



## Surface Analysis and Material Elements in The Excavator Tooth Bucket Which is Affected by Corrosion With The SEM and EDX Method

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### Abstract

Corrosion in excavator tooth buckets is a major issue in the heavy equipment industry, especially in mining and construction. Exposure to water, humidity, and chemicals accelerates corrosion, reducing strength and wear resistance, which shortens component life and lowers operational efficiency. This study analyzes surface structure and material composition changes due to corrosion, aiming to enhance material durability through better selection and design. Using Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Spectroscopy (EDX), corrosion effects on S45C steel were examined at up to 5000x magnification. The results show increased oxygen (O) from 3.56 WT% to 25.53 WT% and decreased iron (Fe) from 84.21 WT% to 59.35 WT%, indicating severe oxidation. Identified corrosion types include uniform and gap corrosion, highlighting the need for corrosion-resistant materials and protective coatings to improve excavator reliability.

Keywords: Corrosion, Excavator Tooth Bucket, SEM-EDX, Material Degradation

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## INTRODUCTION

Corrosion in the tooth bucket excavator is one of the significant problems in the heavy equipment industry, mainly because excavators often operate in extreme environments, such as mining or construction, where exposure to water, humidity, and chemicals can accelerate the corrosion process. The surface of a corrosion tooth bucket tends to show a decrease in workers and wear resistance, thereby reducing the effectiveness of equipment and shortening the life life of the components. Through analysis using the SEM (Scanning Electron Microscopy) and EDX (Energy Dispersive X-Ray Spectroscopy) methods, in-depth characterization of surface structure changes and composition of material elements that experience



degradation due to corrosion process. The SEM method allows detailed visualization of physical damage to the surface, while EDX provides important information related to the increase in oxygen (O<sub>2</sub>) and decreased iron (Fe), which are signs of oxidation and reduction in the material. Identification of corrosion types, such as uniform corrosion and gap corrosion, is very important in understanding the mechanism of damage and providing insight for design improvement and material selection that is more resistant to corrosion, which in turn can increase the operational reliability of the tooth bucket excavator in a hard environment.

Excavator bucket is one of the important components used in excavator heavy equipment to dig and move materials such as soil, sand, or stone [1]. Excavators are heavy equipment used in large industries such as construction, agriculture or forestry, mining, etc. that require the ability outside of human ability. Excavators have a proboscis consisting of two pistons. Excavators also have a bucket (dredging bucket) called a dipper. The driver's room or operator space is called a house, located above the wheel (trackshoe), and can rotate 360 degrees. One important component of the excavator is the bucket located in the trunk of the excavator. Bucket is located on the excavator arm near the bucket. [2] Bucket excavator must be strong enough to work reliably in severe working conditions. Bucket excavator usually works under cyclic movement during the excavation process. Because of this recurring work nature, cyclic voltage can occur in some parts of the excavator [3].

Excavators have 4 types, namely: front shovel, drag line, clamshell and backhoe. Backhoe operations are generally for excavation of channels, tunnels, or basements. 1 Backhoe consists of a driving device that can be a crawler or tire, boom, stick, and bucket [4]. Bucket must have the toughness and strength of the material that is high, so that it can affect the life time of these components and reduce down time. In this study will be discussed about the characterization of Bucket Tear Excavator material using metalographic observation methods, chemical composition testing, and testing of violence that are useful for knowing the price of violence in Bucket Teeth with, as can provide information to local industries and companies that use bucket teeth regarding specifications material suitable for making bucket teeth [5].



The main function of an excavator bucket is to explore, lift, and move material from one location to another in various construction, mining, or civil work projects. As the name implies, this heavy equipment excavator has the main function for excavation work. But it is not limited to that, excavators can also do construction work such as making a slope, loading, stone breaking and so on [6]. Understanding Heavy Equipment Dredging is a type of heavy equipment consisting of bars, pole, basket and casings that have a rotary force. The main task of this heavy equipment is to help in various operations that involve great forces [7]. Therefore excavators are often used to take over the role of certain tools with special functions, such as cranes that are commonly used to lift equipment and materials. There are many tools and/or materials that need to be moved at the work location, such as trench boxes, long pipes, small equipment, or a number of other materials that must be moved from point A to point B [8].

