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## **Performance of Boom Cylinder Repair Mechanism and Auto Lubrication System of EX 2500 Hitachi Excavator**

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### **ABSTRACT**

*Excavators is one of the heavy equipment used to do transport, excavation, loading work that is operated using hydraulic energy. Excavator construction consists of three main parts, which consist of undercarriage, upper structure, and front attachment. During operation, one of the front attachment parts that has the highest performance is the boom cylinder actuator because it carries the entire load of the front attachment activity. The continuous work of the hydraulic boom cylinder will definitely suffer damage that cannot be avoided and can interfere with the performance of the unit. The damage is in the form of external leaks, internal leaks, scratches, and wear. This research aims to identify the types of damage, causal factors, and impacts caused by boom cylinder damage, explain the boom cylinder maintenance system and process, identify bends in the cylinder rod, and provide a reference price for repairing the Hitachi excavator boom cylinder. The methods used in this research are literature study, observation, and interviews. The results indicate that damage can be minimized by performing scheduled maintenance, such as selecting and replacing the right hydraulic oil and grease, cleaning the hydraulic oil cooler every 500 hours, replacing the oil filter every 250 hours according to the maintenance schedule, performing the inspection process during daily checks, operating the unit in the right way, avoiding modifications that can cause overloading, and performing oil analysis every 250 hours to ensure high availability of the unit as planned.*

**Keywords:** *Boom Cylinder, Excavator, Performance*

## INTRODUCTION

Excavators are the most widely used heavy equipment in the mining sector because of their function to dig, therefore excavators are very compatible in mining areas and in development construction (Hidayat & Putro, 2019). Excavators are heavy equipment with three main parts consisting of undercarriage, upperstructure and front attachment (Andrianto & Sulistyanto, 2022). The three main parts of the excavator each have a primary function of digging, excavating, and lifting or moving materials. In performing these functions, all front attachment activities will be supported by the boom cylinder. During operation, excavators are often rendered inoperable due to damage to the boom cylinder (Iskandar et al., 2021).

Boom cylinders are components on the front left and right of the excavator. This component is used to move the bucket optimally by using hydraulic oil flow (Ardianto & Putro, 2019). The hydraulic system has a significant role in the operation of heavy equipment. The basic principles of hydraulics are applied to the hydraulic system for implement, steering system, breaking system, and power train system (Subarkah et al., 2020). In order to repair or minimize damage to boom cylinders, a correct and efficient maintenance strategy is required to keep the unit availability rate above 90% per year. This maintenance is intended to maintain the condition of this equipment before it is permanently damaged. Basically, maintenance is conducted to prevent unexpected damage from occurring and to recognize circumstances that can cause production facilities to malfunction when used in the production process (Haikal, 2019).

PT Hexindo Adiperkasa Tbk is a distributor of Hitachi heavy equipment serving sales and after sales services, both in the mining, infrastructure and forestry sectors. The largest contribution of heavy equipment sales, especially excavators, is supported by the mining sector. In the mining sector, high availability of excavators is an important foundation for achieving planned production targets (Liu et al., 2022).

Due to the background of various problems to ensure the reliability of the unit and how to maintain the boom cylinder on the excavator, this research aims to identify the types of damage, causal factors, and impacts caused by boom cylinder damage; explain the boom cylinder maintenance system and process; identify cylinder rod bending; and provide a reference price for repairing the Hitachi excavator boom cylinder.

