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Project Report

Study on the Corrosion Characteristics of Grounding Materials in Acid Red Soil

Jiadong Shen [1], Duosheng Li [2,*], Jiyuan Guan [2] and Youbin Gao [2]

[1] Tongji Zhejiang College, Jiaxing, Zhejiang 3304001, China
[2] School of Materials Science and Engineering, Nanchang Hangkong University, Nanchang 330063, China
* Correspondence: 502346589@qq.com

Abstract: The corrosion of grounding materials seriously threatens the safe operation of the power system. Grounding materials as carbon steel, galvanized steel, galvanized steel, copper exhibit different corrosion resistance behaviors respectively. The corrosion rate of these grounding materials firstly increases and then decreases. Pitting corrosion is the main corrosion mode of carbon steel. The carbon steel has the fastest corrosion rate. The corrosion rate of galvanized steel drops and is 2.6316 g/dm^2·a. The corrosion rate of copper is reduced to 0.6646 g/dm^2·a, which has good corrosion resistance, but the cost is high. It is also easy to cause heavy metal pollution. The corrosion rate of Zn-Al coated steel is the lowest, only 0.6606 g/dm^2·a. It exhibits good corrosion resistance characteristics.

Keywords: Acid red soil; grounding material; Zn-Al coating; corrosion resistance

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1. Introduction

The grounding equipment is the basic guarantee for the safe operation of the power system. But the grounding material works long in soil environment and grounding equipment is inevitably damaged by corrosion [1–6].

Corrosion studies on grounding materials were usually focused on carbon steel [7]. Maocheng Yan etc. [8] found there were many iron oxides in the red soil, it can be used as the cathode depolarization agent to accelerate the corrosion. Wang Sen [9] studied the corrosion behavior of H62 brass. Xu, etc. [10] studied the corrosion characteristics of Al coating, Al-Si alloy coating and Ni-Al alloy coating. Lin Bilan [11] investigated the corrosion behavior of zinc and Zn15Al coating materials in Dagang soil. The corrosion resistance of Zn15Al coating is better. Vanessa DE Freitas Cunha Linus, etc. [12] studied the soil corrosion of X52 API carbon steel by electrochemical method. The corrosion characteristics of different materials are also different [13,14]. The corrosion characteristics of carbon steel, galvanized steel, aluminum-zinc steel and copper were studied through laboratory and acid red soil.

2. Experimental

Electrochemical workstation (4000 PARSTAT) is used to test polarization curve by using the three electrode system. Working electrode (carbon steel, galvanized steel, Zn-Al coating steel, copper) top welding leads to copper wire, around encapsulated by epoxy resin. Auxiliary electrode is platinum sheet, and reference electrode is sulfate saturated copper electrode. Corrosion medium is 20% moisture content red soil of Qili substation, temperature of the medium is 60 °C. Scanning speed of testis 0.5 mV/s, and scanning potential ranges from −100 mV to 100 mV. Those specimens were buried in the red soil for 10 months.

3. The Results and Discussion

The polarization curve corrosion test of four grounding materials were carried out in the laboratory for 7 days, 14 days, and 21 days as Figure 1.

Figure 1 shows that, with the decrease of the scanning potential, the corrosion currents of grounding materials increase rapidly first, then the increasing speed is slower, and finally increases rapidly. At the beginning, the cathode surface is sufficiently oxygen-supplied and the reaction rate is fast. After a period of time, the oxygen potential has a linear relationship with the logarithm of the current density, which is consistent with the Tafel formula. As the corrosion current density increases gradually, the oxygen on the cathode surface begins to be insufficiently supplied, and is controlled by oxygen diffusion and ion reaction, and the current density increases. Due to the slower oxygen diffusion rate, the oxygen content on the cathode surface is further reduced, the cathode polarization is intensified, and hydrogen evolution corrosion occurs, and the corrosion current density begins to increase sharply. Acid red soil has higher hydrogen ion content and lower oxygen content, which aggravates the corrosion of grounding materials.

