Proceedings of the 9th World Congress on Mechanical, Chemical, and Material Engineering (MCM'23)
Brunel University, London, United Kingdom - August 06-08, 2023
Paper No. ICMIE 130
DOI: 10.11159/icmie23.130

Numerical Analysis of Gas Diffusion Characteristics during Thermal Runaway in Lithium-Ion Battery Module

Dong Woo Kim[1], Young Man Lee[1], Seong Hyuk Lee[2] and Hong Sun Ryou[2]
[1]Fire Prevention System Institution/Alllitelife Co,. Ltd.
72 Deockcheon-ro 72, Manan-gu, Anayang-si 01847, Republic of Korea
First.dwkim@alllitelife.com; Second.ymlee@alllitelife.com
[2]School of Mechanical Engineering /Chung-Ang University
84 Heukseok-ro Dongjak-gu, Seoul 06974, Republic of Korea
Third. cfdmec@cau.ac.kr; Fourth. Shlee89@cau.ac.kr

Extended Abstract

Lithium-ion batteries are widely used as secondary batteries due to their high energy density and low self-discharge. However, the lithium-ion batteries have the risk factor, such as explosions and toxic gas emissions caused by thermal runaway. Thermal runaway is a phenomenon where the temperature of the battery rapidly increases due to external factors, which leads to chemical reactions inside the battery, and the generation and ejection of various gases such as H_2, CO, CO_2, and VOCs to the outside.[1,2] Analyzing the vented gas flow from the battery is essential for designing fire safety devices, such as early detection systems for battery fires. The CO_2 gas is known most advantageous for early detection of thermal runaway [3]. However, most previous studies on gas flow analysis have been performed in single cells, while lithium-ion batteries are typically used as battery modules.[4,5] Therefore, this study was used to analyse the gas diffusion inside the module where thermal runaway of the battery occurred. This study performed numerical analysis using the commercial program Ansys fluent 19.1. The standard k-ε model is used for gas diffusion in the battery module and the species transport model to simulate the gas generated from the battery. The analysis was unsteady, with a time step of 0.01 s, and set for an analysis time of 100 s. The results show that at the beginning of gas ejection, the gas diffuses rapidly to adjacent cells where thermal runaway occurs. The gas velocity distribution before 7 seconds after thermal runaway describes the gradual diffusion of the gas into the module. However, the amount of gas initially ejected is small, and the CO2 mass fraction distribution before 10 seconds is low. After 8 seconds, there is a region where the gas diffusion rate suddenly increases. This is because of the flow that hits the module wall due to the vortex, and the flow moves into the center of the module due to the vortex. After 10 seconds, the released CO_2 gas gradually accumulates at the end of the module and diffuses throughout the interior.

Acknowledgements

This work was supported by the Research and Development of Fire Safety Technology for ESS Hydrogen Facilities, 20011568.

References

[1] Xuning Feng, Minggao Ouyang, Xiang Liu, Languang Lu, Young Xia, and Xiangming He. “Thermal runaway mechanism of lithium ion battery for electric vehicles: a review.”, *Energy Storage Mater*, vol. 10, 246-267, 2018.
[2] Andrey W. Golubkov, David Fuchs, Julian Wagner, Helmar Wiltsche, Christoph Stangl, Gisela Fauler, Gernot Voitic, Alexander Thalera and Viktor Hacker. “Thermal-runaway experiments on consumer li-ion batteries with metal-oxide and olivin-type cathodes”, *RSC Advances*, vol. 4, pp. 3615-3620, 2014
[3] Ting Cai, Puneet Valecha, Vivian Tran, Brian Engle, Anna Stefanopoulou, Jason Siegel. “Detection of Li-ion battery failure and venting with carbon dioxide”, *eTransportation*, vol. 7, 100100, 2021
[4] Jason K. Ostanek, Weisi Li, Partha P. Mukherjee, K.R. Crompton, Christopher Hacker “Simulating onset and evolution of thermal runaway in Li-ion cells using a coupled thermal and venting model”, *Applied Energy*, Vol. 268, 114972, 2020
[5] Zhenghai Liao, Shen Zhang, Kang Li, Guoqiang Zhang, Thomas G. Habetler. “A survey of methods for monitoring and detecting thermal runaway of lithium-ion batteries”, *Journal of Power Sources*, Vol. 436, 226879, 2019