Reliability Centered Maintenance of Mining Equipment: A Case Study in Mining of a Cement Plant Industry

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Abstract. Today's industrial growth is inseparable from the free market mechanism which is a consequence of economic globalization and thus cannot be avoided by any country. All this leads to a very keen business competition. This can be seen in the high competition of the Indonesian national cement industry and worsened by the oversupply of domestic cement in Indonesia. Semen Padang Co. as a national cement company sets the optimization of production capacity as one of the focus of initiatives. To achieve this, maintenance of production equipment is very important. In the mining unit, the occurrences of breakdown are very high in the crusher plant and conveyor belts having a large number of equipment and serial production activities that need to be set up for effective maintenance planning. The purpose of this study is to develop preventive maintenance planning with the implementation of the Reliability Centered Maintenance methodology and to submit a schedule of planned preventive maintenance activities with the limitation of meeting the target production hours of conveying limestone and silica to each plant. Based on the calculation results from the implementation of preventive maintenance planning, it can reduce the breakdown time by 42% and it is recommended to be applicable. The next study is to calculate the maintenance costs needed in accordance with the maintenance plan that is made with the Reliability Centered Maintenance methodology. This step is expected help the company in minimizing the cost of maintaining crusher plant and conveyor belts.

Keywords: Reliability-centered maintenance · Preventive maintenance · Mining

1 Introduction

Maintenance is an important task to keep equipment reliability to ensure that all production activities run smoothly according to the set schedule and target [1]. The high occurrences of machine breakdown is a problem that many companies face with today. This condition certainly results in the production process in the company becoming unproductive and inefficient [2]. Mining activities are the first series of work activities

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at Semen Padang Co. The activities are mining limestone and silica stone as the main ingredients for making cement. Unit of mining in Semen Padang Co. also faces with a high breakdown of equipment operating conditions that have exceeding the set target. The problem of high breakdown will be explained by the Reliability Centered Maintenance (RCM) approach [3]. The application of RCM can help to decide what the different maintenance strategies required to ensure a high reliability of equipment with a reasonable cost [1, 4].

2 Reliability Centered Maintenance

RCM is the optimal mix of reactive, time-based, interval-based, condition-based, and proactive maintenance [1, 5]. RCM is used to determine what failure management strategies must be implemented to ensure that the system reaches the desired level of safety, reliability, environmental health and operational readiness in the most cost-effective way. Often, the purpose of maintenance is to prevent all possible failures, and produce an over-maintenance program and maintenance activities to be ineffective [6]. The application of RCM will produce a treatment program that is truly applicable and effective [3, 7].

RCM recognizes the value of your personnel and takes advantage of their extensive experience running the equipment [1, 8]. Run to Failure (RTF) works on the assumption that it is most cost effective to let equipment run unattended until it fails. This type of maintenance is used for the lowest priority equipment. Preventive Maintenance (PM) comprises maintenance tasks on a piece of equipment at regular intervals regardless whether the equipment needs it or not. When well implemented, PM may produce savings in excess of 25 percent [1, 9]. Even though PM is an improvement over RTF, abrupt failures that cause unscheduled downtime still occur. Predictive Maintenance (PDM) is maintenance based on real-time data collected on a piece of equipment. The data show the "health" of the equipment. Proactive Maintenance (PAM) determines the root causes of failure and implements "fixes" (e.g., redesign the equipment so that it does not break down as frequently).

3 Case Study

The case study herein was carried out in Semen Padang Co. mine conveyor belt system. The conveyors transport crushed lime stone or silica stone to storages in the plant. This study takes operating and repairs data from 2015 to 2017. The operation of the conveyor system must be able to maintain the availability of limestone and silica in each plant's storage capacity at least 50%. Totally, annual requirement for limestone is 9,850,000 tons and 750,000 tons of silica stone for all plant. Processing and transport activities of material must be carried out safely by taking into account the safety of the operator and maintenance crew and not causing pollution to the environment. In the conveying system of Semen Padang Co. mine there are 42 conveyor items. RCM applications are implemented in the most critical machines. The critical value of the machine is determined by weighing several aspects of the scale of assessment in accordance with the operational requirements of the equipment.

