

Microstructure and Electrical Contact Performance of Wires in Corrosion Air

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Abstract—The high contact resistance of the corrosion products is more likely to cause contact failure. Based on service condition and natural environment of transmission and transformation equipment, the deterioration mechanism of electrical wires was investigated from the view of corrosion. The surface morphology of specimens after corrosion is observed by stereoscopic microscope and scanning electron microscope (SEM). Chemical constitution was examined by X-ray energy spectrum. The contact resistance was measured by four-point method. The experiment results show that the corrosion is mainly electrochemical corrosion. Humidity and air pollutants are the main factors of effecting the corrosion. The corrosion products formed on the surface layer of testing specimens is loose and uneven, and easy to fall off in the role of external force. The inner corrosion layer is dense and combined closely with the substrate. The EDS analysis results there is large quantity of O and S, and Cu oxide and sulfide are probably existed. The corrosion and pollution which come from the surrounding environment can increase the static contact resistance obviously, and the maximum value can reach to about 2000m Ω .

Keywords—power grid; electrical contact; overheating; corrosion; air pollution

I. INTRODUCTION

The reliability of the high voltage electric network has been strongly dependent on the reliability of electrical contacts [1-3]. At the same time, it is well known that the environment can negatively affect the reliability of electrical contacts. In recent years, atmospheric haze becomes more and more severe in the north of China. The accidents caused by electrical contact are remarkably increasing [4]. Lin & Zhang [5] reported that dust in air can corrode and deteriorate electrical contact and even seriously damage electrical contact. Chen Wei, et al[6] explained the mechanisms and dynamics principle of electrical contact corrosion in detail. It is found that corrosion product due to the surrounding environment, such as atmospheric corrosion, temperature, humidity, dust contamination [7-10], has long been known as one of

the major degradation mechanisms for electrical contacts, which will cause high contact resistance and even poor reliability of electric system. Contact failure caused by corrosion shows that the corrosion behavior of connectors should be taken under consideration, especially for the devices used in field environments [11-14].

In the high voltage electric network, there are many Cu fittings. Cu is good conductor materials, but their anti-corrosion abilities are poor. These fittings are fully exposed to the air. Corrosion products can make overheating phenomenon. At present, there are little related research reports about corrosion failure, corrosion types and mechanisms of fittings. In this paper, the organization and corrosion product of actual power grid wires after serving 10 years were made, which is beneficial for safety use of fittings material.

II. EXPERIMENTAL MATERIALS AND METHODS

The wires were selected from the substations and the material is Cu. There are a number of chemical plants and steel mills nearby the substation. Exhaust emissions from these plants contain large quantities of sulfide. To study the electrical contact behavior and corrosion mechanism, a series of inspections and analytic research methods are introduced. The surface morphology of the specimens after corrosion was observed by stereoscopic microscopy and scanning electron microscopy (SEM). Chemical composition was examined by X-ray energy spectrum (EDS). The contact resistances were measured by four-point method.

III. RESULTS AND DISCUSSION

A. Microstructure and Corrosion Mechanisms Analysis

The stereoscopic microscope and SEM were used to observe the surface topography of result of wire clips, as shown in Fig .1. It can be seen that the corrosion products formed on the surface layer of testing specimens is loose and uneven, and easy to fall off in the role of external force. The inner corrosion layer is dense and combined closely with the substrate.

The chemical constitution of this corrosion product is listed in Fig .2 and Table I. There is large quantity of O and S, and Cu oxide and sulfide are probably existed. It is indicated that element of Zn is etched off and the corrosion degree is serious. The existing of elements of S can be attributed to the facts that there are a number of chemical plants and steel mills nearby substation. Exhaust emissions of these plants contain large quantities of sulfide. Study shows that SO₂ pollution is the most important factor in corrosion of zinc. The combined effect of humidity and SO₂ pollution will accelerate the corrosion of zinc corrosion. Pollutants or particulate pollutants, as the rainfall of rain, snow, fog or hail fell on the surface of wires and fittings. Sulfide dissolves in the water which becomes electrolyte solution. Zinc life is directly proportional to the thickness of the zinc coating. Although the galvanized surface may extend the life of wires and fittings, however, due to relatively thin zinc, as soon as the zinc layer is damaged, the zinc layer and the substrate will be accelerated corrosion. When water droplet forms on the pore region, pollutants dissolves in the water which becomes electrolyte solution. In addition, the existence of impurities in base metals promotes the occurrence of corrosion and provides channels into the substrate. Electrolyte solution penetrates into the pore and reacts with either zinc or copper. The substrate possesses much lower electric potential than zinc and the zinc plating becomes the cathodic portion during the corrosion reaction. The corroded products will grow and the reaction continues. The concentration of sulfide is higher enough to corrode the surface layer. The corrosion made the base metal to expose to the corrosion air. Due to changes in temperature, moisture and oxygen content, the corrosion reaction is further aggravated.

