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Experimental Study on Fire and Explosion Suppression of Self-ignition of Lithium Ion Battery

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Abstract

This study adopted the external heating method to generate the lithium ion battery spontaneous combustion, spraying HFC-227ea and CO_2 to conduct fire suppression explosion test, and researched the explosion suppression effect of the gas suppression on lithium ion battery. The results show that HFC-227ea and CO_2 mainly inhibit the explosion of the lithium ion battery through the method of cooling. The HFC-227ea and CO_2 can extinguish the open flame, reduce the combustion temperature and weaken the explosive strength. The combustion temperature of lithium ion battery undergoes three stages: initial growth, sharp rise and decay. It is necessary to take measures to extinguish fire and explosion in the initial growth stage.

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Keywords: lithium ion batteries, fire suppression, explosion suppression, gas extinguishing agent, combustion temperature

Lithium ion battery have been widely used in new energy vehicles. In recent years, the occurrence of new energy vehicles explosion accident makes its security issues have been widespread concern and attention. Lithium ion battery is at risk of burning and even exploding in extreme cases such as excess charging, collisions and high temperatures, and they are difficult to put out. Both HFC-227ea and CO_2 belong to the gas extinguishing agent, which is fast fire-fighting. Therefore, HFC-227ea and CO_2 are used as the explosion suppression media to study the effect of the explosion suppression of lithium ion batteries.

1. Analysis of lithium ion battery combustion mechanism and explosion suppression mechanism

1.1. Analysis of combustion process and characteristics of lithium ion battery

The lithium ion battery mainly consists of positive pole, negative pole, diaphragm, electrolyte, shell and other components. The positive material is always intercalated transition metal oxides or polyanionic compounds, the negative material is mostly made of graphite, and the electrolyte is mainly composed of organic mixed solution and lithium salt. The diaphragm acts as a barrier between the positive and the negative, preventing electrons from passing through which cause short circuit and allowing ions to pass through the electrolyte.

When the battery is used, Carbon negative electrode, positive electrode active material and electrolyte will produce electrochemical or chemical reaction and give off heat. The temperature of the battery will be raised, which will further promote the reaction. However, in the case of short circuit, high temperature, collision and other abuse, the battery inside

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easy to cause thermal runaway, the rapid release of energy leads to electrolyte combustion, and the temperature of the battery rises rapidly Because other components of the lithium ion battery are all burning substances [1], such as graphite anode, diaphragm, cathode, which causes the battery materials to burn and even explode. After the battery shell is broken, the intense oxidation of air with lithium also causes the battery to burn and even explode [2].

When lithium ion batteries burn, the cathode material breaks down and releases O_2, and the battery combustion will also release CO and other combustible gases [3]. The large amount of heat released by internal reaction can also provide energy for lithium ion battery combustion. These factors also make lithium ion battery burn even in confined environments. Once burned, it is extremely difficult to extinguish.

1.2. Analysis on attenuation mechanism of gas suppressor

HFC-227ea is colorless, almost tasteless and low toxic gas at normal temperature and atmospheric pressure, with good thermal stability and chemical stability. At 20℃, the saturated vapor pressure of HFC-227ea is 0.391MPa. HFC-227ea realizes the fire suppression and explosion suppression through chemical inhibition and physical method, such as reducing the oxygen concentration, absorbing heat. Liquid HFC-227ea will rapidly vaporized and expanded volume after being ejected, which reduces the oxygen concentration. The vaporization will absorb large amounts of heat that sharply reduce the reaction temperature of combustion and combustion reaction activity, Thus the liquid HFC-227ea can play a role of fire suppression and explosion suppression. At the same time, HFC-227ea pyrolysis will produce free radicals and react with the active radicals such as O, H, OH and other reactive radicals during the combustion reaction, thereby, the chemical chain reaction in the combustion process is interrupted and the combustion reaction is suppressed [4].

CO_2 is a colorless and odorless gas at normal temperature, with low toxic, it will not support combustion. At 20℃, the saturated vapor pressure of CO_2 is 5.72MPa, which belongs to high pressure liquefied gas. The mechanism of fire and explosion suppression of CO_2 mainly has the effect of suffocation and cooling: The CO_2 is stored in a liquid form in a cylinder and rapidly vaporized after being ejected, which produces a large amount of CO_2 in the process of vaporization to reduce the concentration of O_2; the process of vaporization needs to absorb a lot of heat. At the same time, because of the enthalpy drop, the temperature of CO_2 decreases sharply to form fine solid dry ice particles, and the dry ice absorbs its surrounding heat and sublimation, so the CO_2 has a cooling effect.

2. Test method and apparatus for fire suppression and explosion suppression

2.1. Test arrangement

The box body of the Self-made test cabinet is 380mm×280 mm×375 mm, the front of box is provided with an observation window, the window size is 150mm×150mm. The rear side of the box is provided with a thermocouple mounting interface, and the pressure sensor installation interface is arranged at the top and the two sides. In the test, 3 thermocouples are installed on the back of the box, the installation position is 10cm above the battery, and the thermocouple is connected with a paperless recorder. A pressure sensor is installed on the left and right sides of the upper part of the test case, which is connected with the data acquisition system to monitor the explosion pressure in the test chamber. During the test, the infrared thermometer is used to monitor the surface temperature of the battery.

The test mainly monitors the burning temperature of the lithium ion battery and the explosion pressure in the box. The combustion temperature is monitored by armored K-type thermocouples, the monitoring temperature range is 0℃ to 1000℃. The thermocouple monitoring value was recorded using a paperless recorder, and the recording interval was 2s. Through the pressure sensor and data acquisition system to collect the value of the explosion chamber pressure, the pressure sensor measuring range 0~30KPa; the infrared thermometer can monitor the range -20℃~550℃to monitor the surface temperature of lithium ion batteries.

2.2. Experiment method

The test battery is ternary polymer electric vehicle lithium ion battery which is removed shell, the ternary polymer material is the lithium nickel cobalt manganese, which use nickel salt, cobalt salt, manganese salt as raw material, the ratio of nickel salt, cobalt salt, manganese salt can be adjusted, and the negative material is graphite. In the Test, the rated voltage of the battery is 48V, and the rated current of the battery is 10A, the state of charge for the factory power, the size of battery is 285×92×72mm. The external heating method is used to make the lithium ion battery spontaneously. By heating the bottom of the test box, the battery is heated continuously. When the battery is on fire, the fuel under the tank is removed, and the bottom plate of the box body is stopped.