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Reliability Analysis to Determine Mean Time between Failures (MTBF) on Machinery

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Abstract

Machinery maintenance is an activity system for maintaining, developing and maximizing all machinery facilities. To prevent damage and failure on machinery, time-based maintenance techniques are planned actions are used, but this maintenance are not effective enough to prevent failure. Thus, it is necessary to analyze machinery reliability to determine mean time between failures (MTBF). Using this method, maintenance can be done before machinery break down, which can reduce maintenance cost. This method can be perform using simple statistic as Weibull distribution, because this distribution can be used for various models of failure. Using component failures data collected at a mill, such as: explosive; broken throat-ring; lower-gate jam; plate wear; start fail; and leakage, using Weibull distribution, the result show that value of MTBF obtained from each failure as follows: broken throat-ring at 84636 hours; lower-gate jammed at 1104 hours; plate wear at 4378 hours; machine start fail at 2685 hours; and leakage at 40456 hours. Using calculation results above, maintenance should be conduct before MTBF time to keep machine work properly.

Keywords: machinery, maintenance, essential, failure, statistics

1. Introduction

In an industry, maintenance department plays an important role to support production process smoothness. Machinery maintenance is defined as the work needed to keep a machine in good condition. Maintenance can be identified into five general philosophy: a) corrective maintenance; b) preventive maintenance; c) predictive maintenance; d) zero-hours maintenance; and e) periodic maintenance. Every maintenance has the disadvantages of that each equipment needs a mix of each of these maintenance types, we cannot apply one types of maintenance to particular machinery (Blisckhe, 2000, Bossche, 1993).

Preventive maintenance mission is to maintain a level of certain service on equipment, programming the intervention of their vulnerabilities in the most opportune time. Preventive maintenance activity including partial or complete equipment inspection, overhauls of certain periods, oil change, lubrication and so on. By this method, worker can record equipment damage so that it can be known when equipment turnover or repair worn equipment before causing system failure (Narayan, 2004). It is designed to maintain and improved equipment reliability by replacing aging components before they actually fail.

Charles E. Ebeling said that, "*Reliability is defined to be the probability that component or system will perform required function for a given period of time when use understate operating condition*". Reliability is theoretically defined as the probability of success; as the frequency of failures. In this case, we can calculate reliability by using failures data obtained in the field. This data recorded every equipment failure, starting from the first time equipment is operated. Data failures hold an important role in reliability calculation.

2. Methods

A first approach would be to determine equipment criticality. Among the principal analytical tools available we find (Bloch, 1933):

- Cause-and-effect diagram
- Reliability estimating and predicting
- Failure mode and effect analysis (FMEA)
- Availability analysis

- Fault tree analysis
- Hazard analysis
- Field investigation
- Detailed design review

To support reliability-based maintenance system, it is necessary performed an analysis to determine appropriate inspection interval time. Time table mill inspection shown on fig. 1.

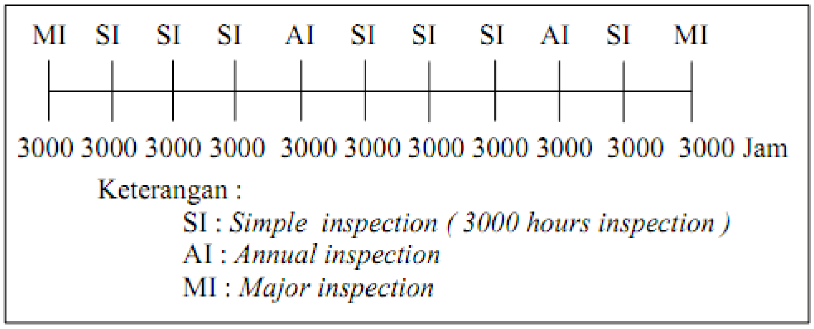

Fig. 1: Time table inspection

Mill block diagram on fig. 2 used to define the system equipment. From this diagram, essentials part of the equipment can be known and analyzed. As an example, a mill failures data describe as follows: explosive; broken throat-ring; lower-gate jam; plate wear; start fail; and leakage.

