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Reliability Analysis of Hydraulic Components and Excavator Engine in Maintenance of Mine Heavy Equipment

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Abstract
This research aims to analyze the reliability analysis of hydraulic components and excavator engine in maintenance of mine heavy equipment. In this research determined reliability and critical component replacement interval of hydraulic system and engine unit excavator. Determination critical component replacement interval of hydraulic system and engine was done by using minimal maintenance cost model. Reliability value of excavator EH 4 is the lowest compared to EH 3 and EH 5 at the time t is equal to 96 hours. Reliability value of Excavator EH 4 is 0.002, EH 5 is 0.33 and EH 3 is equal to 0.49. Component with maximum replacement interval is fuel filter Excavator EH 4 that is equal to 432 hours and component with minimum replacement interval is component Hose Pilot of excavator EH 3 that is 22398 hours
Keywords: *Reliability, Critical components,* hydraulic, excavator

1. Introduction

With the increasing global industrial competition, the reliability of equipment (equipment reliability) is a business requirement that is needed by every company [Campbell, 2001]. The company that owns the equipment or a powerful engine will be able to carry out the operation or production to the maximum. So that production targets can be met and continually improved from the previous year.

The value of reliability (reliability) of a machine is a measure of the performance of a system. If a machine has high reliability (close to the value 1) the probability of the possibility of such machinery or equipment susceptible to interference / damage is rare. The conditions will be achieved if the unit is operated in accordance with procedures and treatments performed periodic maintenance. The existence of appropriate decisions in replacement strategy optimization components, especially the determination of component replacement interval [Jardine, 1973], will be able to improve the reliability of the system and keep the engine always operates.

The reliability of the system must be backed by the reliability of each component that make up a system. Therefore, improving reliability oriented component (component-oriented) will be easier, faster, with financing more effective to replace components or fix it, so that the machine returns can operate [Burrows and David, 2006], while the damage to the components it can be repaired for further use on other equipment appropriate in the future

Excavators are heavy equipment used in mining activities limestone that serves as an unloading limestone into dumptruck in Area I's Ministry of Mines PTSP. The cause of disruption Excavator damage that often occurs is the interference with the hydraulic system and engine components as seen in Figure 1.

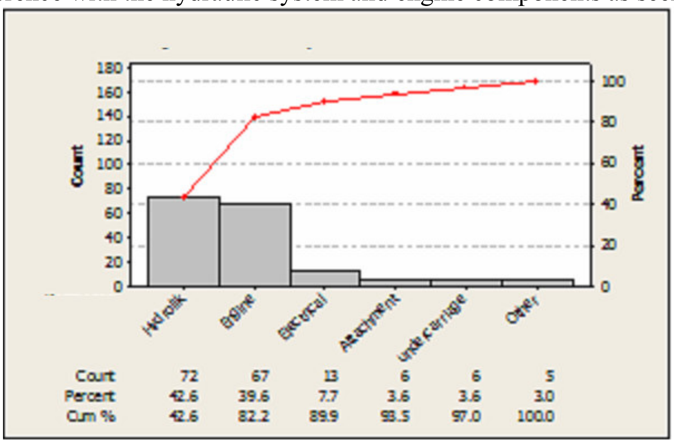

Figure 1. Diagram Pareto Causes Excavator Shutdown

Malfunction of the hydraulic system and engine properly will make the performance Excavators be no maximum. Because this section is a vital component which is provides power for the excavator when operating. The important role which is owned by the hydraulic system and engine shutdown excavator and how frequently caused by damage to the hydraulic system and cause the engine needs special attention in maintenance activities and maintenance of hydraulic systems and engine excavators and good scheduling. Most of the maintenance actions performed on the hydraulic system and engine excavator usually requires shutdown (discharge operation) of the machine in question. Heavy equipment shutdown decisions are made through advance planning to seek approval from the Bureau of Maintenance of mining heavy equipment, especially to perform preventive maintenance.

