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Designing a Thermal Management System for Lithium Ion Battery Packs in Electric Vehicles

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Abstract : Rechargeable lithium-ion batteries have been replacing lead-acid batteries for the last decade due to their outstanding properties such as high energy density, long shelf life, and almost no memory effect. Besides these, being very light compared to lead acid batteries has gained them their dominant place in the portable electronics market, and they are now the leading candidate for electric vehicles (EVs) and hybrid electric vehicles (HEVs). However, their performance strongly depends on temperature, and this causes some inconveniences for their utilization in extreme temperatures. Since weather conditions vary across the globe, this situation limits their utilization for EVs and HEVs and makes a thermal management system obligatory for the battery units. The objective of this study is to understand thermal characteristics of Li-ion battery modules for various operation conditions and design a thermal management system to enhance battery performance in EVs and HEVs. In the first part of our study, we investigated thermal behavior of commercially available pouch type 20Ah $LiFePO_4$ (LFP) cells under various conditions. Main parameters were chosen as ambient temperature and discharge current rate. Each cell was charged and discharged at temperatures of 0°C, 10°C, 20°C, 30°C, 40°C, and 50°C. The current rate of charging process was 1C while it was 1C, 2C, 3C, 4C, and 5C for discharge process. Temperatures of 7 different points on the cells were measured throughout charging and discharging with N-type thermocouples, and a detailed temperature profile was obtained. In the second part of our study, we connected 4 cells in series by clinching and prepared 4S1P battery modules similar to ones in EVs and HEVs. Three reference points were determined according to the findings of the first part of the study, and a thermocouple is placed on each reference point on the cells composing the 4S1P battery modules. In the end, temperatures of 6 points in the module and 3 points on the top surface were measured and changes in the surface temperatures were recorded for different discharge rates (0.2C, 0.5C, 0.7C, and 1C) at various ambient temperatures (0°C – 50°C). Afterwards, aluminum plates with channels were placed between the cells in the 4S1P battery modules, and temperatures were controlled with airflow. Airflow was provided with a regular compressor, and the effect of flow rate on cell temperature was analyzed. Diameters of the channels were in mm range, and shapes of the channels were determined in order to make the cell temperatures uniform. Results showed that the designed thermal management system could help keeping the cell temperatures in the modules uniform throughout charge and discharge processes. Other than temperature uniformity, the system was also beneficial to keep cell temperature close to the optimum working temperature of Li-ion batteries. It is known that keeping the temperature at an optimum degree and maintaining uniform temperature throughout utilization can help obtaining maximum power from the cells in battery modules for a longer time. Furthermore, it will increase safety by decreasing the risk of thermal runaways. Therefore, the current study is believed to be beneficial for wider use of Li batteries for battery modules of EVs and HEVs globally.

Keywords : lithium ion batteries, thermal management system, electric vehicles, hybrid electric vehicles
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