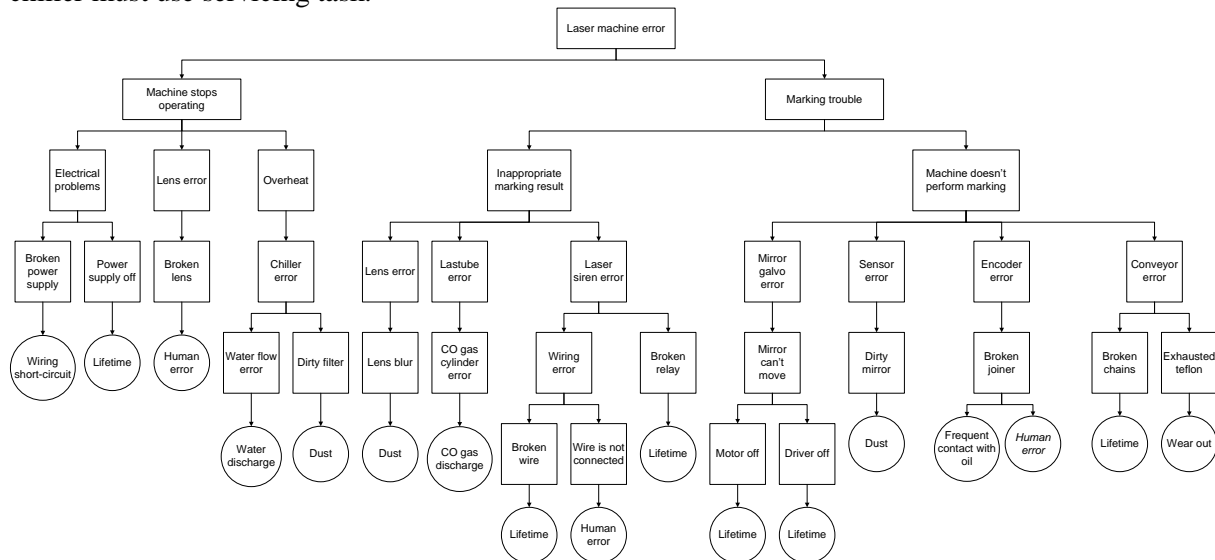


Figure 1. Fault Tree Analysis (FTA)

Table 3. Failure Mode and Effect Analysis (FMEA)

Component	Function	Potential Failure Mode	Failure Effect	Cause of Failure	O	S	D	RPN	RANK
Power Supply	Providing electricity to the power supply or other components in order to work properly	Power supply is broke	Laser machine stops operating	Wiring short-circuit	3	5	8	120	4
		Power supply off		Lifetime	2	5	7	70	11
Lens	As a way to fire a laser beam	Lens blur	Error marking	Dust	8	7	2	112	5
		Lens broke	Laser machine stops operating	Human error	1	5	2	10	15
Chiller	Keeping the condition inside the laser machine remains in proper temperature and not overheat	Error water flow	Laser machine stops operating	Water discharge	7	5	3	105	6
		Dirty filter		Dust	7	5	3	105	6
Laser Siren	Produce a siren sound as a sign that something goes wrong with the machine	Broken wires	Error marking	Lifetime	2	8	3	48	12
		Wire is not connected		Human error	2	8	2	32	14
Lastube	A place to store CO which fired to produce writings	Broken relay	Error marking	Lifetime	2	8	3	48	12
		Error CO gas cylinder		CO gas discharge	7	5	4	140	1
Encoder	Component in charge of determine when sensor fire a laser	Joiner with conveyor broke	Error marking	Frequent contact with oil	3	7	5	105	6
				Human error	3	7	5	105	6
Conveyor	Move the products from one station to another station	Broken chain	Error marking	Lifetime	2	5	1	10	15
		Exhausted Teflon		Wear out	7	7	2	98	10
Mirror Galvo	The components that reflect the laser in order to shoot right at the specified position	Motor is off	Error marking	Lifetime	3	7	6	126	2
		Driver is off		Lifetime	3	7	6	126	2

Table 4. Category consequences of failure and RCM decision of laser machine

Component	Cause of Failure	RPN	Ranking	Category Failure Consequences	Maintenance Task
Lastube	CO gas discharge	140	1	Operational consequences	Time-directed life-renewal task, servicing task
Mirror Galvo	Lifetime of motor	126	2	Operational consequences	Time-directed life-renewal task
Mirror Galvo	Lifetime of driver	126	2	Operational consequences	Time-directed life-renewal task
Power Supply	Wiring short-circuit	120	4	Hidden failure consequences, operational consequences	Time-directed life-renewal task, failure finding task
Lens	Dust	112	5	Operational consequences	Time-directed life-renewal task
Chiller	Water discharge on water flow	105	6	Operational consequences	Time-directed life-renewal task, servicing task
Chiller	Dirty filter	105	6	Operational consequences	Time-directed life-renewal task
Encoder	Frequent contact with oil	105	6	Hidden failure consequences, operational consequences	Time-directed life-renewal task, failure finding task
Encoder	Human error	105	6	Hidden failure consequences, operational consequences	Time-directed life-renewal task
Conveyor	Teflon is wear out	98	10	Operational consequences	Time-directed life-renewal task
Power Supply	Lifetime of power supply	70	11	Hidden failure consequences, operational consequences	Time-directed life-renewal task
Laser Siren	Lifetime of wire	48	12	Hidden failure consequences, safety consequences	Time-directed life-renewal task, failure finding task
Laser Siren	Lifetime of relay	48	12	Hidden failure consequences, safety consequences	Time-directed life-renewal task, failure finding task
Laser Siren	Human error	32	14	Hidden failure consequences, safety consequences	Time-directed life-renewal task, failure finding task
Lens	Human error	10	15	Operational consequences	Time-directed life-renewal task
Conveyor	Lifetime of chains	10	15	Operational consequences	Time-directed life-renewal task

Assuming the firm needs that reliability of the machine be 85% reliable according to world class standard [14], the company must be decreased the downtime from 1,273.76 minutes (before applying the RCM and inspection to the machine) to 17 minutes (after applying the RCM and inspection to the machine).

Based on the downtime data, it can be seen that the average value of failures per month is 1 time and with the assumption of an average inspection time is 2 hours or 0.00625 months and the average number of the repair time is 4 hours or 0.0125 months. Then using equation (8) we can find that the optimal number of inspection is once a month for through inspection on a laser machine and its components.

4. Conclusion

In this research, we calculate total downtime from all machine in line 1-4, then we choose the line 2 with longest downtime and determine that laser machine in line 2 is the critical machine. After that, we applied RCM method to determine the critical component of laser machine and its optimal frequency of inspection for laser machine in line 2 at filling lithos process PT. X. Based on the processing data then it was found that the total downtime of the laser machine is 6,115 minutes with an average downtime 1,273.76 minutes and reliability 24.54%. Then we determine the maintenance task that suitable for each component of laser machine as seen on Table 4. Also, we calculate the optimal frequency of inspection for laser machine is once a month. By assuming that the machine's condition must at 85% after doing maintenance task and inspection, we get the total downtime decreased to 17 minutes.

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