International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 12 | Dec-2017 www.irjet.net p-ISSN: 2395-0072

Enhancement of Heat Transfer in Heat Pipes using Silver/Benzene based Nano-coolants

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Abstract - *Now a days, the transfer of heat from the engineering systems is a major problem in the world, And limited approaches are available to solve such type of problems. To increase heat transfer rate and capacity, many researchers found that the Nanofluid is one of the feasible medium which increase the working efficiency of many engineering devices with extracting heat from the system. Electronic equipment dissipates enormous amount of heat while in operation which affect the working efficiency of the systems. To increase the efficiency it is mandatory to remove the heat by using proper medium. Hence, heat pipes are employed in electronic devices to remove the heat with flow of cooling medium in it. Nano-coolants can be used to improve the heat transfer rate in heat pipe. In this research work, thermo physical properties of different types of base fluids with Silver (Ag) Nanoparticles have been investigated with different concentrations of Nanoparticles 1 to 5 percentage by volume at 27^{0}C temperature. The effective thermal conductivity of Nanofluids is compared with the base fluid and the results show increment in thermal conductivity. The thermal conductivity of Nanofluid is increased up to 15% at 27^{0}C with 1 % by volume concentration of nanoparticles and 24% at 5% by volume of concentration as compared to Benzene (C_6H_6) base fluid.*

Keywords - Heat Transfer, Nano-fluid, Heat pipe, Thermo physical properties.

1. INTRODUCTION

In a recent years, the amount of heat dissipated by the transportation applications, manufacturing, microelectronic, industries, high speed engines, medical applications and defense applications has immensely increased which affect the working efficiency of the instruments. Recent development of Nano technology brings out a new heat transfer coolant called 'nanofluids'. These fluids exhibit larger thermal properties than conventional coolants. The much larger relative surface area of nanoparticles, compares to these of conventional particles, not only significantly improves heat transfer capabilities, but also increases the stability of the suspension.

In Cheol Bang et al [1] reported that the Nanofluids have poor heat transfer performance as compared to pure water in natural convection. Farooq U et al [2] investigated on the two layers vertical channels with Non-Newtonian fluid having different properties as compared to clear fluid at each layer. Heat transfer characteristics in double tube heat exchanger are water increased with the increase in the mass flow rate and also with Dean Number. Fairly stable Nanofluid is prepared by Madusree Kole et al [4] using prolonged ultrasonication (>60 hrs) process and thermal conductivity of Nanofluid is investigated. Moreover, stable Cu-distilled water Nanofluid and at different inclination of wick heat pipe was also prepared [5].

In addition, Cluster formation and the role of interfacial layer on the effective thermal conductivity of Cu- gear oil Nanofluid is studied in the past [6]. Viscosity of ZnO-ethylene glycol (EG) is changed from Newtonian to Non-Newtonian at higher concentrations and hence the viscosity of ZnO-EG was found to be independent of ZnO Nanoparticles [7]. The nucleate pool boiling heat transfer characteristics and critical heat flux (CHF) of Nano-fluid was also investigated [8, 14]. When the concentration of nanoparticles increases, CHF also increases, which means CHF depends on Nanoparticles and not on Nanofluid [9]. Enhancement of carbon dioxide (CO_2) absorption in methanol-based Nanofluid is examined by Jae Won Lee et al [10]and also it was perceived that the PH variation is associated with the absorption of CO_2. Arttu Meriläinen et [11] reported that small, spherical and smooth particles are better in enhancing heat transfer with reasonable pressure losses. In hollow fiber membrane contactor, absorption performance of carbon nanotube (CNT) based Nano-fluid is higher than silica based Nano-fluid and absorption efficiency of Nano-fluids decrease with increasing in temperature [12]. Agarwal et al [13] investigated Kerosene-alumina Nano- fluid for thrust chamber cooling in a semi cryogenic rocket engine. Different types of Non-Newtonian Nanofluids is prepared and enhancement in thermal conductivity is measured experimentally [15]. Rheological behavior of Nanofluids is examined by Xiaoke Li et al [16] and thermal conductivity of heterogeneous mixture having continuous and a discontinuous phase was investigated by Hamilton R.L. et al [17]. Further, cooling of transformer using Nanofluids was reported by Dondapati et al [18].Conventional heat transfer fluids have extremely poor the present work the heat transfer enhancement using Nanofluids in heat pipe is considered.

