Research of "three-span" anchor clamp crimping for overhead transmission lines

Ke-jian Ouyang\textsuperscript{1,a} Jun Hu\textsuperscript{2} Ming-cai Duan\textsuperscript{3} Chao-wen Fang\textsuperscript{4} Chao Feng\textsuperscript{1} Yi Xie\textsuperscript{1} Li-hua Xiao\textsuperscript{5}

\textsuperscript{1}State Grid Hunan Electric Power Company Limited Research Institute, Changsha 410007, China
\textsuperscript{2}State Grid Changsha power supply company, Changsha 410015, China
\textsuperscript{3}State Grid Chenzhou Power Supply Company, Chenzhou 423000, China
\textsuperscript{4}State Grid Xiangtan Power Supply Company, Xiangtan 411100, China
\textsuperscript{5}State Grid Hunan Electric Power Company Limited, Changsha 410004, China
\textsuperscript{a} Corresponding author: ouykj@126.com

Abstract. In this paper, according to the "three-span" anchor clamp crimping quality inspection work plan and the statistical data of the overhead data transmission line, the quality problems of the anchor clamp crimping are summarized and the corrective measures are proposed. In order to compare the non-destructive testing effect of the "three-span" anchor clamp crimping quality of the transmission line and the influence of the crimping defects on the mechanical properties, the contrast test between the radiation detection and the ultrasonic inspection was also carried out. The test shows that the radiographic imaging can clearly show the internal defects of the crimping in the radiographic inspection, and the ultrasonic thickness measurement can quickly identify the defects.

1. Work overview

The operation security of overhead transmission lines is threatened by the disconnection between strain clamp or splicing sleeve and conductor. The quality of anchor clamps is getting more and more attention\cite{1-5}. According to the Notice of the State Grid Corporation on Printing and Distributing the "Three-Span" Major Anti-accident Measures (Trial) for Overhead Transmission Lines (National Grid Transportation Inspection [2016] No. 413), the quality inspection of "three-span" anchor clamp crimping for overhead transmission lines work program and the troubleshoot data statistics report were written. Besides, because of the fact that the provincial inspection personnel do not understand the radiation detection, the innovative ultrasonic thickness measurement method is used instead of the high-altitude radiation detection, which avoids the problems of bulky equipment and strong radiation in the equipment. At the same time, the “Metal Testing Technology for Power Grid Testing” was held at the Electric Power School and the technicians which attended the conference were trained. Through power outage maintenance, on-site technical training was conducted on the transmission and transformation engineering company, Zhangjiajie Company, Zhangzhou Company, Yueyang Company, Xiangtan Company, Shaoyang Company and Loudi Company, so that the first-line team members mastered the testing methods in a short period of time.
2. Problem discovered

2.1 One of the two steel anchor grooves of the tension clamp is not crimped into place

The defect which one of the two steel anchor grooves of the tension clamp is not crimped into place in the "three-span" anchor clamp of the transmission line is a common problem. Such as the transmission and transformation company found 500kV Kunding line #316 tower A, B, C three-phase anchor clamp. Zhangjiajie 220kV Huling Line #248 tower B phase right sub-wire anchor clamp and Zhangzhou 220kV Sufu I line #34 tower A, B, C three-phase anchor clamps have similar defects. The defect is similar to the situation shown in Figure 1.

![Figure 1. Defect diagram](image)

2.2 The anchor clamp steel anchor model does not match the wire

Zhangjiajie 220kV Huling Line #198 Tower A, B, C three-phase conductor model is LGJ300/40, but the anchor clamp steel anchor model is NY300/50. Using the big anchor to replace the small one* will lead to steel core holding force Lower.

3. Rectification measures

For the defect which one of the two steel anchor grooves of the tension clamp is not crimped into place, it is recommended to use the pre-twisted wire safety backup clamp for temporary reinforcement and reinforcement for the transmission line with short inspection period. Under the condition of power interruption time, it is recommended to use a molding machine to crimp a groove of the uncompressed position to improve the holding force of the tension clamp.

In view of the mismatch between the model of the anchor clamp and the wire mismatch, it is recommended to use the pre-twisted wire safety backup clamp for temporary reinforcement and reinforcement of the transmission line with short inspection period. Under the condition of power interruption time, it should be cut off and reconnected.

4. Contrast test between radiation detection and ultrasonic inspection

4.1 Test survey

In order to compare the non-destructive testing effect of the "three-span" anchor clamp crimping quality of the transmission line and the mechanical properties of the crimping defects, two typical conductors LGJ400/50 and LGJ300/40 in 500kV and 220kV transmission lines were selected respectively to simulate crimping defect test. The corresponding anchor clamp models are NY400/50 and NY300/40, as shown in Figure 2. One end of the two kinds of wires is normally crimped according to the requirements of the DL/T5285-2013 "Technical Regulations for Overhead Conductors and Grounding Hydraulic Pressure Connections for Transmission and Transformation Engineering". The normal crimping is shown in Figure 3. The other end of the wire LGJ300/40 simulates a groove that is not crimped, as shown in Figure 4. The other end of the wire LGJ400/50 simulates two grooves that are not crimped, as shown in Figure 5.

4.2 Radiation detection

The portable X-ray inspection device has a total weight of 3kg, an axial maximum imaging length of 480mm, a voltage of 75kV, and a current of 0.35mA. The ray machine adopts a rechargeable battery, and the imaging data is wirelessly transmitted in real-time, and the detecting device is as shown in Figure 6. After the sample is crimped, the first non-destructive testing of the radiation is performed.
The radiographic imaging can clearly show the internal defects of the crimping. The radiographic imaging of the normal crimping end of two of the wires is shown in Figures 7. The simulated defect imaging is shown in Figures 8-9, respectively.