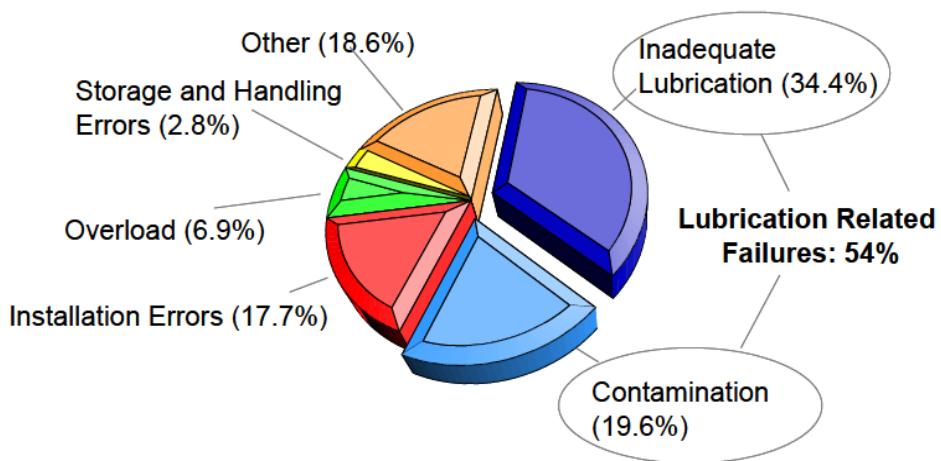
## RESEARCH METHODOLOGY

There are three research methods used in this research, which are library research method, observation method, and interview method. The literature research method is a method of collecting data by reading and reviewing various literature by referring to manuals, operational principles, part catalogs, and others (Wishinta & Suroso, 2022). Meanwhile, the observation method is data collection through direct observation in the field and systematic notes on the research object (Ling Jen, 2023). While the interview method is a method of collecting data through direct interviews with employees of the Kideco and Remanufacturing divisions at PT Hexindo Adiperkasa Tbk who have information and data related to the research topic, which can provide assistance and explanation of the research problem.

## RESULT AND DISCUSSION

### Malfunction Causes of Boom Cylinders

According to a factory-conducted study at a major component manufacturer, it was reported that more than 50% of machine failures on excavators were caused by improper lubrication, or the inappropriate type of lubricant (hydraulic oil and grease) used on the machine and contamination that entered into the hydraulic system.



**Figure 1.** Component Major Damage Tabulation

Source: Lubretec (2023)

The damages of the boom cylinder can be categorized as follows:

**Table 1.** The Damages on the Boom Cylinder

No.	Damage	Damaged Component	Cause	Picture
1.	Internal Leak	Ring Seal Slide Ring O-Ring	Scratch Contamination Overheat	
2.	External Leak	U-ring Ring Back Up Seal Dust O-ring	Scratch Contamination Overheat	
3.	Scratch	Cylinder rod Cylinder tube Cylinder Head Piston rod	Contamination	
4.	Wear	Eye tube Eye rod Pin Bushing	Auto lubrication does not function properly	

Source: Processed Data of Researchers (2023)

## Repair of Boom Cylinder

### 1. Disassembly Boom Cylinder

- a. Place the boom cylinder on the benchwork.



**Figure 2.** Boom Cylinder Benchwork

Source: Personal Documentation of Researchers

- b. Remove all accessories attached to the cylinder, such as pipes, joint blocks, and slow return valves.



**Figure 3.** Boom Cylinder Piping

Source: Personal Documentation of Researchers

- c. Move the boom cylinder to the rotary cylinder bench machine to facilitate rod removal with the overhead crane.



**Figure 4.** Lifting Boom Cylinder

Source: Personal Documentation of Researchers

- d. Attach a clamp to the boom cylinder and tie the eye tube to prevent it from falling when positioned vertically.



**Figure 5.** Rotary Cylinder Benchwork

Source: Personal Documentation of Researchers

- e. Position the boom cylinder from horizontal to vertical with the rotary cylinder bench machine.



**Figure 6.** Boom Cylinder Positioned Vertically

Source: Personal Documentation of Researchers

- f. Remove the cylinder head bolts using hydrolic torque or impact gun. Leave two bolts unremoved so that when the cylinder rod is removed, the cylinder head does not come off near the eye rod.



**Figure 7.** Removing The Cylinder Head Bolts

Source: Personal Documentation of Researchers

- g. When fully extended, remove the two remaining bolts so that the cylinder tube and rod can be separated during the inspection and measurement process.



