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Research on the Performance of Brass Alloy Main transformer terminal

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Abstract—In order to determine the material of the main transformer terminal, the electrical conductivity, mechanical properties and stress corrosion resistance of brass alloy terminal were studied by XRD, mechanical properties test and ammonia fumigation test. The results show that H59 alloy consists of (Cu,Zn) phase, Cu₅Zn₈ phase and CuZn phase, H70 alloy consists of (Cu,Zn) phase and dendritic Cu_{0.64}Zn_{0.36} phase, H80 alloy and H90 alloy are both (Cu,Zn) phase. With the increase of Cu content, the strength of brass decreases, the conductivity increases, and the stress corrosion resistance increases. H90 alloy has excellent plasticity and toughness, excellent resistance to ammonia fumigation stress corrosion, and can be used as main transformer terminal material.

1. Introduction

Substation plays an important role in changing voltage levels, collecting current, distributing electric energy and adjusting voltage^[1], so it is a very important link in transmission lines, and reducing the occurrence of faults is of great significance to its safe operation. Since the 13th Five-Year Plan, China has clearly put forward the development policy of improving the quality of power supply and focusing on solving the problem of weak distribution network. In substation, the main function of main transformer terminal is to connect the lead and high voltage bushing and fix the lead, generally made of H59 brass alloy. Because the terminals are exposed to the outdoor environment for a long time, they suffer from complex corrosion stress under the action of rain erosion, wind, vibration, lead gravity and other factors. Therefore, terminals need to have excellent electrical conductivity, mechanical properties and corrosion resistance. However, H59 terminals often crack during service, and the cracking location mainly occurs on the outer surface of the hoop under tensile stress. Therefore, the reliability of H59 brass alloy terminals cannot be guaranteed^[2-4], which often leads to power failure.





Fig.1 H59 brass alloy terminals with crack

Given the H59 terminals of the cracking phenomenon, in order to improve the using reliability of terminals, in this paper, from the perspective of terminal materials, a comparative study of brass alloy electric conductivity, mechanical properties and corrosion resistance, consolidate the foundation research for its security applications, is of great significance to solve the problem of main transformer terminal failure.

2. Methods and Materials

H59, H70, H80 and H90 $\phi 60$ mm round rods were selected as experimental materials. After hot forging and air cooling, terminals of H59, H70, H80 and H90 were prepared and aged for 1 year. Their chemical composition is shown in Table 1. $\phi 5$ mm tensile samples were made, and sample size is shown in Figure 2.

Table 1 Chemical composition of H59, H70, H80, H90 brass alloy (wt.%)

	Cu	Zn	Fe	Pb	Ni	P
H59	59.892	38.496	0.691	0.052	0.869	—
H70	70.741	28.210	0.130	0.038	0.741	0.14
H80	80.321	18.926	0.077	0.037	0.639	—
H90	90.526	8.456	0.083	0.045	0.890	—

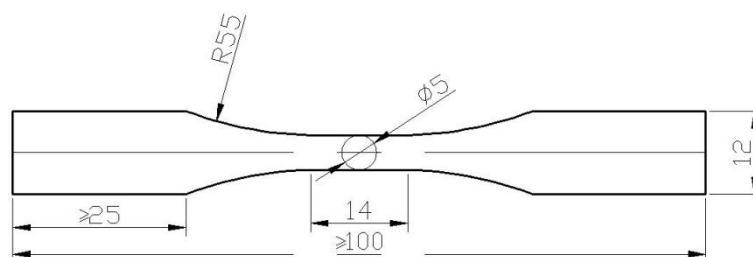


Fig.2 Dimensions of tensile specimens

Stress corrosion performance of brass alloy terminals were tested under airtight container, with 14%wt. ammonia solution. The dosage of ammonia solution per liter container, total volume of not less than 166 mL per square decimeter sample surface area of not less than 100 mL, sample not touch each other and not direct contact with ammonia, according to the power system, the internal inspection brass stress ammonia smoked method, The test time was set at 24 hours. The objects of ammonia fumigation are bolted terminals. After ammonia fumigation, the corrosion products were removed with

1:2 nitric acid solution and dried. The corrosion resistance of various copper alloys was analyzed by staining method.



