Electrical Erosion Characteristics of Cu-Cr-Zr-Ag Alloy Contact under DC Load

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Abstract: The analysis of electrical erosion characteristics of contacts under DC load is conducive to the in-depth study of the electrical erosion mechanism. The electrical experiments on the electrical erosion status of the Cu-Cr-Zr-Ag alloy contacts under DC load of 25 V/15 A and the electrical erosion mechanism were carried out by electrical contact test machine and SEM. The surface micromorphologies, microstructures and material transfer phenomenon of the contacts were studied in this paper. The results showed that the Cu-Cr-Zr-Ag contacts have excellent anti-welding properties. The electrical erosion surfaces of the material showed a large number of paste-like coagulum and bubbles. There are some micro-cracks existing on the surface of the Cu-Cr-Zr-Ag alloy contacts. The obvious material transfer phenomenon occurs between the movable and static contacts under DC load.

Key words: metal material; Cu-Cr-Zr-Ag alloy; DC load; electrical erosion; microtophography
CIF number: TG146.3^{+}2 **Document code:** A **Article ID:** 1004-0676(2014)02-0001-05

直流负载条件下 Cu-Cr-Zr-Ag 合金的电侵蚀特性

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摘 要：直流负载下触头的电侵蚀特性分析有助于深入研究其电弧侵蚀机理。通过对 Cu-Cr-Zr-Ag 合金触头进行电性能实验，研究了 25 V/15 A 直流负载条件下，合金触头的电侵蚀情况。采用电接触试验机和扫描电镜，研究了合金材料的电弧侵蚀机理，表面形貌，微观结构和材料转移现象。结果表明：Cu-Cr-Zr-Ag 合金触头具有优异的抗熔焊性能，合金触头的电弧侵蚀微观形貌表现为浆糊状凝固物和气泡，且在触头侵蚀表面存在微裂纹。直流负载条件下动静触头间会发生明显的材料转移现象。

关键词：金属材料；Cu-Cr-Zr-Ag 合金；直流负载；电侵蚀；微观形貌

Copper system alloys are considered as a new type of prospective copper alloy with excellent conductivity, high strength and good anti-electrical erosion properties, which is widely used in electrical contacts and wires[1-8]. The study on the electric erosion phenolmenon of copper system alloy contacts is significant to improve their service life and reliability[9-12]. In recent years, many researchers have been interested in the study of arc erosion, surface morphologies, microstructures and material transfer

Received: 2013-05-17
Foundation item: National Natural Science Foundation of China (51164015); Yunnan Province Innovation Team Project (2012HC027); Kunming City Innovation Team Project (20120101AR070005); Natural Science Foundation of Yunnan Province (2011FA026).
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phenomenon of copper system alloy contact materials[13-18]. It was reported by HE Xiaoyan that[19], the Cu-Ag-Ce alloy showed excellent wearing resistance and surface deterioration resistance, and then the service life is extended. ZHAO Laijun studied[20] the mass loss and the surface structure of Cu-Cr alloy contacts. The eroded contact surface structure showed a clear difference. The cathode contact surface was uniform and each cathode contact surface had an obvious arc erosion pit.

In order to study the electrical erosion mechanism, the surface morphologies, microstructures and material transfer phenomenon of Cu-0.75Cr-0.2Zr-0.2Ag alloy contact materials were studied by electrical contact test machine and SEM of SN-3400 in present paper.

1 Experiment

The Cu-0.75Cr-0.2Zr-0.2Ag alloy was made through a series of processes of melting, casting, hot forging and cold working. Cu-Cr-Zr-Ag alloy contact samples are riveted with the diameter of 2.5 mm. The electrical contact experiments were tested by the electric contact test machine developed by KIPS at the operating frequency of 60 times/min. The electrical erosion surface was characterized by scanning electron microscopy of SN-3400. The weight of the sample was tested by electronic balance of METTER AB135-S. The experimental conditions of DC lamp load are shown in Tab.1.

Tab.1 Parameters of arc erosion experiment
表 1 电弧侵蚀实验参数

Variables	Magnitude
Voltage /V	25
Current/A	15
Distance between the contacts/mm	1.0
Closure pressure /cN	10
Number of operation	10000

2 Results and discussion

2.1 Determination of the separation acceleration during the single-breaking process

During the single-breaking process, the state of the contact changes from a closed one to an open one. As shown in Fig.1, the movable contact will move from position 1 to position 2. From the principles of the experimental apparatus, we know that this movement is a uniformly accelerated motion process. When the contact is at position 1, the current reaches to the minimum value while the voltage reaches to the maximum value. As the static and movable contacts break from each other, the current value is 0. By measuring the time that contacts move from position 1 to position 2, we can obtain the acceleration of the breaking process by calculation formula:

$$a = s/t^2$$

where a refers to the acceleration, t refers to the time, s refers to the distance between two contacts, and the average velocity of the movable contact can be obtained by calculation formula:

$$v = (v_t+v_0)/2 = at/2$$

where v_0 refers to the initial velocity, v refers to the average velocity. when s = 1 mm, t=0.2 s, therefore, a=25 mm/s^2, v=2.5 mm/s.

