Applied Thermal Engineering 210 (2022) 118369

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Research Paper

Heat transfer and electrical discharge of hybrid nanofluid coolants in a fuel cell cooling channel application

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ARTICLE INFO

Keywords:
Hybrid nanofluids
TiO_2:SiO_2
Thermal engineering
PEM fuel cells
Coolants

ABSTRACT

Hybrid nanofluid coolants is a new approach for advanced thermal management of Polymer Electrolyte Membrane fuel cells. Due to the high electrical conductivity of nanofluids, electrical discharge when a nanofluid coolant is used in a fuel cell is a concern and needs to be fundamentally studied. The objective is to obtain experimental correlations between heat transfer and electrical discharge rates of a nanofluid coolant in the form of a novel electro-thermal transfer ratio as a reference for future progress. A hybrid of 1%v TiO_2 and SiO_2 nanoparticles dispersed in a water and ethylene glycol (40:60) base fluid mixture was tested. The heated surface temperatures of the cooling channel were at 60 °C and 70 °C while the electrical power was nominally discharged through the test section at 0.7 V and 3 A. Under laminar flow, the concurrent changes to the temperature profile and active current were observed. The cooling was improved for the 40:60 hybrid TiO_2:SiO_2 nanofluid coolant with an enhancement factor of up to 2 times while the measured electrical current was visibly lower than the nominal current. The electro-thermal transfer ratio reduced exponentially with Reynolds number, indicating that electrical discharge strength into the coolant reduced at higher flow rates compared to the rate of heat transfer. These preliminary findings provide a new improved perspective in the assessment of nanofluid coolants for fuel cell systems and electrically-active systems in general.

1. Introduction

The need for advanced coolants has led to progressive research in the technology of nanofluids. Coolants not only maintain the thermal requirement of a system, but also lead to opportunities for more compact system designs. The cooling environment for electrical systems requires a coolant capable of high cooling densities due to space constraints, as well as avoid the occurrence of shunt current or electrical loss through the coolant. In fuel cell technology, advanced thermal management methods contribute towards optimal power outputs and greater power densities. The Polymer Electrolyte Membrane (PEM) fuel cell directly generates electricity from the partial reactions of hydrogen and oxygen. It generates heat as a by-product at an approximately equal magnitude to its electrical power output due to process irreversibilities, ohmic resistance and exothermic reactions [1].

The objectives of advanced thermal management for PEM fuel cells are mainly to avoid membrane dehydration due to excessive temperature, to promote temperature uniformity across the stack as well as to develop highly efficient cooling systems for a more compact system architecture. Baroutaji et al. [2] reviewed the current states in advanced thermal management methods for fuel cells, inclusive of waste heat recovery. In general, proposed technologies include the use of vapour chambers [3], embedded heat pipes into the bipolar plates [4], heat spreaders using high thermal conductivity pyrolytic graphite sheet [5], metal open-pore cellular foam as air flow passages [6], air-cooled closed cathode stacks [1] and two-phase cooling with boiling [7].

Waste heat recovery is also a growing focus in advanced thermal management of fuel cells. Kwan et al. [8] stated that fuel cell systems integrated with energy recovery enhance the energy efficiency and fuel utilization. Fuel cells with gas turbines, TEG, heat pumps, electronic devices, desalination and absorption chillers have been proposed. Technologies such as the Steam Rankine cycle, Organic Rankine cycle and Kalina cycle are suitable for high temperature fuel cells (above 232 °C). The integration of thermoelectric generators (TEG) and fuel cells was also explored with various designs and applications to improve the power density of the system. Khanmohammadi et al. [9] developed a system of compressed air energy storage, PEM fuel cell and TEG. Sulaiman et al. [10] applied a heat pipe-heat sink-TEG module design to a 2 kW PEM fuel cell with power outputs between 200 and 300 μW for a

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https://doi.org/10.1016/j.applthermaleng.2022.118369
Received 19 August 2021; Received in revised form 12 February 2022; Accepted 17 March 2022
Available online 19 March 2022
1359-4311/