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Simulation Study of Mono and Hybrid Nanofluids for a Battery Thermal Management System with Different Concentrations Under High Discharge Conditions

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ABSTRACT

Electric vehicles (EVs) have recently witnessed rapid development compared to conventional internal combustion engine vehicles (ICEVs) due to favorable advantages such as improved energy efficiency and lower greenhouse gas emissions. Lithium-ion batteries are the most commonly adopted EV energy storage technology due to their high specific energy, large capacity, low self-discharge, and long lifetime. With the rapid increase in electric vehicles (EVs) power demand, newer and more efficient thermal management systems are required to maintain the EV battery temperature within the optimum range to ensure a safe and efficient operation. Despite their promising characteristics, lithium-ion batteries suffer from critical temperature-related problems such as the high lifetime dependence on temperature as well as the risk of thermal runaway and explosion under extreme operating temperatures. While nanofluids improve heat transfer due to their higher thermal conductivity compared to conventional fluids, they also lead to higher pressure losses caused by the higher flow viscosity. This research aims to address this gap by examining the influence of mono and hybrid nanofluids (SWCNT and Fe3O4 TiO2 water nanofluids) on BTMS performance under different volumetric concentrations, considering both heat transfer enhancement and the resulting pressure drop increase. To address these requirements, this research simulated the overall performance of a nanofluid BTMS for a 12-cell lithium-ion battery module. The analysis was conducted using a 3C discharge rate. Mono and hybrid nanoparticles (SWCNT and Fe3O4 TiO2) were investigated under three different volumetric concentrations (1%, 2%, 3%) and compared to the base fluid (water), the evaluation was based on the highest temperature and temperature uniformity, pressure drop, in addition to a performance factor which considers the nanofluid heat transfer enhancement and the resulting pressure drop increase. Based on the performance evaluation, the BTMS maximum temperature and temperature difference are found to be inversely proportional to the nanofluid concentration, and the optimum nanofluid is found to be SWCNT water nanofluid with 3% concentration, compared to water, it achieved a 3.56% and 13.81% reduction in maximum temperature and temperature difference respectively, yielding a performance factor of 1.58.