At this time, the Bureau of Mines Heavy Equipment Maintenance own maintenance schedule heavy mining equipment. However, preventive care policies are applied not achieve optimal results. Because of the high costs incurred for the replacement and maintenance of heavy equipment components. So we need research that ensures the reliability of some units of excavators, EH 3, EH 4, and EH 5 particularly the reliability on these critical components are often impaired that the components of the hydraulic system and engine so that the operation can continue to run smoothly, while costs incurred to perform maintenance on the unit component can be minimized by the time interval replacement of critical components for each unit.

Under these conditions, the researchers are interested in knowing how the inspection interval tire loader and dump truck tire maintenance activity as a form of heavy equipment in the Ministry of Mines.

Research Method

The research methodology needs to be structured so that the settlement of a case study conducted more focused. The method used is the study of literature and reliability analysis with mathematical calculations. While the research objects are components of the hydraulic system of the excavator. While the collection of data retrieved from the data of the hydraulic system damage and engine components on each of the excavator, the time data replacement hydraulic systems and engine components on each excavator and data maintenance costs of hydraulic systems and engine components on each excavator. Then the reliability analysis performed to determine the reliability of each unit Excavator.

To determine the reliability of each unit Excavator steps are as follows;

1. Determine the time between failures of each Excavator
2. Determine the distribution of damage each Excavator
3. Determine the distribution parameters of damage Excavator
4. Test match Excavator damage distribution
5. Determine the reliability function Excavator

Using the model Age replacement, the replacement timing of hydraulic components EH 3 is based on the following steps;

1. Determine the replacement cost of damage prevention (C_P / cost of preventive replacement)
2. Determine the replacement cost of damage (C_f / cost replacement failure)
3. Determine f (t) or a probability density function (probability density function) of a component malfunction
4. Determine T_p or the time required for preventive replacement, constant value and assumed for 1 hour.
5. Determine T_f or the time required for the replacement of damage (failure replacement).
6. Determine the total expected cost of reimbursement per unit time C (t_p) with minimum replacement cost criteria

Reimbursement policies are doing preventive replacement when the equipment has reached a specific age tp, and additionally perform replacement failure at any given moment. The policy cycle, there are two possibilities, which is illustrated in Figures 2 and 3.

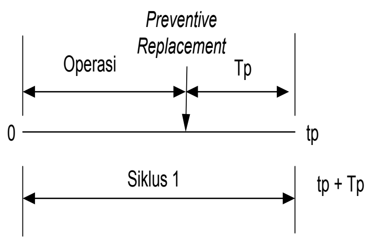

Figure 2 Possible of Cycle 1

Or the possibility of a second;

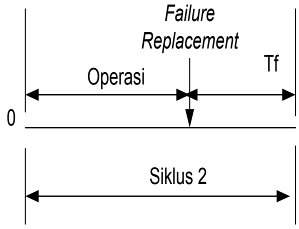

Figure 3 Possible of cycle 2

In the first cycle, component life according to the time plan (tp), the time to perform preventive replacement. After the interval the operating unit there is no damage to the components. While on the second cycle, the unit stopped operating because of damage to the component, and the reimbursement of damage (failure replacement). That is because the damage component can not be determined precisely and can occur at any time (when Necessary).

The total expected cost of reimbursement per unit time C (t) is the total expected cost of replacement per cycle divided by the expected length of the cycle, as formulated in the following equation, namely;

$C(t_p+ = \frac{\text{expectations for total cost of replacement per cycle}}{\text{long-expected cycle}}$

Expectations cycle length in this case is assumed (the cost interval of operation of the unit), so that the long-expected cycle is (charge cycle preventive replacement x probability of cycle preventive replacement) + (cost of the cycle of failure replacement x probability of cycle failure replacement).

Because, $F(t^p) = 1 - R(t^p)$

Meaning the total expected cost of replacement per cycle is formulated as follows;

$$C_p \; x \; R(t_p) + C_f \left[1 - R(t_p)\right]$$

$$F(t^p) = \int_0^{t_p} f(t_p)\,dt$$

Meaning the total expected cost of reimbursement per unit time is,

$$C(t_p) = \frac{C_p . R(t_p) + C_f . \left[1 - R(t_p)\right]}{(t_p + T_p)R(t_p) + \left[M(t_p) + T_f\left[1 - R(t_p)\right]\right]}$$

Where:

1. C_P is the cost of preventive replacement
2. C_f is The cost of failure is replacement
3. $f(t)$ is the probability density function (probability density function) of a component malfunction
4. T^p is the time required for preventive replacement
5. T^f is the time required for the replacement of damage
6. $R(t^p)$ is the value function of the reliability of critical components
7. $M(t^p)$ is average time of damage critical components for replacement at the time (t^p), the value of MTBF.

