Metallographic Identification on the Fracture of Transformer Copper Conductor

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Abstract. Microstructures of the fractured transformer conductor features the mechanism of the failure. The difference of the microstructures in different part of the fractured conductor can be identified by macro and metallographic analyses. The macro morphologies, grain size, twins and sub grain boundaries are described as parameters for the qualitative analysis of the fracture of the conductor.

Introduction

Flat copper conductor has been widely applied in power transmission and transformation system. The failure of transformer will often accompany with the fracture of copper conductor. Different metallographic microstructures often related with different failure reasons. GB/T 16840.4-1997 Technical determination methods for electrical fire evidence -Part 4:Metallographic method[1] introduces a method for analyzing the electrical evidence of copper wire during fire. In this paper, metallographic method has been applied for the determination on the failure of copper conductor of a 220kV transformer.

Sample Preparation

Fractured copper conductor has been prepared from a failed 220kV transformer. The sample has been cut and cleaned before further observation.

Cut the fracture from the middle axis of the conductor, grinding with metallographic abrasive paper from W70, W20, W10, W7 and W2. Observing under metallographic microscope to check the scratches. Polishing after no large scratches exists. During polishing, using rough polishing cloth and larger polishing particle size paste. After smooth surface obtained, to polishing the sample with fine polishing cloth and small polishing size paste W1. After polishing, rinsing by distill water and ethyl alcohol. The etchant is composed of 5%FeCl₃-HCl-ethyl alcohol solution. The portion is 5g Fe Cl₃, 15ml HCl and 80ml CH₃CH₂OH. Etching the surface of the sample for about 10seconds and blowing with drier. Putting the etched sample under Olympus-PMG3, Olympus-GX71 for microstructure observation.

Macro Observation

The macro appearance of the fractured copper conductor is shown in figure 1a. The conductor is slightly bended with dark area near the fractured part. Figure 1b is the magnification of the fracture area by stereo microscope. The surface is smooth with gas holes, pits and burnt product. A remelt border can be seen at the lower right part of figure 1b. According to [2], the appearance shows the feature of secondary short circuited melted mark.
Metallographic Analysis

According to the macro observation, the sample has been divided into 3 parts, fracturing zone, burnt zone and base metal zone, refers to figure 2. Metallographic analysis has been carried out in different part of the sample. Figure 3 shows the microstructure of at the tip of the fracturing area. The grain size at the edge of the fracture is small, it is because of the quick cooling condition compared with the inner part of the conductor.
Figure 4 shows the microstructure of the burnt zone of the fractured copper conductor. Large column grain can be found. Sub grain boundary and twins are shown in the inner of the grains, which means this zone has undergone high temperature. Re-crystallization process occurred in this zone.

Figure 4. Microstructure of the burnt area.

Figure 5 shows the microstructure of the base metal 8mm to the fractured area of the copper conductor. The grain size is small compared with the burnt zone and fractured zone. No big column grain has been found in this zone. No twins are shown in the inner of the grain.

Figure 5. Microstructure of the base metal.

Figure 6 shows the maximum grain size in different part of the sample. It can be concluded that the grain sizes in the fractured zone and burnt zone are much larger compared with the base metal zone. The maximum size of the grown grain is in the burnt zone, which means this area has underwent high temperature.

Figure 6. Relationship of grain size and different zone of the fractured copper conductor.
Summary

1. According to the macro analysis, the fracture is partly melted with small melting area, few surface gas holes distributed on the surface. The fracture surface shows primary circuited melt mark.
2. The grain sizes in different zone of the fractured sample changes. In the near fractured zone, the grain size reaches the maximum.
3. Twins and sub-grain boundaries can be found in the burnt zone of the copper conductor.

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References

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