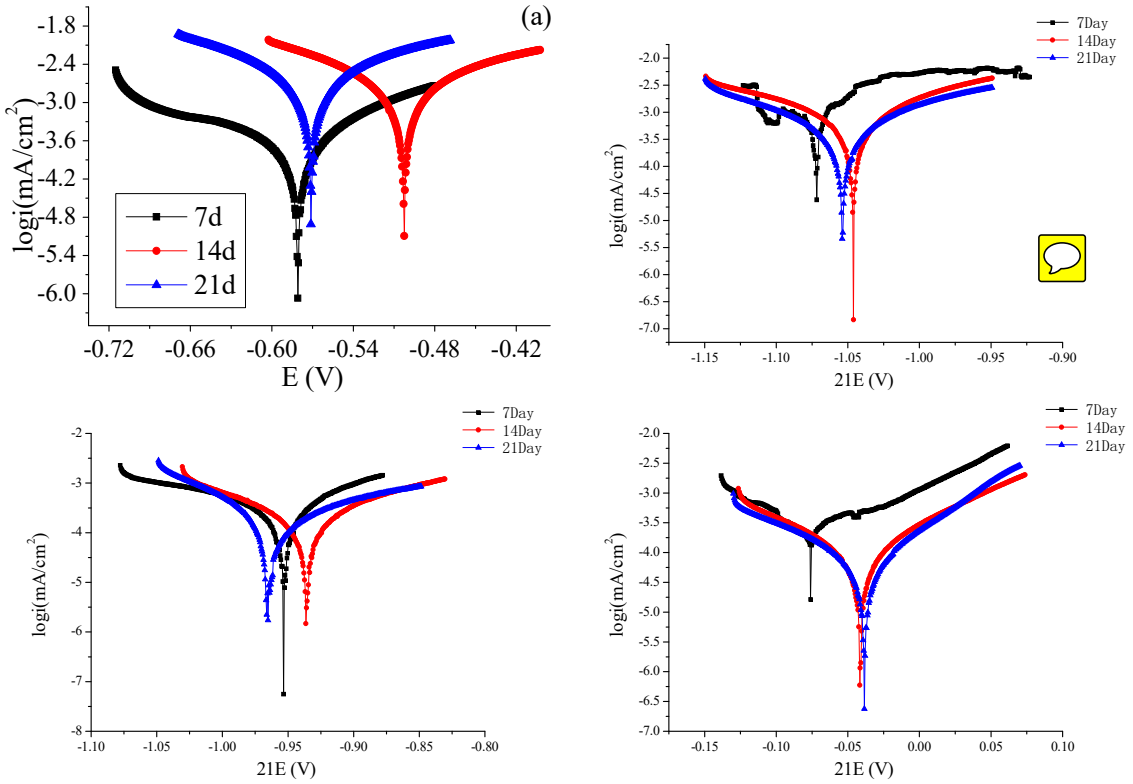


Figure 1. The polarization curves of four grounding materials undergoing corrosion at different time, (**a**) carbon steel, (**b**) galvanized steel, (**c**) Zn-Al coated steel, (**d**) copper.

According to the results of the polarization curve (Figure 1) above, the corrosion potential and corrosion current density of the grounding materials were fitted as Figure 2a,b.

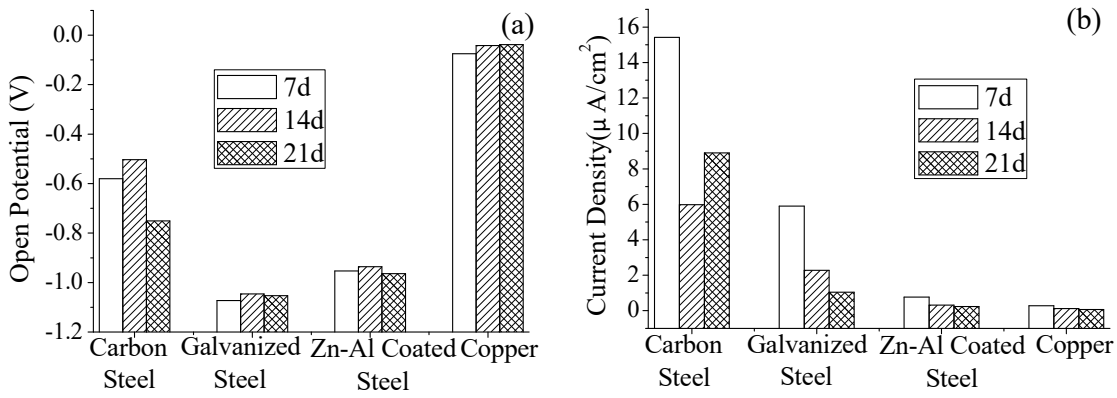


Figure 2. Fitting results of polarization curves of 4 kinds of grounding materials, (**a**) fitting open potential, (**b**) fitting current density.

