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Study on the influence of the thermal protection material on the heat dissipation of the battery pack for energy storage

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Abstract. The thermal runaway chain reaction of batteries is an important cause of the battery energy storage system (BESS) accidents, and safety protection technology is the key technology to protect the BESS. Although the flame retardant thermal protection material can delay the thermal runaway chain reaction between batteries and reduce the heat conduction between batteries, it has a negative influence on the normal heat dissipation of batteries. In this paper, 12 series of batteries were assembled into the battery pack. The battery pack with closely arranged batteries, the battery pack with 3mm air gap between batteries and the battery pack with flame retardant thermal protection material between batteries were studied. The battery temperatures and temperature differences of these three types of battery packs were cyclically charged and discharged at rated power, and the effects of air gap and flame retardant thermal protection materials on the heat dissipation of batteries under charge/discharge cycle were analysed.

1 Introduction

In recent years, due to the massive access of renewable energy and distributed energy in large power grids, combined with the popularization and application of microgrid and electric vehicles, energy storage technology has become an important link to coordinate these applications. Among many energy storage technologies, lithium ion battery energy storage technology is the most widely used and relatively mature energy storage technology at present. However, there have been many battery energy storage power station fires at home and abroad, such as more than 20 energy storage power station fires in South Korea and a 2MWh energy storage system fires in the United States. In recent years, there have also been several battery energy storage system (BESS) fires in China, which have attracted great attention.

According to the national investigation report on BESS fire accident in South Korea, there are some problems such as defects in BESS and inadequate protection system against electric shock, and the safety management at product and system level should be greatly strengthened. According to the BESS fire accident investigation report in America, it is necessary to adopt the design of battery and BESS which can actively slow down or stop the cascade or propagation of battery thermal runaway. China has also carried out a lot of work in improving the safety of BESS. For example, Cao et al. analysed the current fire safety status of BESS from the aspects of fire characteristics of lithium ion batteries, applicability of fire extinguishing agents, matching of firefighting equipment and technical specifications, and pointed out the possible technical ways of prefabricated cabin BESS in fire safety design [1]; Yuan et al. proposed to introduce functional safety specifications into the battery management system(BMS), and put forward a set of BMS design scheme in line with IEC 61508 standard to reduce the risk to a reasonable and tolerable range [2]. According to the typical structure and monitoring requirements of BESS, Chen et al. put forward the architecture and construction mode of BESS monitoring system [3]; Huidong et al. analysed patent applications and authorizations related to the safety of BESS[4], and the results showed that battery protection technology (battery internal protection, such as pressure relief valve technology [5-6]) had the largest number of patents, followed by battery materials (PTC[7] and ceramic diaphragm [8]), with the least number of condition monitoring, and proposed the possible technical development direction of BESS safety protection technology in the future.

In these works, protection technology is an important measure to ensure the safety of BESS, and the use of thermal protection materials in protection technology can delay and avoid the chain reaction of thermal runaway of BESS, reduce the accident scale and the difficulty of extinguishing BESS fires. Therefore, the application of thermal protection materials to improve the safety of BESS has become one of main research directions at present. However, the use of thermal protection materials may have adverse effects on the normal heat dissipation of

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battery packs, because thermal protection materials prevent heat transfer between batteries, and the battery packs will continue to generate heat during normal charge and discharge cycle, which needs to be removed by thermal management. Therefore, the use of thermal protection materials needs to fully evaluate its impact on the heat dissipation of battery packs, and there are few studies in this field at present.

In this paper, the application of thermal protection materials in the battery pack was studied. By assembling small-scale battery packs and charging/discharging them at the rated rate, the temperature changes of battery packs with thermal protection materials during charge/discharge cycle were measured, and the influence of thermal protection materials on heat dissipation of battery packs was analysed.

2 Research program

2.1 Battery pack design

Three battery packs were assembled, each of which used 12 lithium iron phosphate batteries, with rated capacity of 25Ah, working voltage of 2.5 V-3.6 V and rated power of 88 W. The battery spacing in each battery pack was different, which was as follows:

(1) batteries were closely arranged, and there was no gap between batteries;

(2) there was an air gap of 3mm between batteries;

(3) there was the 3mm thermal protection material filled between batteries.

Before packing into the pack, batteries were discharged with the current of 1C rate, and the discharge was stopped after the voltage dropped to 2.5V. Then the batteries were connected in series to form a battery pack, as shown in Fig.1, and micro thermocouples were placed between batteries to check the surface temperature changes of batteries. The battery pack was placed in the battery box, the upper cover plate of the battery box was transparent explosion-proof glass, and the positive and negative electrodes of each battery were connected with signal lines, which was convenient for monitoring the voltage changes of the battery during charge/discharge cycle. Grooves with different widths were machined at the bottom of the battery box, which was convenient to fix the battery and prevent it from moving.

