



## Impact Analysis to Microstructure Primary Short Circuit Melted Mark under Different Heat Dissipation Condition

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### Abstract

In the identification of fire evidence, short circuit can be identified based on the metallurgical characteristics of the melted bead from the wire short-circuit. But because of the complexity in the real fire surroundings, short circuit melted bead is formed in many different ways. On the research, we analyze the microstructure characteristics of the short circuit melted bead in the condition of poor heat dissipation. By doing short circuit experiment in different cooling conditions, we can get the microstructure image of melted bead and compare them. Then analyze the difference and similarities and summary the variation law.

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### 1. Foreword

With the rapid development of electrification degree of China, frequency of electrical fire is rising constantly. According to statistics, annual average electrical fire accounts for 26% of all the annual average fire disasters in a whole year, and annual average loss accounts for 36% of the total loss<sup>[1]</sup>. Serious fire accidents caused by electrical wiring short circuit, overload and electrical equipment trouble happen frequently, bringing about infinite social influence.

According to the fire evidence identification, metallographic analysis method, which is under the careful observation of its microstructure, is usually used. It needs people to summarize the structure characteristics and then get the result whether its primary short circuit or secondary short circuit. But in the real fire conversation, short circuit melted bead is formed under many complex reasons. Sometimes some short circuit bead looks very similar, but maybe there is great difference between them that we cannot find without careful research. For example, a primary short circuit melted bead remains in the fire atmosphere after formed, and it will be similar with the secondary short circuit melted bead<sup>[2]</sup>. Which will lead us make wrong judgment. So we must do some simulate experiment on the basis of the reason to find the forming law, and build some related standards of judgment to improve the metallographic analysis method.

Metallographic analysis method is a way to observe and analyze the wire melted bead in the fire surroundings and normal atmosphere. For now, the metallographic analysis method has developed a lot and national standards have been made. The standards describe the microstructure morphology of wire melted bead from primary and secondary short circuit. But because of the shortage of some related comparing images, fire evidence identification is only built on the basis of qualitative. People often make conclusions based on experiences. But different people usually get different judgment on a same one, which makes fire evidence identification lose its fairness and objectivity. If we combine the exiting case and simulate experiment, we find that either external morphology or micro morphology of primary short circuit melted mark under the condition of poor heat dissipation and secondary short circuit melted mark has great similarities with each other.

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So we need to deeply analyze the short circuit melted bead in order to get their essential difference.

This study is on the basis of short circuit simulate experiment, which is aimed at comparing and analyzing the difference between primary short circuit melted mark under the condition of poor heat dissipation and secondary short circuit melted mark.

## 2. Influencing factors on short circuit melted mark

When under-cooling of liquid metal is below the melting point, it solidifies. At the beginning, some tiny crystal which is formed by the instantaneous crystal is formed in the liquid. Crystalloid turns to crystal nucleus when it reaches a certain size and starts crystal formation, at the same time, new crystal nucleus are formed in the remaining liquid and keep growing until all the metal liquid turns to solid. Thus the solidification of metal is such a process in which the crystal nucleus is formed and grows. In general conditions, the crystal foundation process is according to dendrites crystallization, conventional copper and copper alloy cast product typical macro-structure is obvious tricrystal, the surface chilling level is small crystal shaft, columnar crystal is in the middle, and thick crystal shaft is in the core. Main influencing factors of the organization include the essential property and casting technique of the alloys. General relationship between the cooling velocity of the casting technique and organization is: under small cooling velocity, thick grain and loose dendrites crystal net are always formed, under big cooling velocity, temperature gradient is formed in the frontier of the grain, as a result, the columnar crystal appears and grows, and the dendrites crystal net tends to be close. In case the cooling velocity is added or constantly increased, crystal nucleation in the copper liquid is obviously quicker than the growing speed of the grains, and the grains tend to thin, the dendrites crystal may be thin, or may not be spread easily due to the elements in the liquid phase<sup>[3]</sup>.

Influencing factors on forming short circuit melted mark; firstly, under-cooling, different crystallization process retains different cooling rate because of different cooling conditions. Generally speaking, the higher cooling speeds, the bigger under-cooling, and the tinier crystal. Secondly, short circuit electric current. It has a great effect on the size of the short circuit melted bead, in normal circumstances, the greater electric current, the smaller melted bead.