The corrosion potential of the four materials is shown in Figure 2a. It shows that the corrosion potential of the four materials is relatively stable. The corrosion potential of galvanized steel and Zn-Al steel coating is relatively low, and less than 0.9 V. The zinc layer is active in the soil, and has the effect of sacrificial anode protection cathode on carbon steel substrate, which can prevent corrosion of pitting carbon steel. The Zn layer can form a dense oxide film on the surface, reducing the corrosion rate. The Zn-Al alloy coating formed a stable density compound on the surface. It reduces the area of the pure zinc phase improve the corrosion resistance. The activity of copper in soil is lower than −0.1 V, but it has good corrosion resistance.

The corrosion current density is shown in Figure 2b. It shows that the corrosion current density of carbon steel was the highest. The galvanized steel is less than that of carbon steel. The corrosion current density of Zn-Al coated steel and copper were very small. At the beginning, the corrosion current density of carbon steel was the highest, reaching 15.42 μA/cm^2. Then it gradually decreased to 5.98 μA/cm^2, at last, it increased to 8.90 μA/cm^2 due to peeling of corrosion products. The corrosion current density of galvanized steel is lower than that of carbon steel and only 5.90 μA/cm^2 at the beginning. Then it is reduced to 1.04 μA/cm^2 due to surface passivation. The corrosion current density of Zn-Al coating steel is less than 1.00 μA/cm^2. Although copper has a low current density, it is discarded due to its high cost and environmental pollution. Therefore, Zn-Al coated steel is the best grounding material.

Figure 3 shows optical micrographs of grounding materials in the red soil for 10 months. Figure 3a shows that the surface corrosion of carbon steel is the most serious. Figure 3b exhibits that the surface corrosion products of galvanized steel are reduced. Zn-Al coated has the least surface corrosion as Figure 3c. It is a potential grounding materials. Figure 3d shows that corrosion has obviously occurred on the copper surface.

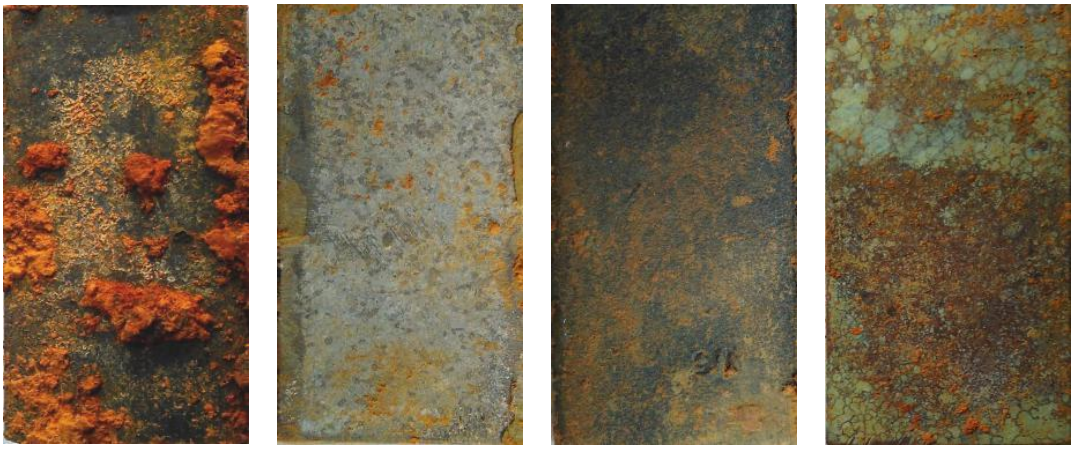


Figure 3. Optical micrographs of four grounded materials that were buried for 10 months without cleaned surface corrosion products, (**a**) carbon steel, (**b**) galvanized steel, (**c**) Zn-Al coated steel, (**d**) copper (Size: 50 mm × 25 mm).