**Figure 8.** Disassembling the Cylindrical Boom  
Source: Personal Documentation of Researchers

- h. Move the cylinder rod to the workbench. Tie the eye rod using the fastener table to clamp the rod so that the rod does not rotate when the piston nut is loosened.



**Figure 9.** Fastener Table  
Source: Personal Documentation of Researchers

- i. Loosen the piston nut with the hydraulic piston and energpac.



**Figure 10.** Special Tools  
Source: Personal Documentation of Researchers

- j. Remove the piston slowly by hand. Then, lift the piston with a crane, as well as the cushion bearing.



**Figure 11.** Disassembling the Piston

Source: Personal Documentation of Researchers

- k. Position the cylinder head to the end of the rod to make it easier to remove from the rod using a crane.



**Figure 12.** Disassembling the Head Cylinder

Source: Personal Documentation of Researchers

## 2. Inspection and Measurement

### a. Piston

Check the condition of the piston surface, piston groove surface and seal group seat (seal ring, ring slide, o-ring) for corrosion or scratches.



**Figure 13.** Piston Inspection

Source: Personal Documentation of Researchers

b. Head Cylinder

Open and check the surface of the cylinder head and seal group (retaining ring, u-ring, back-up ring, o-ring and dust seal) and the seats. Make sure there is no scratch.

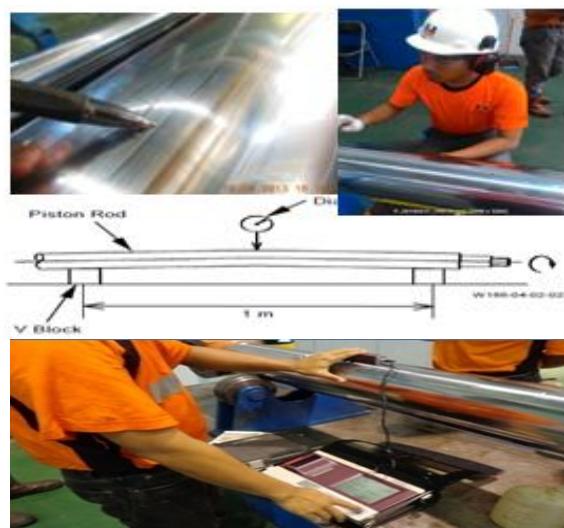


**Figure 14.** Inspecting the Cylinder Head

Source: Personal Documentation of Researchers

c. Cylinder Rod

- 1) Measuring run out or bend using a dial indicator (max 0.05 mm).
- 2) Measuring cylinder rod diameter and roughness using roughness tool (0,05 – 0,1 $\mu$ m).
- 3) Measuring chrome thickness using thickness tool (30 $\mu$ m-200 $\mu$ m).



**Standard Dimensions**

	Backhoe					
	Boom		Arm		Bucket	
	Cylinder Tube Inner Dia (A)	310 $^{+0.081}_{-0.003}$	12.2 $^{+0.0}_{-0.003}$	280 $^{+0.0}_{-0.081}$	11 $^{+0.0}_{-0.003}$	230 $^{+0.0}_{-0.072}$
Rod Dimensions (C) After	230 $^{+0.015}_{-0.025}$	9 $^{+0.0}_{-0.001}$	210 $^{+0.015}_{-0.035}$	8.3 $^{+0.001}_{-0.001}$	170 $^{+0.014}_{-0.032}$	6.7 $^{+0.001}_{-0.001}$

**Figure 15.** Cylinder Rod Inspection

Source: Personal Documentation of Researchers

d. Cylinder Tube

- 1) Measuring the inner diameter at three points, each point three times measuring in the direction of the axis (x,y,z) using a bore gauge (Standard:  $280 \pm 0,080$  reman limit:  $280 \pm 0,120$ mm).
- 2) Measuring the thickness of chrome cylinder tube (standard:  $30-200\mu\text{m}$ ).