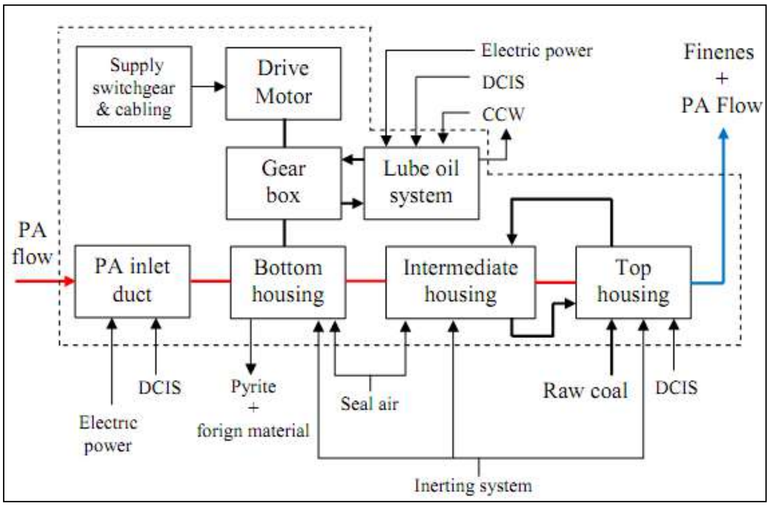

Fig. 2: Mill Block Diagram (Zulfadhli, 2010)

This failure data is analyze using Weibull distribution:

$$R(t) = \left[-\int_0^t \exp \frac{\beta}{\alpha} \left(\frac{t'}{\alpha}\right)^{\beta-1} dt' \right] = e^{-\left(\frac{t}{\alpha}\right)^{\beta}} \quad (1)$$

R (t) used to calculate reilability, with β called shape parameter which provide deep knowledge of failure proccesses behaviour. And α called scale parameter, that affect mean distribution. Weibull shape parameter explained on table 1.

Table 1: Weibull shape parameter

Value	Property
$0 < \beta < 1$	Decreasing Failure Rate (DFR)
$\beta = 1$	Constant Failure Rate (CFR), exponential distribution
$1 < \beta < 2$	Increasing Failure Rate (IFR), concave
$\beta = 2$	Rayleigh distribution (IFR)

$\beta > 2$	Increasing Failure Rate (IFR), convex
$3 \leq \beta \leq 4$	Increasing Failure Rate (IFR), approaches normal distribution, symmetrical

Failure data example show on table 2, this data only to show how to calculate the reliability.

Table 2: Leakage failure data

No	Hours fail
1	17520
2	17880
3	20496
4	22680
5	24792

Using Weibull distribution, statistic parameter of the failure show on table 3. This parameter help us to determine failure processes behavior as mention on table 1.

Table 3: Statistic parameter for failure

Failure types	Weibull Distribution			
	Shape parameter	Scale parameter	Mean	Deviation
Broken throat-ring	6.07	87497.30	81226.90	15566.10
Lower-gate jam	1.04	1577.11	1552.89	1494.67
Plate wear	6.46	4624.17	4307.44	779.15
Start fail	0.99	3836.54	3854.97	3898.36
Leakage	2.12	47639.30	42192.00	20969.50

From statistic parameter on table 3, we can calculate reliability cycles for fail component using equation 1. Reliability cycle for fail component show on table 4.

Table 4: Reliability cycles component

Failure types	Reliability Cycles (hours)				
	0.01	0.1	0.5	0.9	0.99
Broken throat-ring	117894	104426	84636	60865	40342
Lower-gate jam	8999	4175	1104	137	10
Plate wear	6005	5349	4378	3197	2160
Start fail	21257	9969	2675	343	26
Leakage	110795	76625	40456	14850	4254

3. Discussion

Normally, a system consists of a number of functional block diagrams so that the system can perform its function. Major components of the system need to be known so the system properly function. The components can be found through an analysis when and what makes the system fail. Before using reliability analysis, we must perform FMEA (Failure Mode Effects Analysis) methods to find major components and essential machine from the system. Its turn out that the mill is essential machine from the system, using qualitative analysis on existing data consider a complete data even though data are incomplete. Complete data used to calculate reliability from the system. If qualitative reliability considered incomplete, failure analysis necessary to be done on the system.

By conducting reliability analysis using Weibull distribution, for each failure, correlation coefficient value above 0.8. This indicate all failure data can be processed using Weibull distribution and instrument used on this research is valid and reliable.

From table 3, statistic parameter for failure show that on the component of failure there is an increase and decrease failure rate depends on time. It’s also can be explained using bath tub curve below. By looking at the relationship between table 1, table 2 and fig. 2; it is defined that fail start consider as early failure (infant mortality) because shape parameter value between 0 and 1 was the property of (Decreasing Failure Rate) DFR (Ebeling, 1997). Lower-gate jam defined as Increasing Failure Rate (IFR) or wear out failure because value of the shape parameter is between 1 and 2. Another component failure defined as aging process because the shape parameter value above 2.

