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# Fracture analysis of GIS outlet bushing's conductive rod

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**Abstract:** In this paper, a failure of conductive rod of GIS outlet bushing is analyzed from the connection form, welding quality and microstructure of conductive rod and flange, and it is concluded that the failure of conductive rod is caused by bad welding quality and improper assembly and transportation.

## 1. Introduction

GIS equipment is widely used in power system because of its small footprint and high reliability. However, the compaction and fully enclosed structure of GIS equipment makes it is difficult for inspector to detect, locate, repair and remove fault points [1-3]. In this paper, the failure of the central conductor of GIS outlet bushing is analyzed from the aspects of material, welding, metallographic structure and so on.

## 2. Failure process

The inside conductive rod of the GIS outlet bushing was found to fall off during the casing opening process, and the bushing was dismantled immediately. It was found that the welding joint between the conductive rod and the flange on the top of the bushing was broken, and the other two-phase GIS bushing in the same batch was dismantled, and cracks were found at the welding joint between the conductive rod and the flange on the top of the bushing. The GIS bushing is inspected at the scene, and experimental analysis is carried out.

## 3. Investigation and analysis

### 3.1 crack inspection

The fracture area of the GIS conductor is the welding joint between the conductive rod and the top flange of the GIS bushing, as shown in Fig. 1. The conductive rod of the A phase conductor is completely fractured from the flange at the top, causing the conductor to fall off during the opening process. Cracks are visible throughout the whole welding joint of B phase conductor, and Cracks appear in the 3/4 circle of the C phase conductor, as shown in Fig. 2 and Fig. 3.





Fig.1 the image of the fracture of the conductive rod



Fig. 2 the crack on the conductive rod of B phase



Fig. 3 the crack on the conductive rod of C phase

### 3.2 Chemical composition detection

The materials of conductive rod and top flange are tested by hand-held alloy analyzer. The results are shown in Table 1. According to the test results, the conductive rod and the flange both are Al-Si alloy.

Table 1 the materials of the conductive rod and flange

component	Cu	Mg	Si	Fe	Al
conductor	/	/	0.78	0.18	balance
flange	/	/	10.69	0.11	balance

### 3.3 Connecting form of conductive rod and flange

The connecting structure of A-phase conductive rod and flange is checked. The conductive rod and flange are connected by T-type welding joint. The conductive rod is tubular, as shown in Fig. 4. The

connecting structure between the C phase conductor and the flange is the same as that of A phase.

The connection between the B phase and flange is different from the other two phases. The end of the B phase conductive rod is shown in Figure 4. The end of phase B conductor has obvious thread, and the length of thread section is about 10 mm, while there is not similar structure at the end of phase A and C conductor.

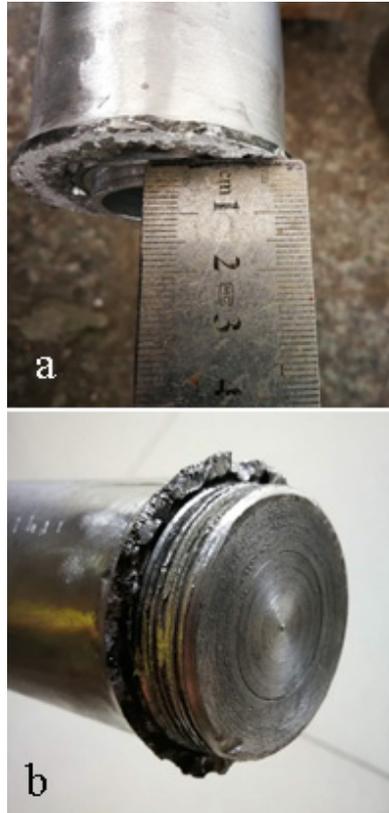


Fig. 4 the end of the conductive rod of A phase (a) and B phase (b)

The end of A phase conductor and B phase conductor can be further observed by splitting the conductor, as shown in Figure 5. The connection structure of A phase and B phase flange is also different, see Figure 6. In summary, the B phase conductor and flange are connected by thread, while the A and C phase conductor and flange are connected by welding joint.

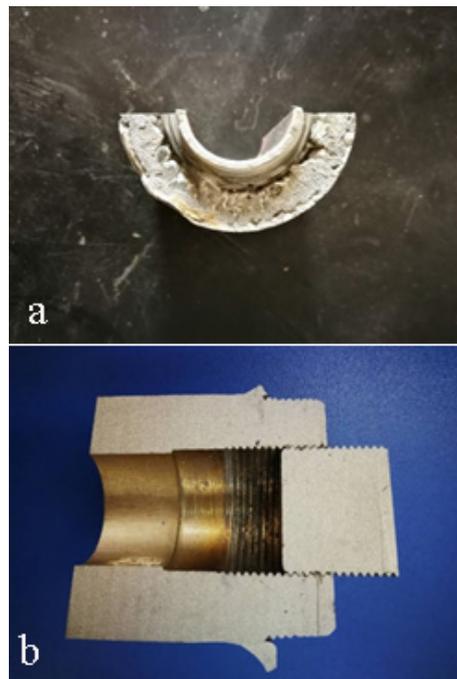


Fig. 5 the microstructure of the conductive rod A phase (a) and B phase (b) after splitting