Fig.3 Bolted terminal

The tensile properties of various brass alloys were tested by wDW-100C universal tensile testing machine at a tensile rate of 2mm/min. The hardness of various copper alloys was tested by HB-3000 Brinell hardness tester. The diameter of hardened steel ball indenter was 5 mm, the load was 50 N, and the load holding time was 15 s.

The conductivity of various copper alloys is measured by FD102 conductivity meter.

D/ MAX-RBX - ray diffraction (XRD) was used to analyze the phase composition of various brass alloys.

3. Test Results and Discussions

3.1. XRD

The results show that H59 alloy consists of (Cu,Zn) phase, Cu_5Zn_8 phase and CuZn phase, H70 alloy consists of (Cu,Zn) phase and dendritic $\text{Cu}_{0.64}\text{Zn}_{0.36}$ phase, H80 alloy and H90 alloy are both (Cu,Zn) phase, as shown in Fig.4.

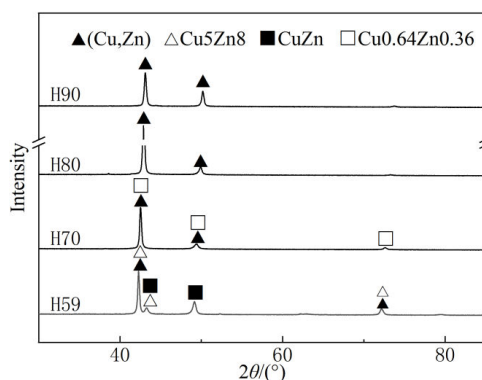


Fig.4 XRD patterns of H59, H79, H80 and H90 brass alloys

3.2. Electrical conductivity

Table 2 shows the electrical conductivity of various brass alloys. It can be found that the conductivity of H59, H70, H80 and H90 brass alloys increases from 23.5% IACS to 35.7% IACS with increasing Cu content.

	H59	H70	H80	H90
Conductivity, %I ACS	22.5	28.3	30.2	42.1

As the conductivity is determined by the scattering effect of alloying elements on electrons, when Zn is solidly dissolved in Cu, the scattering effect on electrons becomes larger due to the incorporation of Zn elements into the pure copper matrix. Therefore, the conductivity of H59, H70, H80 and H90 increases gradually with the decrease of Zn solidly dissolved in Cu.

3.3. Mechanical property

Table 3 shows the mechanical properties of various brass alloys. It can be found that with the increasing Cu content, the strength of H59, H70, H80 and H90 alloys gradually decreases from 389.2 MPa to 319.5 MPa, and the elongation first increases and then decreases, and H80 has the highest elongation. The plasticity of (Cu,Zn) phase is good. With the increase of solid solution Zn content in Cu, the strength increases. When Cu and Zn form intermetallic compound phase, the plasticity of copper alloy decreases, so H59 has the lowest plasticity.

Table 3 Hardness of H59, H70, H80, H90 brass alloy

	H59	H70	H80	H90
Hardness, HB	94.5	95.5	95.9	99.2
Rm, MPa	389.2	369.5	347.6	319.5
Elongation, %	23.5	32.2	49.8	35.7

3.4. Stress corrosion

Fig. 5 shows the surface morphology of ammonia fumigating terminal for colored flaw detection. It can be found that H59, H70 and H80 terminals all have significant cracking characteristics on the outer surface of the collar of the terminals.

