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Study of comparison between thermal conductivity of silver/benzene and TiO_2/benzene nanofluids based on heat pipe application

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Abstract
Use of Nanofluids is widely adopted to enhance the thermal performance of conventional fluids. Numerous experiments have been done on Nanofluid to increase the heat transfer in which different nanoparticles and base fluids are selected. Here, two different nanoparticles Silver (Ag) and titanium dioxide (TiO_2) with 1-5% by volume are introduced in six different base fluids to make Nanofluids, and then thermal property of Nanofluid is inspected. Two distinct correlations are used to investigate the thermal property of Nanofluids of which one is theoretical and other is experimental. Results are compared with both the correlations which shows that Silver/Benzene Nanofluid is better than TiO_2/Benzene for heat transfer in heat pipes. Also it is observed that increasing the concentration of nanoparticles increases the thermal conductivity of Nanofluids. By addition of 1% nanoparticles by volume 3% increment in thermal conductivity can be achieved at 300K temperature. Similarly, at 5% concentration by volume 15% of thermal conductivity may be achieved at same temperature.

Keywords: thermal conductivity, nanofluid, heat pipe, silver (Ag), TiO_2

1. Introduction

In modern industries Nano-fluids playing a vital role in heating as well as cooling process of in many applications. Thermal conductivity of a liquid is an important property that determines its heat transfer performance. Conventional fluids having very less thermal conductivity so that the heat transfers fluid insufficient for extreme high cooling applications. There are many number of research work going on the Nano-technology field. Many projects tried to enhance the thermal conductivity of the conventional fluid using solid particles following Maxwell effective medium theory. Enhancements of heat in the industries, automobiles, electronic equipment and in home apparatus create enormous difficulties which harm the working power of tools. Continuously increasing work load on microelectronic devices and microprocessor resulting the thermal management challenges on the devises. There are many problem associated with heat transfer which may be solved by Nanofluids. Hence, two different types of nanoparticles are selected to prepare Nanofluids which are used to enhance the heat transfer in heat pipes.

The pool bowling heat transfer coefficient is studded and property of Nanofluid is compared by In Chalo bang *et al*. [1]. The layer of non-Newtonian Nanofluid having many different property from that of the clear fluid which is studied by U.Farooq *et al*. [2]. Heat transfer in double tube helical heat exchanger using Nanofluid under laminar flow condition is studded in which CuO and TiO_2 Nanoparticles had been taken by Gambriela *et al*. [3]. Vivek *et al*. [4] investigated the experimental study of Nanofluids that examined the effect of Nanofluid on Critical heat flux in times less than 100s. The best concentrations are found for SiO2/methanol and Al2O3/methanol Nanofluids and also absorption of CO_2 in these Nanofluids is observed by Jae Won Lee *et al*. [5]. Arttu *et al*. [6] presented that heat transfer coefficient is increased when compared with base fluid on the bases of constant Reynolds numbers. Carbon Nano Tubs (CNT) and Silicon dioxide (SiO_2) were used by A. Golkhar *et al*. [7] to investigate the removal efficiency of carbon dioxide in hollow fiber membrane contactor. Investigation of Kerosene-alumina Nanofluid for its stability, thermal conductivity and viscosity at low concentration was taken by Deepak *et al*. [8], also Kerosene-alumina Nanofluid used for thrust chamber cooling in semi-cryogenic rocket engine. The heat transfer coefficient of carboxyl methyl Cellulose (CMC) in water is increased when concentration is decreases also viscosity and different parameters affect the boiling heat transfer performance of Nanofluids [9]. M. Hojjat *et al*. [10] investigated the Thermal conductivity of the base fluid and Nano-fluid with various Nano-particles loading at different temperatures were measured experimentally. Using rheometer rheological behaviour of ethylene glycol based Nanofluid having spherical shaped is investigated by Xiaoke Li *et al*. [11]. Thermal conductivity of particle shape, composition and pure component upon heterogeneous two-component mixture having continuous and a discontinuous phase was studied by R.L. Hamilton *et al*. [12]. Also Dayal Raj *et al*. [14] has investigated the enhancement of heat transfer in heat pipe using TiO_2/Benzene based nano-coolant. C.Y. Tso studded the enthalpy of evaporation, saturated vapor pressure and evaporation rate of aqueous nanofluid also, using 0.01% of

TiO_2 based Nanofluid as an adsorbate enhance the cooling performance.Now, different research works are going on Nanofluids. Still, it is not possible to select that which nanoparticles are better for heat transfer.