Figure 1. Battery pack picture

2.2 Battery pack test scheme

Before the battery pack was charged/discharged, the protection voltage range of the battery pack was set firstly. Because of the series structure, the protection voltage of the battery pack was set to 2.4-3.7 V, and the working voltage range of the battery pack was 30-43.8 V. The charge/discharge cycle test was carried out on the battery pack with rated power of 1P, and three packs of tests were carried out in turn, and the cycle times of each pack were 3-4 times. After the charge/discharge cycle, the temperature change of the battery was recorded continuously until the temperature dropped to room temperature.

3 Discussion and analysis

3.1 Battery pack with closely arranged batteries

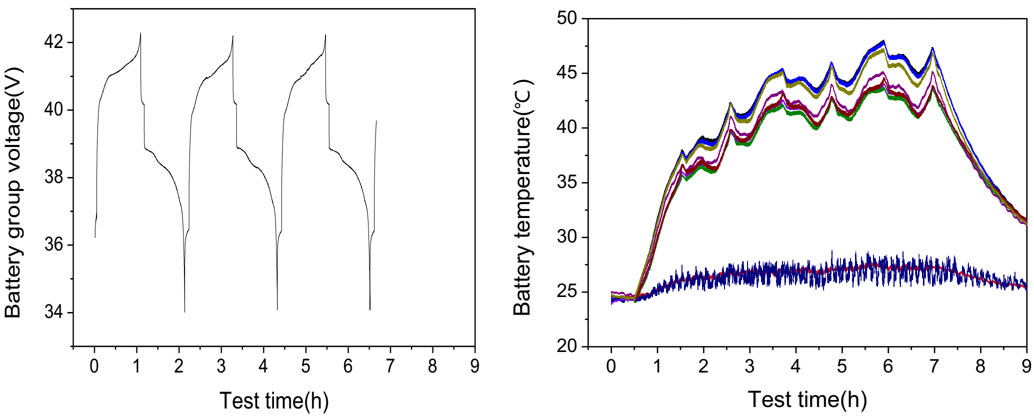

Figure 2. (a)the battery voltage and (b) temperature change within the battery pack

Fig. 2(a) is the charge/discharge curve of closely arranged batteries under 1P power charge/discharge cycle. The battery pack was charged/discharged for three times, and then stopped charging. Due to the inconsistency between batteries, individual batteries firstly reached the upper limit of battery voltage during charging step, and individual batteries firstly reached the lower limit of battery voltage during discharging step, so the total voltage of the battery pack during charge/discharge cycle remained between 34-42 V, which did not fully reach the designed working voltage range of the battery pack. Fig. 2(b) shows the change of battery surface temperature during the charge/discharge process. It can be seen from the figure that the ambient temperature fluctuated between 25-27°C. During the first charging process, the battery temperature rase rapidly, and then with the charge/discharge process, the battery temperature fluctuated greatly and rase gradually. After the charge/discharge cycle ended, the battery temperature dropped rapidly. Also, due to the inconsistency of batteries, the temperature of the battery pack varied greatly during the whole process, with the highest temperature reaching 48.1°C and the maximum temperature difference reaching 4°C.

3.2 Battery pack with 3mm air gap

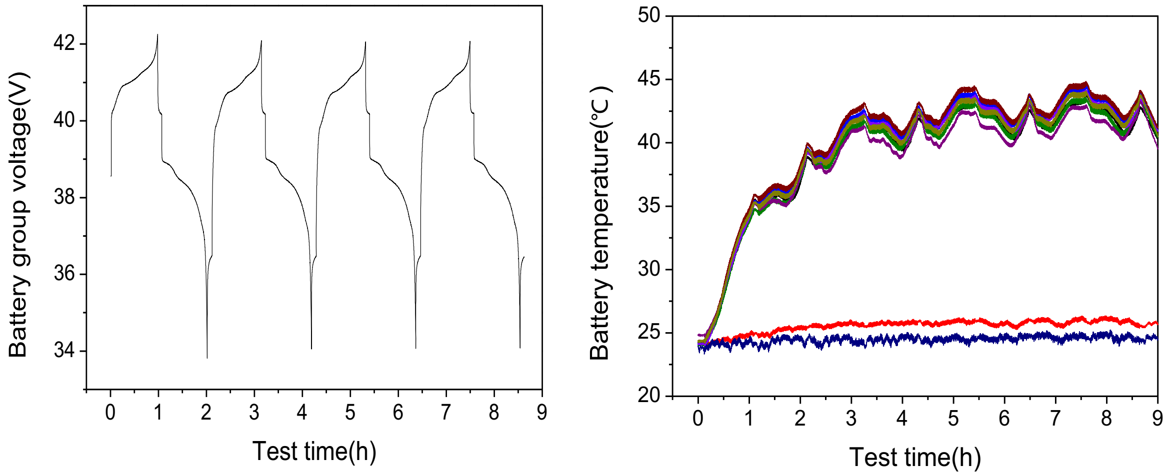

Figure 3. (a)the battery voltage and (b) temperature change within the battery pack

