Decreasing inventory of a cement factory roller mill parts using reliability centered maintenance method

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Abstract. According to data from maintenance planning and control, it was obtained that highest inventory value is non-routine components. Maintenance components are components which procured based on maintenance activities. The problem happens because there is no synchronization between maintenance activities and the components required. Reliability Centered Maintenance method is used to overcome the problem by reevaluating maintenance activities required components. The case chosen is roller mill system because it has the highest unscheduled downtime record. Components required for each maintenance activities will be determined by its failure distribution, so the number of components needed could be predicted. Moreover, those components will be reclassified from routine component to be non-routine component, so the procurement could be carried out regularly. Based on the conducted analysis, failure happens in almost every maintenance task are classified to become scheduled on condition task, scheduled discard task, schedule restoration task and no schedule maintenance. From 87 used components for maintenance activities are evaluated and there 19 components that experience reclassification from non-routine components to routine components. Then the reliability and need of those components were calculated for one-year operation period. Based on this invention, it is suggested to change all of the components in overhaul activity to increase the reliability of roller mill system.

Besides, the inventory system should follow maintenance schedule and the number of required components in maintenance activity so the value of procurement will be decreased and the reliability system will increase.

1. Introduction

Inventory is needed for the sake of the production process smoothness in a company. But too much inventories would be a problem. According to a cement factory data, it was obtained that value of 3 types of inventories are so high. They are raw materials for 51 billion, routine components for 227 billion and non-routine components for 647 billion. Raw materials and routine components are fast moving inventories that has been already determined by ERP the minimum-maximum quantity of inventory and time of order on the ERP system while non-routine components are a slow-moving inventory and hard to control because it was purchased based on user request.

The components availability in maintenance activities becomes big issues. In one side, the user assigned to do maintenance activities want their components always on stock when machine break down. On the other hand, Department of Planning Control Supplies want to keep inventories low but always available when is required. Considering the maintenance activities, components availability and inventory are intertwined, so the determination of required components is a must so then the component availability is always maintained but as low as possible.
2. Research Methodology

The object of this research is a system on material processing unit that has the highest downtime frequency which is roller mill system. The related problem about reliability, downtime frequency and the availability of components for maintenance activity should be solved by determining the components needed on the right maintenance task. Reliability Centered Maintenance method will be used to evaluate the whole system to determine the failure distribution each component. Then, the required components will be reclassified from non-routine component to become routine component, so the inventory system can be determined. The expected outcome is to reduce the value of inventory while still keeping the components availability so the maintenance activity could be running smoothly.

The input data in this experiment is a time to failure data from each of the components. By using a software, failures data was processes to the appropriate distribution including known parameters and can be used to calculate the components needed. But before calculating the components need, a component reclassification will be conducted first, following the process in figure 1.

FIGURE 1. Component Reclassification Stage

2.1. System Analysis

The first step is conducting the system analysis. The RCM process analysis is conducted on system level then on component level. It’s because of the function failure of a system that usually can be seen from system level first and then it could be determined the supporting function of the system on component level. The system analysis is using a pareto diagram to obtain the system that has the highest downtime.

2.2. Subsystem Analysis

Next is subsystem analysis which is conducted on chosen system. Each of the subsystems were explained their functions, so it can be formed a unity of subsystem that compiles system in a Functional Block Diagram [1].

2.3. Function Analysis and Function Failure

Function and failure function forms from each subsystem were determined and arranged in RCM Information Worksheet [1] just like in table 1.

| RCM INFORMATION WORKSHEET |
|---------------------------|
| Function | Functional Failure | Failure Mode | Failure Effect |

2.4. Maintenance Task Analysis

After the failure function forms of each subsystem is already known, next the right maintenance task could be determined, using RCM Decision Worksheet [1] just like in table 2.

| RCM Decision Worksheet |
|------------------------|
| Information Reference | Consequence Evaluation | Default Action | Proposed Task |
| FI | FF | FM | H | S | E | O | FI | FF | FM | H | S | E | O |

2.5. Supporting Component Analysis

Determine the supporting components during maintenance activity which is obtained from work order system data, then it is arranged in a System Work Breakdown Structure (SWBS) [2] component in each subsystem just like in table 3.
2.6. Determine the Component Needs

The number of needed components (N) for a certain period is obtained by using this equation below\textsuperscript{[3]}.

\[
N = \frac{t}{T} + \frac{K^2 - 1}{2} + K \sqrt{\frac{t}{T}} \Phi^{-1}(p)
\]

Where:
- \(N\) = the number of needed components
- \(t\) = the period of planned operation
- \(T\) = MTTF
- \(K\) = coefficient variation of MTTF
- \(\Phi^{-1}(p)\) = service level

3. Analysis

3.1. System Analysis

Based on cement production process in A cement factory, the material processing unit is chosen as an experiment object, so those systems in this unit will be shown in figure 3. Those systems on material processing unit works consecutively from raw material reclaimer process to rolled material. In the running of the process, there have been a downtime for sure, either it’s scheduled downtime or unscheduled downtime. Unscheduled downtime is the main source that causing the loss of productivity in most part of the company. Because of that, this experiment will conduct an analysis in the system that has the highest unscheduled downtime which is the roller mill, it is shown in figure 4.
3.2. Subsystem Analysis

Roller mill system in PT. Semen Indonesia is a Vertical Roller Mill which is divided in 4 subsystems as shown in figure 5. The subsystem are:

- **Grinding Subsystem**
  In this subsystem, the material grinding process occurs which is conducted by roller and mill table.