Result and Discussion

Reliability Analysis of Excavator

Reliability or reliability is the probability of the unit's ability to operate in accordance with the desired function within a specific time interval. The higher the value the reliability of the unit (near the value 1), then the states ability unit can operate well, and vice versa.

The reliability of the excavator can be determined after calculating the time between the damage done to the unit. In this case, the measure used is the Mean Time between Failure (MTBF), which is the average period between failures (h) of a unit. The longer the MTBF, the reliability is getting better. This measure states that how often a failure occurs on a unit / machine. MTBF determination is done by using the concept of statistical sciences. So it can be known with certainty how appropriate maintenance actions against the failure / damage to the unit.

Based on the reliability calculation, the excavator which has the lowest level of reliability is EH 4. While the highest reliability in the EH 3. Due to the excavator unit has a parallel system configuration, then damage to one unit will not affect the other units.

Reliability Analysis of Excavator EH 3

The calculation shows that the average time between failures in EH 3 (MTBF) amounted to 266.01 hours. Distribution damage EH 3 follow a Weibull distribution with parameter values α = 187 105 (stating age), and β = 1,103 (stating the form of the curve). Great shape parameter value of 1 is highly at risk of failure. This means that failure is increasing in line with the function of time t. The reliability value during the first 24 hours operated unit is equal to 0852.

Excavator EH 3 has the highest reliability than other excavators, the overhaul carried out within the framework of the treatment of the excavator EH 3 that has long operated. Overhaul of the excavator EH 3 causes an increase in its performance. This is what causes the value of the reliability of this excavator is higher when compared to other excavator, although other excavator EH, EH 4 and 5 are newer than the excavator EH 3

Reliability Analysis of Excavator EH 4

The average time between failures on EH 4 (MTBF) obtained at 117 576 hours. Distribution damage EH 4 follows the Weibull distribution. Value parameter α = 106 827 (stating age), and β = 1,244 (stating the form of the curve). During the first 12 hours, the value of the reliability of the unit is 0876, the value is the lowest value compared with other units.

Excavator EH 4 has a value lower than the reliability of most other excavator operating in the area of I Department of Mines PTSP. This is due to the severity of the workload and the work site excavator. Besides frequent overtime carried out by the Ministry of Mines PTSP to meet production targets cause excavator working EH 4 was by itself exceeds the working hours should apply at the Department of Mines PTSP 12 hours per day. The use of other components, namely components EH 3 (EH 3 can be used for EH 4 and 3 are the same type excavator EX-1800) to replace the faulty component EH 4 is another thing that causes the low value of the reliability of EH 4.

Reliability Analysis of Excavator EH 5

In the calculations showed that the average time between failures on EH 5 (MTBF) amounted to 180 283 hours. Distribution damage EH 5 also follows the Weibull distribution. Value parameter α = 163 185 (stating age), and β = 1,166 (stating the form of the curve). The reliability value during the first 24 hours operated unit is equal to 0795.

Excavator EH 5 has a value lower reliability than the excavator EH 3 though 5 EH EH newer than 3. This is due to the severity of the workload and the work site excavator. Burden of work to be done by the excavator caused by EH EH 5 5 has a loading capacity than most of the other so that EH 5 excavator to work extra ffor can meet production targets. Besides frequent overtime carried out by the Ministry of Mines PTSP to meet production targets cause excavator working EH 5 was by itself exceeds the working hours should apply in Mine PTSP ie 12 hours per day.

Reliability Analysis of Hydraulic Components and Engine Excavator

Hydraulic components and engines is a very important component in implementing the excavator operation, which includes limestone into a dumptruck. If the components are susceptible to interference damage, the unit can not function properly. The calculation of the reliability of each component of hydraulic and engine is based on the amount of damage the highest priority. Analysis tools used are Pareto diagram.

