Study on Nondestructive Testing Methods for Crimping Quality of Steel Cored Aluminum Strand

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Abstract. The crimping quality of steel cored aluminum strand for overhead transmission lines has a direct influence on the safe and stable operation of lines. The common crimping quality problem of splicing sleeve is analyzed in this paper. It is indicated that the core issues of crimping of steel cored aluminum strand is the inaccurate crimping positioning of the aluminum tube of splicing sleeve. At present, there is no effective and convenient nondestructive method to implement quality supervision during crimping process. Aiming at the above problem, magnetic detection can be used to indicate the relative position between the non-crimped area of steel and aluminum tubes since they have different magnetic properties. We propose to strengthen the crimping quality supervision of steel cored aluminum strand in order to ensure the safe operation of transmission lines.

1. Introduction
Steel cored aluminum strand of overhead transmission lines is the high way of electrical energy. Splicing sleeve is inevitably used for crimping of steel cored aluminum strand to satisfy the needs of overhead transmission lines, because it is a long way of transmission lines and route of transmission lines is influenced by land form and load center. In recent years, to increase the security lever of a very few of important ultra-high voltage transmission lines, steel cored aluminum strand is required to be made by fixed measurements to avoid the using of splicing sleeve, though it is not promoted widely. So splicing sleeve is still widely existence in the overhead transmission lines of network system[1].

Crimping installation of splicing sleeve is always the key point and difficult point in quality control of overhead transmission lines construction. Construction technology for crimping and work instruction cards will be compiled by each project management organization for training. The problems of crimping for steel cored aluminum strand are regulated in industry standards, however, crimping for splicing sleeve is often operated at high place, so quality supervisors hardly supervise in the field. Furthermore, crimping technology is concealed work, and there is no method to inspect
quality except performing destructive tests after completion of construction. Uncontrollable human factors are left in the crimping quality, because crimping quality control can only rely on the construction workers to consciously abide by the construction technology.

Operational experience from 500kV EHV line to 110kV general line, the crimping quality of steel cored aluminum strand has been found, which has led to line tripping and power failure, even led to high-speed rail outage. In this paper, the problem of crimping quality inspection of steel cored aluminum strand is discussed, the causes of the quality event are analyzed and corresponding nondestructive testing techniques are researched, so as to achieve the goal of technical supervision of the crimping.

2. Quality analysis of crimping

Based on failure cases in the past and domestic literature\(^2\text{-}^3\), there are two kinds of crimping quality problems of splicing sleeve. One kind is not-qualified margin, the other kind is inaccurate positioning crimped, because of inaccurate locating of the aluminum splicing sleeve crimping, the center of the aluminum splicing sleeve and the center of the steel splicing sleeve of which being crimped outside the steel core are not coincident. It causes that the length of the sides of aluminum splicing sleeve inconsistent with the actual length of crimping area, there is lacking crimping of aluminum splicing sleeve inside where is near to steel splicing sleeve as Figure 1.

![Figure 1. A locating mistake of crimping of the splicing sleeve](image)

The unqualified on margin of the aluminum tubes crimping is mainly caused by the abnormal output of the hydraulic system, in accordance with standards, the rated working pressure of hydraulic system should not be less than 63MPa under normal circumstances when crimping sleeve of aluminum alloy are crimped. After being crimped only one group value of three sets of margins S is allowed to be no greater than 0.866kD (k: 0.990-0.986, D: crimping sleeve diameter). If the output of hydraulic system and rated work pressure deviation is big, the margin after being crimped would not meet the standard demand\(^4\), what will eventually cause the aluminum tubes to be not crimped tightly or too tightly to be damaged. Because the splicing sleeve is installed in the span of the transmission line and there is a height dispersion between adjacent towers, there is a certain inclination in the splicing sleeve. The rain inevitably goes through the line into the non-crimped and inclined aluminum splicing sleeve, for which results in corrosion and useless of the steel core and the steel tube. These problems can be solved through technical supervision and verification or retesting the margin.