## 3. Short circuit simulate experiment

This study is on the basis of conventional and poor heat dissipation primary short circuit experiment and conventional secondary short circuit experiment under different electric current (160A, 300A, 500A). We can get the melted bead under these three conditions. Then make the metallographic in order to observe and analyze the microstructure and find the difference and similarities by using DMI5000 Metallurgical Microscope.

Table 3-1. Short circuit conditions

No.	Cooling conditions	Short circuit category	Current(A)	Means of cooling	Test groups
1	Air cooling (bare wire)	Primary short circuit	160	Air cooling	3
2			300	Air cooling	3
3			500	Air cooling	3
4	Poor heat dissipation (with insulating cover)	Primary short circuit	160	Air cooling	3
5			300	Air cooling	3
6			500	Air cooling	3
7	Fire high temperature surroundings	Secondary short circuit	160	Air cooling	3
8			300	Air cooling	3
9			500	Air cooling	3

When doing conventional primary short circuit experiment, we connect two copper wires, the cross essential area of which is 2.5 mm<sup>2</sup>, without insulating cover, to the positive and negative part of the welding machine, and then set up an electric current to make short circuit happen in order to get the melted bead. In doing the poor heat dissipation primary short circuit experiment, the material is still the copper wires with insulating cover, making them contact in the insulating cover, and then set up an electric current to get the bead. The secondary short circuit experiment, we twine two same copper wires with insulating cover, and then put a brazier with alcohol in under it, ignite the alcohol while set up an electric current, when the insulating cover is burn down, short circuit happens, and we can get the melted bead.

After we get these, alcohol will be used to wash the surface of the melted bead. Then we mix denture powder and self-

curing denture water thoroughly in order to make the melted bead cured in the copper tube with the solution to get the metallographic sample, next, we need to coarse grinding, finely grinding and polishing the sample, at last, corrode the sample with  $FeCl_3$  solution. Only in this way can we use the LeicaDMI5000 Metallographic Microscope to observe and analyze the shape, colour, stoma of the melted mark.

#### 4. Comparisons of short circuit melted mark microstructure characteristics

Choose suitable magnification in the software system of the LeicaDMI5000 Metallographic Microscope to take photos of the metallographic microstructure, and sign the magnification (unites: Micron), then select some representative images to form the short circuit melted mark metallographic chart in different electric currents and cooling conditions.

##### 4.1 Metallographic photos

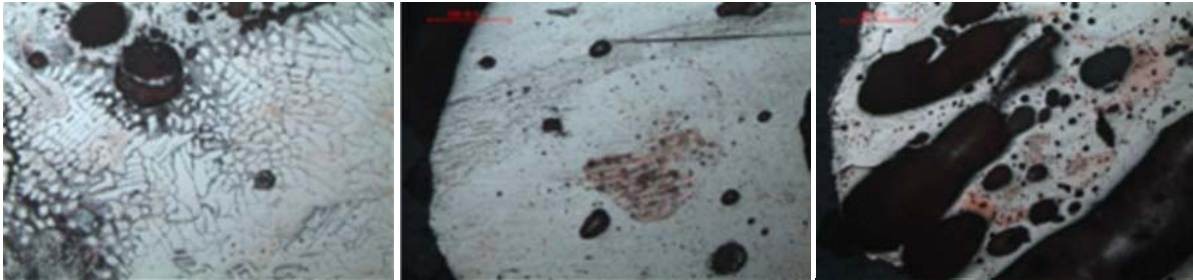


Fig.4-1 Three short circuit conditions melted bead (160A 100X)



Fig.4-2 Three short circuit conditions melted bead (300A 100X)

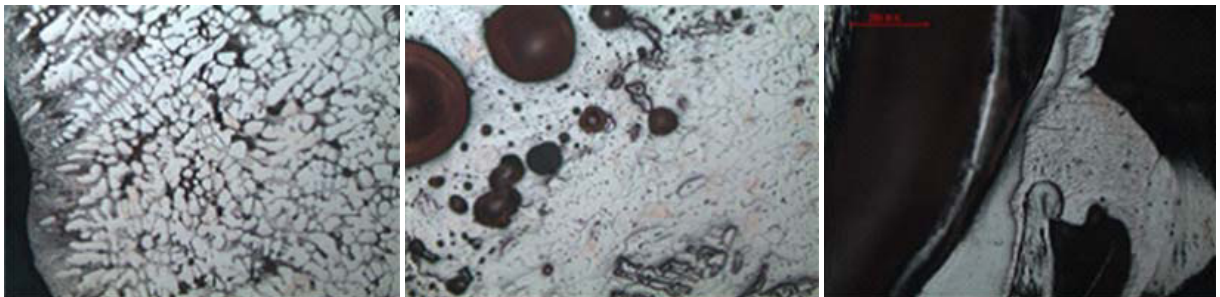


Fig.4-3 Three short circuit conditions melted bead (500A 100X)

Notes: (1) Three short circuit conditions means conventional primary short circuit, poor heat dissipation primary short circuit and secondary short circuit.