Hydraulic components are often damaged on each excavator is a component hose, where the hose is often damaged almost the same bucket cylinder components Hose, Hose cylinder arm, pilot Hose, Hose swing motors. Other hydraulic components are often damaged O-ring is a component of hose. While the components are often damaged in the engine is a component of the fuel filter.

Often the damage caused to any hose component type, component and component fuel filter O-ring hose caused by the NII severity of the work to be performed by the component. Hose is not only used in hydraulic systems but linked to the overall excavator. Things that often cause damage to the hose component is friction fellow hose consequently the weight of the work done by hose, hose also further damage caused by hose age who have passed through the life time recommended on the manufacturer. Damage to the fuel filter component is also caused by the weight of the work to be performed by the component.

Weighing workload carried by the hose components, fuel filters, and the O-ring hose and vital functions possessed by these components causes the required special attention in the maintenance of these components.

Proper maintenance of the components will be able to improve performance and reduce the occurrence shut down excavator due to damage to the component.

Reliability Analysis of Hydraulic Components and Engine EH 3

Critical components include a hydraulic bucket cylinder Hose, Hose cylinder arm, pilot Hose, Hose swing motors, O-ring hose. The engine is a critical component of the fuel filter. Based on the calculation, that the distribution of the damage these components follow a Weibull distribution and exponential distribution. The components of the Weibull distribution among other pilots Hose, Hose swing motors, O-ring hose and fuel filter. Hose pilot parameter values α = 672 733, while the value of the parameter β = 0711. Hose swing motors which is one of the critical components of the hydraulic system has a parameter α = 387 452, and β = 0819. And the fuel filter parameter α = 434 099, β = 1,107. While the O-ring hose has a value of α = 1876.887, and β = 1,367.

Components that are exponentially distributed Hose and Hose cylinder bucket cylinder arm. Parameter distribution is λ, and has a value of 0.0001078 and 0.0001142. During an interval of 360 hours, a score reliability of critical components and engine hydraulic highest bucket cylinder hose with a value of 0.9646. The lowest is O-ring hose components with a value of 0.1714. That is, these components are very susceptible to corruption. Need to be prepared so that the allocation of funds for the replacement of faulty components.

The damage was done to the hose component of any kind caused by the NII severity of work to be done by the hose. Hose is not only used in hydraulic systems but linked to the overall excavator. Things that often cause damage to the hose component is friction fellow hose consequently the weight of the work done by hose, hose also further damage caused by hose age who have passed through the life time recommended on the manufacturer.

Reliability Analysis of Hydraulic Components and Engine EH 4

Critical components include the Hose cylinder hydraulic bucket, pilot Hose, Hose swing motors, O-ring hose. The engine is a critical component of the fuel filter. Based on the calculation, the distribution of component damage is following the Weibull and exponential distribution with varying parameter values. Weibull distribution component is a bucket cylinder hose, O-ring hose and fuel filter. Hose cylinder bucket parameter values α = 3557.829, while the value of the parameter β = 1,123. fuel filter parameter α = 220 841, β = 1,294. While the O-ring hose has a value of α = 941 635, and β = 0988.

Components that are exponentially distributed pilot Hose and Hose swing motors. Parameter distribution is λ, and has a value of 0.00037921 and 0.00032401. During an interval of 360 hours, a score is the highest reliability of critical components is a pilot hose with a value of 0.8899. The value of the lowest reliability is a component of the fuel filter with a value of 0.0001. Need to be prepared so that the allocation of funds for the replacement of faulty components.

The damage was done to the hose component of any kind caused by the NII severity of work to be done by the hose. Hose is not only used in hydraulic systems but linked to the overall excavator. Things that often cause damage to the hose component is friction fellow hose consequently the weight of the work done by hose, hose also further damage caused by hose age who have passed through the life time recommended on the manufacturer.

