Identification on the Fuse Fracture Properties of Electro thermal Apparatus

WANG Lian-tie\textsuperscript{a,b,*}, GAO Wei\textsuperscript{a,b}, WU Ying\textsuperscript{a,b}, DI Man\textsuperscript{a,b}, WU Ying\textsuperscript{a,b}

\textsuperscript{a}Shenyang fire research institute, Shenyang 110034, China
\textsuperscript{b}Key laboratory of fire scene investigation and evidence identification, Ministry of Public Security, Shenyang 110034, China

Abstract

In the fire scene, the fracture trails of fuse were often found. There are various reasons of fracture, such as outside mechanical force, melting fracture due to overheating, short-circuit and high temperature of fire. By the fuse fracture experiments of daily electrothermal apparatus and corresponding trace analysis; this paper summarizes an identification method of fuse fracture properties, which can provide technical support for the investigators to identify the cause of the fire. Trace traits can be applied to the macro method and metallographic method. By macro method it is seen that the cut edge of mechanical force and tensile fracture is right or sharp-angled form. Traces ends formed under the condition of short-circuit are most spherical. The shape of trace formed by high temperature of fire is between the traces shapes of the above, a smooth, but less spherical shape. Using metallographic method, untouched region by the temperature of ruptured fuse by mechanical force is observed with the ferrite microspheres small equiaxial crystal. Deformation organization is noticed of tensile fracture and cut of fuse fracture place. While the microstructure in the high temperature effect is the equiaxial crystal, and the microstructures of short-circuit fusing in molten mark end (or local) show big grain boundaries, inner of which still has not neat columnar crystal, in addition, there is an obvious transition region between the melting parts and matrix.

© 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.

Key words: heating wire; fracture trace; identify

1. Foreword

Along with our country's rapid economic development, the application of electrothermal apparatus wider and wider, induced by fire are more attention of the society. In daily life, we often use electric water heater, electric kettle, hot etc electrothermal apparatus, most with resistance wire as heat source. Resistance wire material usually for nickel chrome or chrome alloy iron, including nickel chrome resistance wire because its price expensive and mostly in military, daily life with iron chromium aluminum most widely used. Iron chromium aluminum heating wire of main composition is iron, several other ingredients and content of chromium (12-27.8%), aluminum (3.0-
7.0 2%-5), molybdenum (1.8-2.2 %), niobium (about 0.5 %), melting point for 1600 °C around by the temperature, plastic, break easily after reducing. The scene of the fire can to extract of heating wire broken trails are: from external fracture, energized, due to a failure due to overheating 13a fuse and fire short-circuit heat action make its fusing. The author of the above several broken trails experiment research and analysis, this paper summarizes identification features, so as to provide more accurate scientific appraisal basis.

2. Fracture reason

2.1. Brittle fracture

Mainly refers to the rupture of wire by external force.

2.2. Energized fracture

1) Heating wire overheating and fusing because of over-current.
2) Mainly refers to the rupture of wire due to heating wire short-circuit.

2.3. High temperature melting fracture

Mainly refers to the rupture of wire due to flame high temperature melting heating wire.

3. Simulation experiment

3.1. By mechanical force and rupture

Stretch fracture, shear fracture and break the samples by temperature after all three groups.

3.2. Normal service condition

Take 300w, 500w, 1000w heating wire 800w and all three pillars and separately under experiment: in 220V ac voltage under electrify 20 minutes, heating wire in the normal service condition, and then will cut off power supply.

3.3. Fault state

3.3.1 Overvoltage experiment

Apply 380V ac voltage at both ends of the heating wire, about 10 minutes after heating wire light, then quickly local issued fusing, and demonstrating dazzling spark (see figure 1). Melting broken trails for air cooling, Numbers for later use.

3.3.2 Short circuit experiment

Apply an 220V ac voltage at both ends of the heating wire, for heating wire aglow, local short-circuit, undertake local short circuit experiment, melting broken trails for air cooling, Numbers for later use.

3.3.3 Trace fire experiment

Use oxygen acetylene fire will resistance wire, melting broken trails for melting air cooling, Numbers for later use.
4. Trace identification

4.1. Appearance identification

4.1.1 Mechanical trace
Tensile fracture and cut edge is right or traces of fractal sharp-angled (see figure 2, 3); By temperature after traces of the broken edges indented (see figure 4).
4.1.2 Short-circuit trace  
Formed under the condition of short-circuit traces ends most be spherical (see figure 5).

4.1.3 Fire trace  
Fire formed between traces shape between the above, a smooth, but less spherical shape (see figure 6). Application macro method can rough discriminant out those three cases, formation, but sometimes must be traces of metallographic method to trace application reasons of the formation of make accurate analysis.

![Fig. 5.](image1) ![Fig. 6.](image2)

![Fig. 7.](image3)

4.2. Organization identification

4.2.1 Mechanical trace  
By mechanical force and rupture of resistance wire fracture place has the obvious tensile fracture and cut the deformation traces, matrix organization in ferritic microspheres small equiaxial crystal (see figure 7).

