Corrosion analysis of angle steel used in 500kV transmission tower

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Abstract: Transmission tower is the load-bearing structure of high-voltage transmission line, and its stability is very important for the reliable operation of grid equipment. In recent years, the corrosion of transmission towers has become increasingly prominent due to long-term service in the harsh field, which seriously affects its service life. In this paper, the corroded angle steel of high-voltage power tower was studied by different physical and chemical testing methods such as macro inspection, metallographic analysis, mechanical property test, chemical composition analysis, energy spectrum analysis, and scanning electron micrograph analysis. The result revealed that the galvanized protective layer of the angle steel was well preserved without corrosion damage, and the corrosion spot on surface of the tower material was caused by the corrosion of other metal parts nearby and then the rusting outcome flowed with rain water to its surface.

1. Introduction
As the skeleton of power system, the reliability of transmission tower is of great importance in transmission and distribution of electric energy [1-3]. In the process of the transmission line inspection with the Unmanned Aerial Vehicles (UAV), it is found that some angle steel of transmission tower corroded. The transmission line has been put into operation for 20 years and there are no heavy industrial pollution enterprises around it. The hot dip galvanizing process is adopt for corrosion protection of the corroded angle steel, which is made of Q235. Meanwhile, the thickness and the width of the angle steel are 5mm and 56mm, respectively. In this paper, the corrosion causes of the angle steel of high-voltage transmission tower was studied by different testing methods and targeted anti-corrosion suggestions were put forward to avoid the recurrence of similar corrosion failure.

2. Experiment results and analysis
2.1. Macro inspection
Figure 1 shows the macro-morphology of the corroded angle steel of high-voltage transmission tower. It is clearly observed that the galvanized layer in most areas of angle steel for iron tower has been well preserved and its color is silvery white. In addition, there are a small amount of light brown corrosion products distributed in the local area of angle steel, without obvious plastic deformation and
mechanical damage. In order to guarantee better anti-corrosion effect for the auxiliary materials of iron tower, the double anti-corrosion system of hot-dip galvanizing and coating is adopt. Due to bending and twisting in the process of disassembly, the anti-corrosion coating has peeled and fallen off in some areas.

Figure 1. The macro morphology of the corroded angle steel.

2.2. Metallographic structure Analysis

Figure 2 shows the metallographic microstructures of the corroded angle steel. It is clearly seen that the metallographic structures of the angle steel are equiaxed pearlite and ferrite, without abnormal microstructure and its thickness of zinc coating on the surface is about 120μm, which is much higher than the minimum thickness of 70μm required in the standard.

Figure 2. The metallographic structure of the corroded angle steel.
2.3. Chemical composition analysis

The chemical compositions of the corroded angle steel used for the transmission tower are determined by means of chemical composition analysis and the testing results are shown in Table 1. The result illustrates that the contents of each element in the angle steel meet the requirement of standard GB / T 700-2006 for Q235B steel.

| Chemical element | C   | Si   | Mn   | P     | S     |
|------------------|-----|------|------|-------|-------|
| Rod part         | 0.11| 0.10 | 0.39 | 0.026 | 0.012 |
| Standard requirements | ≤0.22 | ≤0.35 | ≤1.40 | ≤0.045 | ≤0.045 |

2.4. Microstructure and energy spectrum analysis of corrosion products

Figure 3 shows the micro morphology of the corrosion products sampled from the corroded angle steel and it could be observed that the corrosion products are dense clusters with different sizes on the surface.

The chemical compositions of the corrosion products on the surface of the angle steel are analyzed by energy spectrum analyzer and the testing result is shown in Figure 4 and table 2. The result reveals that the corrosion products of the angle steel are mainly composed of iron, zinc and oxygen elements. The higher zinc content on the surface of angle steel indicates that the zinc coating has been well preserved, so it could effectively inhibit the corrosion of transmission tower. And silicon element in the corrosion products of the angle steel should exist in the form of oxide, which is mainly caused by the adsorption of sand on its surface.
2.5. Mechanical properties testing

The mechanical properties of the corroded angle steel are tested by universal tensile testing machine at room temperature and the testing result is shown in Table 3. The result shows that the tensile strength, yield strength and percentage elongation after fracture of the angle steel meet the requirement of standard GB/T 700-2006.

### Table 3. The test result of mechanical properties of the corroded angle steel (20°C)

| Test item                     | Yield strength /MPa | Tensile strength /MPa | Percentage elongation after fracture /% |
|-------------------------------|---------------------|-----------------------|-----------------------------------------|
| Standard requirements         | ≥235                | 370～500              | ≥26                                     |
| Test values                   | 300                 | 406                   | 36                                      |

3. Analysis and discussion

The chemical composition of the corroded angle steel used for 500kV transmission tower meets the requirements of the standard, which eliminates the possibility of corrosion caused by misuse of materials. Meanwhile, the metallographic structures of the angle steel are equiaxed pearlite and ferrite, without abnormal microstructure. The galvanized layer in most areas of angle steel for iron tower has been well preserved with its thickness of 120μm, which is much higher than the minimum thickness of 70μm required in the standard [4-7]. In addition, the result of energy spectrum analysis shows that there is a large amount of zinc on the surface of the angle steel, which indicates that the zinc coating is not serious corroded and could effectively inhibit the corrosion of the iron tower. Therefore, the corrosion on the surface of the angle steel should be caused by the external corrosion products flowing to the surface of the iron tower by rain and snow. Considering the mechanical test results of the angle steel, the transmission tower could be used continuously [8,9].

4. Conclusions

In this paper, the corrosion reason of angle steel used for high-voltage transmission tower was systematically studied and analyzed. Through comparing and analyzing the experimental results, the following conclusions are drawn.
1) The corrosion of the angle steel in the transmission tower is mainly caused by the corrosion of the other metallic component nearby that has not been protected by effective anti-corrosion protection, and its corrosion products have been washed to the surface of the angle steel by rainwater or snowwater. Therefore, there is no obvious damage to the zinc coating on the surface of the angle steel, which has little impact on its anti-corrosion effect.

2) The source of rust spots on the surface of corroded angle steel should be investigated, and the adjacent fittings or fasteners with serious corrosion should be replaced in time, so as to avoid the influence of corrosion failure of metallic component on the safe operation of transmission tower [10].

3) The newly replaced angle steel should adopt hot dip galvanizing anti-corrosion process. Meanwhile, the minimum and average thickness of the zinc coating should be not less than 45μm and 70μm respectively, so as to ensure the corrosion resistance of the angle steel [11,12].

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