Effects of Insulating Material Ageing on Ignition Time and Heat Release Rate of the Flame Retardant Cables

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Abstract

The effects of insulating material ageing on the fire performance of flame retardant cables were investigated experimentally by cone calorimeter in the present study. The ageing time and ageing type of the insulating material were concerned, and the fire hazard of cables was represented by the ignition time and the heat release rate (HRR). The results show that both the ignition time and the peak of HRR increase with the ageing time first and then decrease slightly for the flame retardant control cables with polyvinyl chloride insulated and polyvinyl chloride sheathed (ZR-KVV). For the flame retardant control cables with crosslinked polyethylene insulated and polyvinyl chloride sheathed (ZR-KYJV), the ignition time increase and the peak of HRR decrease with the ageing time. The effects of ageing type of insulating material on fire hazard of cables were investigated with the ZR-KVV cables. The ignition time and the HRR of the thermal aged cables were higher than those of the xenon arc aged cables, the ozone aged cables and the hydrothermal aged cables. The results of fire hazard assessment of aged flame retardant cables according to the ignition time might be opposite to those derived from the HRR of cable fires, which should be paid attentions in cable fire safety evaluations.

1. Introduction

The ageing of cables is almost inevitable in the electric power systems. The ageing of cables may cause many problems to the safety of electric system. Moreover, the ageing of cables is an important inducemnt of the cable fire. Therefore, it is necessary to acquire the effects of insulating material ageing on the fire performance of cables.

The cable fire is almost the biggest threaten to the safety of electric system, and it earns much attention [1-3]. Among the studies on cable fires, considerable quantity of the experimental studies was conducted by cone calorimeter. Al-Sayegh et al. [4] investigated the toxicity of polyvinyl chloride (PVC) cable fire productions by using the cone calorimeter. Zhang et al. [5] explored the fire performance of the flame retardant cables, and the HRR, the ignition time and the CO release rate were...
mainly concerned. By using the cone calorimeter, the HRR, mass loss rate and smoke release rate of the PVC cable fire under different external radiation heat fluxes were investigated by Wang et al. [6]. It is observed that the cone calorimeter is widely used in the studies on fire hazard assessment of cables. However, most of the experiments were conducted with the new cables, and the study focused on the fire performance of aged cables was not sufficient. Emanuelsson et al. [7] investigated the effects of ageing on fire performance of cables, and the special attention was paid on how fire behavior affected by the change of plasticizers used in PVC cables during experiments. Sleights [8] conducted an evaluation of the aged armored cables in building wiring systems, and revealed the fire hazard of old cables. Li et al. [9] investigated the effects of thermal ageing on insulation failure of the crosslinked polyethylene (XLPE) cables experimentally. The results showed that the insulation failure temperature of core and the time of insulation failure decreased with the thermal ageing time. Li et al. [10] compared the fire hazard of pre-ageing PVC cables and post-ageing PVC cables by using the microscale combustion calorimetry, thermogravimetric analysis, thermogravimetric analysis-infrared spectrometry and real time infrared spectrometry. Based upon the experimental results, they indicated that the fire hazard of PVC cables increased with the course of use. The studies conducted in this area mainly concerned on the thermal ageing of cables, while the other ageing types have been rarely involved. In addition, the effects of ageing on fire hazard of cables were not consistent among these studies. To sum up, the ageing of cables has obvious effects on its fire performance, and it still requires further exploration.

The effects of ageing on fire performance of the flame retardant cables were investigated in the present study. The cables with different ageing times and ageing types were included, and the fire performance of cables was mainly represented by the ignition time and HRR of cable fires.

2. Materials and Methods

The effects of insulating material ageing on fire performance of the flame retardant cables were investigated experimentally. The flame retardant PVC sheathed cables with the insulating materials of PVC and XLPE were selected, and marked as ZR-KVV and ZR-KYJV in the present study, respectively. Both the effects of ageing time and ageing type of insulating material were explored. The ageing time included 1, 3, 5, 8, 11, 15 days in most of the conducted experiments.

The experiments on cable fires were conducted by cone calorimeter, and the ignition time and HRR were mainly concerned. The external radiation heat flux was 35 kW/m². There were total thirty experiments conducted in the present study, and the details of each scenario were shown in Table 1.

In the studies on effects of ageing type on fire performance of cables, the thermal ageing, the xenon arc ageing, the ozone ageing and the hydrothermal ageing were included. The above four types of cable ageing were formed by the thermal ageing test chamber, the xenon lamp ageing test chamber, the ozone ageing test chamber and the hydrothermal ageing test chamber, respectively.

Table 1. Details of cable fire experiments

<table>
<thead>
<tr>
<th>No.</th>
<th>Cable Type</th>
<th>External radiation heat flux</th>
<th>Ageing Time</th>
<th>Ageing type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5</td>
<td>ZR-KYJV</td>
<td>35 kW/m²</td>
<td>3/8/11/15/25 days</td>
<td>Thermal Ageing</td>
</tr>
<tr>
<td>6-12</td>
<td>ZR-KVV</td>
<td>35 kW/m²</td>
<td>0/1/3/5/8/11/15 days</td>
<td>Thermal Ageing</td>
</tr>
<tr>
<td>13-19</td>
<td>ZR-KVV</td>
<td>35 kW/m²</td>
<td>0/1/3/5/8/11/15 days</td>
<td>Xenon Arc Ageing</td>
</tr>
<tr>
<td>20-26</td>
<td>ZR-KVV</td>
<td>35 kW/m²</td>
<td>0/1/3/5/8/11/15 days</td>
<td>Ozone Ageing</td>
</tr>
<tr>
<td>27-30</td>
<td>ZR-KVV</td>
<td>35 kW/m²</td>
<td>0/1/5/8 days</td>
<td>Hydrothermal Ageing</td>
</tr>
</tbody>
</table>

3. Effects of the Insulating Material Ageing on Ignition time

The ignition time of flame retardant cables with different ageing times of insulating material are shown in Fig. 1. The ageing type of the cables in Fig. 1 was thermal ageing. The cables with the insulating material of XLPE (ZR-KYJV cables) showed lower fire hazard than PVC insulated cables (ZR-KVV cables) from the perspective of ignition time. From Fig. 1, it was found that, the ignition of ZR-KVV cable increased first, and then decreased slightly with the ageing time of insulating material. Therefore, the new service ZR-KVV cables and seriously aged ZR-KVV cables were easier to be ignited. Compared with the ZR-KVV cables, the ignition hazard of the ZR-KYJV cables was more sensitive with the ageing time of insulating material. For the ZR-KYJV cables, the ignition time increased continuously with the ageing time of insulating material. It means that the new service ZR-KYJV cable has more serious ignition hazard in the present study.
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