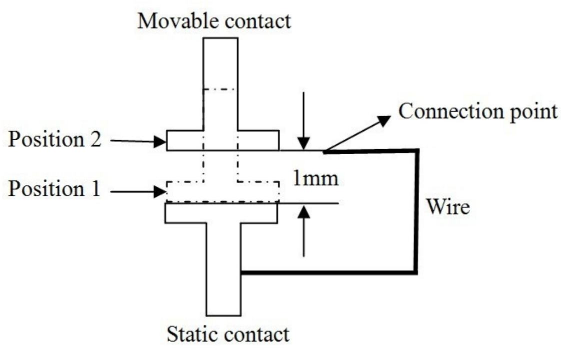

Fig.1 Schematic diagram of measuring separation average velocity
图 1 平均分断速度测量示意图

2.2 Appearance of the electrical erosion surfaces

Fig.2 shows the electrical erosion surface of the Cu-Cr-Zr-Ag alloy contact materials. The electrical erosion surface shows a large number of paste-like coagulum and bubbles. Because of the sticky liquid metal and the fast solidification, there is no time for liquid to spread out, and the paste-like coagulum is formed. From Fig.2 we can clearly see the sags and crests on the surface of the coagulum. This is due to the liquid metal splash and the liquid bridge breaking formed by the action of the arc. With the melt of the material, the oxygen in the air quickly would be dissolved into the liquid. Due to the fast solidification, the dissolved oxygen can not be immediately discharged and then the bubbles are formed.

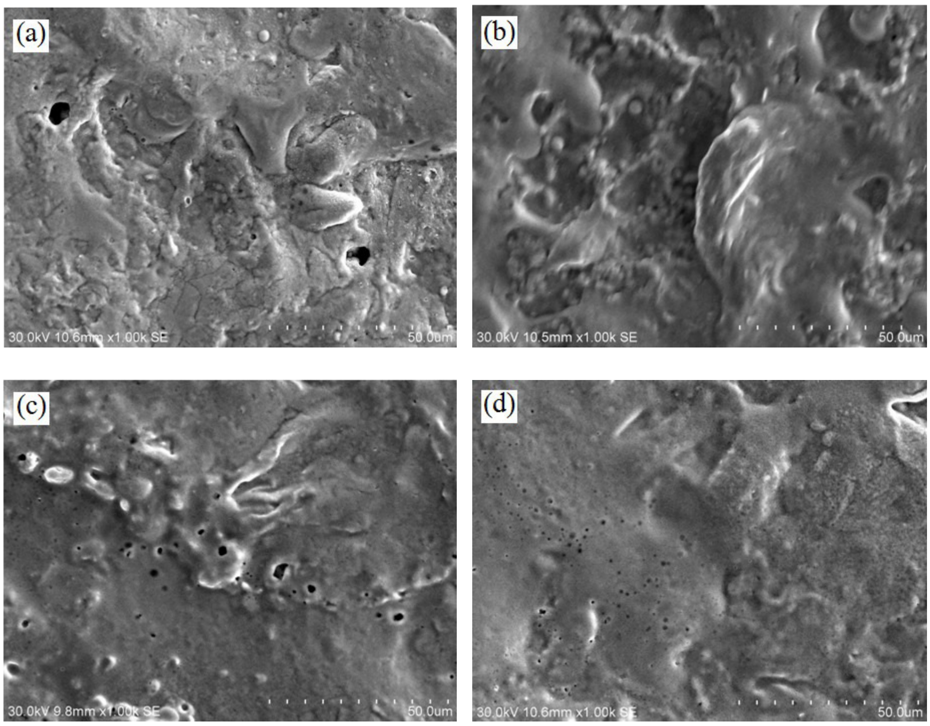

Fig.2 Images of the electrical erosion surface of the Cu-Cr-Zr-Ag alloy contacts

[(a), (b) refer to anode; (c), (d) refer to cathode]

图 2 Cu-Cr-Zr-Ag 合金触头电侵蚀表面照片

[(a)、(b)为阳极；(c)、(d)为阴极]

2.3 Analysis of surface crack

The surface cracks can be divided into three types: phase boundary cracks, thermal stress cracks and holes cracks.