The weighing scale is made with low, medium and high values (with values 1, 2, 3) and the equation used is:

$$MC = 0.2 * L + 0.2 * Q + 0.1 * M + 0.2 * B + 0.3 * E \tag{1}$$

Where machine criticality (MC), conveyor length (L), storage load volume (Q), material transported (M), machine breakdown (B) and environment impact (E). As a result, we get the most critical belt conveyor as A1J12A, with a value of 3 criticality (see Table 1).

Table 1. Criticality of conveyor belt in Semen Padang. Co. Mining (partial)

No	Machine no.	Critical machine criteria										
		Conveyor length		Storage load volume		Material		Breakdown hours		Environment		Total
		Weight	20%	Weight	20%	Weight	10%	Weight	20%	Weight	30%	
		Value	Value × weight	Value	Value × weight	Value	Value × weight	Value	Value × weight	Value	Value × weight	
1	A1J12A	3	0,6	3	0,6	3	0,3	3	0,6	3	0,9	3,00
2	A5J10	3	0,6	3	0,6	2	0,2	3	0,6	3	0,9	2,90
3	A1J12P	3	0,6	3	0,6	3	0,3	2	0,4	3	0,9	2,80
4	A1J12B	3	0,6	2	0,4	3	0,3	3	0,6	3	0,9	2,80
5	A1J12C	1	0,2	3	0,6	3	0,3	1	0,2	3	0,9	2,20
6	A5J11	1	0,2	3	0,6	2	0,2	1	0,2	3	0,9	2,10
7	20104	2	0,4	2	0,4	3	0,3	1	0,2	1	0,3	1,60
8	A1J11	1	0,2	3	0,6	3	0,3	1	0,2	1	0,3	1,60
9	A4J14	2	0,4	2	0,4	3	0,3	1	0,2	1	0,3	1,60
10	15107	1	0,2	3	0,6	2	0,2	1	0,2	1	0,3	1,50

The next step is to create a Fault Tree Analysis (FTA) that aims to identify each failure and find the root cause of the failure that can be generated from each machine component. Examples of FTA on conveyor A1J12A can be seen in the Fig. 1.

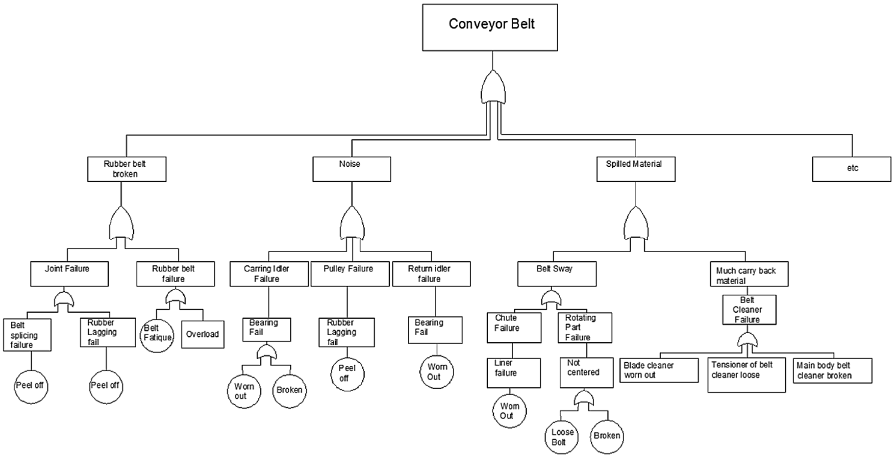

Fig. 1. Partial fault tree analysis of conveyor belt

Reliability data is needed to decide whether an item is critical. This data describes the failure process and optimizes the scheduling of preventive maintenance time. Examples of such data are those at average time between failures (MTTF), average repair time (MTTR) and failure rate function. Furthermore, an analysis of Failure Mode and Effect Analysis (FMEA) was developed which consisted of tabulation failure modes obtained from FTA and machine reliability data.