1.1PROBLEM SPECIFICATION AND RESULTS

In the present study the effective thermal conductivity of Nanofluids is investigated by using various theoretical and experimental correlations. First of all, thermal conductivity of six base fluid at 25^0 C and 0.8 Mpa pressure has been evaluated and compared with each other. The investigated thermal conductivity of the different base fluids is shown in the table [2].The figure [1] shows that the thermal conductivity of benzene base fluid is higher than other base fluids. The thermal conductivity of benzene is found to be 0.14781W/m-K.

The thermal conductivity Silver is 429 W/m-K.

1 to 5% by volume of Nanoparticle is mixed in benzene, Toluene, 1-Octene, Ethyl benzene, Cyclo hexane and 1-Nonene base fluids. Effective Thermal Conductivity is calculated by using different correlations available in the literature [19].

k_{eff}	Effective thermal conductivity(W/m.K)
k_p	Thermal conductivity of particle(W/m.K)
k	Thermal conductivity if base fluid(W/m.K)
Φ	Concentration of nanoparticles (%)
T	Temperature (K)

Table -1: Different Theoretical and Experimental correlations of Thermal conductivity

Model	Reference	Year	Correlation	Relevant information
Theoretical	axwell [19]	1881	$\frac{k_{eff}}{k_f} = \frac{k_p + 2k_f + 2\Phi(K_p - k_f)}{k_p + 2k_f - \Phi(k_p - k_f)}$	uid and Solid Suspension Spherical Particles
	Hamilton and Crosser [19]	1962	$\frac{k_{eff}}{k_f} = \frac{k_p + (n-1)k_f + (n-1)\Phi(k_p - k_f)}{k_p + (n-1)k_f - \Phi(k_p - k_f)}$ =4.97Φ² +2.72Φ+1	$Where\ \frac{k_p}{k_f}$ 100 , n 3 Spherical and Non-Spherical Particles Micro-dimension
	Wasp [19]	1977	$\frac{k_{eff}}{k_f} = \frac{k_p + 2k_f + 2\Phi(K_p - k_f)}{k_p + 2k_f - \Phi(k_p - k_f)}$	Various Particle shape
	and Lin [19]	1996	$\frac{k_{eff}}{k_f} = 1 + a\Phi + b\Phi^2$	$for: k$ 10,a 2.25,b 2.27 $for: k$ ∞,a 3.00,b 4.51
	Xue [19]	2005	$\frac{k_{eff}}{k_f} = \frac{\left(1 - \Phi + 2\Phi\frac{k_p}{k_p - k_f}\right)(\ln\frac{k_p + k_f}{2k_f})}{\left(1 - \Phi + 2\Phi\frac{k_f}{k_p - k_f}\right)(\ln\frac{k_p + k_f}{2k_f})}$	Nanospheres with interfacial shell
Experimental	Li and Peterson [19]	2006	$\frac{k_{eff} - k_f}{k_f} = 0.764\Phi + 0.0187(T - 273.15) - 0.462$ $\frac{k_{eff} - k_f}{k_f} = 3.761\Phi + 0.0179(T - 273.15) - 0.307$	Ag/Water Nanofluids CuO/Water Nanofluids
	mofeeva et al [19]	2007	$k_{eff} = (1+3\Phi)k_f$	Ag/Water Nanofluids
	Duangthongs u and Wongwises [19]	2009	$\frac{k_{eff}}{k_f} = a + b\Phi$	a 1.0225,b 0.0272$at: T$ 15C a 1.0204,b 0.0249$at: T$ 25C a 1.0139,b 0.0250$at: T$ 35C
	dson et al [19]	2010	$\frac{k_{eff}}{k_f} = 0.9692\Phi + 0.9508$	Ag/Water Nanofluids EG/Water Nanofluids

2. THERMAL CONDUCTIVITY OF BASE FLUID

Base Fluid	**Thermal Conductivity**
Benzene(C_6H_6)	0.14781
Toluene(C_7H_8)	0.13391
1-Octene(C_8H_{18})	0.12928
Ethyl benzene(C_6H_{10})	0.12947
Cylohexane(C_6H_{12})	0.1261
1-Nonene(C_9H_{18})	0.11832