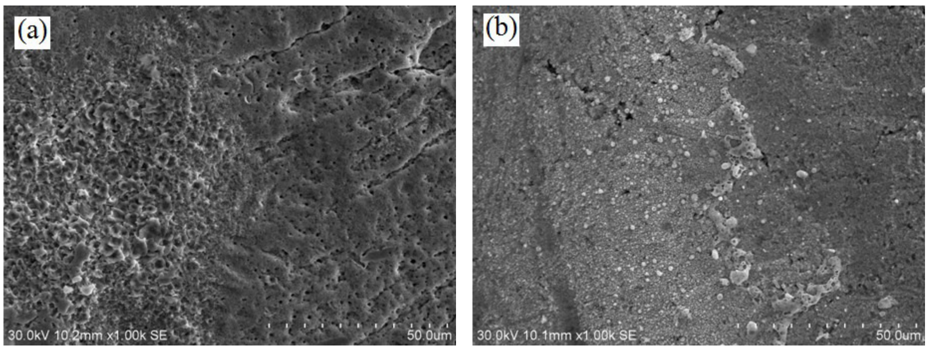

Fig.3 Images of the surface cracks of the Cu-Cr-Zr-Ag alloy contacts after 10000 times breaking operations

[(a) thermal stress cracks; (b) holes cracks]

图 3　10000 次分断操作后 Cu-Cr-Zr-Ag 合金触头表面裂纹照片

[(a) 热应力裂纹；(b) 孔洞裂纹]

It can be seen from Fig.3 that the thermal stress cracks (as shown in Fig.3 (a)), and holes cracks (as shown in Fig.3 (b)) exist on the surface of the Cu-Cr-Zr-Ag alloy contacts. After the formation of bubbles by air entering into the melting pool, the bubbles begin to grow up, and then burst by the arc force. After a certain number of operating cycles, the bubbles eventually develop into cracks. It should be noted that, because the electrical contact process is a comprehensive process of heat, force and electric, based on the action of thermal shock, stress concentration areas will come into being inside the contacts and finally become the cracks.

2.4 Material transfer of the contacts

When a pair of contacts is eroded by the arc, due to the different energy input and heat flux between the anode and cathode, mass transfer process will occur. We use Δm to indicate the weight change between two contacts by multiple breaking operations. Fig.4 (a) and Fig.4 (b) show the image of the mutual mass transfer between the anode and cathode of the Cu-Cr-Zr-Ag alloy contacts. As shown in Fig.4, there are some micro-pits on the surface of the anode and some micro-bumps on the surface of the cathode. It indicates that mass transfers from the anode to the cathode. Tab.2 shows the mass transfer between the anode and cathode of different number of operations. As the number of operations is increased, the valve of Δm also increased gradually. During the operation process, the evaporation and splashing of the material lead to the mass transfer from the anode to the cathode of the Cu-Cr-Zr-Ag alloy. Experiments indicated that the anode mass transfer is the main form of the mass transfer. Therefore, under DC load condition, choosing the anti mass transfer material as the anode is a way to improve the life of the electrical contacts.

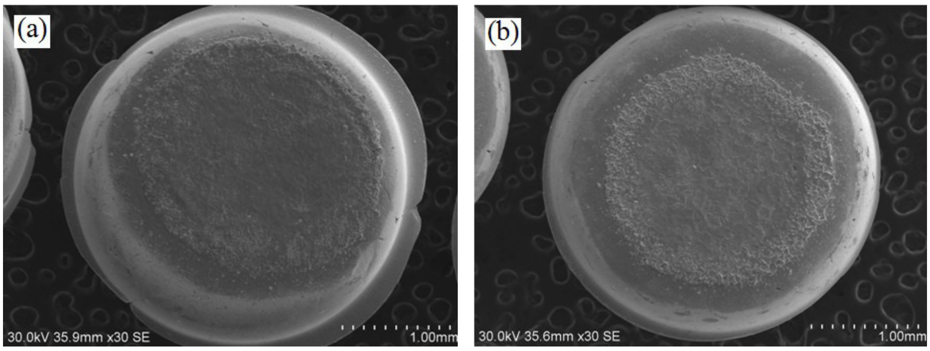

Fig.4 Image of the mutual mass transfer between the anode (a) and cathode (b)

图 4 阳极(a)和阴极(b)之间材料相互转移照片

Tab.2 Mass transfer between the anode and cathode after different number of operations

表 2 不同操作次数后阳极和阴极之间材料的转移

Number of operations	500	1000	5000	10000	20000	50000	100000
Δm /(10^{-2}g)	0.05	0.12	0.19	0.25	0.36	0.74	1.52

3 Conclusions

By analysis of the appearance of electrical corrosion, surface crack and material transfer, we get a deeper understanding of the mechanism of the electrical contact phenomena of Cu-Cr-Zr-Ag alloy contacts. The Cu-Cr-Zr-Ag contacts have excellent anti-welding properties. The arc erosion surfaces of the Cu-Cr-Zr-Ag alloy contacts show a large number of paste-like coagulum and bubbles, and there are some micro-cracks existing on the surface of the Cu-Cr-Zr-Ag alloy contacts. The obvious material transfer phenomenon occurs between the movable and static contacts under DC load. Cu-Cr-Zr-Ag alloys with excellent anti-welding, good stability and electrical conductivity could be a promising electrical contact material in the future.

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