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Study on material properties of power cable based on thermogravimetry and cytotoxicity test

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Study on material properties of power cable based on thermogravimetry and cytotoxicity test

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Abstract. There are many indicators to measure the performance of power cable materials, among which flame retardancy, conductivity and environmental protection are the most important. In experiment 1, the flame retardancy of sample cables was studied by thermogravimetric analysis, and an analytical method for flame retardancy of cable materials was provided. In experiment 2, the environmental protection performance of the sample cable was analyzed by cytotoxicity test. Finally, a reasonable prospect and forecast for the new power cable in the future is given.

1. Introduction

The properties of power cable materials are determined by many factors, such as flame retardancy, environmental protection, conductivity and so on. In particular, flame retardancy is closely related to life and production, and the pyrolysis process of combustible materials is an important factor in the occurrence and development of fires. The insulating layer of wire and cable is generally a polymer that is easy to burn. Thermal decomposition or thermal degradation of insulating materials occurs firstly with the increase of temperature in fire environment, which results in Material Ignition and provides necessary and sufficient gas combustibles for subsequent fire spread. The destruction of insulation will even expose internal conductors, causing accidents such as short-circuit and electric shock. If the combustion of cable materials occurs in a confined building space, the flammable gas may also cause flashover. Whether abroad or at home, the greening of electrical products is proceeding intensively, and the toxicity of products and the content of harmful elements are important indicators of greening.PVC and other halogen-containing materials are commonly used as insulation for wires and cables in China. However, in case of fire, the combustion of these materials will produce smoke containing a large amount of hydrogen halide gas, which will cause asphyxiation and death.

2. Study on flame retardancy

2.1. Experimental preparation

Thermogravimetric analysis is a commonly used method to study the pyrolysis kinetics of polymers. It studies the relationship between the mass of substances and temperature in the pyrolysis process under controlled programmed temperature. The pyrolysis weight loss rate and other parameters are analyzed from the thermogravimetric (TG) curve, and the pyrolysis kinetics principle is used to quantitatively describe the pyrolysis of polymers. The mechanism of pyrolysis reaction is deduced by the change of activation energy in the process of combustion. The apparent pyrolysis weightlessness behavior and activation energy at different reaction rates are studied.

2.2. Experimental process
The experimental instrument is Q50 type thermal analyzer. The sample is selected as a low voltage cable commonly used in subway stations, with a model of ZRC-VV22-3×240.

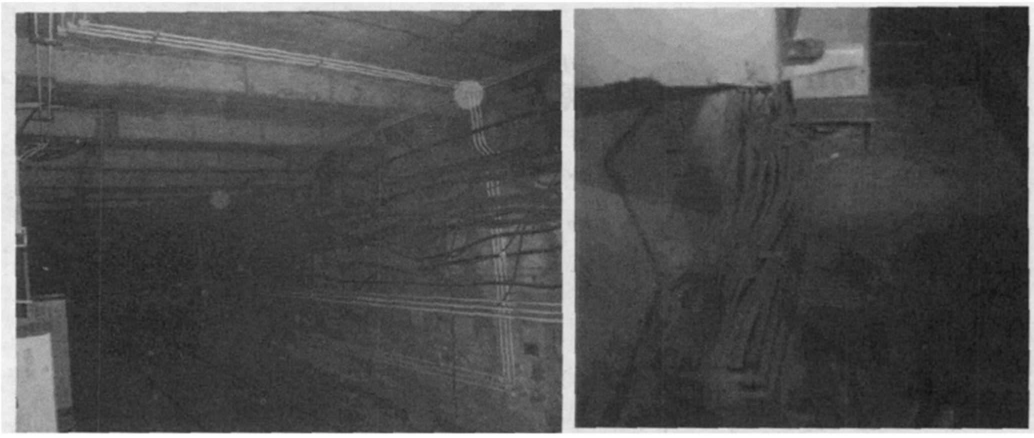

Figure 1. Wires and cables used in subway tunnels

Based on Thermogravimetric data, researchers have proposed various mathematical methods for dynamic analysis in order to obtain more reasonable and reliable kinetic parameters. The modeless function method (also called equal conversion method) is widely used. The basic principles are as follows:

Assuming that the reaction process of thermal degradation of polymers can be expressed as B(s)->C(s)+D(g), according to Arrhenis equation, the total degradation rate is expressed as follows:

$$\frac{\mathrm{d}\alpha}{\mathrm{dt}} = \mathrm{k}(T)f(\alpha) = A^{-E_\alpha/RT} f(\alpha) \tag{1}$$

Under constant heating rate, $\beta = dT/dt$, Formula (1) can be deformed into

$$\frac{\mathrm{d}\alpha}{\mathrm{dt}} = \frac{A^{-E_\alpha/RT}}{\beta} f(\alpha) \tag{2}$$

Among them, A is the pre-exponential factor, α ,t, E_α ,T and R are the conversion rate, reaction time, apparent activation energy, reaction temperature and gas constant. Conversion rate is defined as the residual mass of the sample at t time and the mass of the sample at the beginning and end of pyrolysis, respectively. $f(\alpha)$ is related to the reaction mechanism.There are still some shortcomings in this equation. The widely used transformation methods based on modeless functions are Kissinger method,Flynn-Wall and Ozawa method,Friedman method etc.