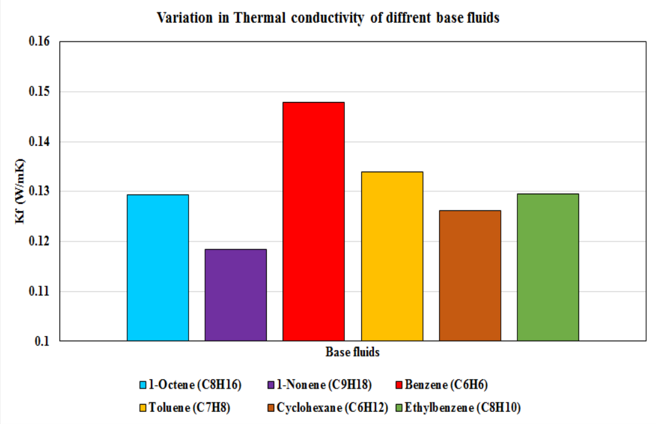

Figure 1.Comparison of thermal conductivity of different type of Base fluids

3. THEORETICAL CORRELATION

Variation in k_{eff} at different concentration of Silver Nanoparticle

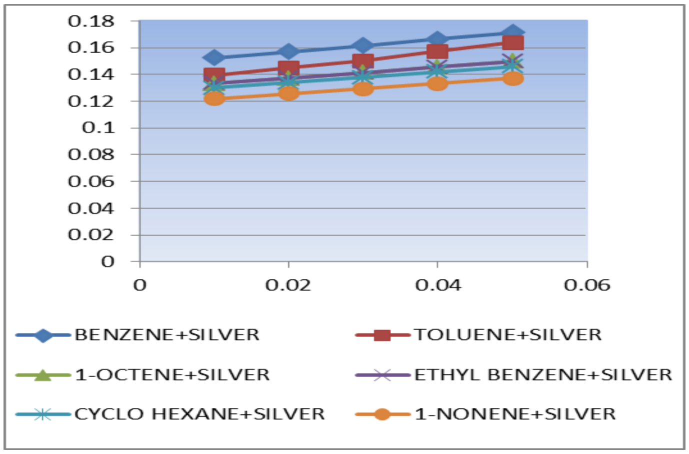

Figure 2.Variation in k_{eff} at different concentration of Silver nanoparticles by Maxwell Correlations

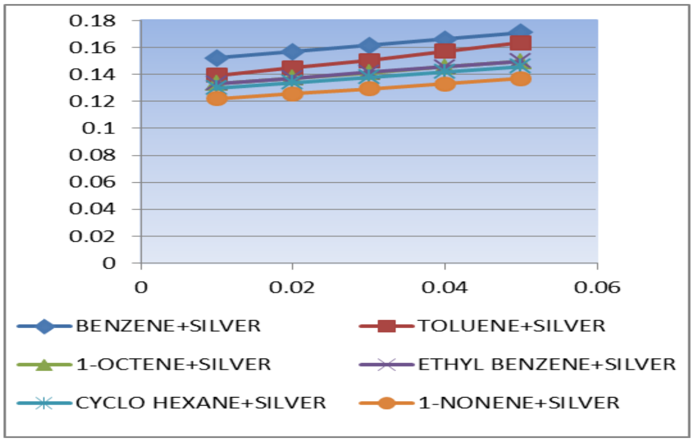

Figure 3.Variation in k_{eff} at different concentration of Silver nanoparticles by Hamilton and Crosser correlation

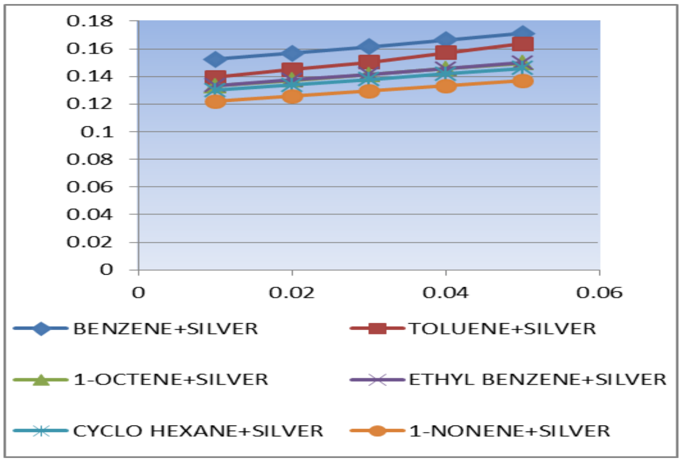

Figure 4.Variation in k_{eff} at different concentration of Silver nanoparticles by Wasp correlation

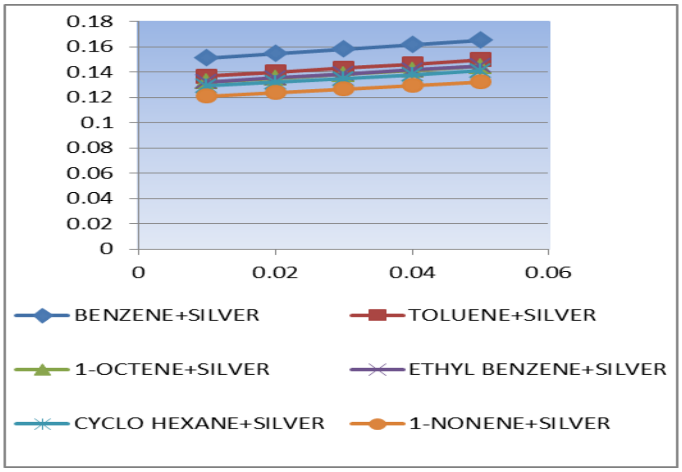

Figure 5.Variation in k_{eff} at different concentration of Silver nanoparticles by Lu and Lin correlation