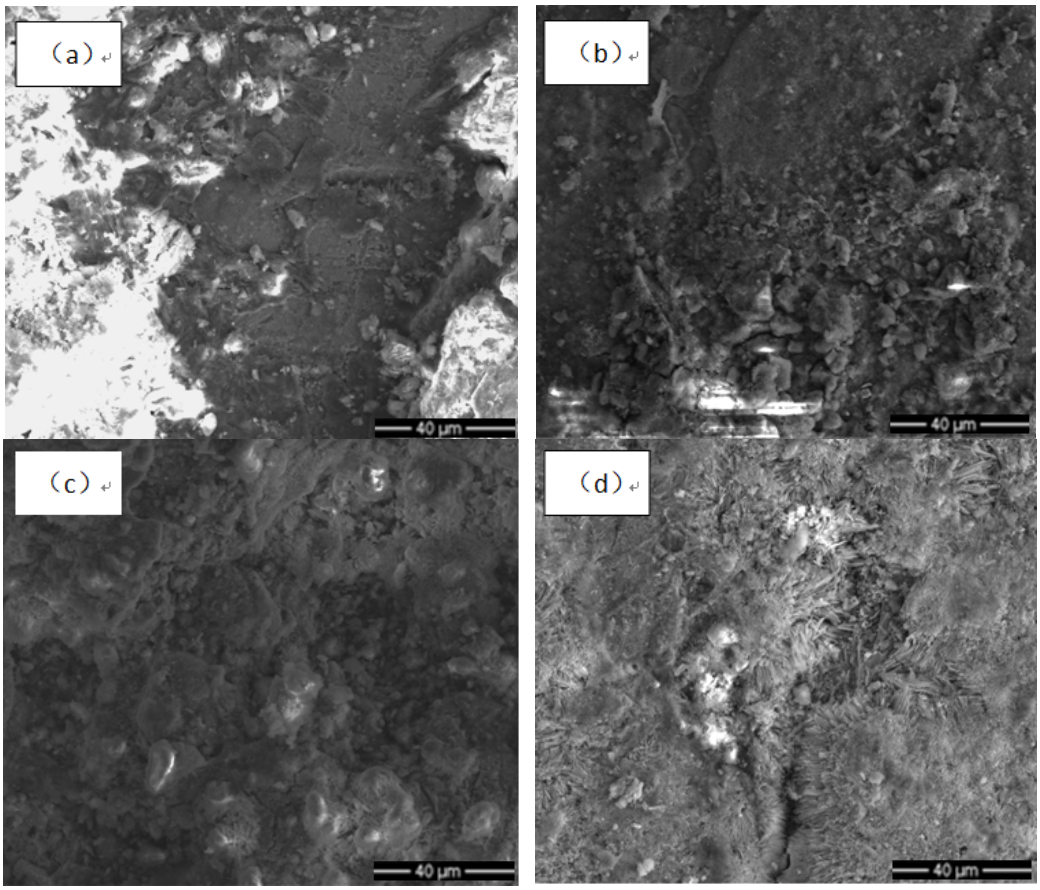


Figure 4. SEM micrograph of corrosion product of four grounding materials, (**a**) carbon steel, (**b**) galvanized steel, (**c**) Zn-Al coated steel, (**d**) copper.