**Figure 16.** Cylinder Tube Inspection

Source: Personal Documentation of Researchers

3. Assembly

Clean all boom cylinder components, such as cylinder tube, cylinder rod, piston, cylinder head, slow return valve and bolts.



**Figure 17.** Cleaning and Washing

Source: Personal Documentation of Researchers

- a. Cylinder Head
  - 1) Install ring retaining.
  - 2) Install O-ring and ring back up, then grease.
  - 3) Install U-ring dan ring back up (heated to 700°C for 30 minutes).
  - 4) Install dust seal dust using special tools hydrolic pressure.



**Figure 18.** Assembling Cylinder Seal Head

Source: Personal Documentation of Researchers

- b. Piston Rod

- 1) Install seal group (O-ring and ring back up). Lubricate with grease.
- 2) Install o-rings and piston seals on the outside using special tools.
- 3) Install slide ring.
- 4) Install the outer O-ring using special tools. Lubricate with grease.



**Figure 19.** Assembling Piston Seals

Source: Personal Documentation of Researchers

## c. Cylinder Rod

- 1) Place the cylinder rod on the benchwork.
- 2) Spray chemical liquid on the cylinder rod and cylinder head.



**Figure 20.** Spraying Chemical Liquid

Source: Personal Documentation of Researchers

- 3) Install the cylinder head.



**Figure 21.** Installing Cylinder Head

Source: Personal Documentation of Researchers

- 4) Install the cushion bearing with a rubber mallet.



**Figure 22.** Installing Cushion Bearing

Source: Personal Documentation of Researchers

- 5) Install the piston with a rubber mallet. Cover the o-ring and slide ring with insulating paper.



**Figure 23.** Installing Piston

Source: Personal Documentation of Researchers

- 6) Install the nut using special tools and a hydraulics jack.



**Figure 24.** Tightening the Nut

Source: Personal Documentation of Researchers

d. Boom Cylinder

- 1) Place the boom cylinder on the rotary bench work, lock it with a clamp, then position the boom cylinder vertically.



**Figure 25.** Rotary Benchwork

Source: Personal Documentation of Researchers

- 2) Assembly cylinder tube with cylinder rod. Do it carefully to avoid scratches on the cylinder tube.



**Figure 26.** Assembling Boom Cylinder

Source: Personal Documentation of Researchers

- 3) Install all bolts using an impact gun or hydraulic torque.



**Figure 27.** Tightening the Cylinder Head Bolts

Source: Personal Documentation of Researchers

- 4) Assembly the slow return valve and the pipe.



**Figure 28.** Assembling the Slow Return Valve

Source: Personal Documentation of Researchers

## Maintenance of Boom Cylinder

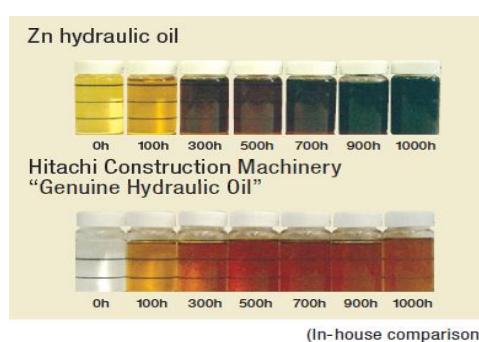
Boom cylinder maintenance is one of the most critical things to keep the reliability of the excavator unit above 90% per year. The reliability of this excavator unit aims to achieve the coal production target that has been set (Ferdian & Ansosry, 2019). Damage to the boom cylinder will have a serious impact with a long breakdown time and expensive spare parts, as well as loss of machine productivity.