Fig. 6 the flange of A phase (a) and B phase (b)

### 3.4 Quality of welding joint

Figure 7 shows the welding joint microstructure of the A phase conductor. The welding joint is T-type joint. The welding depth (the wall thickness of conductive tube) is about 15mm. According to GB/T

985.3-2008 Recommended joint preparation for gas-shield arc welding on aluminium and its alloys [4], the blunt edge should be less than 2mm, and the groove angle should be greater than  $50^\circ$ . However, it is measured that the blunt edge is about 6~7mm, which does not meet the standard requirements. Defects such as non-fusion and pore can be observed in welding joint microstructure, as shown in Figure 8.

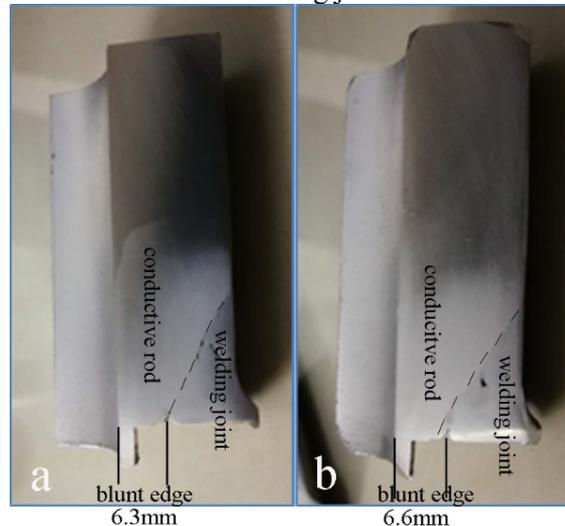


Fig. 7 the microstructure of the welding joint of the flange of A phase (a) and C phase (b)

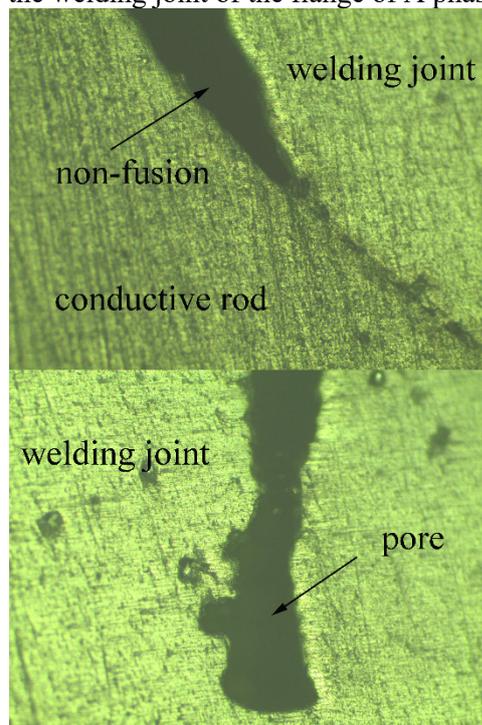


Fig. 8 the non-fusion and pore in the welding joint

The structure design of GIS outlet bushing is mature enough, the connection form between the conductive rod and flange includes insertion connection, threaded connection, T-type welding connection [5]. In this failure, conductive rod and casing flange are joined by T-type welding joint, which is a mature form of connection. However, its welding quality is poor [6], such as incomplete penetration, non-fusion and unreasonable welding groove. In the case of bumping up and down during transportation, the conductive rod is like a cantilever beam with one end fixed. The welding joint of the

flange and the conductive rod bears bending load, because of the poor welding quality of the welding joint, cracks initiates at the welding joint between the flange and the conductive rod under the action of bending loading.

#### 4. Conclusions

The connection form of A and C phase conductor and flange of 110kV GIS outlet bushing is T-type welding joint, and the connection form between B phase conductor and flange is threading-type. The T-type welding joint of A and C phase conductors have welding defects such as non-fusion and incomplete penetration, resulting the strength of the welding joint is insufficient. During the loading and transportation of the GIS, the welding joints of the conductor rod and the flange are broken under bending loading.

It is suggested that the manufacturer replaces the connection form between the conductor rod and flange of the GIS outlet bushing from T-type welding joint to plug-in connection form, strictly control the welding quality, carry out the welding process evaluation and the non-destructive inspection of the weld when the welding connection is adopted. At the same time, the inspection personnel of the operation and maintenance unit should inquire the relevant information and carry out the spot inspection of the weld quality in the work of equipment acceptance.

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