![Anchor clamp test sample](image)

Figure 2. Anchor clamp test sample

![Crimping according to standard requirements](image)

Figure 3. Crimping according to standard requirements

![Simulating a groove not crimped (LGJ300/40)](image)

Figure 4. Simulating a groove not crimped (LGJ300/40)

![Simulates two grooves not crimped(LGJ400/50)](image)

Figure 5. Simulates two grooves not crimped(LGJ400/50)

![Portable X-ray inspection device](image)

Figure 6. Portable X-ray inspection device
4.3 Ultrasonic testing
The ultrasonic thickness measurement was performed on the crimping test, and the method can quickly distinguish the defects. The test results are shown in Table 1.

Table 1. Ultrasonic thickness measurement

| Anchor clamp | Thickness measurement at the groove of the normal crimping ends | Simulated defect ends |
|--------------|---------------------------------------------------------------|-----------------------|
| NY400/50     | The two maximum values are 7.49mm and 7.50mm, and the minimum average value is 5.33mm. | The average thickness is 5.34mm |
| NY300/40     | The two maximum values are 6.90mm and 6.88mm, and the minimum average value is 5.09mm. | The maximum value is 6.89mm, and the minimum average value is 5.10mm. |

4.4 Mechanical properties test
The mechanical properties of the two wires were tested. The tensile test is shown in Figure 10. During the tensile test, the two anchor clamp aluminum sleeves simulating the crimping defects have a certain amount of slip on the steel anchor, while the other normal crimping end has no slip. The test found that the NY400/50 anchor clamps with two grooves not pressed have the larger slip, indicating that the holding force between the aluminum sleeve and the steel anchor is insufficient due to the defect, and the load is mainly borne by the steel core. After the break, both tension clamps slide out of the steel anchor, which is consistent with the appearance of the 2015 500kV Wahai 2 Line, Hongwa 2 Line and Nuclear South Line 1 and 2 lines of Liaoning Company. The tensile strength of the anchor clamp of the two grooves which are not crimped is 79.7% of the value of the tensile force of the wire, while the anchor clamp of a groove which is not crimped is 104%. The test shows that the aluminum conductor partially bears part of the load on the conductor, which varies with the type of conductor. The test results are shown in Table 2. The tensile test is shown in figure 11–14.
Table 2. Mechanical properties test

| Cases                                      | Conductor breaking force (kN) | Test value (kN) |
|--------------------------------------------|------------------------------|-----------------|
| The two grooves are not pressed (LGJ400/50)| 123.4                       | 98.4            |
| A groove is not pressed (LGJ300/40)        | 92.22                        | 96.1            |

Figure 10. Mechanical properties test

Table 3. Comparison of ray and ultrasonic testing methods

| Detection method       | Equipment weight | The tower-operation time (a anchor clamp) | Advantages | Disadvantages                                                                 |
|------------------------|------------------|------------------------------------------|------------|-------------------------------------------------------------------------------|
| Radiation detection    | 3kg              | 40 minutes                                | Real-time imaging, clear and clear, can detect steel anchors. | Strong radiation, personnel need to evacuate; equipment is heavier, testing time is longer; need professional testing institutions to implement. |
| Ultrasonic testing     | 223g             | 10 seconds                                | Lightweight and fast to detect. | Steel anchors cannot be tested, and frontline personnel need certain testing experience. |

Figure 11. Tension clamp (NY300/40) aluminum casing slips off from the steel anchor

Figure 12. Aluminum casing slips off the steel anchor leaving the aluminum block (one groove is not crimped)
Figure 13. Tension clamp (NY400/50) aluminum casing slips off from the steel anchor

Figure 14. The aluminum sleeve slips off the steel anchor (the two grooves are not crimped)

4.5 tower-operation test
A tower of 500kV Kunsha I line retreat section was selected for tower-operation inspection. The tower-operation is shown in Figure 15, and the radiation detection image is shown in Figure 16. The two methods are as shown in Table 3.

5. Conclusion
In this paper, according to the "three-span" anchor clamp crimping quality inspection work plan and the statistical data of the overhead data transmission line, the quality problems of the anchor clamp crimping are summarized and the corrective measures are proposed. In order to compare the non-destructive testing effect of the "three-span" anchor clamp crimping quality of the transmission line and the influence of the crimping defects on the mechanical properties, the contrast test between the radiation detection and the ultrasonic inspection was also carried out. The test shows that the radiographic imaging can clearly show the internal defects of the crimping in the radiographic inspection, and the ultrasonic thickness measurement can quickly identify the defects.

Figure 15. The tower-operation ray detection

Figure 16. The tower-operation ray detection implementation imaging

References
[1] P. Zhang, Y. Qin, X.T. Xiong, L.Y. Chen, D.Jia, H.M. Kuang, Elec. Pow. Eng. Tec. 34 65-68 (2015)
[2] W.G. Meng, Enter. Sci. Tec. Dev. **21** 23-25 (2012)
[3] C.L. Yu, Chi. Sci. Tec. Inv. **28** 168 (2017)
[4] Z.H. Lin, G.H. Zheng, Mod. Ind. Econ. Infor. **4** 17-18 (2018)
[5] J.F. Ye, J.Q. Wang, Hub. Elec. Pow. **12** 37-38 (2014)