Research on the Fire Evidence Identification Method of Electric Water Heater

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Abstract. With the presentation of a fire accident caused by the improper use of electric water heater, this paper introduces how to use the metallographic method to judge the state of the electric water heater before the fire broke out. This method is simple, reliable and efficient, which can not only help fire investigators improve the accuracy of the fire cause identification, but also provide the necessary help and support.

Introduction

Along with the progress of society, the development of economy, the quickening rhythm of life, the use of various home appliances become increasingly common, while the incidence of electrical fires also rank first in all fire emergencies. According to the statistics on China fire services (2009-2011), from 2008 to 2010, the proportion of electrical fires in the total number of fires were 29.7%, 30.2% and 31.1% respectively, which showed a upward trend, including the three years electrical fire accidents caused by electric heating appliances accounted for 7.74%, 6.40% and 6.99% respectively [1-3]. By reason of simple operation, easy to use, cheap price, high efficiency, electric water heater is more widely used, especially the application of the university dormitories. However, due to product quality problem, improper operation and other reasons, fire accidents caused by it are common, which induce great hidden dangers to people's lives, property security and social stability.

For the identification of fire reason to the electric water heater, the primary problem is to conform whether the electric water heater is in use before a fire broke out through the residues in the fire scene, which is the key issue to identify such a fire [4]. In the process of fire scene inspection, if the power cord or heating wire with residual melted marks of the electric water heater can be extracted, the identification organization can apply the metallographic method to determine the characteristic of the melted marks; or if there are not available metal melted marks for the technical identification to be found, the metallographic method also can be used to contrast the microstructure on the different locations of the casing of the electric water heater in order to judge whether the organizations are formed by itself fever or outside fire in the same way. This method is an important technical support for fire investigation, the identification of fire cause and the distinction of fire accident responsibility [5].

Working Principle

Electric water heater is a kind of immersing liquid heater, mainly consisted of casing, heating wire, terminal and power cord, shown in Figure 1. The casing is usually 6 ~ 8mm thick stainless steel pipe or copper with spiral heating wire inside, and filled with insulation materials such as quartz sand or magnesium oxide powder, the pipe terminal is sealed with silicone or epoxy, as shown in Figure 2. Electric water heater is made by the heating wire fever principle, and the heating process is actually converting electrical energy into heat energy, i.e., after the heating wire convert electrical energy into

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heat energy which is delivered to liquid through insulating materials by the external metal pipe to achieve the purpose of heating.

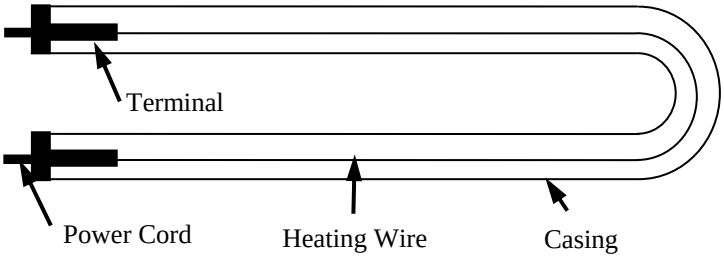

Figure 1. Basic structure of electric water heater

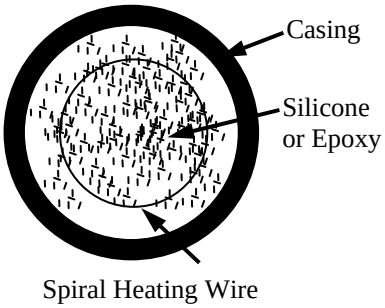

Figure 2. Section plane of electric water heater

Fire Hazard

1)Due to the problems of product quality or service life, the insulation of the power cord of the electric water heater is easy to damage, aging or failure, which may induce a short circuit, then ignite surrounding combustibles, at last cause a fire.

2)Due to the bad connecting between the power cord and the terminal, it may create large resistance in some location, and produce resistive heating which is another causing of fire.

3)Due to the improper use such as dry up water in electricity for long time or directly place it on combustible, it can ignite surrounding flammable materials to set a fire.

Fire Case Analysis

In April 2012, a university student dormitory was on fire, which resulted in most of the items in the bedroom burned, but fortunately no casualties. It is worth noting that this school has occurred a dormitory fire case in 2011 due to the illegal use of electric water heaters, so this case has enormous influence. By investigation, the school takes power brownouts measure, there is electricity to supply only in everyday early, middle and night, and there were no students in the bedroom when the power was on in afternoon, and it was about 10 minutes from electricity supply to fire. In the process of inquiry, the bedroom students denied the use of electric water heater or other electric heating appliances, only used computers, lights and other electrical appliances by the regulations.

Evidence Extraction and Inspection

Because there were apparent location features of traces in fire scene, so after fire site ascertained, the evidence exacted contained debris of electric heating pipe, the cord of power plug seat and debris of plug seat, as shown in Figure 3. By inspection, there are no metal melted traces for technical identification on all evidence extracted. By means of dismantling, the heating wire in casing maintains integrity, no fusing, which brings great difficulties to the identification of fire cause.