Fig. 3(a) is the charge/discharge curve of the battery pack with air gap of 3mm under 1P power. This battery pack was cycled for 4 times and stopped charging at the end of the fourth discharge process. Also, due to the inconsistency of the battery, the working voltage of the battery pack was kept between 34-42 V. It can be seen from fig. 3(b) that the temperature change of the battery pack with air gap was gentler than that of the battery pack with close arrangement, and the maximum temperature was 45°C and the maximum temperature difference was 2.5°C. This showed that properly increasing the distance between batteries will benefit the heat dissipation of batteries and reduce the temperature difference between batteries. For a closely arranged battery pack, because there is no heat dissipation channel inside it, the heat generated by charge/discharge the battery is all due to raising the temperature of the battery itself, while a battery pack with a gap can dissipate part of the heat to the outside of the battery pack through the air gap.

3.3 Battery pack with 3mm thermal protection material

Fig. 4(a) is the temperature change curve of the battery pack filled with thermal protection material after charge/discharge cycle. It can be seen from fig. 4(a) that the maximum temperature of the battery pack was 45.6°C, and the maximum temperature difference was 3°C.

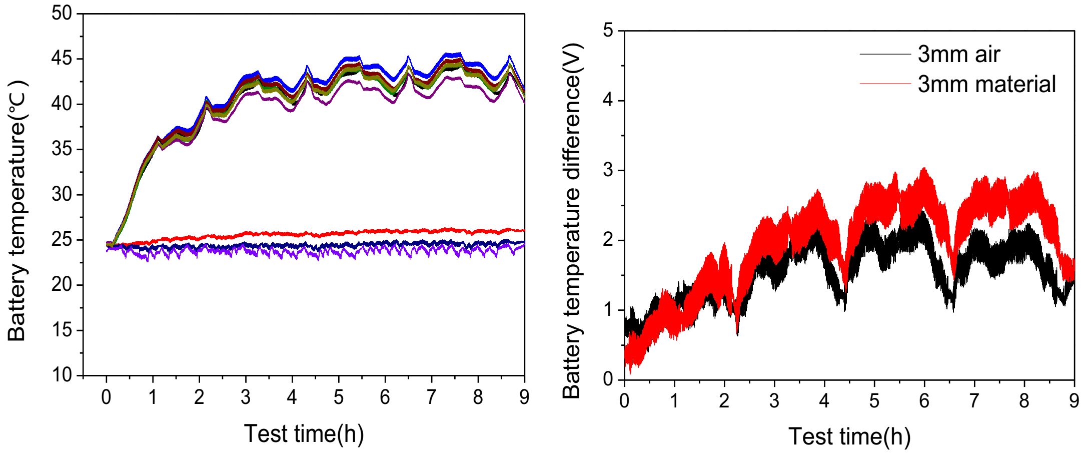

Figure 4. (a)the battery temperature and (b)temperature difference within the battery pack

From the comparison between Fig.3 and Fig.4, it can be seen that the temperature of the battery pack increased slightly after filling the air gap with thermal protection material, which was because the thermal protection material played a role of heat isolation, so that the heat generated by the battery could not be quickly transferred to the air, but the thermal protection material was not a thermal insulation material, and the temperature of the filled battery pack was only 0.6℃ higher than that of the battery pack with air gap. In addition, the temperature difference of batteries containing thermal protection materials was generally higher than that of batteries with air gaps, which was about 0.5°C higher. It shows that in normal air circulation environment, the thermal protection material has certain influence on battery heat dissipation, but the influence degree is limited.

4 Conclusion

In this paper, the influence of thermal protection material on the heat dissipation of battery pack was studied. The charge/discharge cycle test results of 12 series of battery packs showed that:

(1) Increasing the distance between batteries properly was beneficial to the heat dissipation of batteries and reduce the temperature difference between batteries.

(2) After the gap between batteries was filled with thermal protection material, the temperature of the battery pack increased slightly. Under the condition of 1P cycle, the maximum temperature was greater than 0.6°C, and the temperature difference was greater than 0.5°C. Under normal air circulation environment, thermal protection material had certain influence on battery heat dissipation, but the influence degree was limited.

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