The breakdown time spent to remove and install the boom cylinder according to the Standard Operating Procedure (SOP) is approximately 4 hours (B. et al., 2022). However, the estimated time does not include the delivery time to the project site which can take days, resulting in a decrease in excavator productivity. Besides that, the price of the boom cylinder is relatively expensive. For remanufacturing products, for instance, it costs around USD 43,197.45 per item or approximately IDR 548,607,615 per item. For Hitachi genuine products are at a price of around USD 143,991.49 per item or approximately IDR 1,828,691,923 per item, making it particularly burdensome for the excavator owner to conduct a boom cylinder maintenance. Therefore, prevention of damage and maintenance of the boom cylinder can be accomplished with the steps below:

### 1. Proper Oil Selection and Hydraulic Oil Change

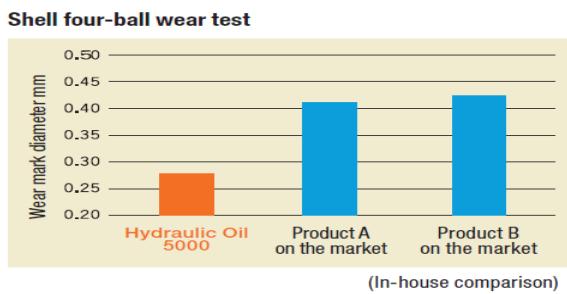
One way to maintain the performance and lifetime of the boom cylinder is to choose the right hydraulic oil according to the recommendation of the dealer, PT Hexindo. The oils recommended by PT Hexindo are Hitachi Genuine Hydraulic Oil and Hexindo Oil (genuine hydraulic 46TP). The advantages that Hitachi Oil has compared to other brands of oil are as follows:

- Hitachi Oil contains good oxidation stability to extend component lifetime. Tests conducted by Hitachi to compare Hitachi Oil products with other brands have concluded that Hitachi Oil has high oxidation stability, making sludge less likely to occur. Sludge can interfere with and cause damage to the oil filter. In addition, sludge can also cause scratches on components that grind against each other, such as piston rod and cylinder tube.



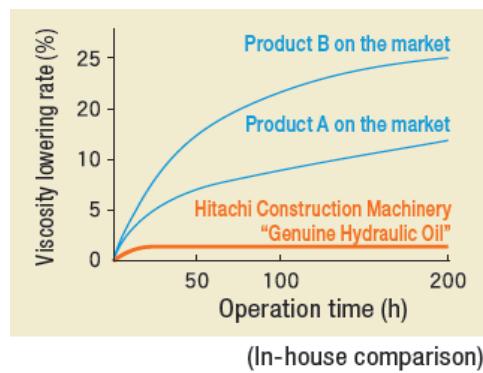
**Figure 30.** Life Time Comparison of Hitachi Hydraulic

- b. According to the results of the four-ball wear shell test, Hitachi Genuine Oil 5000 has high frictional resistance and is effective in reducing wear on hydraulic components.



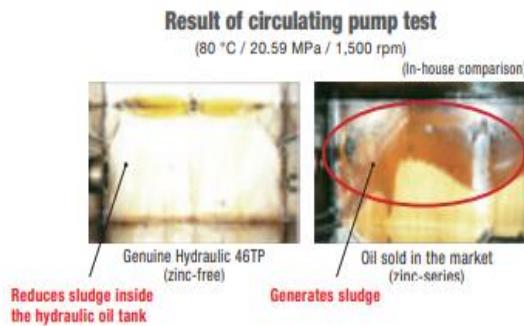
**Figure 31.** Diagram of Testing for Wear

- c. Hitachi Genuine Hydrolic Oil 46TP has good shear force stability so that it can reduce viscosity changes even if the engine or component is operated and does not perform oil changes on time.



**Figure 32.** Viscosity Testing Chart

- d. Hitachi Genuine Hydrolic Oil 46TP is a Zinc-free hydraulic oil. Zinc can improve the lubrication performance. However, when Zinc reacts with sulfur elements, it will produce sludge. Sludge can interfere with the hydraulic system because it can cause damage to the seal and even the pump. In addition, sludge will also increase wear on components that rub against each other, such as pumps, boom cylinders (pistons with cylinder tubes) and others. Therefore, testing was carried out, where Hitachi Genuine Hydraulic Oil 46TP only contained a small amount of sludge in the hydraulic tank when compared to hydraulic oil containing Zinc.



