Modeling a Thermal Management System for Battery Units of Electric Vehicles

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Recent developments have made electric vehicles (EVs) and hybrid electric vehicles (HEVs) promising alternatives to replace fossil fuel based vehicles. Between many rechargeable battery options, Li batteries are the most common choice for the battery units of EVs and HEVs, due to their outstanding properties such as high energy density, high power density, light weight, long shelf life, and no memory effect [1]. Despite their outstanding properties, utilization of the lithium batteries is limited because their performance strongly depends on ambient and operation temperatures. Thus, a thermal management system is required for battery units of EVs and HEVs to enable their utilization in extreme temperatures as well as to improve cell performance by controlling the cell temperatures during operation. Aim of this study is to model air-cooled channel systems for battery units and to produce an efficient thermal management system to keep the cells at an optimum temperature during operation.

Commercially available high capacity (20Ah) cells containing an olivine cathode material ($LiFePO_4$, aka LFP) are studied in this work for having high gravimetric capacity, fast charging, and lower material and maintenance costs [2]. Cells having $LiFePO_4$ positive electrode, an aluminum current collector, $LiPF_6$ w/EC:DEC (1:1) electrolyte, graphite negative electrode, and a copper negative current collector are modeled exactly the same as the purchased commercial 20Ah cells by a finite element simulation software called COMSOL Multiphysics. Then, heating behavior is modeled for outer and inner surfaces in 4S1P battery packs and change in temperature is investigated at different points in the packs for various current rates (1C, 2C, 3C, 4C, 5C) and ambient temperatures (0°C, 10°C, 20°C, 30°C, 40°C, and 50°C).

In order to verify the developed model, 4S1P battery packs, composed of 20Ah cells, are prepared in our lab and surface temperature of 12 points are measured for the same current rates and ambient temperatures studied in the model. N-type thermocouples are used to measure the surface temperatures while the ambient temperature is kept constant by a thermal chamber (POL-EKO Aparatura) throughout the charge discharge processes.

Once the developed model is verified, air-cooled aluminum plates having different channel configurations are placed between cells in the model and efficiency of different designs are compared for various air flow rates. Finally, the most efficient channel configuration is produced in the lab and its effects on temperature control are studied for 4S1P battery packs.

The produced model is believed to help development of a thermal management system for Li-ion battery packs in EVs and HEVs.

References

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