Failure analysis of excavator hydraulic pump

H Hidayat1,*, D Aviva1, A Muis1, A Halik1, S Sudarsono2, S Pranoto3 and D Cahyadi4

1 Department of Mechanical Engineering, Politeknik Negeri Samarinda, Kalimantan Timur, 75131, Indonesia
2 Department of Mechanical Engineering, Universitas Halu Oleo, Kendari, 93132, Indonesia
3 Department of Electrical Engineering, Politeknik Negeri Ujung Pandang, Makassar, 90245, Indonesia
4 Department of Design, Politeknik Negeri Samarinda, Kalimantan Timur, 75131, Indonesia

*Corresponding author: hidayat@polnes.ac.id

Abstract. Hydraulic pump failures may be related to hardware or problem in oil. In this study, the excavator hydraulic pump failures were investigated by using visual observed and measuring the part component. The disassembled process of the pump was performed considering the manual part book of the excavator hydraulic pump. The abrasive wear on the pump slipper and swash plate was observed by comparing the guidelines for the reusable part. The value of more than 1.07 mm clearance within piston and cylinder bore was measured then the results over the allowable limit considering the manual part book. Properly analyzing of component failure can provide valuable information about what caused the failure and thus can be to avoiding future unscheduled downtime.

1. Introduction

All pumps can be classified into two, namely positive and non-positive displacement. A hydraulic pump is a class of positive displacement machine in fluid applications to provide hydraulic flow to fluid powered devices such as heavy equipment, heavy vehicle, tractor, etc. For heavy equipment in construction or mining such as excavator, hydraulic power provides to move booms, arm or bucket. It is often easy the main equipment in local good mining breakdown due to hydraulic system failure. A hydraulic pump failure can be caused by several factors for example, poor system design, using low quality fluid and poor contamination control.

Several researchers on the failure analysis and diagnostic of hydraulic pumps have been reported. A fault diagnosis method of an intelligent hydraulic pumps considering a non-linear unknown input observer had been proposed [1]. The method was great significance in improving the reliability of the intelligent hydraulic pump system. The other method is a diagnosis ball bearing of hydraulic pump applied using a vibration signal for the maintenance [2]. An engineering driven performance degradation analysis method considering the nature of mechanical wear of hydraulic pumps had been proposed [3]. Another study concerned with early fault diagnosis of hydraulic pump that are the heart of hydraulic tube tester [4]. The result indicate that the proposed approach detecting the signal of hydraulic pump. A study on the causes, reasons and solution due to effects of the exaggerated elastic
deformation and the fracture, such as the slipper and retainer that leads to the loss of performance of the axial piston pump, had been carried out [5]. A work based on the study of the thermoelastic deformation mechanism of the slipper retainer which is revealed by its deformation and fracture, had been done [6]. A method on the basis of the elastohydrodynamic lubrication model to analyze the wear behavior of the swash plate had been presented [7]. The new intelligent fault diagnosis scheme based on many signal processing techniques had been proposed [8]. A study presents the mathematical model of a hydraulic axial piston pump developed in order to replicate the dynamic behavior of the swash plate for PHM application [9].

As far as the previously published from the other researcher, there is no study on failure hydraulic pumps on main equipment such as an excavator. The purpose of this study is to analyze the failure of the hydraulic pump on heavy mining equipment, in this case, is the excavator. The hydraulic pump was dissembled to investigate the condition of the part inside the hydraulic pump, such as the piston, retainer and cylinder block. All component was observed by visual inspection or measuring the dimension considering the manual part book.

2. Method

2.1. Specification

The hydraulic pump used in this research is taken from Excavator Hitachi 1200-6. This excavator is a revolutionary hydraulic excavator in which takes advantage of the latest developments technology by Hitachi. The Excavator Hitachi 1200-6 was designed and built to apply in major works such as mines and civil engineering construction projects. The specifications of the engine are shown below.

Merk : Hitcahi Zaxis 1200-6  
Serial Number : 10Z10536  
Model : CumminsQSK23 C  
Cylinder : 6 Cylinder, inline  
Fuel System : Direct Injection Type  
Firing Order : 1-5-3-6-2-4  
Speed : 1800 rpm  
Oil Engine : 18.5 gal

Firstly, failure analysis of the hydraulic pump was performing by disassembling and assembling procedures to find out the component of the pump is still usable or has to be replaced. Secondly, the component was measured, considering the specification range measurement of manual parts.

2.2 Observation (Visual and Measurement)

The disassembly hydraulic pump had been done considering the procedure from the manual part book. The hydraulic pump component was disassembled by using specific tools.

Figure 1 shows the disassemble hydraulic pump component. The component of the hydraulic pump was released by using some special tool kit. Then, the swash plate which is used as controller oil flow to the system, was removed from the top surface of the hydraulic pump. Then, the plunger was removed from the cylinder block located inside the hydraulic pump.
The cylinder block in which component of the hydraulic pump used as a house of the driven shaft is shown in figure 2.

![Figure 2. Cylinder Block](image)

The cylinder block is also used to compress the oil by plunger and barrel so that the oil from the hydraulic pump has high pressure. Finally, removed all spring which located under the housing of plunger. All components inside the hydraulic pump were investigated by measurement or visual inspection. Measurement of component is the process of observing and recording the observations collected as part of this research. The component was measured to compare with the manual part book in order to define that the component is still reusable or not. As for the visual inspection, the condition of the component was observed by viewing or touching, considering the manual parts book.

