# Non-Destructive Testing of Hydraulic Cylinder Excavator Bucket and Failure Analysis

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https://doi.org/10.5109/7395627

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 11, pp.955-959, 2025-10-30. International Exchange and Innovation Conference on Engineering & Sciences
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# Non-Destructive Testing of Hydraulic Cylinder Excavator Bucket and Failure Analysis

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**Abstract:** *The bucket cylinder is one of the important components in the front attachment of the excavator. The component is combined with a hose that flows the hydraulic oil flow from the hydraulic pump, and control valve to the bucket cylinder, which moves the bucket on the excavator. If the bucket cylinder does not work according to standards, a malfunction will occur which causes problems with the excavator so that damage occurs to the inner parts components. The research method used is an observation of the damaged bucket cylinder components, after observing the bucket cylinder check, interviewing the excavator operator, and checking using a dye penetrant, the bucket disassembly process is carried out to determine the condition of the bucket cylinder components to make it easier to observe the damage that occurs to the bucket cylinder, then the bucket cylinder component disassembly process is carried out then the inspection process is carried out using dye penetrant and hydraulic oil sampling to make it easier to collect data on the damage that occurs to the bucket cylinder components after the inspection of the damaged parts is carried out, repairs and replacement of spare parts with new ones so that the bucket cylinder can be reused.*

**Keywords:** Non-Destructive Testing; Hydraulic cylinder; Excavator bucket; Failure

## 1. INTRODUCTION

The use of heavy equipment such as excavators in pond construction work significantly facilitates the process, especially during the excavation of soil and the formation of ponds, which require heavy machinery to improve work efficiency [1–7]. However, during the operation, issues frequently arise with the excavator due to environmental factors, such as muddy terrain, seawater exposure that can cause corrosion on metal components, and the types of materials being handled, including soil, sand, mud, stones, wood, and water [8–10]. In addition to environmental factors, human negligence in performing regular inspections and intensive maintenance on the excavator unit can also lead to problems [11]. One of the excavator components that often experiences damage during operation is the bucket cylinder, which is used to move the bucket when handling sand, rocks, or soil [12–15]. This research focuses on identifying the root causes of oil leakage issues in the bucket cylinder, analyzing the damage to its components, detailing the repair process, and proposing preventive measures to address these issues [16, 17].

Excavators are versatile machines that can be used for road maintenance or repair, soil excavation, trench loading, loading materials into dump trucks or timber onto trailers, and for pond construction or repair in fish farming operations [18–25]. The main components of the bucket cylinder include the piston, cylinder housing, seal kit, bushing, eye rod, nut, and cylinder rod. Figure 1 (a) is the detail parts in the excavator and (b) is an illustration of the hydraulic components of the bucket cylinder.

