Thermal Conductivity of Nanofluids – Experimental and Theoretical

M. J. Assael, I. N. Metaxa, K. Kakosimos, and D. Constantinou

The thermal conductivity of nanofluids has been studied experimentally using the transient hot-wire method, and it is shown that a significant increase can be obtained. Existing methods for the prediction and correlation of the thermal conductivity are discussed. It is shown that a lot of work still needs to be done in this area.

KEY WORDS: carbon nanotubes; heat transfer; nanofluids; thermal conductivity.

1. INTRODUCTION

The fluids that have been traditionally used for heat transfer applications have a rather low thermal conductivity, taking into account the rising demands of modern technology. Thus, there is a need to develop new types of fluids that will be more effective in terms of heat exchange performance. In order to achieve this, it has been recently proposed [1–4] to disperse small amounts of nanometer-sized solids in the fluid. The resulting “nanofluid” is a multiphase material that is macroscopically uniform. It is noted that the term thermal conductivity refers to the property of a single-phase system. In this paper, for practical purposes, this term is used to describe the effective property of the multiphase assembly.

The study of nanofluids has gained considerable interest recently because they are likely to be used in various applications [1–7]. The dispersion of copper (Cu) nanoparticles and alternatively carbon...
nanotubes (C-NTs) has provided the most promising results so far, with reported thermal conductivity enhancements of up to 40% and 160%, respectively, in relation to the base fluid [2–5]. There is thus, a need to prepare stable nanofluids with the desired characteristics and to measure their properties. Furthermore, a great challenge is to understand the mechanisms responsible for the unique thermal behavior of nanofluids and to predict these properties. This work follows our previous studies [3, 4, 8] and is an attempt to get a more comprehensive perspective on the subject.

2. THERMAL CONDUCTIVITY MEASUREMENTS

The thermal conductivity of the nanofluids was studied by our group, and it was measured with the transient hot-wire method. An instrument was built for this purpose, and it was operated with a standard uncertainty of better than 2% as described in an earlier publication [3]. Ethylene glycol and water were selected as the primary base fluids, because they are widely used in heat-transfer applications. The particular interest in water is noted, because of its presence in biological systems. Spherical Cu nanoparticles and carbon multi-walled nanotubes (C-MWNTs) were employed as the dispersed phase in most cases, since they are more likely to be used for a number of applications of nanofluids for increased heat transfer, due to their enhanced thermal conductivity. Moreover, several dispersants were used to aid the formation of homogeneous and stable suspensions.

A summary of the thermal conductivity measurements of nanofluids conducted by our group is shown in Table I.

2.1. Nanosphere Suspensions

As was aforementioned, the suspensions of spherical nanoparticles studied in our previous work [8] involved mainly the dispersion of Cu nanoparticles. Other types of nanospheres have been also employed, showing interesting results [8–12].

2.1.1. Suspensions of Cu Nanoparticles

The Cu nanospheres were dispersed in ethylene glycol, both provided by MER Corporation U.S.A., with the aid of ultrasonic homogenization for 60 min (Bandelin Electronics Model HD 2200) [8]. The results obtained for the thermal conductivity enhancement of suspensions with various nanoparticle concentrations are shown in Fig. 1, as a ratio of the thermal conductivity of the dispersion \( \lambda \) over the thermal conductivity of the base fluid \( \lambda_0 \). Attempts were made to prepare stable suspensions of Cu nanoparticles in vacuum oil TKO-19Ultra, provided by MER Corporation.