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HEAT TRANSFER PROPERTY OF METALLIC NANOFLUIDS - A STUDY

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Abstract

Prolonged use of domestic and industrial applications gives rise to high heat generation in the systems. Smart materials like nanofluids can be useful to overcome this modern-day problem. In this study we are reporting the water-based nanofluids, to challenge this problem. Due to the availability of water in Bengal, the simplest solution for cooling a machine is to flow water surrounding it. The nanofluids we have synthesized are metallic nanoparticles dispersed in water, which is considered as base fluid. The heat capacity and thermal conductivity of the nanofluids were predicted by the equilibrium molecular dynamics (EMD) simulation. It is observed that dispersed nanoparticles help an enchantment in thermal-conductivity of the fluids whereas the heat capacity decreases by a small value. The low-cost sol-gel method was used to synthesize the Cu and Ag nanoparticles and later disperses the same in distilled water in suitable wt%. Nanofluids were subjected to ultrasonic studies around room temperature. The thermal conductivity of the used fluids is the function of the velocity values of ultrasonic wave propagation through the fluid system. The experimental measured thermal-conductivity values show an enhancement of about 30% in comparison to the base fluid water in ambient temperature.

Keywords: Nanofluids, equilibrium molecular dynamics (EMD) simulation, thermal-conductivity, heat capacity.

I. Introduction

The generation of heat in different types of electronic, electrical, and mechanical machinery in domestic and industrial applications is a major concern, as because it affects the efficiency and longevity of the device. Replacement of conventional materials with modern materials can be helpful, but it will be expensive. So for the developing countries, it will be a burden. Nanofluids can be helpful for these types of applications. Nanoparticles dispersed in low-cost-based fluid like water can improve the base fluid's properties, especially heat transfer properties.

II. Literature review and objective

In the year 1995 in his seminal paper, Choi introduces nanofluids to the world [VIII]. His idea of nanofluids was to disperse submicron solid particles in the liquid. After this reporting different groups [X, VII, III, IX, IV, V] start working with different combinations of nanofluids systems. And it was observed that this fluid can be very useful for heat transfer applications. Sezer Özerinç et. al. [VII] studied nanofluids with metallic and non-metallic nanoparticles, and both theoretical and experimental data show an enhancement in the thermal- conductivity. Lee et al. [III] observed that the improved efficiency of nanofluids can be achieved by increasing particle size and also the temperature of the fluid. Along with the experimental report molecular dynamical-based study of nanofluids are also very popular, this method helps to understand the inner physics of the fluid atoms and particle atoms interactions [I, VI, II]. In this paper, we have represented the experimental and molecular dynamical simulation-based studies on water-based metal nanofluids.

III. Materials and methods

A) Experimental method

Always our approach was to minimize the cost of the system. So to do this, we have used the sol-gel method for the preparation of the metal-based nanofluids. The nitrate solution of metallic Cu and Ag was added with Polyvinylpyrrolidone (PVP) under rigorous starring for almost one hour. After filtration nanoparticles were collected. Then these were dispersed in base fluid water with a definite 0.1 vol%. The nanofluid's thermal conductivity was measured by using a single-frequency continuous-wave ultrasonic interferometer (Model VCT-70A) at a frequency of 2 MHz.

B) Molecular dynamical simulation study

For molecular dynamical simulations, we have used the LAMMPS software. In MD simulations we have taken well-known L-J potential for water atoms, EAM potential for metal atoms, and water-metal atom interaction by using Lorentz- Berthelot rules. The study of thermal-conductivity in equilibrium MD simulation was done by the Green-Kubo method.

IV. Result and Discussions

Table 1 and figure 1 depict the experimental measured results of the thermal conductivity of different nanofluids. Whereas table 2 and figure 2 depict the MD simulation-based results of the thermal conductivity & specific heat of Cu and Ag nanofluids.

A) Experimental result

The size of the nanoparticles prepared by the sol-gel method was characterized by using the X-ray diffraction method, the result shows approximately 15-20nm. The experimental ultrasonic study shows the velocity of a sound wave is higher in the case of nanofluids in comparison to water-based fluid. The localized fluid velocity surrounding the nanoparticles is higher in the case of nanofluids which helps the waves to move with high velocity. This finally gives the enhancement in the nanofluids. But this phenomenon also decreases the heat holding capacity up to a certain percentage. Table 1 shows that the thermal conductivity of water (base-fluid) is 0.58 W/m-K, whereas the thermal conductivity of metallic nanofluids is around 0.67 and 0.7 W/m-K (table 1 & figure 1).