Then, an assessment is carried out so that the risk priority index (RPN) will be obtained from each failure mode. The value of RPN is the multiplication of the values of severity, occurrence and detection. Each of these parameters is made in 10 rating scales.

Table 2. Risk ranking categories

RPN	Risk level	Description
0–15	Low	Acceptable as it is
15–125	Medium	Acceptable with procedures and controls
125 < 425	High	Unacceptable, should be mitigated with specified time
>425	Extreme	Unacceptable, must be mitigated immediately

3.1 Selection of Maintenance Strategy

The next step is selection the maintenance strategy in each failure mode in the FMEA tabulation. Determination of maintenance strategies by using the RCM Logic Tree Diagram (LTA). The maintenance type determination that will be carried out is processed by answering each step of the question that is in the LTA of RCM (Fig. 2).

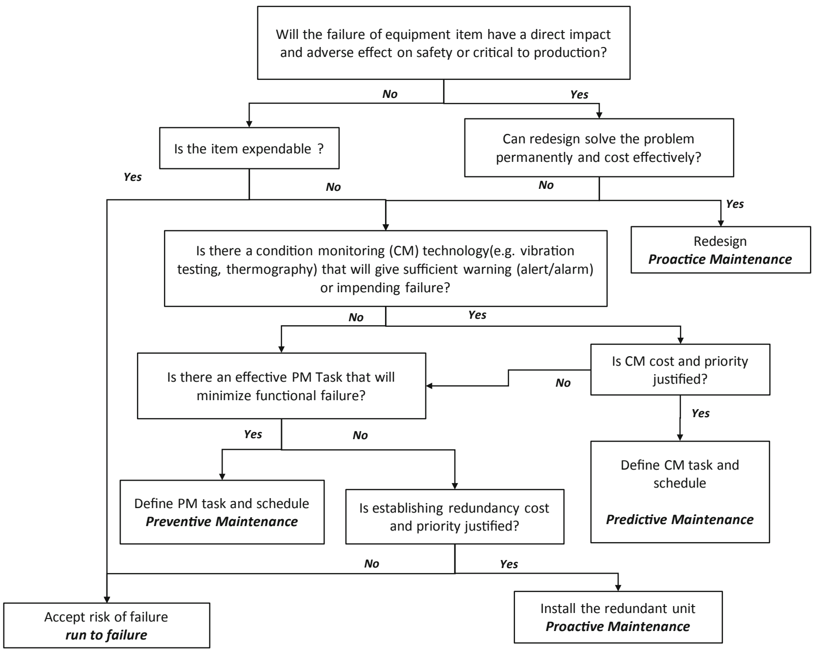

Fig. 2. RCM logic tree diagram

Next is to determine the maintenance interval from the results of the LTA. Maintenance Scheduling is performed on failure modes that have high risk as shown in Table 2.

Table 3. Failure mode and effect analysis for conveyor A1J12A (partial)