### 3. Result and Discussion

Figure 3 shows the abrasive on the piston pump. Abrasive wear usually occurs when a hard rough surface slides across the other surface. In this case, abrasive wear in this area due to frictional force between slipper and swash plate. The swashplate axial piston is a common hydraulic pump used in heavy equipment unit. High pressure operation condition and also interference between valve plate and cylinder block causes abrasive wear on slipper of piston pump.

![Figure 3. Abrasive wear on piston pump slipper](image)

Figure 4 shows the cracking on slipper retainer plate. The crack of the slipper retainer is generally occurce by phenomenon of the slipper getting stuck in the cylinder block. The motion of slipper retainer in axial direction is related to the parts of piston and cylinder block.
Figure 4. Cracking on slipper retainer plate

Figure 5 shows the abrasive wear on the swash plate. Swash plate is one of the components in the hydraulic pump referred to as the rotator group. The displacement of an axial piston pump is controlled by the swash plate angle. The most common case of failure accompanied with swash plates is abrasive wear. The slipper of piston slide along the surface of swash plate. Even though the slipper of the piston is made of the same steel as swash plate, there is no carbide detachment and wear comes from contaminant of the fluid.

Figure 5. Abrasive wear on a swash plate surface

Figure 6 shows measuring the clearance of the piston pump. The clearance between the piston pump and the cylinder bore was measured. The allowable clearance based on the manual part book is 0.94 mm. Then, the measuring result between piston and cylinder bore was found more than 1.07 mm. The measuring result of clearance within the cylinder bore is shown in table 1. Increasing nominal clearances between the rate and stroking piston-cylinder pairs exhibited acceptable pump performance. In this case, further increase in clearance within the cylinder bore and piston pump has indicated a major degradation of the performance of the pump.

Figure 6. Measuring the clearance of piston pump
Table 1. Measuring result of clearance within cylinder bore

| No. | Piston   | Measuring result |
|-----|----------|------------------|
| 1   | Piston 1 | 1.09             |
| 2   | Piston 2 | 1.07             |
| 3   | Piston 3 | 1.07             |
| 4   | Piston 4 | 1.08             |
| 5   | Piston 5 | 1.08             |
| 6   | Piston 6 | 1.07             |
| 7   | Piston 7 | 1.07             |
| 8   | Piston 8 | 1.09             |
| 9   | Piston 9 | 1.09             |

4. Conclusions
The failure analysis of the excavator hydraulic pump had been investigated by using visual inspection and measuring each part of the pump. The visual inspection of the pump had been performed considering the manual part book from the dealer. The most common of failure in hydraulic pump results from oil contamination, blocked or restricted pump inlet, low level of oil and pump case over-pressurization.

References
[1] M. A. Zhonghai, W. Shaoping, S. H. I. Jian, L. I. Tongyang, and W. Xingjian, “Fault diagnosis of an intelligent hydraulic pump based on a nonlinear unknown input observer,” Chinese J. Aeronaut., vol. 31, no. 2, pp. 385–394, 2018.
[2] T. Kim, Y. Jeon, and M. G. Lee, “A Study on Failure Diagnosis System for a Hydraulic Pump in Injection Molding Machinery Using Vibration Analysis,” J. Korean Soc. Manuf. Technol. Eng., vol. 22, no. 3, pp. 343–348, 2013.
[3] Z. Ma, S. Wang, H. Liao, and C. Zhang, “Engineering-driven performance degradation analysis of hydraulic piston pump based on the inverse Gaussian process,” Qual. Reliab. Eng. Int., vol. 35, no. 7, pp. 2278–2296, 2019.
[4] Z. Zhao, M. Jia, F. Wang, and S. Wang, “Intermittent chaos and sliding window symbol sequence statistics-based early fault diagnosis for hydraulic pump on hydraulic tube tester,” Mech. Syst. Signal Process., vol. 23, no. 5, pp. 1573–1585, 2009.
[5] G. Haidak, D. Wang, and E. L. E. Awong, “Modelling of deformation and failure of slipper-retainer assembly in axial piston machine,” Eng. Fail. Anal., vol. 111, p. 104490, 2020.
[6] G. Haidak, D. Wang, and E. Shiju, “Research on the thermo-elastic deformation and fracture mechanism of the slipper retainer in the axial piston pumps and motors,” Eng. Fail. Anal., vol. 100, pp. 259–272, 2019.
[7] J. Ma, J. Chen, J. Li, Q. Li, and C. Ren, “Wear analysis of swash plate/slipper pair of axis piston hydraulic pump,” Tribol. Int., vol. 90, pp. 467–472, 2015.
[8] Y. Lan et al., “Fault diagnosis on slipper abrasion of axial piston pump based on extreme learning machine,” Measurement, vol. 124, pp. 378–385, 2018.
[9] A. Bedotti, M. Pastori, F. Scolari, and P. Casoli, “Dynamic modelling of the swash plate of a hydraulic axial piston pump for condition monitoring applications,” Energy Procedia, vol. 148, pp. 266–273, 2018.