Experiment of Electrical Fire Burned Copper Wire and Parameters Analysis on Metallographic Test of Melted Mark

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Abstract

Heat treatment experimental simulation of the actual situation of the electrical fire melted mark was carried out; the metallograph of copper wire after heating was obtained, and verified with the actual case. And then using digital image processing software to grain size, that in a certain temperature range, the relation between average size and heated temperature was curve; particle size increases with the increase of heating time; water cooling, air cooling, furnace cooling conditions, the grain increases by followed.

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Key Words: Electrical fire; Copper conductor; Fire melted mark; Digital image; Metallographic analysis
1. Introduction

With fire development and smoke propagation, some factors, such as high-temperature, smoke, carbon monoxide, electrical fire left burning copper wire beads melt or melt marks used to identify physical evidence is an important cause of the fire, one of the identification of its role in distinguishing the high-temperature fire, electrical fires caused by short circuit has a key role [1].

In the low-voltage electrical lines commonly used in construction branch of the loop is the cross-section of not less than 2.5 mm², 99.95% purity, density of 8.9 g/cm³, the melting point of 1083 °C and other properties of copper (ie copper). The internal organization of Copper wire is the face-centered cubic crystal, after annealing crystal easily become a equiaxed grains. General microstructure of copper wire was small equiaxed grains, the original equiaxed elongated along the deformation direction, but was fibrous tissue, without the power of the copper wire is annealed organization. In the normal power state, the copper wire still obvious orientation, only to stress the annealing temperature is 200 ~ 280 °C and under a certain time, the direction will disappear. Recrystallization annealing temperature is between 600 ~ 700 °C [2].

As the temperature increases, the metal grains are growing [3-4]. Thus, by observing the microstructure, the heating process can be analyzed. Different holding time for metals, the microstructure of its size has a huge impact. In addition, increased its water jet fire undercooling, the wire will have an impact on the microstructure of metal [5]. By observing the fire in the location of the metal wire with a metal fire-related evidence of the changes of microstructure can be inferred fire the combustion temperature, combustion time, and cooling and so on.

This article focuses only withstand the flames of the fire scene after the high temperature metallurgical rules to distinguish the short melt marks. Some instruments used to carry out a more in-depth study identified metallographic and metallurgical wire trying to establish electrical fire map data, through the combination of the digital optical image processing, searching for the quantitative relationship between electrical fire wire melting metallurgical parameters and the fire environment.

Experiment

(1) Experimental equipments: Bunsen burner, muffle furnace, temperature sensor and data logger.

(2) Experimental Materials: Construction of electrical equipment commonly used in cross-sectional area of 2.5mm² PVC single core copper wire.

(3) Analysis facility: denture base resin (self-curing denture water), denture powder, denture powder and denture for the ratio of water, electronic scales, in full bloom containers and stirring rods; YMP-2 metallographic Sample Mill (metallographic sandpaper 2000 #, 800 #); PG-2 metallographic sample polishing machine (selling diameter 220 mm, speed 900r/min, deerskin, grinding paste, kerosene); beaker, FeCl3 solution, anhydrous ethyl alcohol; hair dryer; Lycra DMI5000M microscope system.

Experimental objectives

Optical microscopy system analysis was used to get the map, curves and tables of metallurgical microstructure and temperature of melted marks, and get the quantification and the intuitive criterion of melted mark identification; used to determine the temperature of the direction of fire spreading, and even the fire point and the final cause of the fire.

Production the sample of the fire melted the marks

(1) Preparation of fire melted marks

One approach to get it is heating the copper wire with the maximum temperature up to 1200 °C in a Bunsen burner. Another method is heating the copper wire continuously in a muffle furnace heating system: experimental conditions change with temperature gradually increasing, the copper wire was placed in the muffle furnace from room temperature to 1100 °C, heating for 10min; 1000 °C holding three kinds of different time. It’s shown in Table 1.

(2) Heating 1000 °C for 5min, 10min, 30min.

(3) After holding 1000 °C for10 min, using different cooling methods to get the melted beads: the muffle furnace cooling; natural cooling in the air; fire-fighting water cooling.

(4) Collection of the fire melted marks and melted bead sampling in the real cases.

Collected these melted marks and melted beads, and produced the matellographic samples. Cleaned the sample surface with alcohol; mixed the self-curing denture denture powder and water thoroughly, and solidified it with the
samples in the sample tube, put ferric chloride solution on the copper wire melt marks after grinding and polishing and then observed and analyzed the grain shape, color, gloss, roughness, porosity of the sample microstructures.

Table 1 Copper wire melt marks in different experimental treatment

<table>
<thead>
<tr>
<th>Number</th>
<th>Temperature (^\text{(^\circ)C})</th>
<th>Time (min)</th>
<th>Cooling method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>200</td>
<td>10</td>
<td>Air cooling</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>10</td>
<td>Air cooling</td>
</tr>
<tr>
<td>3</td>
<td>400</td>
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<tr>
<td>4</td>
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<td>Air cooling</td>
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<tr>
<td>5</td>
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<tr>
<td>7</td>
<td>800</td>
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</tr>
<tr>
<td>11</td>
<td>1000</td>
<td>10</td>
<td>Water-cooling</td>
</tr>
<tr>
<td>12</td>
<td>1000</td>
<td>10</td>
<td>Furnace cooling</td>
</tr>
<tr>
<td>13</td>
<td>1000</td>
<td>30</td>
<td>Air cooling</td>
</tr>
<tr>
<td>14</td>
<td>1100</td>
<td>10</td>
<td>Air cooling</td>
</tr>
</tbody>
</table>

Experiment results and analysis of fire wire melted marks

Metallurgical map of fire melted marks

Selected the representative marks or melt beads with characteristics of temperature changes, cooling conditions or holding time from per wire melting experiments, and made metallographic samples. Took a photograph of the sample and got the microscope images in the metallurgical software, added the micro scales in units of microns (\(\mu\)m), selected representatives of the optical images as the maps. The representation referred to the "heating temperature - holding time - cooling method - optical magnification ","\(\times\)" means the optical magnification, the default is air cooling.

