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Numerical Shape Optimization of a Manifold Mini-Channel for Battery Thermal Management of Electric Vehicles

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Extended Abstract

Electric vehicles are emerging as replacements for internal combustion engine vehicles owing to their environmental sustainability in exhaust gas regulations. Battery thermal management is essential to ensure optimal operating performance in the issue of increased heat dissipation. Extensive studies on battery cooling methods such as air cooling [1], water cooling [2], heat pipe, and phase change materials [3] have been conducted to improve the cooling performance of batteries. However, most studies have limitations to improve the cooling uniformity and reduce the pumping power. Harpole and Eninger [4] proposed a manifold micro-channel heat sink for electronic equipment cooling in micro-scale. The cooling uniformity in the manifold micro-channel was improved owing to the jet impingement effect in the heat source, and the pressure drop significantly decreased owing to the increased hydraulic diameter. In this study, a manifold mini-channel heat sink for electric vehicle battery is designed by applying micro heat sink to the macroscale. The outer dimensions of heat sink are 177.5 mm, 134.5 mm, 9 mm, and 4 mm in length, width, thickness, and fin pitch respectively. A jet plate is designed and inserted in the middle of the heat sink for jet impingement effect and flow distribution from the upper side of heat sink to the heat source. A specified line of the heat sink is analyzed using symmetric conditions by CFD-based numerical analysis. A multi-zone method is used for the mesh to improve the calculation accuracy. The RNG k-ε model is used to imitate the turbulence generation owing to the jet impingement. The inlet flow rate and temperature are set at 10 g sec^{-1} and 25 °C, respectively. The heat flux is set at 7000 W m^{-2} based on 5C discharge. As a result of the numerical analysis, the flow is concentrated at the front and rear of the cooling plate except for the central part. The maximum temperature at the center of the heat source is 36.89 °C, and the difference between the maximum and minimum temperatures is 8.2 °C. The temperature uniformity is poor owing to flow maldistribution. To solve these problems, pressure drop at the jet plate increases because the uniform flow distribution occurs where the pressure drop is dominant [5]. The pressure drop at the jet plate increases by reducing the diameter of the inlet slit which is designed for the jet impingement effect in the jet plate. As the diameter decreases from 0.5 mm and reaches 0 mm, the maximum temperature of the heat source and the standard deviation of temperature converges to a specific value. The pressure drop converges to infinite. The diameter of 0.3 mm is optimum because figure of merit (FOM) which presents cooling performance against pressure drop is the highest. The maximum temperature of the heat source decreases by 2.5 °C, and the difference between the maximum and minimum temperatures decreases by 3 °C. This is because uniform flow distribution is occurred at the jet plate inlet slit of 0.3 mm compared with the original value at 0.5 mm.

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