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Study on pores distribution laws in secondary short circuited melted beads of copper wires

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Abstract

In this paper, the microstructure of the SSCMB had been watched by using scanning electron microscope (SEM2800B). Then the pores distribution characteristics of the pores inside the SSCMB were analyzed. Results based on the distribution of pore diameter, pore number per unit area and pore number inside the SSCMB were gotten. The pores diameter has the consistent trend, and it can be the support of the distinction between PSCMB and SSCMB. And Pore number of SSCMB per unit area was also consistent, and overlapping pores inside SSCMB could become the discrimination between PSCMB and SSCMB. However, pores number per bead insides the SSCMB is the same as insides the PSCMB. So this could not be look on as the SSCMB characteristics. In the paper, these results could provide the fire investigator for a reference of determining fire cause.

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Keywords: fire investigation; the secondary short-circuited melted beads; scanning electron microscope; Quantitative analysis

Nomenclature

n	pore number of each melted bead per unit area
S	area of each melted bead fracture
N	the pore number of each melted bead fracture (n / mm^2)

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1. Introduction

The causes of wires short-circuiting in the fire scene have two: the primary short-circuited melted beads (PSCMB) and the secondary short-circuited melted beads (SSCMB). The short-circuiting happens because of the wires own faults before the fire take places. The high energy of short-circuiting made the copper wires to be the melted beads. The electrical circuit failure made mounts of heat and could cause a fire. The melted beads are called the PSCMB. The short-circuiting happens because of the insulation material of wires. The SSCMB become the results of fire hot. In the process of examining fire scene, when fire investigator found the electrical fault beads, they had to decide if the electrical fault beads were the PSCMB or the SSCMB. However, the PSCMB were easily confused with the SSCMB. It was very difficult to distinguish the reasoning of the melted beads due to the complexity and diversity of the fire environment [1]. In lots of fire cases, the fire investigator could not clearly identify the distinction between the PSCMB and SSCMB. It is not judged certainly because of the similar appearances of the SSCMB and PSCMB. Furthermore, the SSCMB and PSCMB are shaped by arc damaging. But the different characteristics between the PSCMB and SSCMB are not intrinsic and even could not show if it is PSCMB or SSCMB. The key determination depends on the experienced expert conclusions. In a most number of fire scene, many SSCMB could be found. And the PSCMB could be little found. So the SSCMB should be discussed carefully.

The quantitative analysis of the characteristics of the SSCMB and PSCMB has been a trend of research the fire cause. By using optical microscopy, the smoke particle concentration on the surface of bead and some pores could be observed on the surface, and the surface of SSCMB was rough [2]. A simple quantitative method of researching pore number, size, distribution characteristics of the primary short-circuited melted beads were adopted [3−4]. The results of the paper became reference for electrical fire cause identification. So this path was applicable to the secondary short-circuited melted beads well. It was thought that the possibility for discrimination between the PSCMB and the SSCMB will be increased. Some foreign researcher have develop some research for the differences between the PSCMB and the SSCMB. Eui-Pyeong Lee, a Japanese researcher have proposed a method of discrimination between primary molten marks and secondary molten marks by their oxygen concentration and the dendrite arm spacing (DAS) in the molten marks in 2000 [5]. But identification by the oxygen concentration and DAS can only be applied exclusively where an oxidized structure appears and the secondary arm of the dendrite is developed. Eui-Pyeong Lee in 2002 went on studying on discrimination between primary and secondary molten marks using carbonized residue [6]. He thought that the distinguishing method according to the carbonized residue is aimed at electrical molten marks mainly produced by PVC cords used for electric wiring for low voltages, it is inapplicable to non-PVC-coated wires. So he give a results that the crystal structure of the carbonized residue remaining in the molten marks is analyzed and graphitized carbon is detected, it can be judged to be the primary molten marks. However, when only amorphous carbon is detected, nothing can be determined.

2. Experiments

2.1. materials and apparatuses

PVC-coated copper wire.ø2.5mm (allowable current: 32A).comprehensive test-bed for fire Traces evidence (researched and made by Chinese People's Armed Police Force Academy)is used .

2.2. Preparation of samples

Copper wire of 2.5 mm^2 is used to prepare the SSCMB samples. Under the same experimental conditions, 50 V, wire winding, cooling in air, 30 SSCMB samples were prepared. Two Copper wires with insulated coats were jointed together. When the insulated coats of wires were burnt by the flames, and the copper core of wires was short circuited and formed melting beads. The 30 samples of melted beads were prepared. Then the SSCMB were broken apart from copper wire and were observed by SEM and analyzed.

3. Experimental results and discussion

3.1. SSCMB morphology

The pores inside SSCMB were observed by SEM. Fig. 1. a, b shows a number of pores. There were many pores in the bigger pores. And these pores packed closely and uniform distribution of the pores appeared. Fig. 1 (c), (d) shows a porosity in field of view. There were a few large pores and shrinkage. In the same way, some small pores existed in larger pores. Especially multiple shrinkages overlaping could be distinctly observed. So there were more spaces in melted beads, where liquid copper could not be filled to the full. So often hollow melted-beads appeared, shown in Fig. 1 (d).