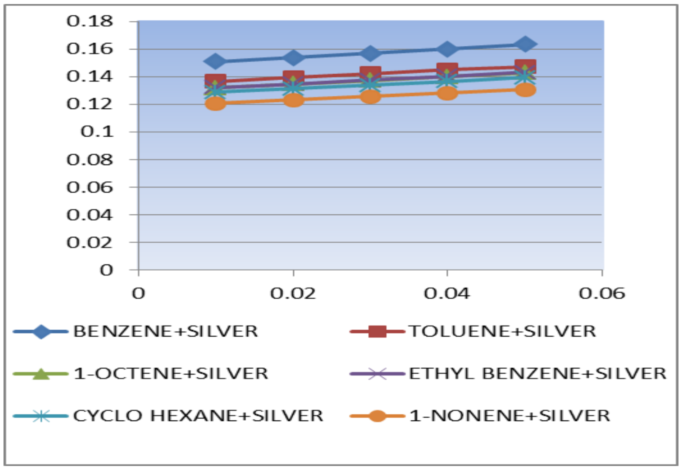

Figure 6. Variation in k_{eff} at different concentration of Silver nanoparticles by Xue correlation

4. EXPERIMENTAL CORRELATIONS

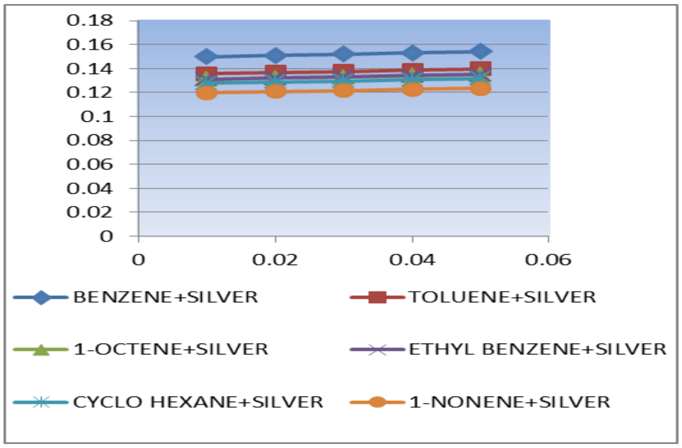

Figure 7.Variation in k_{eff} at different concentration of Silver nanoparticles by Li and Peterson correlation

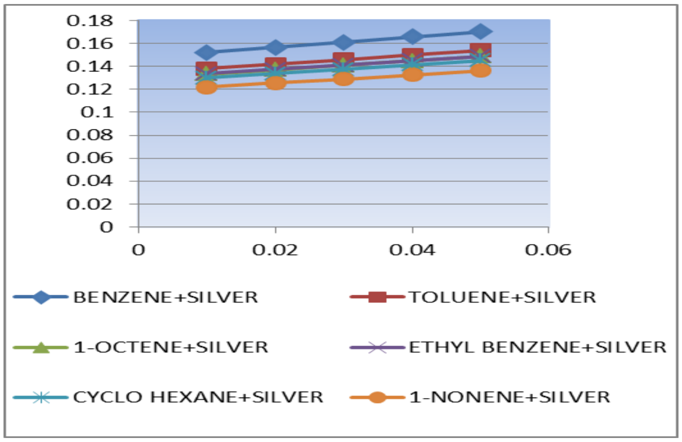

Figure 8.Variation in k_{eff} at different concentration of Silver nanoparticles by Timofeeva correlation

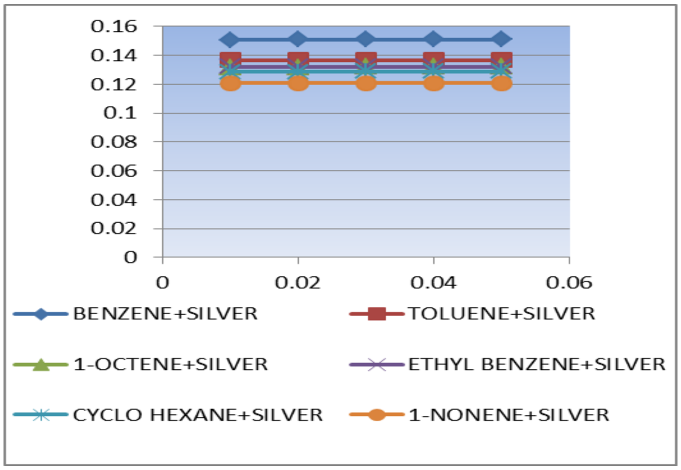

Figure 9.Variation in k_{eff} at different concentration of Silver nanoparticles by Duangthongs u and Wongwises correlation.