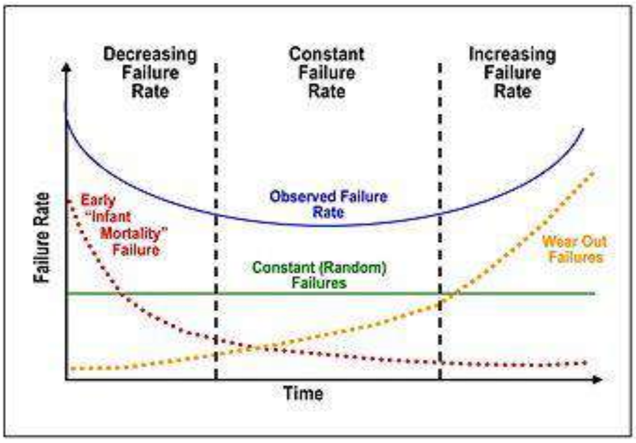

Fig. 3: Bath tub curve

Inspection time interval for maintenance can be explained on table 4. If inspection duration time is close, reliability value or success opportunities close to 100%. This mean that the system will not fail because before it becomes fail, we can prevent it. But, if the duration is to close, maintenance cost will become higher. At value 0.5, reliability can be said well, because it is average from highest and lowest value.

Fig. 4 shows that throat ring data suitable to be processed using Weibull distribution because correlation coefficient value greater than 0.8 (0.949), so the instrument used can be said valid and reliable. Shape parameter value, 6.07, indicates an increase failure rate over time, this happens when there is an aging process, or a section that tends to fail over time. If it refers to the theory, then a good value of reliability is if the value is> 0.7, when used the value of reliability of 0.5, then the mean time between failure MTBF) is 84636.5 hours.

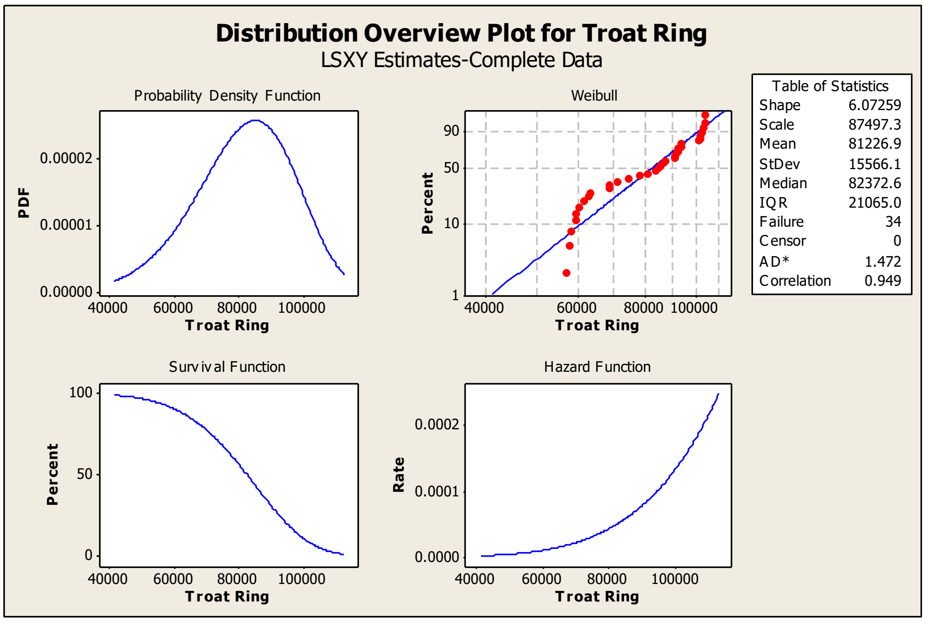

Fig. 4: Weibull distribution for throat ring

4. Conclusion

After performing reliability analysis to determine Mean Time between Failure (MTBF), it can be concluded that:

1. Reliability analysis can be done after machinery reliability assessment effort to understand effort will be used for the analysis.
2. In determining reliability, machine system has to be divided into several level, so if damage or failure occurs, source of failure can be find easily.
3. Best inspection time should be done when reliability cycles value close to 100%, this mean that the system is AGAN (As Good As New).
4. On this research reliability value 0.5 is used, because at this value failure can be prevent using correct maintenance.
5. Time inspection should be adjusted to MTBF value to prevent machinery failure.
6. The result show that value of MTBF obtained from each failure as follows: broken throat-ring at 84636 hours; lower-gate jammed at 1104 hours; plate wear at 4378 hours; machine start fail at 2685 hours; and leakage at 40456 hours.

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