(1) Kissinger method. For formula (1), when the thermogravimetric rate reaches the maximum, d(d α /dt)/dt=0,

$$\frac{d(\ln\beta/T_p^2)}{d(1/T_p)}=-\frac{E_\alpha}{R} \tag{3}$$

In the formula, T_p is the temperature corresponding to the maximum thermogravimetric rate and β is the heating rate in thermogravimetric experiments, which need to be carried out at different heating rates. E_α can be obtained by drawing and linear fitting.

(2)Flynn-Wall and Ozawa method. The formula (1) can also be changed into the following form:

$$\frac{d\alpha}{(1-\alpha)^n}=\frac{A}{\beta}e^{-\frac{E_\alpha}{RT}}dT \tag{4}$$

Pairs of (5) integral and Doyle approximate processing can be obtained.

$$\ln\beta=\ln\left[A\frac{f(\alpha)}{(d\alpha/dt)}\right]-\frac{E_\alpha}{RT} \tag{5}$$

The activation energy can be obtained by linear fitting with $\ln\beta$ - $\frac{1}{T}$ diagram.

2.3. Experimental result

According to the relevant data, the results calculated by Kissinger method are shown in Figure two. In this paper, the results of Kissinger method are analyzed. The corresponding pyrolytic activation energy table of material is found in Table 1. It can be seen that the kinetic parameters can be obtained by calculating without knowing or determining the mechanism of thermal degradation. After treatment, the linear relationship is very good, the correlation coefficient is 0.93772, and the activation energy of pyrolysis is 226.7kJ/mol.

Table 1. Calculation results of Kissinger method

sample	E_α /(kJ/mol)	correlation coefficient r
Selected low voltage cables	226.7	0.93772

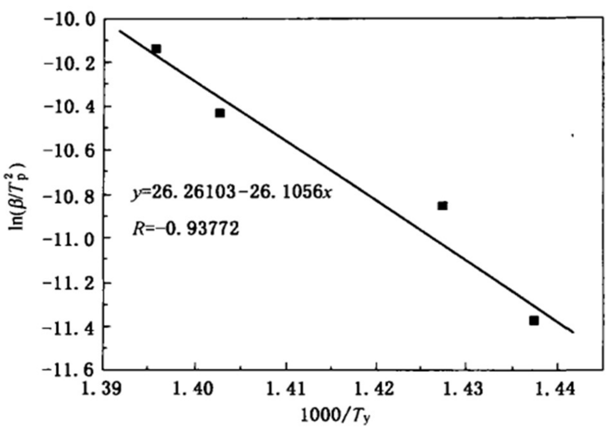

Figure 2. Thermal degradation kinetics curve fitted by Kissinger method

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Thermal decomposition or thermal degradation is a special stage when the material is heated before reaching the ignition point. In this stage, the pyrolysis of matter itself will release flammable gas molecules and even accumulate energy to accelerate the ignition of matter. Therefore, pyrolysis is a preparatory process in the ignition stage and is a typical phenomenon controlled by chemical reaction kinetics. According to the transition state theory of reaction rate, the energy provided by the surrounding environment must reach the activation energy required for the reaction to occur. The increase of activation energy in the thermal oxidation degradation process of materials necessarily corresponds to the decrease of combustion performance of such materials. Therefore, the activation energy in the pyrolysis process can be used to evaluate the combustion performance of materials. An important index of fire risk. The above results show that the activation energy of this kind of cable material is higher at any conversion rate except the initial thermal decomposition temperature, which indicates that this kind of cable material is not easy to ignite and has low fire risk. This method can also be used to verify other power cable materials.

3. Study on environmental protection

3.1. Experimental preparation

According to the relevant literature, toxicity and harmful element content are two major indicators to measure the greening of cable materials. Considering the cost, efficiency and accuracy, the detection methods for both are generally cytotoxicity test and inductively coupled plasma emission spectrometry. This paper chooses cytotoxicity test to test the sample cable.

3.2. Experimental process

The cell line Bel-7402 was cultured on RPMI 1640 plus 10% FBS. The control group was 96-well plate. The extract was replaced by complete medium. The cell viability and cell morphology were evaluated by MTT.

