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Research on Thermal Runaway of Mechanically Damaged Li-Ion Batteries and Its Stopping by Excess Water

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Abstract. The construction, operating principles, and Li-ion battery thermal runaway mechanisms were analyzed. The external mechanical damage to a Li-ion battery with the uncontrolled thermal runaway development was investigated. The battery self-heating temperature regime was determined. A possible reactions set leading to intense materials self-heating and decomposition was considered. The battery self-heating stopping by immersing it in a container with a water excess relative to the stoichiometric amount for the lithium metal maximum mass that can accumulate was investigated. The change in resulting aqueous solution pH was measured, and the hydrogen release was also recorded. Reaction completion time dependences was established. The water required amount to absorb the heat that could be released during the reaction was calculated, which correlated with the experimental data. Possible measures to Li-ion batteries prevent and stop the burning were considered.

1 Introduction

The modern concept of use developing of the various devices, equipment, machines and mechanisms, the requirements for their autonomy and operation stability, the possibility of the temporary accumulation of the periodic processes energy as the basis of electric power industry some branches have led to the battery systems widespread use. These systems are required to be lightweight, compact, efficient, fire, chemical and environmental safe. The most efficient and developed batteries currently are Li-ion. Their disadvantage is tendency to the thermal runaway (self-heating) under certain conditions, which poses a fire starting risk. World statistics show cases of their catching fire both during use and during storage, which can initiate large-scale fires. In 2017, a backup battery caught fire at a power plant near Brussels, producing a toxic smoke large amount. In 2019, a lithium metal abnormal deposit in the battery caused a cascading fire at Arizona Public Service's Battery Storage System. By the time firefighters arrived, an gases explosive concentration of had already been reached in the building, resulting in a massive explosion when the door was opened. In 2024, several batteries exploded in a warehouse in Seoul, killing 22 people and destroying buildings; in the same year, a fire broke out in a warehouse at the SNAM processing plant (France) and burned 900 tons of lithium batteries. Therefore, modern scientific developments are aimed at reducing the thermal runaway risk, developing cooling systems for such batteries in stationary and emergency operating modes, and predicting the initiating fires possibility. The latter involves studying options for individual batteries thermal runaway, their ignition cases and the large-scale fires development. This paper focuses on the development stages analysis of the damaged battery thermal runaway.

2 Literature Review

The thermal runaway phenomenon has been known since the alkaline batteries invention and occurs during charging. In emergency situations, electrolyte lack or its aging, battery mechanical damage, charging voltage exceeding, continued charging in a charged state, heat dissipation poor conditions,

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absorb the heat generated, but the uniformity of its distribution is crucial for cooling efficiency. The results can be used to develop more effective fire protection measures for lithium-ion batteries. It is recommended to conduct the gas emissions early monitoring before the thermal runaway stage to enable timely response to batteries self-heating and self-ignition, and late monitoring for rapid response to fire at subsequent stages. Flaming can be stopped by spraying water, a inhibitor cloud, or non-flammable gas while simultaneously dousing the battery with water taken in excess. We propose to develop a system for purging the battery with non-flammable gases that do not react with lithium under fire conditions.

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