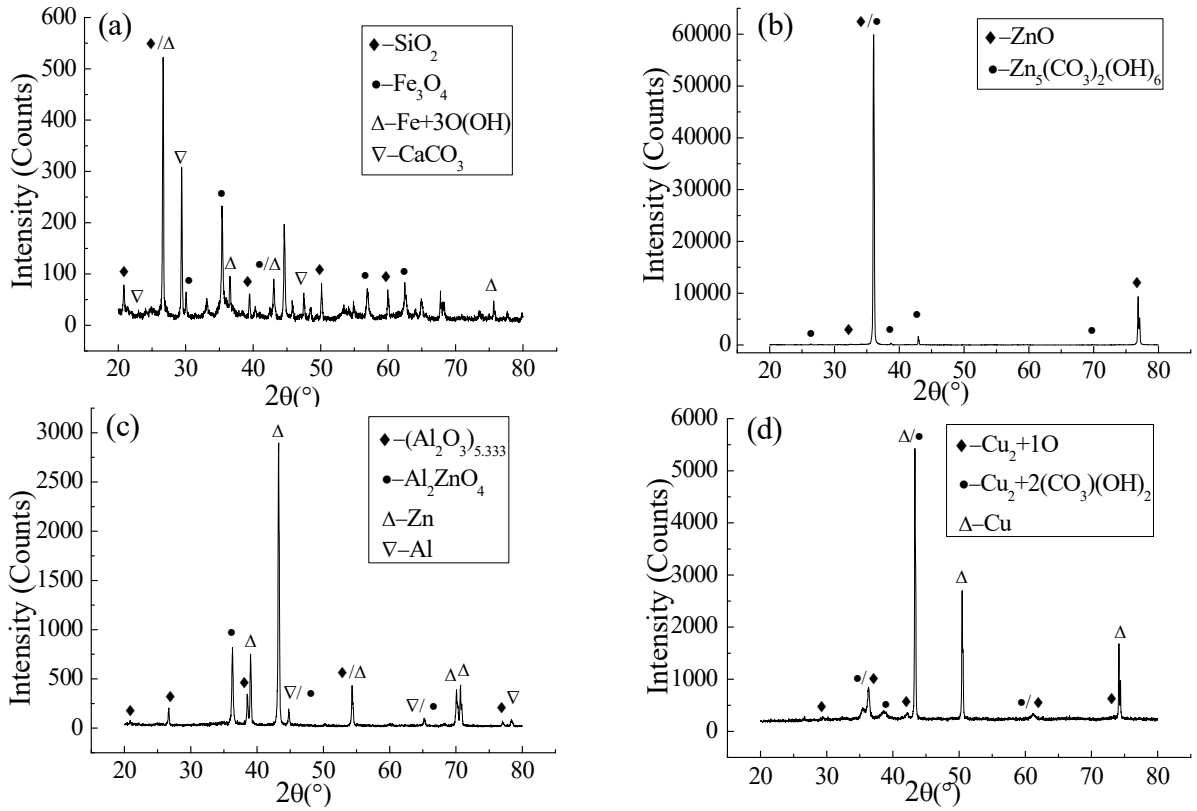


Figure 5. XRD patterns of corrosion product of four grounding materials, (**a**) carbon steel, (**b**) galvanized steel, (**c**) Zn-Al coated steel, (**d**) copper.

SEM and XRD of four grounding materials are shown in Figures 4 and 5. Figure 4a and Figure 5a show the surface corrosion product of carbon steel. It indicated that there is a thick layer of corrosion products, the main components are Fe_3O_4A and FeO(OH).The remaining components are SiO_2 and $CaCO_3$, mainly from the attachment of symbiotic soil. Figure 4b and Figure 5b show that the main corrosion product of galvanized steel is ZnO, $Zn_5(CO_3)_2(OH)_6$, in which $Zn_5(CO_3)_2(OH)_6$ has a smooth and compact structure and uniformly covers. Figure 4(c) and Figure 5(c) show that the corrosion products of the Zn-Al coating steel is mainly Al_2O_3 and Al_2ZnO_4.They are flocculent and closely packed and improve the corrosion resistance. Figure 4(d) and Figure 5(d) show that the surface corrosion product of copper is mainly Cu_2O, $Cu_2(CO_3)(OH)_2$. It is a needle-like corrosion products. The above analysis shows that the corrosion resistance of carbon steel is the worst. Zn-Al coated steel has the best corrosion resistance .It increased the service life of the grounding material.

The corrosion rate of four grounding materials in red soil was calculated by weight loss method. The calculation results are shown in Table 1.

Table 1. The weight loss of four specimens in acid red soil (After 10 months).

Types	Weight loss (g)	Corrosion weight loss rate ($g/dm^2 \cdot a$)
carbon steel	1.4634	6.0557
Galvanized steel	0.6798	2.6316
Zn-Al coating	0.2202	0.6606
copper	0.2215	0.6646

Table 1 shows that carbon steel has the fastest corrosion rate. Galvanized steel has a lower corrosion rate than steel. The corrosion rate of Zn-Al coated steel is very low. It has

a good corrosion resistance. Zn-Al coating can form a stable and dense composite on the surface and improve the corrosion resistance. It greatly extends the service life of the grounding material. The corrosion rate of copper is also low, but the cost is high and heavy metal ion pollution. The grounding material of Zn-Al coated steel has the best corrosion resistance. After 10 months of burial, the corrosion rate is only 0.6606 g/dm²·a.

4. Conclusion

The corrosion rate of the four grounding materials first increased and then decreased. Zn-Al coated steel is always maintained at low corrosion rate. The corrosion rate of carbon steel is the highest. Galvanized steel, Zn-Al coated steel and copper are mainly uniform corrosion and presented good corrosion resistance. Carbon steel is mainly pitting corrosion. Carbon steel has the worst corrosion resistance and the corrosion rate is 6.9393 g/dm²·a. The corrosion rate of galvanized steel is 3.2575 g/dm²·a. It has a better protection than carbon steel. However, its performance is affected by its thickness. Zn-Al coated steel has a low corrosion rate and is only 0.6606 g/dm²·a. It has excellent corrosion resistance and is also a potential grounding material.

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