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Experimental measurement of thermophysical properties of oxide–water nano-fluids down to ice-point

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ABSTRACT

This paper presents the measurement of the thermal conductivity and the dynamic viscosity of Al_2O_3–water (1–4% particle volume fraction) and TiO_2–water (1–6% particle volume fraction) nano-fluids carried out at atmospheric pressure in the temperature range from 1 to 40 °C, which is particularly interesting for the application of nano-fluids as thermal medium in refrigeration and air-conditioning.

The thermal conductivity measurement was performed by using a Transient Hot Disk TPS 2500S apparatus instrumented with a 7577 probe (2.001 mm in radius) having a maximum uncertainty ($k = 2$) lower than ±5.0% of the reading. The dynamic viscosity measurement and the rheological analysis were carried out by a rotating disc type rheometer Haake Mars II instrumented with a single cone probe (60 mm in diameter and 1° angle) having a maximum uncertainty ($k = 2$) lower than ±5.0% of the reading.

The thermal conductivity measurements of the tested nano-fluids show a great sensitivity to particle volume fraction and temperature and a weak sensitivity to cluster average size: TiO_2–water and Al_2O_3–water nano-fluids show a thermal conductivity enhancement (with reference to pure water) from −2 to 16% and from −2 to 23% respectively.

TiO_2–water and Al_2O_3–water nano-fluids exhibit a Newtonian behaviour in all the investigated ranges of temperature and nano-particle volume fraction. The relative viscosity shows a great sensitivity to particle volume fraction and cluster average size and no sensitivity to temperature: TiO_2–water and Al_2O_3–water nano-fluids show a dynamic viscosity increase with respect to pure water from 17 to 210% and from 15 to 150% respectively.

Al_2O_3–water nano-fluid seems to be more promising as thermal medium than TiO_2–water nano-fluid, particularly at low thermal level (between ambient temperature and ice point) where TiO_2–water is not suitable showing worse performance than pure water.

Present experimental measurements were compared both with available measurements carried out by different researchers and computational models for thermophysical properties of suspensions.

1. Introduction

The nano-fluids are suspensions of solid nano-particles in an ordinary liquid substance such as water, glycol and oil. These solid–liquid composites are very stable and show a great enhancement in thermal conductivity and convective heat transfer with respect to traditional liquids and therefore they seem to be the "*cooling medium of the future*" [1].

Nano-fluids have been investigated recently to quantify the heat transfer performance, to identify the specific transport mechanisms and critical parameters and to develop relevant production, management and measurement techniques. The experimental investigations include metallic nano-particles (Cu, Al, Au and Ag), oxide nano-particles (CuO, Al_2O_3, TiO_2 and SiO_2) and carbon nano-tubes (CNTs) in water, glycol aqueous solutions and different oils in a wide range of nano-particle volume fraction and size. Das et al. [2] and Yu et al. [3] presented comprehensive reviews of the heat transfer characteristics of nano-fluids.

The experimental work carried out till now cannot be considered sufficiently systematic to collect a sound amount of coherent and unambiguous data with respect to methodology and results. However the experimental evidence shows the possibility of successfully applying nano-fluids as transport medium in several systems and processes, such as:

(1) Cooling of components that are subjected to high heat flux such as electronic equipment, medical diagnostics and electrical gears.
(2) Cooling/heating of heat exchangers in process industries.

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