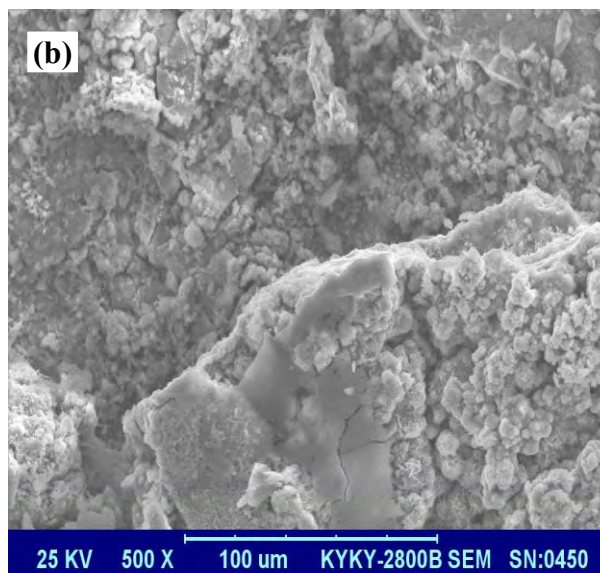


Figure 1. Morphology of wire clips corroded: (a) OEM morphology; (b) SEM morphology;

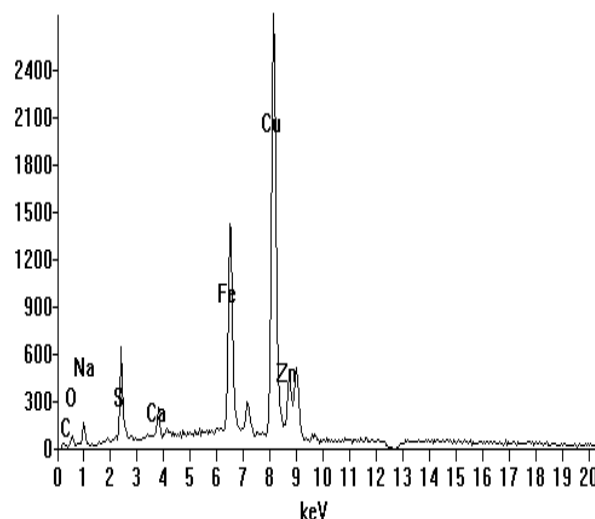


Figure 2. Energy spectrum of wire clips corroded

TABLE I. EDX RESULTS OF WIRE CLIPS CORRODED

elements	wt%	at%
C-(Ka)	0.1522	0.5752
O-(Ka)	7.2718	20.6281
Na-(Ka)	5.8552	11.5591
S-(Ka)	5.3699	7.6009
Ca-(Ka)	1.0248	1.1604
Fe-(Ka)	12.6710	10.2974
Cu-(Ka)	60.5555	43.2497
Zn-(Ka)	7.0996	4.9292

The Fig .3 shows that the morphology of wires after 10years service. It can be seen that the wires are dark and some of them are broken, which indicates that the wires are oxide seriously, as shown in Fig .3 (a). Some Cu wires are wrapped by the corrosion products and pollution, and these corrosion products are exist between the wires, as

shown in Fig .3 (b). The results of EDX analysis of the wires are shown in Figure 4 and Table II. The results show that a large number of S, Na, Ca elements are exist on the surface or gaps of Cu wires. The presence of the corrosion will result in high resistance, which will produce overheating phenomenon. Overheating of electrical contact is a very common phenomenon during the service of transmission and transformation equipment. The overheating defects are always a serious problem in electric network. The overheating of electrical contact not only increases wastage, bus also causes a transformation accident. With the increase of running load, the overheating defects of electrical contact become more frequency and serious. Copper is easily corroded by halogen, sulfur, selenium. Atmospheric haze containing much hydrogen sulfide is very harmful to the safety of electrical contact, especially, the electrical contact of switch equipment which is used in petrochemical factory, paper manufacturer and sewage treatment works.