- **Drying and Transporting Subsystem**
  In this subsystem, the material transporting or feeding process occurs consecutively using rotary feeder and also the material drying process using louvre ring insert and armour ring.

- **Separating Subsystem**
  In this subsystem, soft material and coarse material are separated by classifier and reducer classifier.

- **Hydraulic Subsystem**
  This subsystem functions to control pressure and vibration in roller mill by absorber, rocker arm and bladder accumulator.

![FIGURE 5. Subsystem of Roller Mill](image-url)

Based on the description in the previous subsystem, Functional Block Diagram (FBD) was developed according to figure 6.
This process is started by the material entering through rotary feeder and hot gas entering through hot gas duct which is directed by louvre ring and armor ring to the roller mill. Inside the roller mill occurs the milling process in mill table and 4 rollers so it produces rolled material. In this milling process, the vibration and pressure will be controlled by Hydraulic Spring System. The rolled material will be separated based on its size by guide vane classifier. If the size of the rolled material is already fit to the standard (fine material), then it will be released to product discharge while the rolled material that hasn’t fulfilled the standard (coarse material) will be put in to the reject hopper by scrapper reject through grit return classifier. This coarse material then will be put back to the roller mill to be milled again until the size is fitted to the standard.

3.3. Function Analysis and Function Failure

Analysis on Separating Subsystem which contains function failure, function failure modus and effect of function failure on each of the subsystems that will be shown in table 3.

| Function                                                                 | Functional Failure                                                                 | Failure Mode                          | Failure Effect                              |
|-------------------------------------------------------------------------|------------------------------------------------------------------------------------|---------------------------------------|---------------------------------------------|
| 1. Controlling the material size which is released from roller mill after milling process by separating the material (fine material and coarse material) | A. Blade rotation is not maximum                                                   | 1. Wear on the rotor blade            | The produced materials are too coarse       |
|                                                                         |                                                                                    | 2. Wear on guide vane                 | Too many rejected material                  |
|                                                                         |                                                                                    | 3. Wear on outer seal and inner seal  | Bad lubrication on bearing buffer           |
|                                                                         |                                                                                    | 4. Misalignment on coupling           | High vibration                              |
|                                                                         |                                                                                    | 5. Unbalanced blade classifier        | High vibration                              |

3.4. Maintenance Task Analysis

Maintenance Task analysis on separating subsystem is shown in table 4 below.

| Information Reference | Consequence Evaluation | H1 | H2 | H3 | Default Action | Proposed Task                                      |
|-----------------------|------------------------|----|----|----|----------------|---------------------------------------------------|
| F                     | FF                     | FM | H  | S  | O1            | O2       | O3       | H4 | H5 | S4            | Blade replacement when overhaul, scheduled discard task |
| 1                     | A                      | 1  | Y  | N  | N  | N              | Y        | Blad replacement when overhaul, scheduled discard task |
| 1                     | A                      | 2  | Y  | N  | N  | Y              | N        | Guide vane replacement when overhaul, scheduled discard task |
| 1                     | A                      | 3  | Y  | N  | Y  | N              | Y        | Replacement or service when overhaul, scheduled restoration task |
| 1                     | A                      | 4  | Y  | N  | N  | N              | Y        | Checking or service when scheduled                  |
3.5. Supporting Component Analysis
Supporting component analysis in Separating Subsystem is shown in table 5.

### TABLE 5. SWBS Separating Subsystem

| KODE | EQUIPMENT       | KOMPONEN                        |
|------|-----------------|---------------------------------|
| C.3  | CLASSIFIER      |                                 |
|      | BLADE SEGMENT LINER | C.3.1                            |
|      | BLADE ROTOR BLADE | C.3.2                            |
|      | SEAL UPPER OUTER | C.3.3                            |
|      | COUPLING         | C.3.4                            |
|      | COUPLING FLAK    | C.3.5                            |
|      | SQUARE BAR       | C.3.6                            |
| C.4  | REDUCER CLASSIFIER |                                 |
|      | BEARING          | C.4.1                            |
|      | BEARING          | C.4.2                            |
|      | SLEEVE ADAPTER   | C.4.3                            |
|      | BEARING          | C.4.4                            |
|      | BEARING          | C.4.5                            |
|      | BEARING          | C.4.6                            |
|      | BEARING          | C.4.7                            |
|      | BEARING          | C.4.8                            |
|      | BEARING          | C.4.9                            |
|      | SEAL OIL LOW SPEED | C.4.10                           |
|      | SEAL OIL HIGH SPEED | C.4.11                          |

3.6. Component Reclassification
According to table 5, components that experiencing reclassification are seal upper-outer and rotor blade. Rotor blade is used as material separator after milling process so this component often experiencing wear and tear which is cause by rotor blade is operated on high rotation speed and often experiencing impact with coarse rolled material. If there is a failure on this component, it will cause so many product reject because of the blade’s rotation is not in its maximum condition. Seal upper router is used as a gap closer between the rotor blade and guide vane. The damage of this component usually caused by the time wearing and also it often experiences an impact process with material. Component reclassification on Separating Subsystem is shown in the following table 6.