Reliability Analysis of Hydraulic Components and Engine EH 5

Critical components include a hydraulic bucket cylinder Hose, Hose cylinder arm, pilot Hose, Hose swing motors, O-ring hose. The engine is a critical component of the fuel filter. Based on the calculation, the distribution of component damage is following the Weibull and exponential distribution with varying parameter values. Weibull distribution component is a pilot Hose, O-ring hose and fuel filter. Parameter Hose pilot α = 1032.25, while the value of the parameter β = 0749. O-ring hose has a value of α = 1130.86, and β = 1,294. Fuel filter has a value of α = 585 405 and β = 1,179.

Components that are exponentially distributed Hose bucket cylinder, arm cylinder Hose and Hose swing motors. Value parameter λ are 0.00064574, 0.0001895 and 0.00024549 for each component.

During an interval of 360 hours, a score reliability of critical components and engine is the highest hydraulic cylinder hose arm with a value of 0.9339. The value of the lowest reliability is a component of O-ring hose with a value of 0.1659. Need to be prepared so that the allocation of funds for the replacement of faulty components.

Scheduling Analysis Critical Component Replacement and Engine Hydraulic Excavator scheduling of component replacements performed on components that have the highest percentage of damage. That is always a failure and will cause a shutdown excavator high, for reimbursement of damage. Analysis tools used in this case is the Pareto diagram.

From the data processing is done to obtain interval optimal replacement of critical components of hydraulic and engine respectively excavator, it was found that in general the replacement intervals critical component is not in accordance with the life time given by the factory where the components hose life time ranged between 7000 - 15,000 hours. Component hose replacement interval is less than 7000 hours of pilot hose components excavator EH 4; hose swing motors (in units of excavators unit EH 3, EH4, and EH 5); EH excavator bucket cylinder hose 4; and the excavator arm cylinder hose EH 3, while the life time component that passes issued by the pilot plant is a component hose, bucket cylinder hose (in units of excavators EH 3) and hose components excavator EH pilot 5. But there is also a component replacement intervals in accordance with life time issued by the manufacturer that the component bucket cylinder hose and hose components cylinder arm (On the excavator unit EH 5). The existence of several components that are not in accordance with the replacement interval life time component released by the plant caused by the frequent damage to components outside the factory due to the workload estimates are hard from the unit.

Scheduling Analysis of Critical Component Replacement Engine Hydraulic and EH 3

Scheduling replacement of critical components of hydraulic and engine EH 3 in the fuel filter components, bucket cylinder Hose, Hose cylinder arm, pilot Hose, Hose swing motors, and O-ring hose. After calculating the expected cost of replacement hydraulic hose lowest component after the component is operated for 5000 hours of engine work, at a cost of Rp 668.67 expectations replacement. While the check valve components, change the oil operated for 7000 hours at a cost of Rp 557.87 expectations replacement.

Repair damage to the components of the hydraulic hose lasts for 4 hours, and repair damage to the check valve lasted 4.5 hours. The assumption was that at that time, the components to be replaced and tooling equipment (eg, keys) in use are available so that mechanics can directly replace existing components. In this case, the mechanical assumed to always be ready to work when the replacement arrives (high motivation).

Scheduling Analysis of Critical Replacement Parts Hydraulic and Engine EH 4

Scheduling replacement of critical components and engine EH 4 hydraulic components Hydraulic hose and hose o-ring. After calculating the costs of component replacement hydraulic hose lows after the component is operated for 10000 hours of working machines, at a cost of Rp 461.01 expectations replacement. While on the o-ring component, change the oil operated for 1000 hours at a cost of Rp 443.60 expectations replacement. Replacement of the short is because the components o-ring often suffers damage due to the high frequency of use with pressure.

Repair damage to the components of the hydraulic hose lasts for 4.5 hours, and repair damage to the o-ring lasts 4 hours. The assumption was that at that time, the availability of hose and o-rings to be replaced, as well as equipment and utensils (such as keys) in use are available so that mechanics can directly replace existing components. In this case, the mechanical assumed to always be ready to work when the replacement arrives (high motivation).

