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Thermal Properties Of Sic and BN Nanofluids for Heat Transfer Applications

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Abstract – Nanofluids are a new class of heat transfer fluids with superior thermal properties highly desirable for heat transfer applications. This paper experimentally investigates key thermal properties namely thermal conductivity and thermal diffusivity of two different types of nanofluids which are SiC and BN nanofluids. The nanofluids are prepared by separately dispersing SiC and BN nanoparticles of five volumetric concentrations (0.01, 0.02, 0.03, 0.04, 0.05 vol.%) into a mixture of distilled water (DW) and ethylene glycol (70%DW/30%EG). Thermal conductivity and diffusivity were measured, and their enhancements are evaluated in comparison with their base fluids. The results refer to a good increase in thermal conductivity for both types of nanofluids with rising concentrations until reaching the maximum enhancement of 4.4 % for SiC nanofluid and 7.0% for BN nanofluid at 0.05 vol.%. Thermal diffusivity is also found to increase with the addition of nanoparticles up to 4.2% for SiC nanofluid and 7.2% for BN nanofluid at 0.05 vol.%. The results present a consistency for the enhancements of thermal conductivity and thermal diffusivity of both nanofluids' types. Although the enhancements of these thermal properties are not significantly high, they are obtained at very low concentrations demonstrating great potential of these nanofluids in heat transfer applications.

***Keywords*:** Thermal conductivity, Thermal diffusivity, Nanofluids, Base fluids, SiC and BN nanoparticles.

1. Introduction

Thermal fluids are essential for most applications in industry for cooling and heating processes by numerous types of heat transfer systems (e.g., heat exchangers). In most of the applications traditional thermal fluids such as water and oils are used, and inherently low thermal properties of these fluids are the main barrier for the development of advanced heat transfer systems with improved performance [1]. Therefore, it was found that mixing nanoparticles of metallic or non-metallic with such common thermal fluids can result in enhancing thermal properties and features [2-6] and such mixture of nanoparticles and fluids are widely known as ''nanofluids'' that can be used to improve the heat transfer performance in thermal systems [7,8]. So far, diverse kinds of nanofluids have been used in literature for experimental and numerical investigations with various thermophysical properties [9,10]. Thermal conductivity and thermal diffusivity are considered the key elements responsible for assessing the heat transfer performance of the nanofluids, where enhancing those properties leads to a better heat transfer efficiency [7,11-12]. Thermal conductivity of nanofluids has been investigated for different types of nanoparticles and their concentrations [2, 9]. However, there is still a lack of investigations on some types of nanofluids regarding the nanoparticle types and the used base fluids, as well as an accurate investigation considering both thermal conductivity and thermal diffusivity for their optimum performance in applications. Therefore, this study intends to analyse two important thermal properties namely thermal conductivity and thermal diffusivity of two (SiC and BN) nanofluids at low concentrations. The obtained results of this study can fill the gap in knowledge providing the necessary information for employing nanofluids for heat transfer systems such as heat exchanger.

2. Nanofluid preparation and properties measurements

The preparation of the nanofluids samples started by using the SiC (Silicon carbide) nanoparticles of 50-60 nm size and BN (Boron Nitride) nanoparticles of 70 nm size from IoLiTec (Germany) to be separately mixed with the base fluid of 70% distilled water (DW) and 30% ethylene glycol (EG) for the five concentrations from 0.01 to 0.05 vol.%. Also, an ultrasonication mixing process is applied for 20 minutes (using the Hielscher UP200Ht ultrasonicator at an amplitude of 60%) to improve the dispersion and stability of the nanoparticles into the base fluids. Additionally, thermal conductivity and thermal diffusivity of nanofluid samples are measured on the same day of the preparation for the good level of stability.

In this study, the thermal properties of the nanofluids were evaluated at room temperature (20°C) by Thermal Properties Analyzer (METER Group) which works based on transient hot-wire (THW) technique and using a single needle type KS-3 sensor for the thermal conductivity and a dual-needle type SH-3 sensor for the thermal diffusivity. The process of determining thermal diffusivity through dual-needle can be found elsewhere [13]. Several readings for each sample (nanofluid) were done with resting time between the measurements by 25 minutes. Moreover, the used experimental device was calibrated with the base fluid and the maximum found variation was 1.8% from the standard referenced values.

3. Results and Discussion

The results presented in Fig. 1 refer to higher thermal conductivity of the two types of nanofluids compared to the base fluids. Thermal conductivity increases with increasing nanoparticle concentrations until reaching the maximum enhancement of 4.4 % for SiC nanofluid and 7.0% for BN nanofluid at 0.05 vol.%. The higher values of BN nanofluids are due to the higher thermal conductivity of BN nanoparticles in comparison with SiC nanoparticles. However, given that the SiC nanoparticle is abundantly available and cheap (compared to BN), such enhancements are also very significant for the heat transfer applications of their nanofluids.