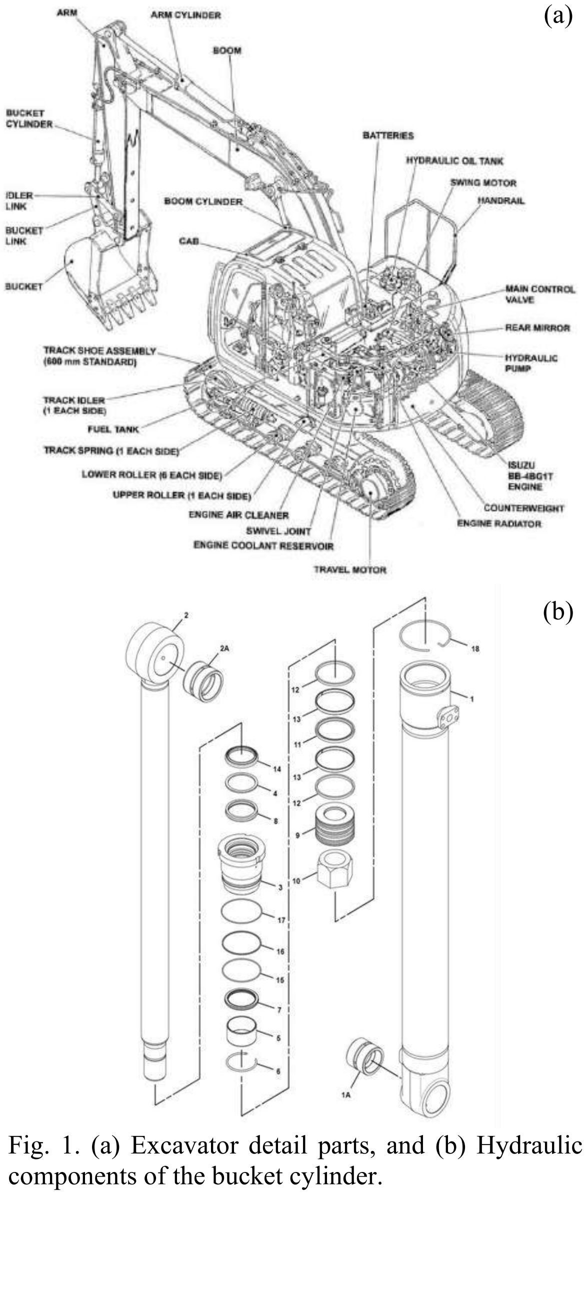


Fig. 1. (a) Excavator detail parts, and (b) Hydraulic components of the bucket cylinder.

Hydraulic components of the bucket cylinder, consist of several parts i.e. piston cylinder rod is the piston cylinder rod moves up and down within the cylinder tube in response to hydraulic fluid pressure. The others components such as housing cylinder serves as a tube to contain the internal components of the cylinder, such as the piston, rod, seal, and hydraulic oil.
In addition, the head cylinder acts as an inlet and outlet pathway for hydraulic fluid and connects the cylinder to attachments for specific applications [26]. The piston transfers hydraulic power from the fluid to the device being operated, when hydraulic pressure is applied to one side of the piston, it moves in the opposite direction to transfer the load or perform the desired task [27]. The seal kit is a crucial part of the hydraulic components, preventing hydraulic fluid leakage and keeping external contaminants from entering the cylinder [28].

## 2. RESEARCH METHOD

This research method involved conducting interviews with excavator operators, field observations by analyzing and directly observing the condition of the excavator unit, inspecting the bucket cylinder components to analyze the failed components, and performing oil sampling.
The excavator unit observation is begin with using dye penetrant to inspect the surface material of the cylinder. Then, followed by the visual inspection for oil leakage in the cylinder. Furthermore, measuring the bucket cylinder and documenting the observation results to prepare a damage report on the bucket cylinder. The parts inspection process was conducted using visual and penetrant tests to facilitate the identification of damaged and undamaged parts. Oil sampling was conducted to analyze the quality of the oil used and to identify whether contaminants were present in the oil. Figure 2 is the step by step of the non-destructive testing through the dye penetrant process when applied to the bucket cylinder.

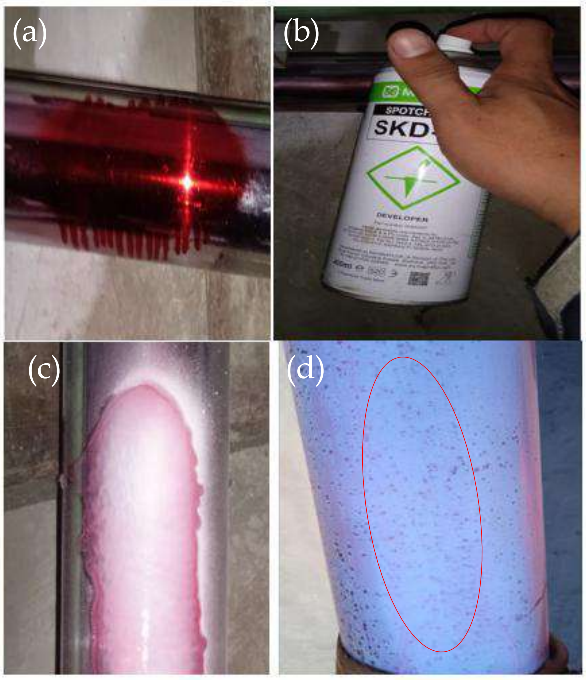


Fig. 2. (a) Sampling area for 150x150 mm, (b) Dye penetrant spray, (c) Sampling area with sprayed, and (d) Dye penetrant test result.