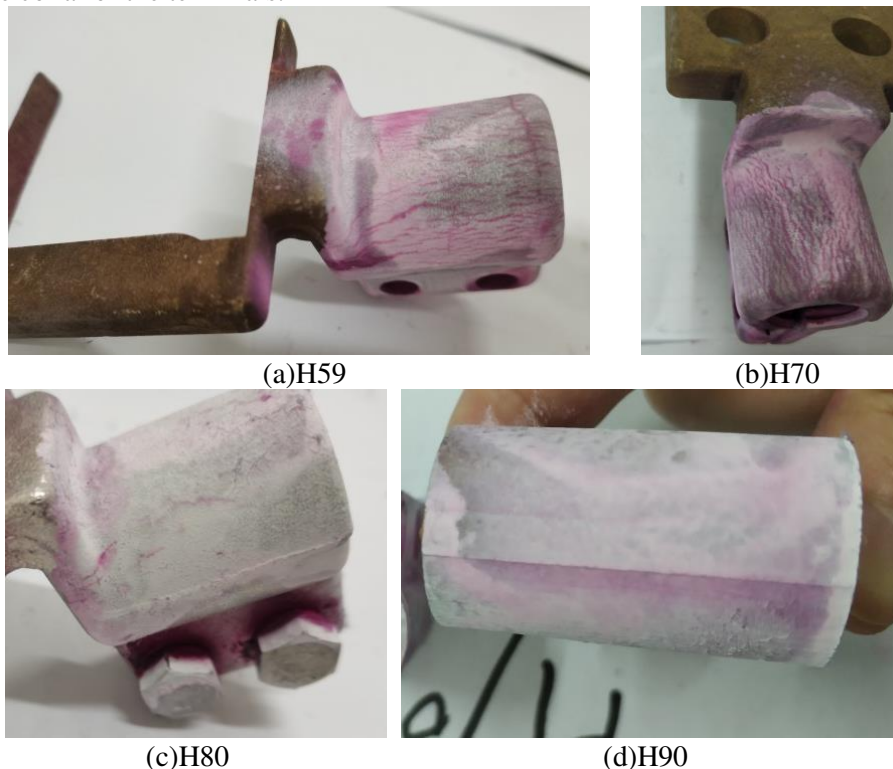


Fig.5 Surface morphology of ammonia fumigating terminal

With increasing Cu content, terminal clamp under the surface cracking characteristics gradually reduce, when Cu content increased to 80%, H80 terminal clamp under the surface rendering the capillaries of the initiation of crack characteristics, no significant crack phenomenon, when Cu content increased to 90%, while the H90 terminal clamp under the surface corrosion crack characteristics disappear. As brass with less than 15% Zn has corrosion resistance completely similar to red copper in various corrosive media, brass with more than 15% Zn, especially (Cu,Zn)+CuZn brass, has prominent stress corrosion problems^[5]. Therefore, the material of the terminal is H90, which has good application reliability.

3.5. Discussion

Dou et al.^[6] found that H68A copper alloy and Hal77-2A copper alloy did not break during ammonia fuming under compressive stress, but both did under tensile stress. And with the increase of tensile stress, the degree of transgranular corrosion increases [14]. This may be due to the fact that compressive stress is beneficial to suppress or eliminate all kinds of microscopic failures caused by plastic deformation in crystal, while tensile stress aggravates all kinds of microscopic failures caused by plastic deformation in crystal and promotes the initiation and propagation of cracks.

Because there are a lot of CuZn and Cu₅Zn₈ phases in H59 brass alloy, the micro-pits have many nucleation positions, and the micro-pits formed on the fracture are small in size, shallow and poor in plasticity. In addition, due to the hard and brittle properties of Cu₅Zn₈, (Cu,Zn) has good plasticity and toughness. During tensile deformation, large Cu₅Zn₈ and (Cu,Zn) deformation are not coordinated, leading to the formation of micropores at the phase boundary. Micropores gather and form microcracks, which expand along the Cu₅Zn₈/(Cu,Zn) phase boundary and form intergranular cracks. Tensile stress leads to micro-pits and micro-cracks at the phase boundary of H59 brass alloy, which further intensifies the initiation and propagation of cracks under ammonia fumigation. Therefore, THE plasticity of H59 brass alloy is the lowest and the stress corrosion resistance is insufficient.

With the decrease of Zn content, the intermetallic phase of Cu and Zn decreases and the ductility becomes better. Since there is no Cu and Zn intermetallic compound phase in H90 structure, and H90 is a (Cu,Zn) phase single-phase material with excellent plastic toughness, tensile stress does not lead to various microscopic damage caused by plastic deformation, and it has excellent ammonia corrosion resistance under ammonia fumigation conditions.

According to the above experimental results, the terminal block made of brass alloy with copper content greater than 90% has better performance. The terminal block has been produced and put into use in some areas of Hunan Province, and has excellent performance in actual working conditions without cracking phenomenon, which further confirms the experimental conclusion of this paper.

4. Conclusion

Based on the results and discussions presented above, the conclusions are obtained as below:

- (1) With the decrease of Zn content, the strength of brass decreases, the elongation increases first and then decreases, and the conductivity increases.
- (2) Under tensile stress and ammonia fume corrosion conditions, H59 and H70 brass alloy terminal hoop surface showed significant crack characteristics, H80 brass alloy surface showed crack initiation characteristics, H90 surface corrosion crack characteristics disappear. It shows that H90 terminal has good resistance to stress corrosion and can be used.

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