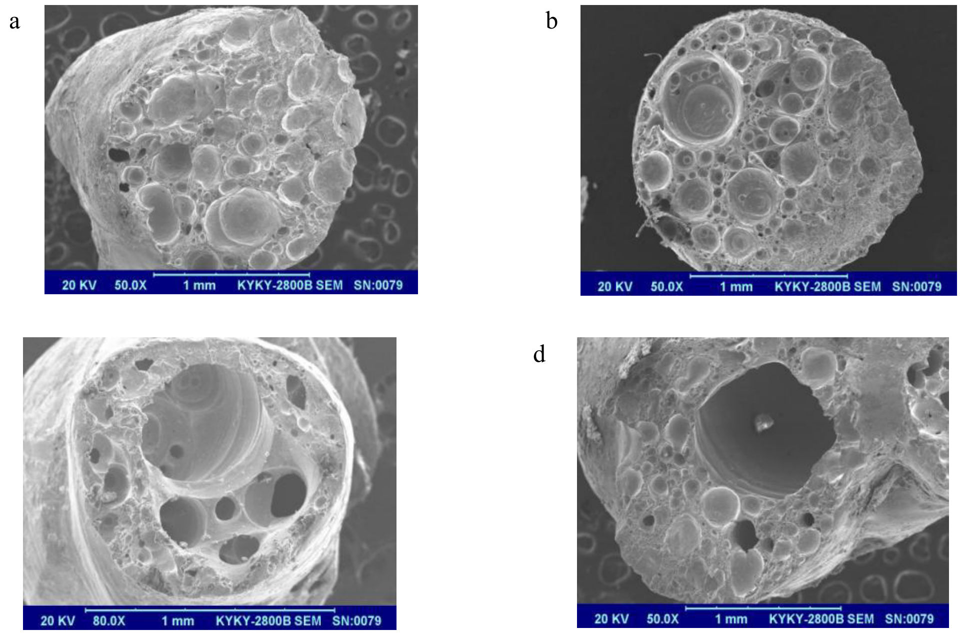

Fig. 1. cross-section characteristics in SSCMB.

3.2. Quantitative analysis of pores distribution in SSCMB

Using Photoshop 7.0 software, the pore diameter, pore area and pore numbers on the sample photos were signed and measured. The 1406 pores were analyzed inside SSCMB [7].

3.2.1. Statistical analysis of pores numbers in individual melted bead sample

The number of pores on the fracture surface of the 30 SSCMB samples was analyzed statistically. In the Fig. 2, it is proved the beads with 14-65 pores accounted for 80% of samples. The rest 20% beads had 65-84 pores. A few beads appeared that some pores is so big, that the pores number of the single beads is few. But there were 5-60 pores accounted 83% of samples inside PSCMB. The 10% beads had 0-10 pores, and the 3.3% beads had 200 pores inside PSCMB [3]. So the distribution of the pore numbers inside PSCMB and SSCMB were interlaced.

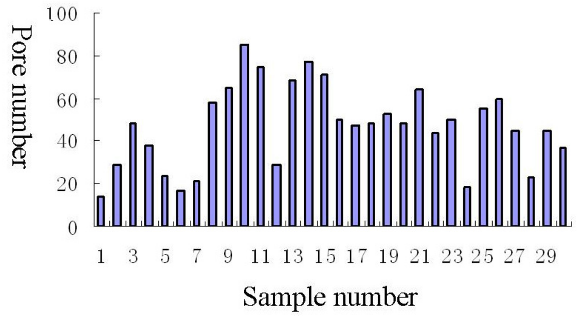

Fig. 2. SSCMB pore quantity of Per bead.

3.2.2. statistics analysis of pores numbers in individual melted bead sample per mm^2

According to different size of SSCMB, the analysis of the pore numbers per mm^2 in beads was necessary. Utilizing SPSS software, results were obtained by using Equation 1. The pore number per mm^2 were mainly distributed between 8 and 32, accounting for 90% of the total sample. And the number of pores per mm^2 was between 50 and 110, only accounting for 10%. But the pore number per mm^2 inside PSCMB were mainly distributed between 15 and 50, accounting for 90% of the total sample. And the number of pores per mm^2 between 50 and 110, accounting for 23%. The average of pore numbers of per mm^2 was 44.01, standard deviation is 54.89.

In the Fig. 3, it is showed that the distribution of normal curve has the right off tail-peak. The data concentrated from 10 to 40. And there were only 2 samples between 60 and 110. It was proved that the distribution of pore number of SSCMB per mm^2 was consistent and had significant distribution characteristics. These data were different scopes between PSCMB and SSCMB.

$$n = \frac{N}{S} \tag{2}$$

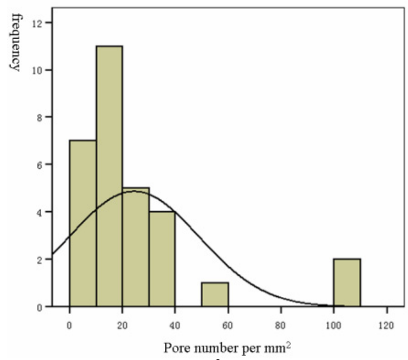

Fig. 3. The pore number per mm^2 of the frequency distribution.