The test procedures are as follows:

(1)add the cable paste 23g to 120 mL PBS under sterile conditions.At 37°C, 96 h was stirred and stirred; (2) Bel-7402 cells were inoculated to 96 orifice plates 24 h ahead of time.

(3)Dilute the extract at multiple ratio and add it to the cultured cells. Choose no extract as blank control;

(4)inoculate the extract for 48 hours and take photos under the light microscope, and do MTT analysis at the same time, convert it into cell survival rate (%). The MTT results of cytotoxicity test could be obtained by repeating the above tests for 6 times. The relationship between the cell viability ratio and dilution multiple of the extract and the control group was shown in Fig. 1. Bel-7402 cells were grafted.After 48h of the drug,the light microscopic photographs are shown in Figure 2. By calculating, the half lethal concentration (i.e.the half lethal concentration of the poisoned cells) of the cable paste can be obtained. IG50 = 24gL (i.e. 24g cable paste per liter of solution), whereas the general IC50 > 0.1gL is considered to be non-toxic.

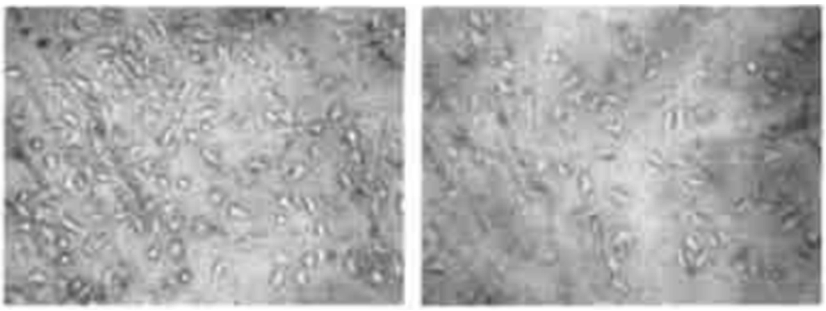

Figure 3. Relationship between cell viability and dilution multiple (left: 128 times right: 64 times)

3.3. Experimental analysis
It can be seen that the cable material after decomposition has great damage to cells, plants and animals will have a certain impact, but also is not conducive to the environment. According to some EU regulations, it is required that lead, mercury, cadmium, chromium, polybrominated diphenyl ethers and polybrominated biphenyls are not contained in electronic and electrical equipment. In addition, excessive aluminium content is harmful to workers'health. At present, the most common cable material in our country is polyvinyl chloride, which has low heat and cold resistance. Usually, it can only be used in the range of 15-60℃. Moreover, polyvinyl chloride releases harmful gases when it burns, which is not conducive to environmental protection.

4. Conclusion
With the development of science and technology, the requirements for power cable materials are getting higher and higher. At the same time, more and more new materials appear, such as XLPE cable material, which is a halogen-free cable material. The most prominent advantage of this material is green and environmental protection. XLPE insulated power produced by XLPE cable material Cables not only have certain advantages in electrical performance, but also have great advantages in new halogen-free cables with good mechanical characteristics of thermal overload. In recent years, with the rapid development of domestic economy and the demand of Metro and optoelectronic communication industry, halogen-free flame-retardant polyolefin cable materials have attracted wide attention. In addition, their superior flame retardancy and environmental protection have occupied a favorable position in the market. Starting with the analysis, testing and research of various properties of power cable materials, and understanding the impact and harm degree of various elements on human body, is very conducive to the development of new power cable.

References
[1] Sergei M L,Irina L D,Svetlana M B,Gennadi E Z.Kinetic study of polypropylene nanocomposite thermo-oxidative degradation [J].Polymer International,2005,54:999-1006.
[2] Vyazovkin S,Dranca I,Fan X W.Kinetics of the thermal and thermao-oxidative degradation of a poly-styrene-clay nanocomposite [J].Macromolecular Rapid Communication,2004,25:498-503.
[3] Hamill L, Gilbert N.Social circles: A simple structure for agent-based social network models[J].Journal of Artificial Societies and Social Simulation, 2009, 23(12).
[4] Heider F.The psychology of interpersonal relations[M].[S.l.]: Psychology Press, 1982: 1-317
[5] Wilensky U.NetLogo[EB/OL].(2012)[2014-03-31].http: //ccl.northwestern.edu/netlogo/
[6] WANG Chao, BI Guihong, ZHANG Shouming. The Agent Based Competition Model of Circles Network[J]. Computer Engineering and Applications, 2016, (7): 1-16
[7] DONG Jie, Jan Blommaert. Language and Movement in Space[J]. The Journal of Chinese sociolinguistics, 2011, (1): 1-9
[8] Mira J, Paredes A.Interlinguistic similarity and language death dynamics[J].Europhysics Letters, 2005, 69(6): 1031-1034.