Trace Analysis

In order to validate whether the electric water heater was in power-up state, the different positions of casing of the electric water heater were selected for metallographic analysis, specific selected positions were shown in Figure 4. Position 1 located in lower of the heating casing, which had heating wire inside; position 2 was in the center of heating casing with heating wire as well; position 3 was in the bottom of the heating casing, there was the terminal inside, and no heating wire.

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Figure3. Appearance of fire scene residues

Figure 4. Sampling on the different positions of the electric water heater casing

In the same magnification of metallurgical microscope, the significant differences are observed between the organization characteristics of traces in position 3 and the organizational characteristics of traces in position 1, 2. More specifically, the microstructures of traces in position 1, 2 present huge, massive equiaxial crystals, as shown in Figure 5, and 6, and have no obvious difference, which can be used to confirm that the temperatures are basically same in position 1 and position 2 when the fire broke out, while the microstructures of traces in position 3 traces is small, density fragment crystals, shown in Figure 7. According to differences, it could be identified that the temperature in position 1 and 2 is higher than position 3 when the fire occurred, which was caused by the electric water heater worked on no water heating condition.

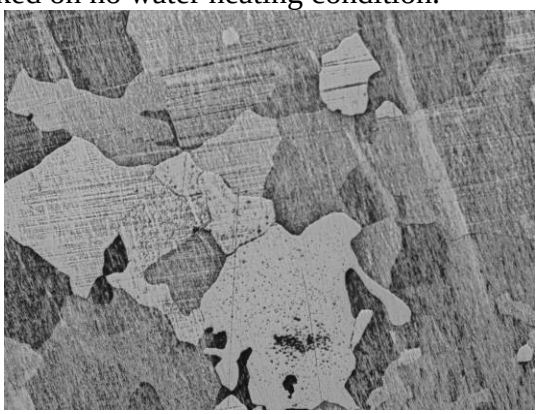

Figure 5 Microstructure of traces in position 1

100×

Figure 6 Microstructure of traces in position 2

100×

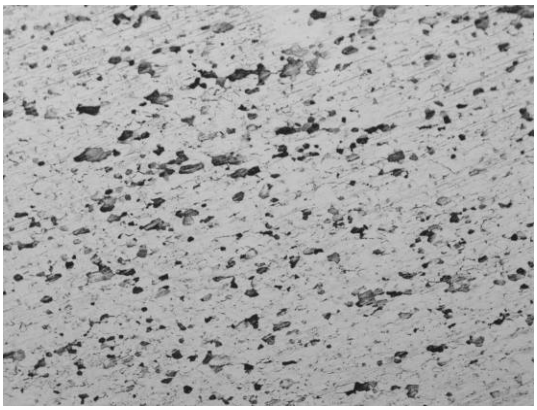

Figure 7 Microstructure of traces in position 3

100×

Cause Analysis

In the case of normal use of electric water heater, the operating temperature of heating wire is 1000~1050°C, the operating temperature of the insulating material (magnesium oxide, or quartz sand) wrapped in heating wire surface is l500~1700°C[6], the heat power generated by galvanic heating wire is transmitted from the surrounding insulation materials to the casing surface, while the heated water temperature outside the casing does not exceed 100°C. When the thermal equilibrium is stable, the casing temperature to maintain load is 120℃ or so, accordingly the maximum temperature at the position of terminal without heating wire is about 100℃. In the state of normal power use, the temperature rise at three selected locations are almost same, so the microstructures formed by fire role after cooling are not very different.

Under the circumstance of overheating, because of the water in the thermos burned dry, the electric water heater losses the heat exchange environment, which induces the temperature to continue to rise due to the heat power generated by the heating wire is not easy to diffuse. Within 1min to 2min, the casing reaches to the highest temperature, about 750 ℃, it is easy to roast combustible materials, cause a fire. Since the melting point of steel is 1430°C, while the fire scene temperature is generally 900℃~1200℃, the casing of electric water heater will not melt. However, the grain growth rate of the internal microstructure formed by different heat before the fire happened between the terminal position without heating wire (i.e. position 3) and the position with heating wire (i.e. position 1 and position 2) will be distinctly differences. Thus, when outside fire impacts on the casing again, the microstructures of selected positions will appear significant differences.

Conclusions

Because the situation of the fire scene is more complex, which results in the great effects on the formation of morphology characteristics of casing surface of the electric water heater, so only from the macro method to judge whether the electric water heater is on power before the fire happens has great limitations, while using scanning electron microscopy (SEM) to analysis and identify the microstructure of the heating wire is relatively more complicated, therefore the metallographic method is presented in this paper, which determines by means of sampling, comparison and analysis on the different parts of the casing. This method is simple, fast and efficient, and can provide the necessary help and support for the precise identification of fire cause.

Acknowledgements

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