Specific heat capacity of carbon nanofiber nanocoolant

S. Zainal Abidin[1*], I.S. Mohamad[1,2], A.Y. Bani Hashim[3], N. A. B. Masripan[1,2] and A. Abdullah[1]

[1)] Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2)] Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[3)] Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[*]Corresponding e-mail: syazwani2792@gmail.com

Keywords: Specific heat capacity; carbon nanofiber; nanocoolant

ABSTRACT – With the rising demand for modern technology for process intensification and device miniaturization, there was a need to develop new types of fluids that are more effective in terms of thermophysical performance. To achieve this, a new generation coolant has been proposed recently, which known as nanocoolant. However, it is evident from literature that less attention has been given to the heat capacity studies for these fluids. In this research, we have presented an experimental investigation of the specific heat (Cp) of carbon nanofiber based nanocoolant in deionized water and ethylene glycol with a calorimeter bomb. The result indicates that the specific heat of nanocoolant decreases gradually as the nanoparticle volume fraction increases from 0.8wt% to 1.0wt%.

1. INTRODUCTION

Specific heat capacity determines the amounts of energy absorbed, released or even the enthalpy change in a body before changes of temperature [1]. The value of the specific heat capacity is highly crucial for evaluating the heat transfer coefficients in heat transfer studies. Very few experiments were carried out by researchers to study the specific heat capacity of CNF based nanofluids. Recently, the differential scanning calorimeter and double hot-wire methods were used to estimate the specific heat capacities of water-based silica, alumina, and copper oxide nanofluids [2]. These experimental results were well predicted by the theoretical model based on classical and statistical mechanisms. However, numerical and experimental studies for determining the specific heat capacity of nanofluids had been conducted by only a few researchers at a specific room temperature.

As a matter of fact, the accurate determination of specific heat capacity was determined in this studies in evaluating the thermal performance of nanocoolant produced from the dispersion of carbon nanofiber in deionized water and ethylene glycol based.

2. METHODOLOGY

Type of carbon nanofiber used in this research is Pyrograf III Carbon Nanofiber, High Heat Treated 24 (HHT24) grade. The nanocoolant was prepared using two-step method with several different concentrations of CNFs used in the base fluids. The PVP was used as the stabilizing agent. The weight percentage of CNFs varied from 0.1wt% up to 1.0wt% with the interval of 0.1wt%. The ratio used between deionized water (DI) and ethylene glycol (EG) was set to 50:50. These mixtures were then being homogenized using the mechanical homogenizer for five minutes by using a Digital Homogenizer LHG-15 at 10000 rpm rotational speed. To ensure homogeneity and uniformity of nanocoolant, sonication was carried out using Elmasonic S30H ultrasonicator at 25°C for 5 minutes at 37 kHz frequency was used. All stabilized and adequately dispersed nanocoolant were tested for their thermal conductivity. KD2 Pro Thermal Properties Analyser (Decagon Devices, Inc.) was used to measure the thermal conductivity at three different temperatures of 6°C, 25°C and 40°C. This test was the benchmark test as the best three samples which enhance the highest thermal conductivity were chosen to undergo heat capacity test.

The usage of calorimeter bomb is to measure specific heat value for the nanocoolant. In this research, IKA C 200 (Werke GmbH & Co. KG) was used to know the heat capacity value of the formulated nanocoolant.

3. RESULTS AND DISCUSSION

3.1 Thermal conductivity

The thermal conductivity of CNF based nanocoolant was measured at different volume fractions and various temperatures as shown in Figure 3.1.