(2) Short circuit electric current is 160A, 300A, 500A. Magnification of the photos is 100X.

#### 4.2 Chart description

Generally speaking, diameter of the primary short circuited melted bead is small; temperature of the short dot is between 2000°C to 3000°C. Temperature of the whole guide line is close to the normal condition. There is a large difference in temperature of the transit zone between the melted part of the guide line and the guide line itself, transit at the guide line joining point is obvious, besides, surface reflect of part of the melted bead is obvious, and there is little prominence at the exterior of some melted marks. Primary short circuit guide line melting liquid metal has surface tension which solidifies into round melted bead; at the transit zone of temperature difference the grain mark features are obvious. Primary short circuited melted bead has short coagulation time<sup>[4]</sup>. While crystallizing, the solid liquid inter-phase transports in the form of branches in the space. Grains interlace as branches, namely dendrite. Meanwhile, the air holes inside the melted bead is little and small. Due to the low temperature of the nearby surroundings, its melted marks can be cooled with faster cooling velocity, and its metallographic micro-structure is composed of thin columnar crystal and cellular crystal and there are many but small air holes<sup>[5,6]</sup>.

Formation mechanism of the shrinkage cavity; the melted liquid metal casing curd very quickly, but the molten liquid is still in the bead, so the outer covering cannot shrink and is fixed. When the internal liquid curd, some liquid shrink and cannot get supplement, so the shrinkage cavity form. A lower under cooling lead to more shrinkage cavity in the melted bead, formation of the stoma; the existing gas, combustion products, water vapour diffuse into the liquid melted bead in the process of solidification.

In the above charts, it can be found that there are fewer shrinkage cavity and stoma in the melted bead of the primary short circuit, in the melted bead of poor heat dissipation primary short circuit, there are more regular shape stoma and less few shrinkage cavity, and there are more irregular shape big shrinkage cavity in the bead of conventional secondary short circuit. And there are more holes in the melted bead of the above three conditions in the low electric current.

Compare the conventional primary short circuit melted bead in different electric current, with the short circuit current increasing; it varies from tiny cylindrical crystal to big isometric crystal, the bigger the current is, the bigger the average grain size is. Because the bigger the current is, the electricity load of the copper conductor can bear, the higher the short dot temperature, the faster the crystallization speed is, the thicker the melted mark grains, meanwhile, grains space also increases.

Compare the conventional primary short circuit melted bead and poor heat dissipation primary short circuit bead in a same current, because of the exiting insulating cover, the under cooling is a little smaller in the process of forming a bead, so big branch crystal and cylindrical crystal occurs. But when the electric current increase, the obvious difference occurs in the size of the stoma, there is more stoma because of the exiting insulating cover.

Compare the poor heat dissipation primary short circuit and conventional secondary short circuit, because the surroundings, temperature field, cooling rate is different, the stoma size is bigger in the conventional secondary short circuit.

#### 5. Conclusions

The metallographic micro-structure of primary short circuited melted mark in electrical fire is mainly columnar crystal or cellular crystal. While the metallographic micro-structure of secondary short circuited melted mark is mainly columnar crystal or cellular crystal that are thicker than those in primary short circuit. Metallographic structure differs under different current and different material conditions.

- (1) Under the same cooling conditions, with the electric current increasing, the crystal and the boundary become bigger.
- (2) Under the same electric current, due to different cooling conditions, the smaller the cooling rate, the bigger the crystal and the inanition.
- (3) There are few stomas and hardly shrinkage cavity in the primary short circuit melted bead, more stoma and few shrinkage cavities in the poor heat dissipation primary short circuit bead, and there is a large number of shrinkage cavities in the secondary short circuit melted bead, The smaller the under cooling, the easier the shrinkage cavity forms.

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