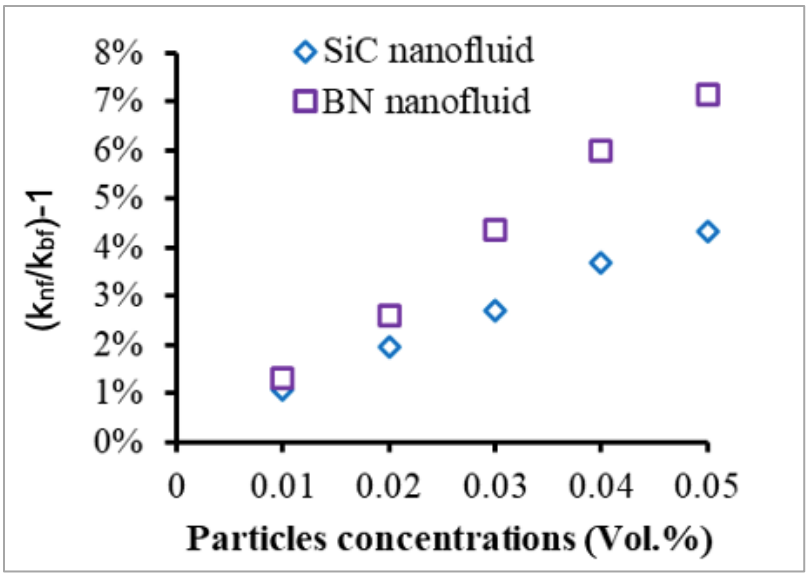

Fig. 1 Thermal conductivity enhancement of SiC and BN nanofluids with nanoparticles loading.

Moreover, thermal diffusivity is found to increase with the addition of nanoparticles up to 4.2% for SiC nanofluid and 7.2% for BN nanofluid at 0.05 vol.%, as shown in Fig. 2. Although the enhancements are moderate, they are obtained at very low concentrations. It is to be noted that very limited studies [13] have been reported in the literature where thermal diffusivity of nanofluids are measured. As the thermal conductivity of nanofluids was found to be higher than that of the base fluids it is anticipated that the thermal diffusivity also be higher and increase with increasing concentration of nanoparticles. The current results present a consistency for the enhancements of thermal conductivity and thermal diffusivity of both nanofluids' types and the findings agreed with the conclusions of literature studies for similar nanofluids [14,15].

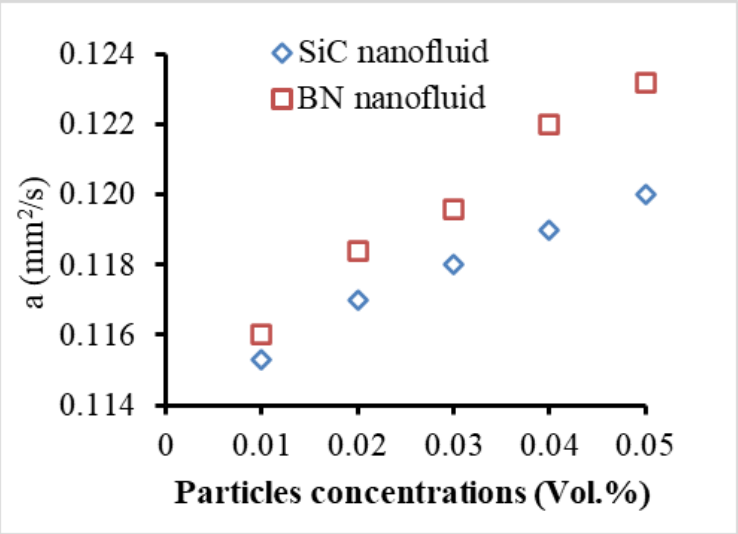

Fig. 2 Thermal diffusivity of SiC and BN nanofluids as a function of nanoparticles concentrations.

4. Conclusions

In this work, SiC and NB nanofluids (0.01-0.05 vol.%) are prepared and their thermal properties such as thermal conductivity and thermal diffusivity are measured. Effect of concentration of these nanoparticles on these properties are studied. The enhancement of thermal conductivity for the different two types of nanoparticles and different concentrations are presented, reporting a maximum enhancement of about 7.0% for BN nanofluid and the maximum thermal diffusivity is found about 7.2% for BN nanofluid at 0.05 vol.% concentration. Moreover, thermal conductivity and diffusivity were found to increase with increasing nanoparticles' concentration in a similar trend for both types of nanofluids with lower enhancement for SiC nanofluids (around 4.2 % maximum enhancement). Such enhancements of these two important thermal properties of these nanofluids demonstrates their potential for heat transfer applications.

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