Nomenclature

k_{eff} Effective thermal conductivity (W/m.K)

k_p Thermal conductivity of particles (W/m.K)

k_f Thermal conductivity of base fluid (W/m.K)

ϕ Concentration of nanoparticles (in %)

T Temperature (K)

2. Problem specification and results

The purpose of this study is to innovate high thermal conductivity Nanofluids and nanoparticles. First of all six base fluids has been selected, in which Benzene having high thermal conductivity than other base fluids. Similarly, two different nanoparticles are selected having different thermal conductivities. The thermal conductivity of Benzene base fluid is 0.14781 W/m-K at 300K temperature moreover, thermal conductivity of Silver (Ag) and titanium Dioxide (TiO_2) nanoparticles are taken from the literature which are 40 and 13 W/m-K respectively. Different (1 to 5% by volume) concentrations of nanoparticles are introduced in base fluids to make Nanofluids. Now, two correlations are used to find the thermal conductivity of Nanofluids in which one of them is Theoretical and other one is Experimental. By these correlations the performance of different nanoparticles with different base fluids is evaluated which are in table 1. When effective thermal conductivity of Nanofluids are evaluated and compared with both the correlations it shows approximate same value thus, these correlations are used here. Moreover Timofeeva *et al.* [13] correlation is used for Silver/Water Nanofluids however here it is used for TiO_2/Benzene, Silver/Benzene and different types of Nanofluids.

From the figure 1 it is clear that the thermal conductivity of Ag based nanoparticles is increased at different concentrations of nanoparticles and maximum thermal conductivity of Nanofluid is obtained with Benzene base fluid. In the same way, thermal conductivity of TiO_2 based Nanoparticles are also evaluated by the Maxwell correlations which also shows the thermal conductivity enhancement with Benzene base fluid.

Table 1: Theoretical and Experimental correlations of Thermal conductivity

	Reference	Year	Correlation	Relevant information
Theoretical	Maxwell [13]	1881	$\frac{k_{eff}}{k_f} = \frac{k_p + 2k_f + 2\phi(k_p - k_f)}{k_p + 2k_f - \phi(k_p - k_f)}$	Liquid and Solid Suspension Spherical Particles

Table 2: Thermal conductivity of different Base fluids

Base Fluids	Thermal Conductivity
Benzene(C_6H_6)	0.14781
Toluene(C_7H_8)	0.13391
1-Octane(C_8H_{18})	0.12928
Ethyl benzene(C_6H_{10})	0.12947
Cyclo hexane(C_6H_{12})	0.1261

