Discussion and analysis on corrosion causes of metallic components used in transmission tower

Chen Hao1,2,a*, Tian Wentao1,2,b, Guo Yang1,2,c, Zhang Zhihao1,2,d, Bai Haolun1,2,e

1Inner Mongolia Power Research Institute, Hohhot, Inner Mongolia, China
2Inner Mongolia Enterprise Key Laboratory of High Voltage and Insulation Technology, Hohhot, Inner Mongolia, China

*aemail: chenhao3@impc.com.cn
bemail: tianwentao2432@126.com, cemail: guoyang1981@163.com,
demail: 35642333455@qq.com, eemail: baihailun1998@163.com

Abstract: With the rapid development of power grid and the continuous aggravation of heavy industry pollution, more and more attention would be paid to the corrosion of metallic components of transmission line. The chemical and electrochemical corrosion of transmission tower and its fittings would shorten the service life. Therefore, it requires regular anti-corrosion coating treatment or even overall replacement, which not only wastes a lot of financial and material resources, but also causes safety accidents. In this paper, different testing methods such as macro inspection, metallographic analysis and energy spectrum analysis were adopt to investigat and analyse corrosion behaviour of cotter pin, fitting, guyed rod and angle steel used in transmission tower. Additionally, corresponding anti-corrosion measures were put forward in order to improve the anti-corrosion performance of the metallic components and guarantee the safety and stability of transmission line.

1. Introduction

As the skeleton of the transmission line, transmission towers are usually set up in a variety of natural environment, which would encounter different corrosion damage. Once the transmission tower is corroded, its bearing capacity would be greatly reduced, so that the safety and stability of the transmission line would be seriously affected[1,2]. In this paper, metallic components used for transmission equipment, such as cotter pins used for fittings of cross arm and ground wire hanging point, fitting used for suspension composite insulator, angle steel and guyed rod of high-voltage transmission tower, were investigated by different physical and chemical test methods. Meanwhile, the corrosion causes of the above metallic components were systematically studied and the corresponding precautions were put forward to avoid the recurrence of the similar corrosion.

2. Cotter pin

2.1. Corrosion failure case

In the process of the transmission line inspection with the Unmanned Aerial Vehicles (UAV), it is found that some cotter pins used for fittings of cross arm and ground wire hanging point were seriously corroded, and its macro morphology, microstructure and EDS results are shown in Figure 1 and Table 1. On the surface of the cotter pins, it is clearly observed that yellowish-brown corrosion
products are distributed in lamellar form and microstructure are composed of a few diffused carbides and massive ferrite. Moreover, the EDS result reveals that the cotter pin was made of carbon steel, and its corrosion products are mainly composed of oxygen, iron, sulfur, silicon and aluminum, which should be ferrous sulfate and iron oxide.

![Macro morphology](image1.png) ![Microstructure](image2.png)

Figure 1 The physical and chemical test results of the corroded cotter pins.

| Chemical element | Fe   | Si  | O   | S   | Al  | C   |
|------------------|------|-----|-----|-----|-----|-----|
| Base metal       | 95.02|     |     |     |     | 4.98|
| Corrosion products| 65.74| 6.58| 23.10| 2.07| 2.51|     |

2.2. Corrosion cause
The chemical composition of the cotter pin is mainly iron and carbon, without austenite forming elements such as nickel and manganese. At the same time, chrome chromium was found to improve the corrosion resistance of the steel. Therefore, it could be concluded that the cotter pin is made of ordinary carbon steel instead of austenitic stainless ones, resulting in insufficient corrosion resistance. In addition, the long-term industrial pollution makes the content of strong corrosive gas and dust in the atmospheric environment around the tower very high, which lead to rapid corrosion damage of the cotter pin [3,4].

2.3. Precaution
1) Before the cotter pin is put into use, its chemical composition analysis and hardness test should be carried out to avoid premature failure due to insufficient corrosion resistance and elasticity. 2) The cotter pins used in the same batch should be subject to material qualification in order to prevent misuse of material.

3. Fitting
3.1. Corrosion failure case
Figure 2 shows the macroscopic and microscopic morphology and EDS results of the corroded fitting used for suspension composite insulator of 220kV transmission line, and it is clearly seen that connecting plate and right angle hanging plate of insulator at high-voltage side are seriously corroded while the zinc coating of connecting fittings at low-voltage side has preserved intact. Moreover, the microstructure are composed of equiaxed pearlite and polygonal ferrite, and a large number of corrosion pits are irregularly distributed on the surface of the fittings. The EDS result indicates that the
corrosion product is mainly composed of iron oxide, silica, chloride and sulphate, which indicates that the industrial pollution around the transmission line is serious.

(a) Macro morphology                      (b) Microstructure

(c) Energy spectrum analysis chart

Figure 2. The physical and chemical test results of the corroded fitting.

3.2. Corrosion cause

With the continuous emission of industrial waste gas, the content of sulfur dioxide in the atmosphere around 220kV substation is higher. As sulfur dioxide could react with zinc of the fitting to form soluble zinc sulfate, resulting in rapid consumption of galvanized layer and serious corrosion of fitting. In addition, because of the thinner thickness of galvanized layer and insufficient adhesion, the corrosion resistance of some fittings is poor, resulting in acceleration of corrosion process and even premature failure of galvanized layer [5,6].