**Figure 33.** Sludging in the Hydraulic Tank

## 2. Oil Filter Change

In hydraulic systems, the cleanliness of hydraulic oil is the most important thing that must be maintained. Grams or metal debris in hydraulic oil can damage the components of hydraulic components that friction each other so that scratches can occur, which may lead to internal leaks. To overcome this problem, a hydraulic oil filter change should be conducted every 500 hours.



**Figure 34.** Hydraulic Oil Filter

## 3. Inspection and Preventive Maintenance Process

In accordance with the Standard Operating Procedure (SOP), a mechanic is required to check for any potential damage to the boom cylinder during the daily check. First of all, a mechanic should check the boom cylinder area whether there is an external leak or not. Next, the mechanic must check whether the hydraulic oil level is still in a standard state. If the hydraulic oil level is below the standard, then the potential for overheating to interfere with the elasticity of the seal will be greater. If the seal becomes inelastic or rigid, the potential for internal leakage when the unit is operating will increase. The next inspection that must be done is to check the availability of grease in the grease tank. This is carried out in order to prevent wear and tear on the pin, bushing, eye cylinder tube, and rod. Then, the mechanic must check whether there is an external leak in the grease line. Next, the mechanic should check the pressure on Auto-lubrication when the grease comes out of

the vent valve, the pressure that comes out is 2750 psi. Preventive maintenance is carried out when the excavator unit has been operating for 8000-16000 hours. The preventive maintenance performed is replace seals, repair rod and cylinder tube, piston rod, and bushing on the cylinder. This inspection is carried out so that the cylinder performance is optimal again and also prevents the occurrence of external leaks in the cylinder.

#### 4. Proper Operation

One of the factors that can affect boom cylinder damage that is not in accordance with the specified life time is the operation of the machine itself. The operation in question is to add loads that are not in accordance with the specified capacity by modifying the bucket so that the load that can be lifted exceeds its capacity. The capacity for EX 2500-6 or EX 2600-5 is 15 m<sup>3</sup> to 17 m<sup>3</sup>. In reality, the bucket capacity found in the field often reaches 21 m<sup>3</sup>. If this happens, it is certain that the boom cylinder will be replaced before reaching 16,000 hours.

#### 5. Oil Analysis

Oil analysis is a planned action by Hexindo in collaboration with PT Tekenomiks to identify the materials contained in hydraulic oil, so that the potential for component damage to occur can be reduced. Oil analysis is carried out every 250 hours by taking a sampling of hydraulic oil and then sending it to the PT Tekenomiks lab. PT Tekenomiks will carry out diagnostics or inspections so that accurate data is produced. The data is then sent back to Hexindo and PT Tekenomiks will provide recommendations whether the hydraulic oil is still suitable for use. Inspection analysis includes wear metals, contaminants, oil additives, infra red, and physical tests. In the inspection, accurate data will be attached to the data obtained so that potential damage can be identified.

## CONCLUSION

Several conclusions were drawn based on the results of the analysis and discussion of the research regarding the Performance of Boom Cylinder Repair Mechanism and Auto Lubrication System of EX 2500 Hitachi Excavator. There are four types of boom cylinder damage, such as internal leak, external leak, scratch, and wear. The causes of damage to the boom cylinder are malfunctioning auto-lubrication, contamination, scratch, overheat and overload. Boom cylinder maintenance can be accomplished by selecting and changing the right hydraulic oil every 8000 hours, changing the oil filter according to the maintenance schedule every 250 hours, cleaning the hydraulic oil cooler every 500 hours, performing inspection and preventive maintenance processes, proper operation (no modifications), and performing oil analysis every 250 hours. The price of repairing the boom cylinder is around USD 43,197 or around IDR 647,955,000. The bending

tolerance on the cylinder rod is 0.05 mm. Damage to the boom cylinder can cause long unit downtime, huge maintenance costs, and the potential for work accidents.

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