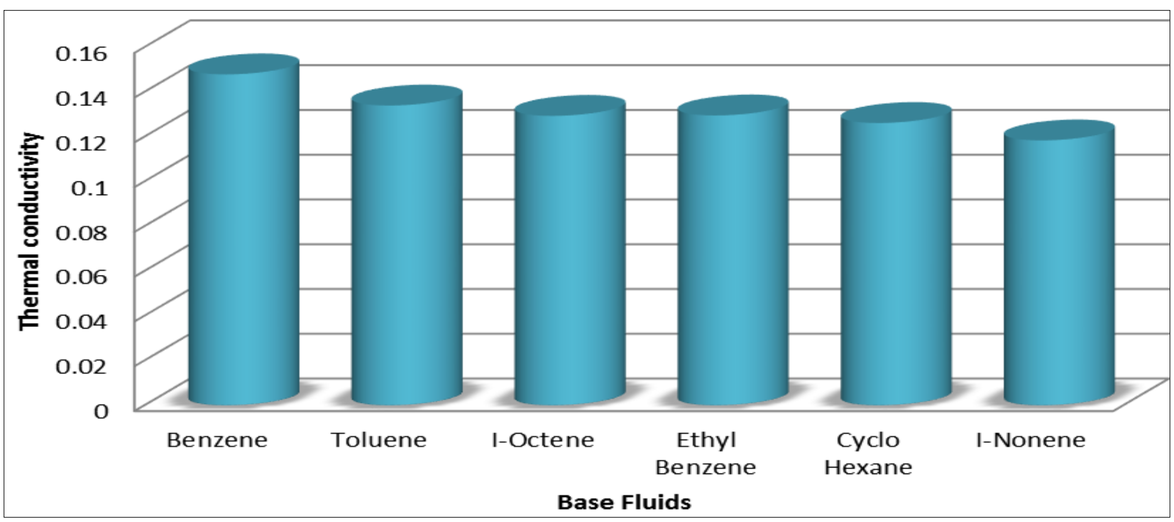

Fig 1: Variation in Thermal Conductivity base fluids

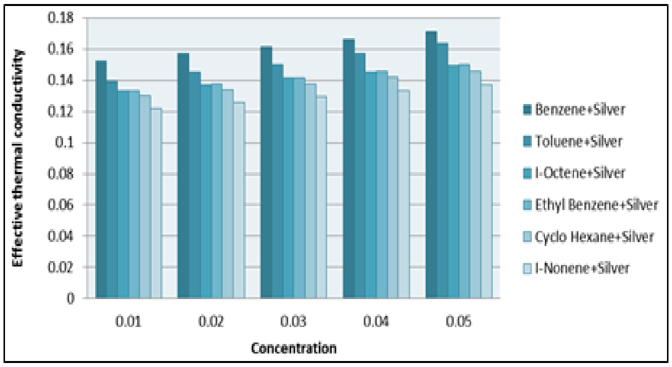

Fig 2: Variation in k_{eff} at different concentration of Silver nanoparticles by Maxwell Correlations

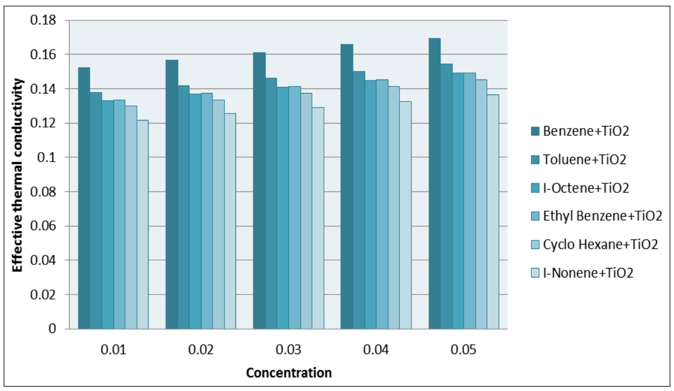

Fig 3: Variation in k_{eff} at different concentration of TiO_2 nanoparticles by Maxwell Correlation

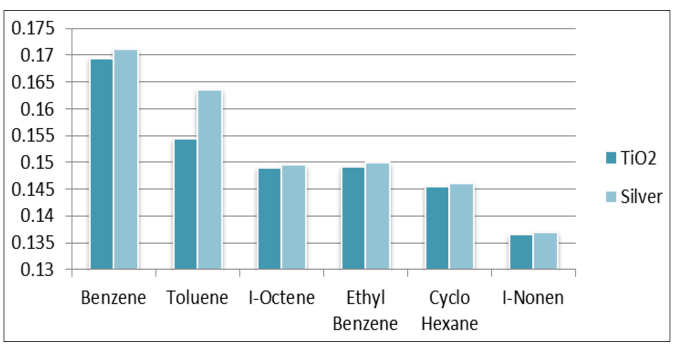

Fig 4: Variation in K_{eff} at different concentrations of TiO_2 and Silver Nanoparticles by Maxwell correlations