Scheduling Analysis of Critical Replacement Parts Hydraulic and Engine EH 5

Scheduling replacement of critical components of hydraulic and engine EH 5 performed in the US and hose components pin lift cylinder. After calculating the cost of replacement parts AS hose lows after the component is operated for 10000 hours of working machines, at a cost of Rp 763.70 expectations replacement. While on the lift cylinder pin components, change the oil every 1000 operating hours of work at a cost of USD 1737.68 expectations replacement. Repair damage to the components of the hydraulic hose lasts for 5 hours, and repair damage to the lift cylinder pin lasted 6 hours.

Conclusions and Suggestions

Conclusion

From the research conducted, it was concluded as follows:

1. From the plot the value of reliability R (t) components for t = 96 hours on any excavator. From the graph reliability (Figure 4.2) it can be seen that the excavator EH 4 is an excavator with the lowest reliability later excavators and excavator EH EH 5 3. Excavator (EH 4) has a reliability of 0.002, excavator EH 5 has a reliability of 0:33 and 3 EH excavators have reliability at 12:49.
2. Shutdown excavator is most often caused by damage to the hydraulic system and engine components. Critical Components Hydraulic System is O-ring Hose and Hose. While the Critical Components Engine is Fuel Filter.
3. Frequency Distribution of Time Between Critical Component damage to the hydraulic system and engine consists of two types of distribution namely weibull distribution and the exponential distribution. Weibull distribution of critical components which are components of fuel filter and O-ring Hose (excavator EH 3, 4 EH, EH 5); pilot hose (3 excavator EH, EH 4); hose excavator swing motors EH 3; EH excavator bucket cylinder hose 4. The critical components are exponentially distributed pilot hose and hose components of motor swing (in units of excavators EH 4); swing motors hose, bucket cylinder hose and hose cylinder arm

(on the excavator unit EH 5).

4. The maximum and minimum change interval equal to each excavator is the maximum is a component of the pilot hose. Where the replacement interval for excavator EH 3 for 133 weeks, excavator EH 4 hose replacement every 29 weeks, and the excavator EH 5 every 85 weeks. While most minimum is a component of the fuel filter. Where the replacement interval for excavator EH 3 for 4 weeks, excavator EH 4 hose replacement every 1 week, and excavator EH 5 hose replacement every 3 weeks.

Suggestion

after doing research on the excavator which operates about determination of critical components replacement interval of hydraulic system and engine, the advice that can be given is:

1. With the results of this research can proceed more extensive research is in terms of planning scheduling ordering parts so that the components to be replaced can be provided at the time will be replaced.
2. At the time of the replacement of components, can be carried out inspections for other components.
3. The results of this study can be used to schedule the replacement interval of critical components and engine hydraulic system on each unit excavator operating in the area of I Department of Mines PTSP.

References

Adianto, Hari, Penerapan Model Preventive Maintenance Smith dan Dekker di PD. Industri Unit Inkaba, *Jurnal Teknik Industri Vol. 7, No. 1*, Juni 200, pp. 51 – 60.

Campbell & Jardine. *Maintenance Excellence*. New York, Marcell Dekker Inc., 2001.

Ding, Quofu, et.al, Active Vibration Control of Excavator Working Equipment with ADAMS. *International ADAMS User Conference,* 2000.

Gani, A. Z., et.al, *Maintenance Management I*, PT. Petrakonsulindo Utama, Bandung.

Jardine, A.K.S., *Topic in Operation Research, Maintenance, Replacement and Reliability.* New York, Pitman Publishing , 1973.

Ramakumar, R., *Engineering Reliability; Fundamental and Aplications*, Prentice-Hall International, Englewood Clifs, New Jersey, 1993.

Sina, Ibnu, Penjadwalan Pemeliharan Komponen Mesin Pulp dengan Kriteria Minimasi Biaya, *Tugas Akhir* Teknik Industri, 2004.

Smith, David J., *Reliability*, *Maintainability and Risk, Practical Methods for Engineers, Fourth Edition,* Clays Ltd, Britain, 1993.

Walpole, Ronald E., Myers, Raymond H., Myers, Sharon L. *Probability and Statistic for Engineers and Scientist*, New Jersey, Prentice Hall International, 1998.

Wolstenholme, Linda C. *Reliability Modelling* : *A Statiscal Approach*. London, Charman & Hall/ CRCR, 1999.