### TABLE 6. Separating Subsystem Reclassification

| EQUIPMENT | COMPONENT       | CLASSIFICATION | RECLASSIFICATION |
|-----------|-----------------|----------------|------------------|
| CLASSIFIER| BLADE SEGMENT LINER | NON-ROUTINE | NON-ROUTINE |
|           | BLADE ROTOR BLADE | NON-ROUTINE | ROUTINE |
|           | SEAL UPPER ROUTER | NON-ROUTINE | ROUTINE |
|           | COUPLING         | NON-ROUTINE | NON-ROUTINE |
|           | COUPLING FLAK    | NON-ROUTINE | NON-ROUTINE |
|           | SQUARE BAR       | NON-ROUTINE | NON-ROUTINE |
| REDUCER   | BEARING          | NON-ROUTINE | NON-ROUTINE |
| CLASSIFIER| SLEEVE ADAPTER   | NON-ROUTINE | NON-ROUTINE |
|           | BEARING          | NON-ROUTINE | NON-ROUTINE |
|           | BEARING          | NON-ROUTINE | NON-ROUTINE |
|           | BEARING          | NON-ROUTINE | NON-ROUTINE |
|           | BEARING          | NON-ROUTINE | NON-ROUTINE |
|           | SEAL OIL LOW SPEED | NON-ROUTINE | NON-ROUTINE |
|           | SEAL OIL HIGH SPEED | NON-ROUTINE | NON-ROUTINE |

3.7. Failure Distribution and Components Needs
In this stage, the rotor blade failure time data in table 7 was inputted in reliasoft Weibull software so it was obtained parameter which is used for component needs calculation.
TABLE 7. Rotor Blade Failure Data

| Waktu Kegagalan | Interval Kegagalan (hari) |
|-----------------|--------------------------|
| 25/6/2011       | 230                      |
| 11/12/2011      | 401                      |
| 15/1/2013       | 505                      |
| 4/6/2014        |                          |

Based on the data test table above, the adjusted distribution is normal distribution with parameter $\mu = 378.7$ and $\sigma = 167.858$, so the Cumulative Density Function graph and failure rate against time is shown in figure 7. The failure probability value $= 1$ for $t > 700$ days, so this component ascertained will be fail if the operation is exceeding the mentioned time. While in figure 7, the failure rate value is larger for longer operation time so this component could be categorized in wear out phase. The condition where it occurs function reduction and failure rate enhancement which are in line with the increasing wear age.

Besides, the inputted parameter to calculate the number of component needs is $MTTF (T) = 378.7$, $\sigma(T) = 167.8$, and $K = 0.44$, so the number of need that should be available for 365 days of operation period with 95% of confidence level for 1.3 components plus the average of need per year for 13.5 components, so the total need of rotor blade that should be available is $14.8 \approx 15$ components.

**FIGURE 7.** CDF Rotor Blade Graph (left) and Rotor Blade Failure Rate Graph (right)

**Discussion and Conclusion**

In roller mill, the component replacement is conducted on the damaged component only or it could be said breakdown maintenance system. This makes the reliability of roller mill becomes lower and cause high cost of component inventory. If a higher reliability system is expected, it’s better to do predictive/preventive maintenance so the component procurement could follow the overhaul schedule and it’s much easier to predict. Therefore the conclusions are:

1. The system that has the highest total of unscheduled downtime is roller mill system. This system is divided into 4 subsystems, which are grinding subsystem, drying and transporting subsystem, separating subsystem and hydraulic subsystem.
2. In roller mill system, it was obtained that 87 components are used for maintenance activity. From these components, there are 19 components that experiencing reclassification from non-routine component to routine component.
3. There are 9 components which are in wear out phase marked with components condition starts to deteriorate and 10 components which are in burn-in phase caused by design or production error, installation error or operator error. The components that are in wear out phase need components replacement to reduce the occurrence of fatal damage probability while the components that are in burn-in phase need the correct installation and maintenance so its reliability could be reobtained.
4. Procurement for 19 components that are experiencing reclassification shouldn’t be done regularly in a certain time interval, but those components will be held regularly on conditional which means
the procurement is only conducted when it will be conducted service activity or overhaul to avoid overstock and stock out components by still considering the procurement lead time.

References

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