ME Seminar

MECHANICAL ENGINEERING
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Experimental and Numerical Studies on Fluid Dynamic and Heat Transfer Characteristics of Nanofluids in Air Coils

Prof. Debendra K. Das, Professor Emeritus, University of Alaska Fairbanks

ABSTRACT

Research was conducted to examine the heat transfer and fluid dynamic performance of various nanofluids in heating and cooling applications using experimental and computational methods. Two experiments were performed to characterize and compare the performance of a Al2O3/60% ethylene glycol (60% EG) nanofluid to that of its base fluid. In the first experiment, the nanofluid was comprised of Al2O3 nanoparticles with 1% volumetric concentration in a 60% ethylene glycol/40% water (60% EG) solution to that of 60%EG in a liquid to air heat exchanger. The test bed used in the experiment was built to simulate a small air handling system typical of that used in heating, ventilating and air conditioning (HVAC) applications. Previously established correlations for thermophysical properties of fluids were used to determine the values of various parameters (e.g., Nusselt number, Reynolds number, and Prandtl number). The testing shows that the 1% Al2O3 nanofluid generates a marginally higher heat rate than the 60% EG under certain conditions. At Re=3,000, the nanofluid produced a heat rate that was 2% higher than that of the 60% EG. The empirically determined Nusselt number for the nanofluid associated with the convection inside the coil tubing follows the behavior predicted by the Dittus-Boelter correlation quite well (R2=0.97), while the empirically determined Nusselt number for the 60% EG follows the Petukhov correlation similarly well (R2=0.97). Pressure loss and hydraulic power for the nanofluid were higher than for the base fluid over the range of conditions tested. The exergy destroyed in the heat exchange and fluid flow processes were between 8 and 13% higher for the nanofluid over the tested range of Reynolds numbers. A second experiment was conducted to characterize and compare the performance of a nanofluid comprised of Al2O3 nanoparticles with 1, 2 and 3% volumetric concentrations in a 60% EG solution to that of 60% EG in a liquid to air heat exchanger. In this experiment, the heating system was operated in a higher temperature regime than in the first experiment. Entering conditions for the air and liquid were selected to emulate typical operating conditions of commercial air handling systems in sub arctic regions (such as Alaska). In the experiment the nanofluids generally did not perform as well as expected based on previous analytical work. The heat rate produced by the 1% nanofluid was generally equal to that of the base fluid considering identical entering conditions. However, the heat rates of the 2% and 3% nanofluids were considerably lower than that of the base fluid. The higher concentration nanofluids produced heat rates up to 14.6% lower than that of the 60%EG, and up to 44.3% lower heat transfer coefficient. The 1% Al2O3/60% EG exhibited 100% higher pressure drop across the coil than the base fluid considering equal heat output.

In the computational portion of the research, the performance of a microchannel heat sink (MCHS), similar to those used to cool microprocessors filled with various nanofluids and the corresponding base fluid without nanoparticles are examined. The MCHS is modeled using a three-dimensional conjugate heat transfer and fluid dynamic finite-volume Ansys Fluent model over a range of conditions. The model incorporates a fixed heat flux of 1,000,000 W/m2 at the base of the heat sink. The thermophysical properties of the fluids are based on previously obtained correlations and vary with temperature. Nanofluids considered include 60% Ethylene Glycol/40% Water solutions with CuO, SiO2, and Al2O3 nanoparticles dispersed in volumetric concentrations ranging from 1 to 3%. The flow conditions analyzed are in the laminar range ($50 \leq Re \leq 300$) and considered multiple inlet temperatures. The analyses predict that when compared on an equal Reynolds number basis, the 60%EG/3% CuO nanofluid exhibits the highest heat transfer coefficient, and the largest reduction in average base temperature. At an inlet Reynolds number of 300, and an inlet temperature of 308K the nanofluid is predicted to have an average heat transfer coefficient that is 30% higher than that of the base fluid, while the average temperature on the base of the heat exchanger is 1K cooler than that produced by the base fluid. In contrast, the inlet pressure required for these entering conditions is 192% higher than that for the base fluid, while the required hydraulic power to drive the flow is 366% higher than that required by the base fluid.

ABOUT THE SPEAKER

Dr. Debendra Das is Professor of Mechanical Engineering Emeritus and Past Chair, ME Department, University of Alaska Fairbanks, USA. His educational details are: B.S. Mechanical Engineering, Regional Engineering College Rourkela, Best Graduate Gold Medal recipient for securing highest percentage of marks among two engineering colleges in Orissa in 1972 under Sambalpur University; M.S. Mechanical Engineering, Brown University, Rhode Island, USA, 1974; Ph.D. Mechanical Engineering, University of Rhode Island, 1983 under Advisor: Prof. Frank M. White, internationally known Fluid Dynamicist, USA. Prof. Das' academic experience spans: Assistant, Associate and Full Professor at University of Alaska from 1984 to 2018, USA.

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