![](image1.png)

Fig. 1 Original structure 200\(\times\)

![](image2.png)

Fig. 2 200\(^\text{\(^\circ\)C}\)-10min-50\(\times\)
1.1. **Characteristics of melting marks of burning wires**

Of the three groups subjected to high temperature melted marks optical image conductor statistical analysis found the following characteristics and laws:

(1) Fig. 1 is the fiber microstructure with a clear direction of the copper wire which had not been annealed. Fig. 2 to Fig. 14, these representative heating Metallography, to stress from room temperature to annealing temperature (200 ~ 280 °C), at this temperature diffusion of atoms within the metal wire is weak, lower internal energy, relative stability, although some recovery occurred in the phenomenon of grain, but the microstructure remained largely original, so little change in grain size, orientation is still obvious; but more than recrystallization temperature (500 ~ 600 °C) After rising as the temperature, the grain gradually accumulating and growing, that part of the grain growth, part of the reduced and finally disappeared. Grain recovery and recrystallization take some time, this study set the holding time is 10min, although the temperature exceeds the recrystallization temperature, but the lack of holding time, although the grain to grow, but not complete recrystallization, grain structure irregular polygon, and also has a certain direction, as shown in Fig. 4, Fig. 5. When the temperature increased to 800 ~ 1000 °C, the much higher than the recrystallization temperature, wire high temperature recrystallization occurs, the rapid grain growth, the coarse equiaxed transition, as shown in Fig. 6 to Fig. 14.

(2) The fire melted the wire marks the flame at the fire scene because the temperature is higher than its melting point and melting produced marks, the metallurgical microstructure of the annealed structure is obvious, since fire does not melt marks generated by the fire in the circuit, that the relative speed of heating and cooling is slow, the melting process of scar formation, the transformation from liquid to solid, that is, the process of nucleation and growth, so the metallurgical microstructure was coarse equiaxed.

When the heating temperature is close to and over the melting point, when the metallographic microstructure of copper wire had a very significant change: When the heating temperature exceeds the melting point of copper conductors (such as to reach 1100 °C), the equiaxed grains occur within the surface like basketball Ma points or grid-like pattern, ie the original equiaxed grains has not been seen by the oxygen diffusion into the molten copper in the emergence of compound (Cu Cu2O) eutectic; wire outer edge of the emergence of fine crystal and cellular a small number of columnar crystals.

(3) there is no transition zone across the organization; fire to melt mark even though it can fully absorb the gas and the fire environment in the oxidation reaction, but because of the high fire temperatures, slow cooling rate, solidification time is longer, the dissolved metal melting can fully escape the gas, so the organization is almost non-existent pores (holes), and metallographic polished surface is very smooth.

1.2. **The fire melted marks compared with actual case**

On July 30, 2009, a garment factory located in Zhongshan City caught fire; fire investigators at the scene model room in the middle of the fourth floor of the multi-strand copper wire extracted do metallographic analysis and identification. Testing materials for the multi-strand copper wire, with two thick wire, connect one end of a wire connection screws, labeled 1-1,1-2 No physical evidence; a smaller scale for the multi-strand wire, 2 evidence; most A thin copper wire labeled 3 evidence. Macro observation: evidence for the period 1 wire and a screw connected with the copper wiring. The phenomenon of surface over fire wire: Copper surface yellow, dull, there is a gap at one end away from the wire, rugged section of the local dust, nicks section color was copper color. Wire 2 surface exhibits dark, dull, some covered with green oxide, exhibit 3 is a fine multi-strand copper wire, wire strands stick together at one end, the surface covered with a layer of metal, the color was silver, near the tumor on the surface of a wire with small holes tilting. Metallographic analysis: After macroscopic observation and microstructure analysis, 1-1, 1-2, 2, 3 metallographic structures is big wire equiaxed crystals, no holes, formed for the fire (see Fig. 15 to Fig. 18). Microstructure prepared by experiment in the organization and case comparison, cases effectively verified the experimental design is reasonable.
Fig. 15 Microstructure of wire 1-1-200X
Fig. 16 Microstructure of wire 1-2-100X

Fig. 17 Microstructure of wire 2-100X
Fig. 18 Microstructure of wire 3-200X
2. Conclusion

By setting the thermal parameters such as heating temperature, heating time, cooling rate, we finished the experimental burning heat treatment process, and got the result of influencing factors to the microstructure. The relationship between size and fire conditions: when the conductor experienced temperature below the melting point, the microstructure has characteristics of equated grain and coarse grain boundary; the higher heating temperature, the bigger particle size is, and in a certain temperature range, particle size and heating temperature can be a relationship of curve; when the temperature exceeds the melting point, grain particles began to appear small round cell-like grain and fine columnar grain. Cooling method effect on the grain size: the difference of the grain size in the water cooling and air cooling, but the grain size cooling under the fire is different. Burn marks did not have holes and transition zone.

Acknowledgements

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References