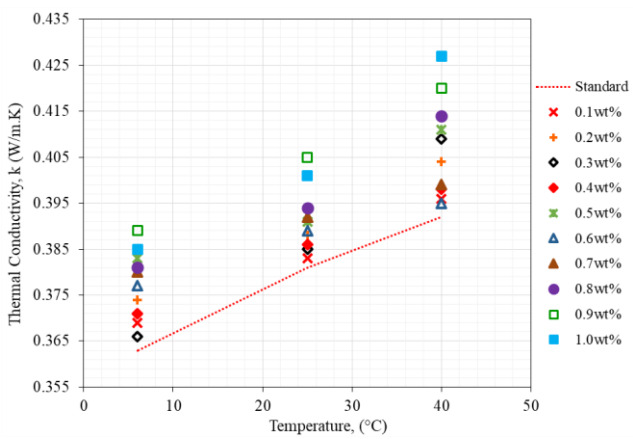

Figure 3.1 Thermal conductivity of 50DI/50EG CNF based nanocoolant

The thermal conductivities of the sample can be

seen to increase as the temperature rises as shown in Figure 3.1. At 6°C, a sample with 0.9wt% of CNF has the highest thermal conductivity at 0.389 W/m.K, followed by 1.0wt% at 0.385 W/m.K and 0.5wt% sample recording thermal conductivity of 0.383 W/m.K. At 25°C, the sample with the highest thermal conductivity is still 0.9wt% at 0.405 W/m.K, then followed by 1.0wt% with thermal conductivity of 0.401 W/m.K and 0.8wt% with thermal conductivity of 0.394 W/m.K. However, at 40°C, the sample that shows the highest thermal conductivity is 1.0wt%, at 0.427 W/m.K. Sample with the second highest thermal conductivity is 0.9wt% at 0.420 W/m.K and thirdly, 0.8wt% with thermal conductivity 0.414 W/m.K. Hence, the addition of CNF systematically increases the thermal conductivity of the nanocoolant, as compared with the base fluid.

This fact is true at all the concentrations and temperatures investigated. The thermal conductivity of an object is carried out through the collision of the particle, hence transferring the energy from one particle to another. At higher temperature, the rate of collision is higher as the particles move at a higher average velocity. This increased rate of random collision is known as Brownian motion. The Brownian motion will result in aggregation of particle which in turn would cause the occurrence of thermal conduction [3]. This phenomenon is shown perfectly in Figure 3.1.

3.2 Specific heat capacity

The heat capacity was determined in order to know how much heat energy of the nanocoolant can carry out if it was used in the cooling system. Data of specific heat capacity of nanocoolant are shown in Figure 3.2.

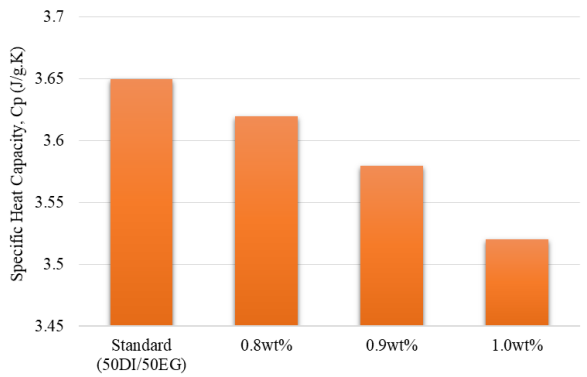

Figure 3.2 Specific heat capacity of nanocoolant

The specific heat capacity of nanocoolant decreased when the volume fraction of CNF nanoparticles increased. The standard Cp value for 50DI/50EG without CNF addition was found to be 3.65 J/g.K and decrease to 3.62 J/g.K for 0.8wt%, 3.58 J/g.K for 0.9wt% and also 3.52 J/g.K for 1.0wt%. The result can further intercede such that low specific heat of nanocoolant can be attained in a large particle volume fraction. The decrease of specific heat capacity was reported for various water-based metallic and inorganic nanofluid systems [4]. This means that the amount of heat required to raise the temperature of the nano-coolant is relatively lower compared to that of the base fluid.

The previous decreasing trend in specific heat is owing to the lower specific heat of solid CNF in comparison with the base fluid and surface effect such as the interaction between the base fluid and CNF that in turn forms a solid-liquid layering at the nanometric scale. The formation of these layers could reduce the energy required to raise the temperature of the nanocoolant. The formation of these layers could reduce the energy required to raise the temperature of the nanocoolant. It is construed from the previous discussion that a new model should be developed for the prediction of specific heat of the nanocoolant by considering the various mechanisms at the molecular level, particularly the nanocoolant with the suspension of CNF.

4. SUMMARY

In this work, the observed heat capacity was not related to the presence of a substructure. On the other hand, the agglomeration of nanoparticles and the formation of clusters can increase the thermal conductivity but, in this work, does not seem to have the same effect on the specific heat. Experimental results and the theoretical understanding of the mechanisms of the nanoparticles are needed to justify the heat capacity and fluid behavior of nanocoolant.

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