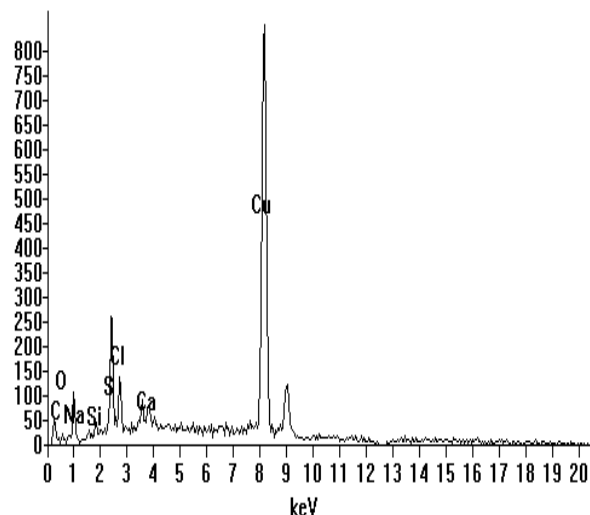


Figure 4. Energy spectrum of wires corroded

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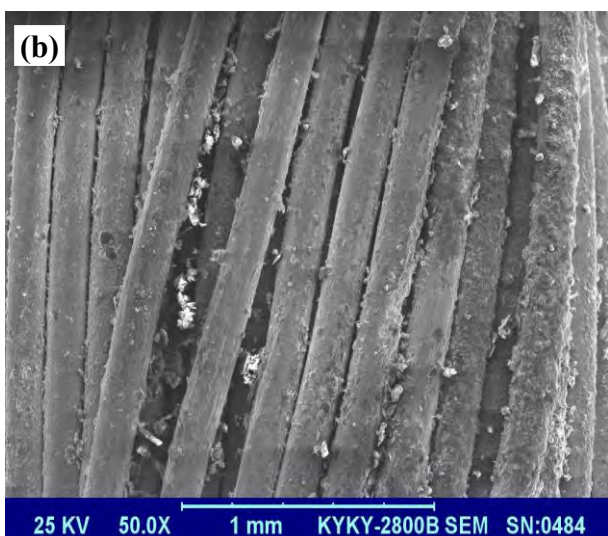


Figure 3. Morphology of wire corroded: (a) OEM morphology; (b) SEM morphology;

B. Contact resistance

Contact resistance is measured on the specimens after corrosion by four-point method. The constant current is 20mA and the normal force is set at 50g, 100g and 150g respectively. Contact resistance is measured for every 0.1m along a straight line through the corroded products. The contact locations are controlled by a micron micrometer.

The experiment results show that the contact resistance is about 10mΩ before corroded. For the corroded wire clip, the contact resistance is found changing from outside point to inside point through the corrosion area. The resistance values are increased rapidly in certain test points and the maximum value can reach to about 2000mΩ, so it can be concluded that the high contact resistance points are the field of corrosion products. The relationship between contact resistance of wire clip specimen corroded and normal force are shown in Fig 5. The resistance decreased with the change of force from 50g to 150g. When the force decreased to 50g, the contact resistance value is 1945 mΩ. The resistance test results show that the contact resistance became high and unstable due to the corrosion.

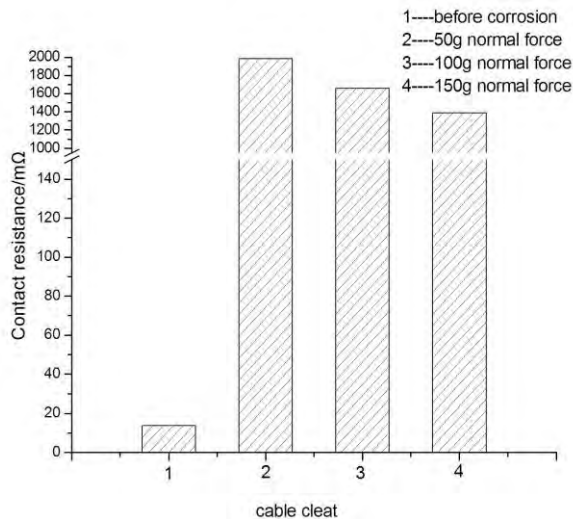


Figure 5. Contact resistance of wire clip

IV. CONCLUSIONS

In this paper, corrosion behavior of wires in power systems after serving up to 10 years has been studied. The surface morphology of the specimens after corrosion was observed by stereoscopic microscopy and scanning electron microscopy (SEM). Chemical composition was examined by X-ray energy spectrum (EDS). The contact resistances were measured by four-point method. Corrosion behavior and mechanism have been investigated, and the main conclusions are as follows:

The corrosion products formed on the surface layer of testing specimens is loose and uneven, and easy to fall off in the role of external force. The inner corrosion layer is dense and combined closely with the substrate. The EDS analysis results there is large quantity of O and S, and Cu oxide and sulfide are probably existed. The existing of elements of S can be attributed to the facts that there are a number of chemical plants and steel mills nearby substation. Exhaust emissions from these plants contain large quantities of sulfide. The corrosion and pollution come from the surrounding environment can increase the static contact resistance obviously, and the maximum value can reach to about 2000mΩ.

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