From the stress analysis, the aluminum splicing sleeve is charged with the stress of the aluminum line through the axial friction which caused by crimping deformation of the outer aluminum line in the steel cored aluminum strand at both ends. For the constant friction coefficient between aluminum splicing sleeve and outer aluminum line in the steel cored aluminum strand, the applied pressure of hydraulic construction is basically constant. So the friction force is determined by the frictional contact area, in other words, the length of the effective crimping area between aluminum splicing sleeve and the outer aluminum line in the steel cored aluminum strand. Since inaccurate locating for aluminum splicing sleeve crimping, the center of the aluminum splicing sleeve and the center of the steel splicing sleeve which is used for the crimping of the core are not coincident. It will cause the lack of the friction in the part of aluminum splicing sleeve where is lack of crimping, and the part will become the weakest part of the whole steel cored aluminum strand, and eventually invalid.
The crimping construction of the connecting pipe splicing sleeve belongs to concealed work, and the misunderstanding for the load transfer after the splicing of the steel cored aluminum strand exists in the mind of the workers. Even most workers mistakenly believing that the steel core is charged with the load and the aluminum line is charged with the current, so that there is the idea that the finishing of crimping between steel core and the steel splicing sleeve is qualified. However, the locating of crimping between the aluminum splicing sleeve and the steel splicing sleeve is not taken seriously. What’s more, there is no simple and effective method to inspect and supervise the locating of crimping at the present stage for concealed works. The locating defects of crimping can hardly be found in the field by nondestructive and quick methods. So, these problems are the difficulties for splicing of the steel cored aluminum strand, and often leads to disconnection or pulling out of transmission lines at the part of splicing, what seriously affects the safe running of the power grid. For example, analyzing of the useless splicing sleeve after the wire of a 110kV line being ripped out at an end of the splicing sleeve, it is found that the center of the aluminum tubes and the center of the splicing sleeve are not coincident. This is a typical locating mistake of crimping of the aluminum tubes, as shown in Figure 2.

![Figure 2. A locating mistake of crimping of the aluminum tubes](image)

3. NDE method of the crimping quality

It is the key factors to determine whether the crimping of the splicing sleeve is located properly whether the non-crimping area of the aluminum splicing sleeve and the center of the steel splicing sleeve used for crimping the steel core inside are coincident. So, the key point to check the quality of the crimping of the splicing sleeve is checking the relative position of the non-crimping between the steel splicing sleeve and the aluminum splicing sleeve. For the stronger ferromagnetic properties of steel, the outer diameter of the steel splicing sleeve is far bigger than the steel core of the steel cored aluminum strand and the magnetic force of the steel splicing sleeve produced in a fixed external magnetic field is much stronger than that of the steel core[5]. So the location of steel splicing sleeve in the aluminum splicing sleeve can be determined by a sudden change in its magnetic force, as shown in Figure 3.

The whole splicing sleeve is examined by magnetic force with a magnetometer assembled by using magnet and cylinder dynamometer. There are magnetic mutations on the both sides of the steel tube inside the aluminum splicing sleeve under external magnetic field. So the location of the steel tube can be calibrated on the surface of aluminum tube, and then the relative positions of the non-crimping area between the steel tube and the aluminum tube should be compared. If the steel tube is in the middle of
the non-crimping area of the aluminum tube, the crimping is qualified. Otherwise, it will not be up to standard.

![Diagram showing magnetic force variation](image)

**Figure 4.** The magnetic variation in the splicing sleeve of substandard crimping quality

Taking the splicing sleeve of an 110kV transmission line as an example, magnetic force gauge is used to measure the magnetic field of the splicing sleeve from right to left, and the non-crimping part of aluminum tube is marked as middle region. By testing, it is found that there is no magnetic mutation in the right crimping region of the aluminum tube, however, there are obvious magnetic mutations in the left crimping region and at the junction between the middle region and the left crimping region, as shown in Figure 4. Therefore, the steel tube can be calibrated not in the middle of the non-crimping area of the aluminum tube, but to move a distance to the left, indicating that the crimping of the aluminum tube is not located accurately.

4. **Conclusions and recommendations**

The crimping quality of the steel cored aluminum strand is the main problem of troubling construction supervision. A lot of line break faults are caused by inaccurately locating of crimping of the aluminum splicing sleeve. From using the large magnetic force produced by the steel splicing sleeve relative to the steel core of the line under the fixed external magnetic field, the relative position of the non-crimping area between the steel splicing sleeve and the aluminum splicing sleeve can be determined to achieve rapid, simple and nondestructive testing purposes.

It is recommended that magnetic testing principle should be made full use of in the transmission line capital construction supervision unit and operation and maintenance unit to strengthen the locating quality supervision of splicing sleeve. And the line operation safety would be ensured.

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