3.3. Precaution

1) Before putting into use, the corrosion resistance of zinc coating for the fittings should be comprehensively tested, and the thickness of zinc coating should be increased as much as possible on the premise of ensuring the dimensional accuracy. 2) In the typical industrial pollution area, because of the rapid consumption of the galvanized layer, the zinc aluminum alloy with stronger resistance to sulfide corrosion should be adopt as anticorrosive coating, so as to avoid the recurrence of similar corrosion failure.
4. Angle steel

4.1. Corrosion failure case
The macroscopic and microscopic morphology of the corroded angle steel of high-voltage transmission tower and the energy spectrum analysis chart of the corrosion products were shown in Figure 3, and there are a small amount of yellow corrosion product distributed in the local area. It is clearly seen that its metallographic structures are equiaxed pearlite and ferrite are and its thickness of zinc coating is about 120μm, which is much higher than the minimum thickness of 70μm required in the standard. Additionally, the higher zinc content on the surface of the corroded angle steel indicates that the zinc coating has been well preserved, so it could effectively inhibit the corrosion of transmission tower.

![Microstructure](image)

(a) Macro morphology (b) Microstructure

![Energy spectrum analysis chart](image)

(c) Energy spectrum analysis chart

Figure 3. The physical and chemical test results of the corroded angle steel.

4.2. Corrosion cause
The corrosion of the angle steel in the transmission tower is mainly caused by the corrosion of the other metal 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 [7,8].

4.3. Precaution
1) 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 metal component on the safe operation of transmission tower. 2) The
hot-dip galvanized process should be adopt for the newly replaced angle steel. Meanwhile, the minimum and average galvanized layer thickness should be not less than 45μm and 70μm respectively, so as to ensure the corrosion resistance properties of the angle steel.

5. Guyed rod

5.1. Corrosion failure case
During the inspection of a high voltage transmission line, some guyed rod of high-voltage towers were found seriously corroded, and its macroscopic and microscopic morphology and energy spectrum analysis chart are shown in Figure 4. And it could be observed that the zinc coating of the corroded guyed rod has completely consumed and the metallographic structures are ferrite and banded pearlite. The corrosion products are mainly composed of carbonate, iron oxide and sulfate, so that it revealed the corrosive sulfate in the soil around the pull rod is high.

![Macro morphology](image1) ![Microstructure](image2) ![Energy spectrum analysis chart](image3)

Figure 4. The physical and chemical test results of the corroded guyed rod.

5.2. Corrosion cause
The high-voltage transmission tower is located around heavy industry pollution enterprises, where is seriously polluted. Many years of industrial production has made the guyed rod in the soil with high sulfate content for a long time. Under the the combined action of electrochemical and chemical corrosion, the galvanized protective layer would react with the sulfur in the soil to form soluble salt constantly, resulting in corrosion and consumption of galvanized steel[9,10].
5.3. **Precaution**

1) The hot-dip galvanized process should be adopted as the anti-corrosion of the newly replaced guyed rod. Meanwhile, its minimum zinc coating thickness is not less than 85 μm, and its diameter is not less than 16mm, so as to ensure sufficient corrosion resistance and bearing capacity. 2) The concrete pouring sealing technology could be considered as a solution to improve the anti-corrosion of guyed rod, in order to avoid the recurrence of similar corrosion failure effectively.

6. **Conclusions**

In this paper, the metal components used in transmission line were studied by different means such as macro inspection, metallographic analysis, energy spectrum analysis and so on. Through comparing and investigating the corrosion failure cases, the corrosion mechanism and behaviour of metallic components used in transmission tower were summarized, and effective anti-corrosion measures were proposed to prevent corrosion failure of metallic components and ensure the reliability and stability of power grid.

**Acknowledgments**

This study was funded by the Science and Technology Projects of Inner Mongolia Power Company (Grant No. 2021-46 and Grant No. 2019-102).

**References**

[1] Yue, Z.W., Li, X.G., Fan, Z.B., Guo, K. (2015) Research on corrosion protection life-cycle cost of transmission steel towers. Electric Power, 48: 150-155.

[2] Li, W.H., Yin, X.T., Zhou, X.J., Zhang, S.P. (2018) Summary on atmospheric corrosion and protection measure of steel components and galvanized components for transmission and distribution projects. Material Protection, 51: 114-118.

[3] Zhang, W.X. (2004) Contact couple corrosion between metal holder and conductor in power transmission and transformation system and protection methods. Material Protection, 37: 38-39.

[4] Zhang, X., Chen, A.S., Ni, M.S. (2009) Corrosion crack analyse of the high voltage transmission steel tower. Anhui Electric Power, 15: 11-15.

[5] Wu, T.B., Wang, Z.J. (2020) Corrosion failure analysis and study on fittings of overhead power transmission lines. Electric Switcher, 58: 69-72.

[6] Chen, J.J., Hu, J.R., Xie, Y., Hu, B.T. (2013) Corrosion analysis and protection measures for fittings of overhead power transmission lines. Electric Power Construction, 34: 95-99.

[7] Wang, D., Sun, Y.J., Ma, X.F., Y, D.W, Wang, S.J. (2018) Corrosion monitoring of the transmission towers in coastal area. Shandong Electric Power, 45: 32-36.

[8] Chen, Y., Zhang, C.M., Wang, G.G., Miao, W.H. (2010) Corrosion and protection of transmission towers. Electric Power Construction, 31: 55-58.

[9] Wan, H. (2014) Concrete foundation construction technology on UHV transmission line in strong corrosion soil areas. Ningxia Electric Power, 3: 14-16.

[10] Tang, Z., Li, B.J. (2011) The corrosion analysis of the earthing device of the UHV transmission tower. Journal of Chongqing Electric Power College, 16: 72-74.