The end of this bucket which plays a role like claws called bucket teeth, is the part that is most likely to fail (worn or broken) when the excavators operate. This can happen because the characteristics of the material used are not good so it does not support the work of the excavator. [9] The main characteristics of excavators are having extensive functionality, efficiency and work reliability. This makes him able to meet the broad -difference technical requirements [10].

Excavator bucket design is usually equipped with sharp teeth on the front, which facilitates excavation and cutting hard material such as stones or solid soil. Although the age of the construction design is limited, the efforts to maintain all components so that they can function properly are obligations for its users, especially when the construction design is used en masse and used for sustainable heavy work [11]. As a result of the complexity and variability of the workload, the excavator load retaining component often fails, especially in the pin joint backhoe. Failure to the Pin Joint Backhoe is usually caused by a combination of bending, torsion fatigue and impact fatigue [12]. Hydraulic pump failures can be caused by several factors, for example, poor system design, low -quality liquid use and poor contamination control. This condition can certainly hamper the activities and performance of the heavy equipment itself. Hydraulic Low Power is a condition



where the excavator cannot function properly due to interference with some parts of the excavator heavy equipment. Pumps are generally grouped according to the design, construction materials, and liquids acting on the pump according to the function of its use [13]. Inappropriate heavy equipment selection can result in an inefficient and inefficient management of project implementation. Therefore, the delay in completion of land projects can increase costs [14]. This technology is an operational backbone, ranging from heavy equipment used in infrastructure development to sophisticated equipment in the production line of consumer goods [15].

The material for making an excavator bucket is usually high quality steel that is designed to be resistant to wear and high pressure when operating in a hard environment. Making a spare part. Power (power) is the product between force and speed. So for the transfer (transmission) of the specified amount of power, the force and voltage in various connecting rods of a mechanism can be reduced by changing the speed through changes in size of the connecting rod. Friction and damage to the engine depends also at speed. For this reason, the determination of speed is needed in a mechanism [16]. The movement of transportation tools in a construction project with two -way movements namely vertical and horizontal. For the type of transportation above the ground surface, it is called horizontal movement while from one height to another height is called vertical movement [17]. Hydraulic cylinders play an important role in facilitating and accelerating the excavator work system. Hydraulic cylinders are useful for moving attachments such as booms, arm, and bucket. Of all the existing attachments, the Bucket cylinder has the largest percentage of damage. Because the application is directly related to work materials such as stones, gravel, tree trunks, mud, water and others. For this reason, the authors took the initiative to review special care for the bucket cylinder to maintain the reliability of the unit [18]. Bucket is a vital substructure of all digging machines, and is intended to realize the fundamental function of the machine - excavation of the soil [19]. Corrosion in the excavator bucket, especially in the tooth (tooth), often occurs due to direct contact with water and abrasive material, which results in surface degradation and decreased tool performance if not carried out appropriate



treatment. In mining activities also often occur mining losses due to several factors. The difference in calculation is based on production targets with Mine Progress and the difference between the actual survey and the calculation of bucket country that is behind the background to conduct research on the achievement of mining production targets based on the survey and bucket count method [20]. In the bucket excavator operation also requires high strength and corrosion resistance. Because in the use of bucket excavators always rub against the ground, it is necessary to do hard facing to increase violence in this bucket excavator [21]. Bucket is a part of the excavator that is often directly damaged in operation caused by direct contact to the field of work. Bucket damage from the excavator that often occurs is found in the flange link, the bucket link that connects the bucket and arm and also the bucket tooth part. One of the causes of this damage is from how to use the excavator [22].

There are still a few studies that explore alternative designs to the excavator tooth bucket that are more resistant to extreme conditions in the operating environment. Not many studies have studied the effect of new metal variations on the excavator tooth bucket in increasing resistance to corrosion and wear. Research on the use of innovative protective coating to reduce the corrosion rate in the excavator tooth bucket is still minimal and needs to be further developed. There is a shortage of research on the impact of certain operating environment, such as salt content or aggressive chemicals in the soil, to the level of damage to the tooth bucket excavator. The study of the performance of the excavator tooth bucket material with the SEM, EDX, and mechanical analysis methods to understand the interaction between changes in material elements and structural strengths is still not much done.