B) Molecular dynamical simulation result

The MD simulation study was done by considering 3nm diameter metallic nanoparticles, which gives a much higher thermal-conductivity value around 2.2 and 3.6 W/m-K and specific-heat values are 3.7 kJ/Kg-K and 3.8 kJ/Kg-K. But simulation study shows the thermal-conductivity of water (base fluid) is very near to the experimental data (0.54 W/m-K) and the specific-heat value is 4.2 kJ/Kg-K(table 2 & figure 2). In both experimental and MD simulation cases, it is observed that the thermal conductivity of nanofluids is increasing.

Table 1: The experimental data of thermal-conductivity & specific-heat nanofluids

Sl.no.	Fluid name	Thermal- conductivity (W/m-K)
1.	Water (base fluid)	0.58
2.	Cu- nanofluid	0.67
3.	Ag-nanofluid	0.7

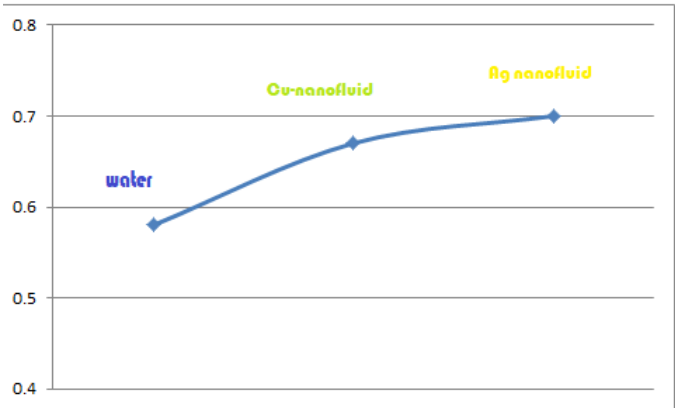

Figure 1. Experimental result of thermal conductivity (W/m-K) of base fluid and nanofluids

Table 2: The MD simulation data of thermal-conductivity & specific-heat of nanofluids

Sl.no.	Fluid name	Thermal- conductivity (W/m-K)	Specific- heat (kJ/Kg-K)
1.	Water (base fluid)	0.54	4.2
2.	Cu- nanofluid	2.2	3.8
3.	Ag-nanofluid	3.6	3.7

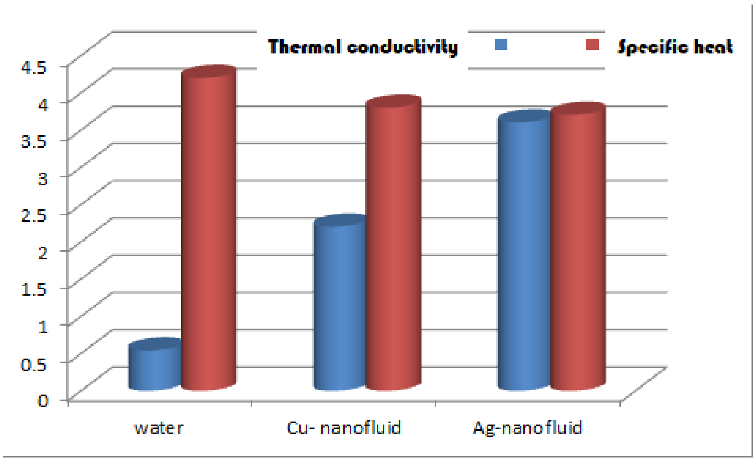

Figure 2. MD simulation results of thermal-conductivity (W/m-K) & specific-heat (kJ/Kg-K) of base fluid and nanofluids

V. Conclusion

The results show an enhancement of approximately 30% in the thermal conductivity for nano-fluid around room temperature. The MD simulation study also shows the enhancement in the nanofluids systems. But the simulation-based study shows and decrement of abound 10% in the specific heat of the nanofluids.

Transparency Declaration

The authors declare that no conflict of interest to report the present study.

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