3.2.3 statistics analysis of pores diameter distribution in individual melted bead sample

Because pores inside several SSCMB were so big that some pores overlapped each other. In the Fig. 4, it showed that pore diameters were more bigger, there were a few pores per unit area. According to statistical results, all the average pore diameter inside SSCMB is 0.1123 mm; a maximum of 0.2104 mm; a minimum is 0.0402 mm. Normal curve distribution skewness is 1.012, a slight right-off tail peak. It was indicated that a few of larger pores exist inside SSCMB. However, the average pore diameter inside PSCMB is 0.069 mm; a maximum of 0.1170 mm; Normal curve distribution skewness is 3.098, a slight right-off tail peak. It was indicated that the pores diameter inside SSCMB was different from the pores inside PSCMB [3]. Pores diameter distribution inside SSCMB has consistent trend.

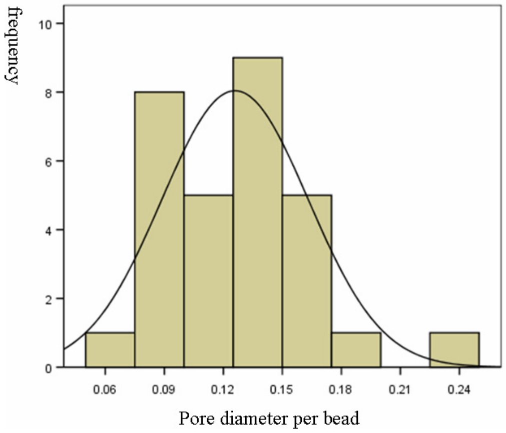

Fig. 4. pore diameter distribution per molten beads.

3.3. Discussions

(1) Under the conditions of the high arc temperature, the copper wires were molten and broken instantaneously. In the fire surroundings there are much soot particles of kinds of combustion. These soot particles enter into the melted copper liquids and don't go out because of the copper liquids melting quickly. These soot particles disturb the melted copper liquids and make the more soot gas bubble. The pores inside SSCMB were shaped. In air, the PSCMB are shaped, in which the only air enter into the melted copper liquids. The substances entering SSCMB are more and more complex than PSCMB. Finally the massive holes (pores and shrinkages) were formed in the melted beads. The pores in majority SSCMB is bigger than in PSCMB. Even the formation of some super big hole implicated that SSCMB was formed.

(2) There were special characteristics in some samples from SSCMB. The minimum of pore diameter in SSCMB is 0.0402 mm. The pores in SSCMB were very small alike PSCMB [3]. The number of pores per mm2 in SSCMB was between 50 and 110, accounting for 10% of the total sample. A lot of small pore were shaped inside SSCMB. Although these cases were very few, these data of samples could not be ignored inside SSCMB. Because the SSCMB was heated up for longer time, the copper wire degree of cooling in the hot fire scene is less than in cold air. The copper liquid crystallized more slowly than in cold air. The bubbles had enough time for escaping from copper liquid. So there are some SSCMB inside which the pores were very few and small.

(3) There were a larger number of pores inside of the SSCMB. It is found that a number of overlapping pores in SSCMB. Mostly pores inside the PSCMB were very small, and there were not overlapping phenomena. The pores overlapping inside SSCMB were commonly seen. The pore overlapping of big pores coating small pores inside SSCMB were shaped because disturbance of hot soot and gas in fire scenes make the bubbles in copper liquids swallowed up each other. When the copper liquids solidified the bubbles overlapping were shaped. It was indicated that the pore overlapping could to be the characteristics of SSCMB. And yet there were the disturbance of hot soot and gas in the cold air the overlapping pores hadn't emerged inside PSCMB.

4. Conclusions

In summary, conclusions can be draw as follows:

(1) The existence of big pores could prove that the melted beads are most possibly SSCMB.

(2) Overlapping Pores in the SSCMB could be the characteristics of SSCMB. The characteristics of pores overlapping became the evidence of discrimination from the PSCMB and the SSCMB.

(3) Pore number per bead could not be look on as the support of SSCMB characteristics.

(4) There are some SSCMB inside which the pores were very small alike PSCMB. But this is not ignored.

Finally, none of the methods has been independently validated, although several validation attempts have been made and led to conclusions of irreproducibility. When the investigators want to determine if the short-circuited beads caused the fire, they must complete the analysis of burning processing in the fire scene. After that, the possible cause of the forming melted beads should be analyzed combined with the conditions of temperature and soot in the fire scenes. So experimental results in the lab could become the reference of determining cause of fire. However, because in the few studies where sufficient samples were used to reach statistical conclusions, the 'cause' and 'victim' bead populations only showed to be trends, not categorical results [8].

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