Item	Failure Mode	Failure Effect	Severity Analysis (production)	Severity Analysis (Safety)	Severity Analysis (Environment)	Severity (S)	Occurrence (O)	Detection (D)	RPN	Risk Group	LTA	Maintenance Task (Current)	Maintenance Task (proposed)
Rubber Belt	Belt Broken	Machine Stop, Downtime For Repair Or Replace 32 Hours	7	1	4	7	1	5	35	Medium	Yes	PM	PM
	Splicing Peel Off	Belt Break Apart, Downtime For Repair Or Replace 3 Hours	1	1	2	2	10	7	140	High	Yes	PM	PAM
	Belt Run Off (Sway)	Material Spilled, Downtime For Repair Or Replace 8 Hours	2	1	4	4	3	1	12	Low	No	RTF	RTF
	Belt Torn (Leaked Out)	Material Spilled, Downtime For Repair Or Replace 3 Hours	1	1	4	4	5	7	140	High	Yes	PM	PAM
	Belt Slip	Machine Stop, Downtime For Repair Or Replace 2 Hours	1	1	1	1	1	7	7	Low	No	RTF	RTF
	Belt Edge Peel Off	The Belt Has The Potential To Get Stuck And Tear Long, Downtime For Repair Or Replace 40 Hours	9	1	1	9	2	1	18	Medium	Yes	RTF	PAM
	Belt Shredded Because Of Iron Entry Or Sharp Objects	Material Spilled, Downtime For Repair Or Replace 48 Hours	10	1	4	10	1	7	70	Medium	Yes	RTF	PAM
Carrying Idler	Idler Is Not Installed Or Detached	Material Spilled, Downtime For Repair Or Replace 1 Hours	1	1	1	1	1	1	1	Low	No	PM	RTF
	Idler Not Rotate	Causing The Belt Sway Dan Material Spilled, Downtime For Repair Or Replace 1 Hours	1	1	8	8	1	1	8	Low	No	PM	RTF
	Bearing Worn Out Or Broken	Noise (Complaints From Surrounding People), Downtime For Repair Or Replace 1 Hours	1	1	6	6	3	7	126	High	Yes	PM	PAM
	Idler Broken	Material Spilled, Downtime For Repair Or Replace 1 Hours	1	1	1	1	1	7	7	Low	No	PM	RTF
	Idler Stand Fall Down	Material Spills Along The Belt, Downtime For Repair Or Replace 1 Hours	1	1	8	8	1	1	8	Low	No	PM	RTF
Return Idler	Idler Is Not Installed Or Detached	Material Spilled, Downtime For Repair Or Replace 1 Hours	1	1	1	1	1	1	1	Low	No	PM	RTF
	Can Not Rotate	Material Spills Along The Belt, Downtime For Repair Or Replace 1 Hours	1	1	8	8	1	1	8	Low	No	PM	RTF
	Bearing Worn Out Or Broken	Noise (Complaints From Surrounding People), Downtime For Repair Or Replace 1 Hours	1	1	6	6	4	7	168	High	Yes	PM	PAM

4 Result and Discussion

Base on the result of FMEA (Table 3), we can see that there are four modes of failure that belong to a "High" criticality group. In accordance with the Table 2, these four failure modes must be mitigated. The failure modes are bearing of return idler worn out or broken, rubber belt splicing peel off, belt torn (leaked out) and bearing of carrying idler worn out or broken. Based on the calculation of MTTR and MTTF using the failure mode distribution approach that occurs, the reduction in downtime is obtained by 629.8–368.8 = 261 h or 41.44% of the down-time generated by the four components that have a "high" criticality, see Table 4.

Table 4. Reduction of downtime by proposed maintenance

Component	Failure mode	MTTF (hours)	MTTR (hours)	MTBF (hours)	Reali bility	Freq. breakdown/year (current)	Down time/year (current)	Time repair (propose)	Down time/year (propose)
Carrying idler	Bearing worn out or broken	820,75	0,65	821,4	0,50	49	31,72	0,5	24,56
Return idler	Bearing worn out or broken	652,7	0,65	653,35	0,26	62	40,32	0,5	30,89
Rubber belt	Belt torn (leaked out)	1719,42	3,22	1722,64	0,14	23	75,45	2,5	58,62
Rubber belt	Splicing peel off	237,44	2,84	240,28	0,37	170	482,34	1,5	254,72
						Total	629,84	Total	368,79

5 Conclusion and Further Research

The application of the RCM approach illustrated in the case study shows an improvement in the maintenance strategy applied to maintenance of the conveyor belt at Semen Padang Co. mine. Furthermore, the critical level of failure mode with FMEA is analyzed and the MTTF, MTTR and reliability calculations are carried out by looking at the distribution of failures that occur. From these results, improvements were made which resulted in a decrease in hours of downtime by 41.44% from the current hour of downtime.

Finally, this case study to be continued on other mining equipment at Semen Padang Co. for obtaining an optimal maintenance strategy in terms of scheduling equipment maintenance and maintenance costs.

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