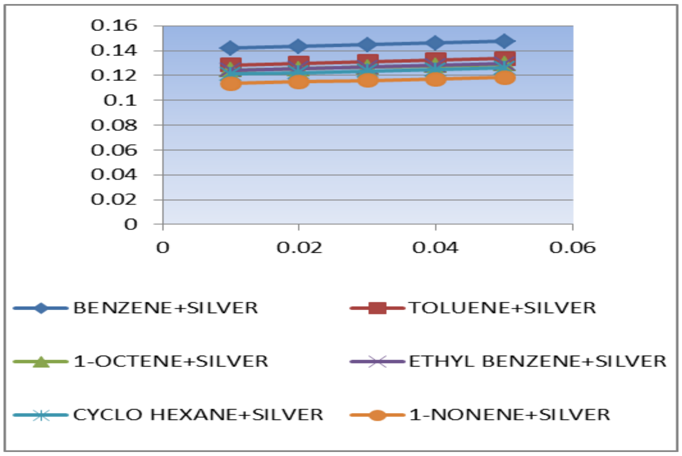

Figure 10.Variation in k_{eff} at different concentration of Silver nanoparticles by Godson correlation.

TABLE 2. Thermal Effectiveness at Different Concentration of Nanoparticles (Silver/Benzene)

NAME	Φ	K_{eff}(W/m-K)
Maxwell	0.01	0.152284417
	0.05	0.171123046
Hamilton & Crosser	0.01	0.152284417
	0.05	0.171123046
Wasp	0.01	0.152284417
	0.05	0.171123046
Lu and Lin	0.01	0.151169277
	0.05	0.165277446
Xue	0.01	0.150796039

	0.05	0.163368383
Li and Peterson	0.01	0.149752223
	0.05	0.154269297
Timofeeva	0.01	0.1522443
	0.05	0.1699815
Duangthongs and wongwises	0.01	0.150862128
	0.05	0.151009347
Godson	0.01	0.141970322
	0.05	0.14770062

All graphs plotted between the variation in K_{eff} in Y-axis and volume percentage of silver in X-axis. The thermal effectiveness at different concentrations of Nanofluid is shown in figure 2 by Maxwell correlation [19].Similarly Hamilton and Crosser and Wasp correlation is also used to find the K_{eff} of the Nanofluid in the figure 3[19] and figure 4[19]. Effective thermal conductivity at given concentration of Nanofluid is shown in figure 5 and figure 6 by Lu & Lin and Xue correlations.

In the table 1, four experimental correlations are also given which represent the approximately same value of K_{eff}; Li and Peterson [19] gave two different correlation which are shown in the table 1 in first correlation is used for Silver/Water Nanofluids and second correlation is used for CuO/Water Nanofuids .The first correlation has been consideration with the C_6H_6/Silver Nanofluids which is displayed in the figure 7. Figure 8 shows experimental correlation which is given by Timofeeva etal [19]. Duangthongsu and Wongwises correlation, large deflection is shown in figure 9 compared to all figure. Similarly, Godson et al also gave the same result in figure 10. The calculated value of K_{eff} by those correlations of C_6H_6/Silver Nanofliud is given in the table 2. In table 2 K_{eff} at 1% and 5% are shown, which represent that the value of K_{eff} increases at higher concentration of Nanoparticles. As the concentration increases the thermal conductivity also increases.

5. CONCLUSIONS

This analytical results show that addition of Silver nanoparticles in Benzene base fluid increases the thermal effectiveness of the Nanofluid- According to the Maxwell at 1% addition of silver by volume in the base fluid, the percentage increment in thermal effectiveness of nanofluids is 15%, at 2% silver addition in base fluid thermal effectiveness increased by 17.5%, at 3% addition of silver thermal effectiveness increased by 19.8%, at 4% silver addition in base fluid thermal effectiveness increased by 22%, and at 5% silver addition in base fluid thermal effectiveness increased by 24%. Same as other experimental correlations are also given the increment of thermal effectiveness of Nanofluid.

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