4.2.2 Out of normal use of heating wire  
Metallographic microstructure appears as the equiaxial crystal grains grew up slightly (see figure 8).
4.2.3 Over-current fusing of heating wire

Resistance wire metallographic microstructure appears as columnar crystal grain boundaries, and was big, each big grain boundary division within the columnar crystal direction almost unanimously. Grain is bulky, have traces, and on the melted overheating part and matrix between transition region boundary is not obvious (see figure 9, 10).

4.2.4 Short-circuit fusing of heating wire

Molten scar tissue characteristic feature is of coarser columnar crystal, some in molten mark end (or local), and big grain boundaries appear bulky-phase internal still has not neat columnar crystal. Melting parts and matrix transition region is obvious (see figure 11, 12).
4.2.5 Fire state
The microstructure of fire melt mark for bulky equiaxial crystal (see figure 13).

Simulation experiments we found overheating melting and short-circuit melting on the exterior no obvious difference, this gives us visually difference traces the causes of the formation of caused great difficulties, therefore, according to the internal organization characteristics to analyze and summarize trace characteristics and reasons for the formation of the corresponding relation are particularly important.

5. Results and analysis

5.1. Heating wire properties

Electrothermal apparatus of heating wire can be divided into austenitic organization of nickel chrome and ferritic organization iron chromium alloy. These two kinds of alloy due to organizational structure is different, the performance is very different. But as electrothermal alloy material with their respective advantages, so in many countries have a lot of production and extensive use. Iron chromium alloy aluminum electrothermal used in atmospheric temperature is high, iron chromium aluminum heating wire 0Cr27AL7Mo2 highest use temperature hot as 1400 °C, while the PTCRS Cr20Ni80 highest use temperature is 1200 °C. Use at the same temperature, iron chrome alloy can live for nickel chrome 2-4 times. Due to the iron chromium alloy allows the use of high temperature, long life, so components surface load can also is a few taller, this not only gives warming faster also can save alloy materials. Iron chrome alloy because do not contain relatively scarce nickel, relative prices nickel chrome much cheaper. Iron chromium alloy shortcomings of high temperature strength low, with temperature increasing, while its plastic nickel chrome high temperature strength than iron chrome alloy to high, high temperature when using not easy deformation.

5.2. Heating wire traces of organization characteristics

Through for iron chromium alloy resistance wire of simulated test and theoretical analysis, we have the characteristics of its traces a system of understanding, according to trace the conditions, now will its make a summary.

5.2.1 Mechanical trace
By mechanical force and rupture of resistance wire, due to the influence of high temperature has not received, and therefore organization is still in ferritic matrix for the small equiaxial crystal, tensile fracture and cut of resistance wire fracture place has the obvious pre-tension deformation characteristics.

5.2.2 The heating wire of normal use
Heating wire in use works under the protection of bushing, which is used to heat up water. As a result, the temperature of fuse is quite low, and it’s microstructure is equiaxial crystal.

5.2.3 Requires special features of heating wire over-current fusing
Heating wire in the flow condition when working at higher temperature range (600 °C above), fusing after the transition matrix temperature area should be higher and not a casting type wall role. In molten mark solidification process, ambient temperature of molten pool almost is consistent, therefore solidification of heat flow direction is pointing to melt on external, solidification way for “shell solidification” [1]. So the organization for presenting melt mark big equiaxial crystal internal direction consistent columnar crystal and the molten part and matrix between transition region boundary is not obvious.

5.2.4 Short-circuit fusing of heating wire
Casting the macroscopic organizations usually have quench wafer area, columnar crystal area and the equiaxial crystal area consisting [2], columnar crystal grain are the characteristic is perpendicular to the type wall arrangement, and parallel to the heat flow direction, in the direction of JingZhou size than the other direction grow long. While in short-circuit trace solidification process, not the melting of matrix part played the role of day type wall heat flux, along the axial movement of heating wire, so columnar crystal perpendicular to the transition zone.

6. Peroration
Usually at the scene of the fire from the material evidence traces can be divided into fire trace and short-circuit trace two [3]. In this paper, only simulation experiment under the condition of heating wire the trace evidence extraction, through macroscopic analysis and metallographic analysis, determine the melting mark properties, to determine whether the fire caused by electrothermal apparatus which provide scientific basis. Due to the different components of heating wire, coupled with the fire of factors affecting trace more, fire formation in the organization may also different, accordingly, in practical application in fire yet to be studied further.

References

[1] HUGengxiang, CAI xun. Fundament of materials science. Shanghai: Shanghai Jiao Tong University. 2000.283.
[2] LIU Quan-kun. Principle of Model Take Shape of Material. Beijing: China Machine PRESS, 2005. 106.
[3] WANG Xi-qing, HAN Baoyu, DI Man. Guidance for electric fire scene survey and identification technique. Shenyang: Liaoning University Publishing Company, 1997.