Surface Analysis and Material Elements in the Ecvator Tooth Bucket that are affected by corrosion is important to be identified in order to understand the mechanism of damage, so that design and material selection can be done better in reducing the risk of corrosion. The SEM and EDX method provides effective techniques for observing changes in microstructure and composition of material elements, providing relevant data to analyze the effects of the operational environment on reliability and age of the excavator component.



The purpose of this study is to analyze changes in surface structure and composition of material elements in the tooth bucket of excavators affected by corrosion, and identify the types of corrosion that occur, in order to provide recommendations to increase material resilience in a hard operational environment.

### **Research Methods**

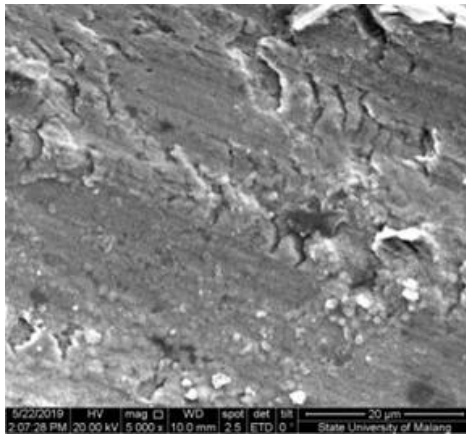
The methodology used in this study aims to analyze changes in surface structure and composition of material elements in the corrosion of excavator tooth bucket. The main techniques used are Electron Microscopy (SEM) Scanning and Energy Dispersive X-Ray Spectroscopy (EDX), which synergistically allows observation of micro morphology and the distribution of chemical elements on the surface of the material. SEM is used to obtain microscopic images of the surface of the material with an enlargement of up to 5000x, so that it can be visually identified with corrosion damage, such as changes in texture or micro crack formation. Meanwhile, EDX is used to analyze the quantitative chemical elements contained in the specimen, both before and after corrosion. Through the comparison of weight data (WT%) and the number of atoms (at%) elements such as oxygen (O) and iron (Fe), this study identifies an increase in the significant increase in oxygen content and decreased iron levels, which is a strong indication of the occurrence of oxidation and material degradation. This study also identifies the types of corrosion that occurs, namely uniform corrosion (uniform corrosion) and corrosion gap (gap corrosion), as a basis for understanding the mechanism of material damage. Overall, this methodological approach aims to provide empirical data that can be used in the development of materials that are more resistant to corrosion and increased design of the excavator tooth bucket component.

### **RESULT AND DISCUSSION**

Figures 1 and 2 show the related SEM -EDX results Comparison of testing before corrosion and after corrosion:



Not corrosion:



corrosion

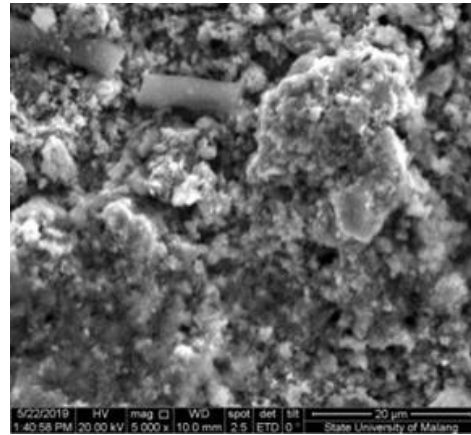


Figure 1 Comparison of SEM morphology with 5000x magnification

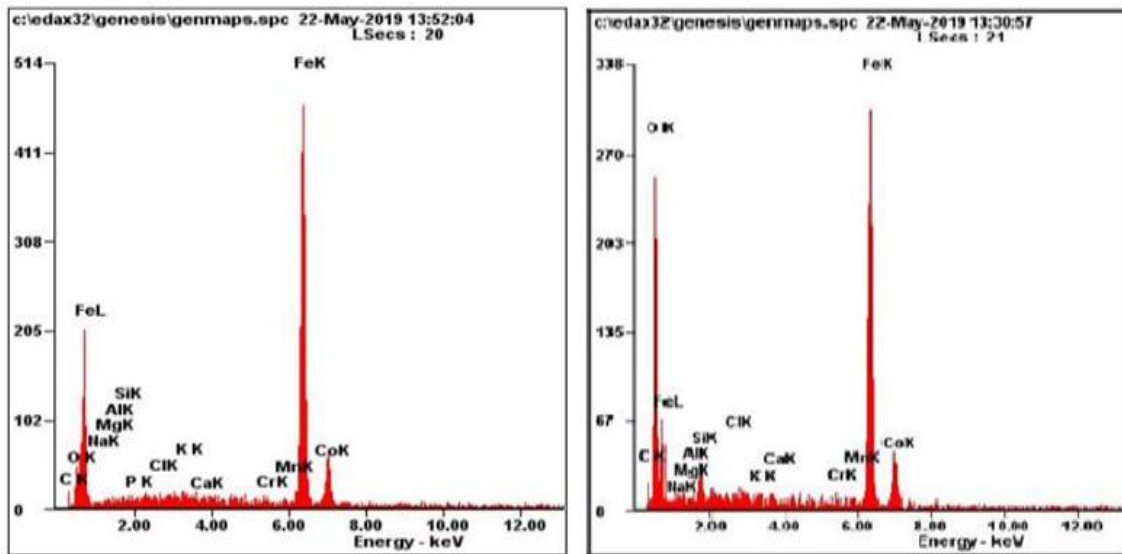


Figure 2 Comparison EDX of non-corrosion test specimens and corrosion.

Table 1. Comparison of non -corrosion test specimens and corrosion.



| Element | Wt%        | At%   | Element | Wt%        | At%   |
|---------|------------|-------|---------|------------|-------|
| CK      | 04.73      | 17.06 | CK      | 06.37      | 12.82 |
| OK      | 03.60      | 09.75 | OK      | 25.53      | 46.20 |
| NaK     | 00.55      | 01.05 | NaK     | 00.92      | 01.16 |
| MgK     | 00.43      | 00.77 | MgK     | 00.70      | 00.83 |
| AlK     | 00.40      | 00.65 | AlK     | 00.59      | 00.63 |
| SiK     | 00.25      | 00.39 | SiK     | 01.92      | 01.98 |
| PK      | 00.13      | 00.19 | CK      | 00.30      | 00.24 |
| CLK     | 00.37      | 00.46 | KK      | 00.32      | 00.24 |
| KK      | 00.46      | 00.51 | CaK     | 00.59      | 00.43 |
| CaK     | 00.37      | 00.40 | CrK     | 00.78      | 00.44 |
| CrK     | 00.75      | 00.62 | MnK     | 00.92      | 00.48 |
| MnK     | 01.00      | 00.79 | FeK     | 59.35      | 30.78 |
| FeK     | 84.21      | 65.36 | CoK     | 01.52      | 00.75 |
| CoK     | 02.73      | 02.01 | Matrix  | Correction | ZAF   |
| Matrix  | Correction | ZAF   |         |            |       |

Table 1 shows the difference between non-corrosion and corrosion. The material difference includes weight (Wt%) and atoms (At%) as in the oxygen (O) element that is not corrosion, the initial weight is 03.56 Wt% and atoms of 09.75 At% while in the oxygen element (O) the final weight corrosion to 25.53 Wt% and atoms of 46.20 at%, so it can be concluded that there is a weight increase (weight%) of 21% or 7 times and the addition of atoms (At%) of 36% or 5 times. Furthermore, differences in the element of iron (Fe) are not corrosion, the initial weight is 84.21 Wt% and atoms of 65.36 at% while in the element of iron (Fe) the final weight corrosion becomes 59.35 Wt% and atoms of 30, 78 at%, so it can be concluded that there is a weight reduction (weight%) by 24% or 1.4 times and the addition of atoms (At%) is 34% or 2 times. It can also be seen in the graph of the comparison of non-corrosion and corrosion test specimens.

### CONCLUSION

Based on the results of the tooth bucket excavator sample test that is not corrosion with corrosion using the SEM and EDX method, there are differences on the surface and material elements.

1. The cause of the damage to the tooth bucket excavator due to corrosion is an increase in oxygen elements (O<sub>2</sub>) on the surface of the material that can cause reduction, whereas the iron element (Fe) has decreased due to the surface experiencing oxidation resulting in surface corrosion.
2. Based on the results of SEM and EDX, the corrosion that occurs in the tooth bucket excavator there are 2 kinds of corrosion, namely uniform corrosion of gaps. and document analysis.

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