## 3. RESULT AND DISCUSSION

The results from field observations and interviews with the operator are the excavator operates 8 hours per day in coastal areas. The materials being transported include stones, sand, soil, water, mud, and wood. The tasks include constructing fish and shrimp ponds, repairing ditches and roads. The bucket cylinder is often submerged in seawater and river water when the excavator works to dredge ditches and load materials. The salty water poses a high risk of corrosion on the metal components of the bucket cylinder. The operator does not clean the excavator after the operation is completed.
The results of bucket cylinder observation on the cylinder area using visual and dye penetrant tests revealed corrosion on the housing and cylinder rod. The damage was caused by dirt friction between the rod and the seal in the housing cylinder, which eroded the chrome layer. The frequent exposure of the rod to seawater and river water led to the peeling of the chrome layer on the cylinder rod, as shown in Figure 3 and 4.

Fig. 3. Corrosion part on the cylinder tube of the housing.

Fig. 4. Condition of the bucket cylinder housing with the hydraulic oil leak.

The results of the used hydraulic oil sampling showed that visually, the oil had already changed in color, and there was a change in the viscosity value of the tested oil. The hydraulic oil used was Turalik 52 (ISO VG 68). The viscosity result was below the standard limit, measured at 41.63°C, compared to the minimum-maximum standard range of 61.41–75.05°C. There are some causes of hydraulic oil viscosity drop such as prior to the unit's breakdown, the unit operated under a high workload, with the excavator operator running the machine at high engine speeds, which caused a temperature rise in the hydraulic oil system, and ccontaminant’s such as dust, dirt, or other chemicals entered the hydraulic oil, reducing its viscosity. Figure 5 and 6 shows the measurement inspection of the cylinder rod and damage inspection in various conditions, respectively.


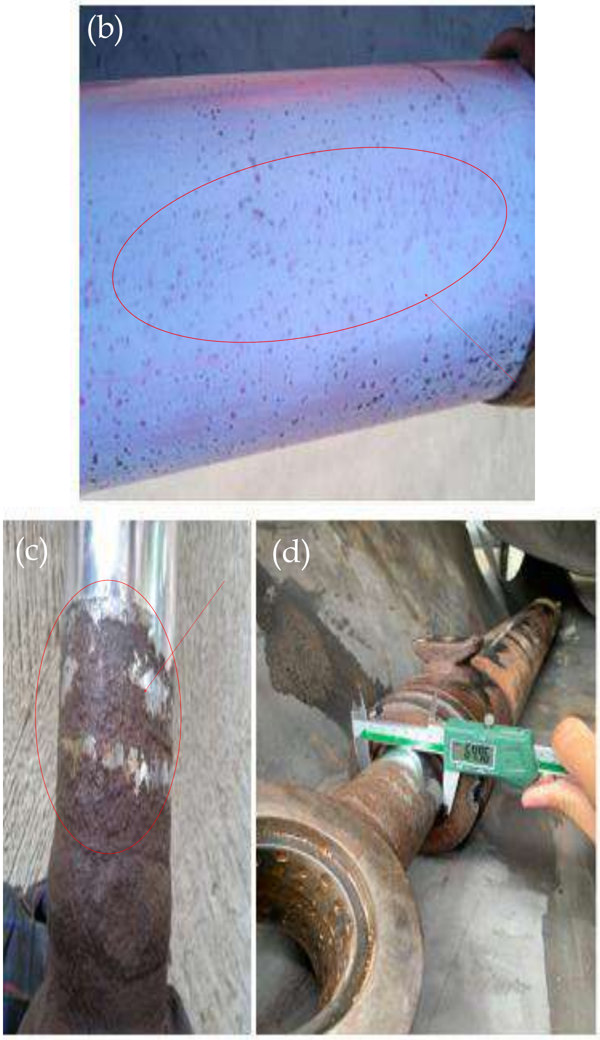


Fig. 5. Inspection of the cylinder rod in (a) dimensioning, (b) surface area with experienced pitting corrosion, (c) a peeling chrome layer, and (d) the results of the measurement of 64.96 mm diameter and 1080 mm rod length.

By hydraulic oil testing is carried out from the visual condition of the oil, the color has changed, and there is a change in the viscosity value of the oil being tested. The hydraulic oil used is the Turalik 52 brand (ISO VG 68). The result of the viscosity value is below the standard value limit, 41.63/°C from the min–max limit of the standard value of 61.41 - 75.05/ °C. The decreased of hydraulic oil viscosity are caused by (a) before the damage to the unit occurred, the unit was operating with a high workload where the excavator operator operated the unit with high engine speed so that the temperature in the hydraulic oil system increased, (b) there are contaminants such as dust, dirt or other chemicals that enter the hydraulic oil and reduce its viscosity.