For both the Nanoparticles it is observed that the thermal conductivity of Silver (Ag) Nanofluid with Benzene base fluid is higher. A Moreover Timofeeva *et al.* [13] experimental correlation is used to evaluate the effective thermal conductivity of Benzene/TiO_2 and Benzene/Silver which is shown in figure 4. Thermal conductivity of Nanofluids is increased when the concentration of TiO_2 and Ag Nanoparticles are increased. Hence, figure 2, 3 shows that the effective thermal conductivity of Benzene/TiO_2 and Benzene/ Ag Nanofluid is higher compare to all Nanofluids at same concentrations. All the Nanofluids are shown in table 2. In which the TiO_2 and Ag nanoparticles are used. From the figure 3 it is seen that there is minor changes in thermal conductivity of Nanofluid at the concentration of 3% by volume of nanoparticles which is negligible.

Table 2: Different types of Nanofluids using different types of nanoparticles and base fluids

Nanofluids with Ag Nanoparticles	Nanofluids with TiO_2 Nanoparticles
Benzene (C_6H_6)/Silver (Ag)	Benzene (C_6H_6)/Titanium Dioxide (TiO_2)
Toluene (C_7H_8)/Silver (Ag)	Toluene (C_7H_8)/Titanium Dioxide (TiO_2)
Ethyl benzene (C_6H_{10})/ Silver (Ag)	Ethyl benzene (C_6H_{10})/Titanium Dioxide (TiO_2)
1-Ocatene (C_8H_{16})/ Silver (Ag)	1-Ocatene (C_8H_{16})/Titanium Dioxide (TiO_2)
Cyclo hexane (C_6H_{12})/ Silver (Ag)	Cyclo hexane (C_6H_{12})/Titanium Dioxide (TiO_2)
1-Nonene (C_9H_{18})/ Silver (Ag)	1-Nonene (C_9H_{18})/Titanium Dioxide (TiO_2)

After 3% by volume concentration of nanoparticles high variation in thermal conductivity is observed which is shown in figure 3. Both the correlations are compared in figure3 for Silver/benzene and TiO_2/Benzene Nanofluids and examined the, the thermal conductivity of Silver/benzene Nanofluid is higher compare to TiO_2/Benzene Nanofluids. The thermal conductivity of Silver/benzene and TiO_2/Benzene based nanofluid is investigated by the experimental and Therotical correlation which is shown in table 1. The thermal conductivity of Benzene based TiO_2 nanofluid is investigated by Abhijit *et al.* [14] which shows that effective thermal conductivity of nanofluid is increasing as we increase the concentration of nanoparticles. Also viscosity of nanofluid is also increases with increasing the concentration of nanoparticle. The Thermal Conductivity of Benzene based Ag Nanofluid is investigated by Swati Verma *et al.* [15] which shows that effective thermal conductivity of nanofluid is increasing as we increase the concentration of nanoparticles. And the overall thermal conductivity of Ag is higher.

3. Conclusion

Various types of base fluids and Ag, TiO_2 Nanoparticles are selected to make the Nanofluids. It is found that different concentrations of nanoparticles containing Benzene as a base fluid have higher thermal conductivity as compared to other base fluids. Also, thermal conductivity of different types of Nanofluids are compared with theoretical and experimental correlations and it is observed that the thermal conductivity of Ag/benzene Nanofluid is higher than TiO_2/Benzene Nanofluid. Moreover, it is observed that at lower concentration of nanoparticles the enhancement of thermal conductivity is significantly less. On other hand, at higher concentrations, an enhancement in effective thermal conductivity is higher. The enhancement of effective thermal conductivity of Nanofluid is found to be 3% at 1% by volume concentration of nanoparticles. Similarly, at 5% concentration of nanoparticles, an increase in 15% in thermal conductivity is observed. Other correlations are also compared however they do not conform to the values as given by Maxwell and Timofeeva *et al.* correlations.

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