Experimental Thermal and Fluid Science 35 (2011) 717–723

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

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

Effect of dispersion method on thermal conductivity and stability of nanofluid

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ARTICLE INFO

Article history:
Received 24 August 2010
Received in revised form 29 November 2010
Accepted 5 January 2011
Available online 18 January 2011

Keywords:
Dispersion method
CNT structures
Nanofluid
Thermal conductivity
Stability

ABSTRACT

Preparing a stable nanofluid with high thermal conductivity is of a great concern. In order to find an optimum dispersion method to achieve a better performance, five different carbon nanotube (CNT) structures, namely SWNTs (single wall CNT), DWNTs (double wall CNT), FWNTs (few wall CNT) and two different MWNTs (multiwall nanotubes) were synthesized to prepare nanofluids with three different dispersion methods namely functionalization, SDS/ultrasonic probe and SDS/ultrasonic bath. The experiments reveal that the best stability and thermal conductivity are associated with the functionalized nanofluids. Specifically, for the times after 50 h, the functionalized profiles begin to level off due to their higher stability, while the other two paths continue their declining trend.

1. Introduction

One of the critical steps in preparing carbon nanofluids is dispersing carbon nanotubes in the base fluid. Due to the high aspect ratio (L/D) of carbon nanotubes, very large specific surface areas and strong Van der Waal's forces between carbon surfaces, dispersion of CNT in aqueous medium can be challenging. CNTs are hydrophobic in nature and thus aggregate and form non-homogeneous and unstable clusters in the CNT nanofluids under normal conditions [1,2].

There are usually two methods to disperse carbon nanotubes in base fluids: mechanical and chemical [3,4]. Mechanical methods generally include ultrasonication using a probe or a bath. Chemical methods include the application of surfactants and CNT-functionalization by using acids. The surfactant method changes the wetting or adhesion behavior which helps in reducing their tendency to agglomerate. However, in nanofluid applications, surfactants might cause several problems such as contamination of the heat transfer media and producing foams when heating. Furthermore surfactant molecules attaching on the surfaces of CNTs may enlarge the thermal resistance between the CNTs and the base fluid, which limits the enhancement of the effective thermal conductivity [5,6].

Chemical functionalization generally involves treating CNTs with acids at high temperature, either at their top or sidewall [1,7,8]. Functional groups on nanotubes are commonly made by treating them in strong oxidants such as sulfuric acid and nitric acid [9–11]. This results in addition of polar groups at defect sites on nanotube surface, thus making CNTs more hydrophilic in nature. However, aggressive chemical functionalization, can damages the structure of CNT sidewalls and even shorten the CNTs [12,13]. Both mechanical and chemical methods can reduce the aspect ratio mean value of the nanotubes, which is not the desired condition. That is because, the higher the aspect ratio, the higher is thermal conductivity [14]. Therefore, proper care has to be taken during processing to minimize adverse effects.

Until now, most of the published data on the factors that influence the nanofluids' stability and thermal conductivity, have been focused on the effects of nanoparticle's concentration [15], dispersant (surfactant) [16], viscosity of base liquid [17,18] and pH value [19,20]. However, no other studies have been found to directly point out the effects of the dispersion method on thermal conductivity and stability of nanofluids.

In this study, in order to prevent aspect ratio reduction (i.e. length decrease), a combination of a mechanical method through ultrasonication, and a chemical method through surfactants or functionalization were used and compared.

2. Experimental procedures and apparatus

2.1. Material

Distilled water as the base fluid and five kinds of carbon nanotubes were used in this research to prepare nanofluids. The carbon nanotubes were synthesized by catalytic decomposition of 20%

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doi:10.1016/j.expthermflusci.2011.01.006