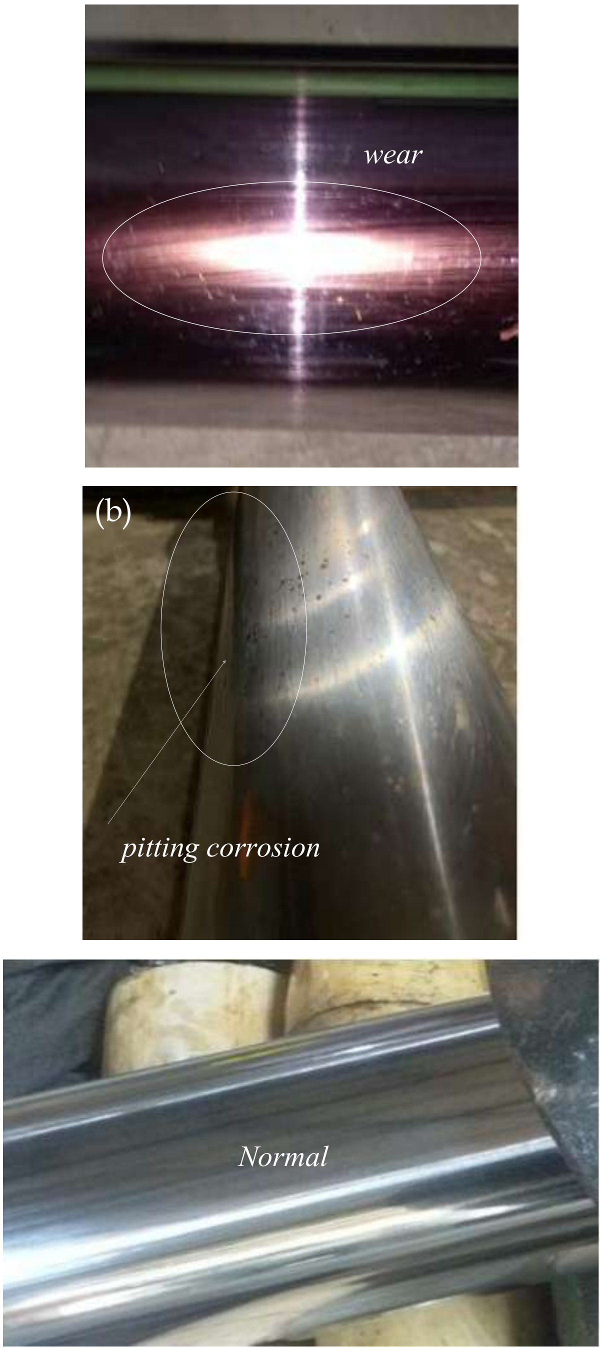


Fig. 6. Damage inspection of the cylinder rod condition in (a) experiencing wear on the surface, (b) experiencing corrosion, pitting, and peeling chrome layer, (c) normal condition or there is no wear, corrosion, and scratch on the surface.

To prevent damage to the bucket cylinder, a daily inspection check sheet is made, to find out the condition of the cylinder whether it is in good working condition or not, and if there is damage to the cylinder after a visual inspection is carried out, then a record is made to facilitate the implementation of the maintenance schedule. This inspection check sheet aims to make it easier for excavator operators and excavator mechanics to monitor the performance and physical condition of the bucket cylinder.

## 4. CONCLUSIONS

The analysis of the causes of damage to the bucket cylinder and hydraulic oil analysis are as follows:

1. The cylinder component material was damaged due to friction between the cylinder and materials being transported, such as sand, soil, mud, and water. This friction caused scratches on the cylinder rod, and dirt buildup led to friction with the cylinder seal, resulting in seal damage and oil leakage.
2. The dirty and wet condition of the cylinder led to oxidation of the metal, causing corrosion in the housing area and peeling of the chrome layer on the rod.
3. The oil sampling results indicated a decrease in oil viscosity, which was measured at 41.63°C, below the standard value range of 61.41–75.05°C. This decrease in viscosity was caused by the excavator operating at high RPM and under heavy workload conditions, leading to a decline in hydraulic oil quality. A drop in hydraulic oil viscosity can result in excessive wear on bucket cylinder components and other hydraulic parts, and if the oil is not replaced and its quality regularly monitored, it may cause significant damage.

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