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Comparison of the thermal performances of two nanofluids at low temperature in a plate heat exchanger

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ABSTRACT

The objective of this study is to compare experimentally the thermal performances of two types of commercial nanofluids. The first is composed of oxides of alumina (γAl_2O_3) dispersed in water and the second one is aqueous suspensions of nanotubes of carbons (CNTs). The viscosity of the nanofluids is measured as a function of the temperature between 2 and 10 °C. An experimental device, containing three thermal buckles controlled in temperature and greatly instrumented permits to study the thermal convective transfers. The evolution of the convective coefficient permits to study the convective thermal transfers. The evolution of the convective coefficient is presented according to the Reynolds number, at low temperature from 0 to 10 °C and for the two aforementioned nanofluids. An assessment of the pressure drops in the circuit as well as of the powers of the circulator and outputs is dealt with.

1. Introduction

The efforts aiming at improving the thermal exchangers in many industrial sectors (automobile, building, electronic, etc.) require the intensification of the heat transfers, Padet [1]. The "passive" improvements at the level of the exchange surfaces have already been extensively explored and have reached their objective limits. In the case of the coolant fluids, the thermal conductivity is one of the first parameters to take in account to value the potential of heat exchange. However the more used fluids such as water, the ethylene–glycol and oil possess a relatively weak thermal conductivity. New ways of optimization consist in using new fluids named "Nanofluids" capable of improving the thermal transfers. The nanofluids are colloïdal solutions composed of metallic particles of nanometric size in suspension in a base liquid. Choi [2] was probably the first to qualify these nanofluids.

To explain the improvement of thermal conductivity that the presence of the nanoparticles brings in these fluids, Keblinski et al. [3] and Eastman et al. [4], lean on the study of the Brownian movement and the effects at the solid/liquid interfaces. Xuan and Li [5] explains this improvement of conductivity by the collision of the particles. The experimental studies done so far, are essentially about the measure of the thermal conductivity [6,7], and the measure of the viscosity [8,9]. Some articles study numerically and experimentally the thermal transfers in tubular exchangers [10,11].

To limit the phenomena of agglomeration, the manufacturers add to these fluids a non-negligible part of surfactant. The viscosity is impacted by this surfactant, and the literature shows that it is difficult to control the spread of the particles and that the usual relations expressing the viscosity do not apply for elevated volumic concentrations. Khaled and Vafai [12] studies the importance of the dispersion and its experimental results show an influence of the surfactant of more than 20% on the number of Nusselt obtained.

When looking at the experimental results, we notice that the usual theoretical relations for the fluids with particles do not apply to the case of the nanofluids, and the experimental study on the thermo physical properties shows important disparities according to the methodology of measure and mixture, sometimes even for the nanofluids [13–15].

With regard to the thermal transfers by convection, some studies show an improvement in presence of nanoparticles [15,16], whereas other studies observe a reduction of these transfers [17]. Ding et al. [18] measured the convective heat transfer coefficient of aqueous suspensions of CNTs in a horizontal tube and reported that for the nanofluids containing 0.5 wt% CNTs, its enhancement rate to water was over 350%. Several reviews of nanofluids show that the associated thermal transfers are not very much understood [19]. Vijjha

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