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Study of Nano Particles for Enhanced Heat Transfer Characteristics of Base Fluids for Cool Thermal Energy System

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ABSTRACT
Reliable heat transfer is very crucial for heat demand and supply related applications where the optimum demand is not met. Cool thermal energy systems are the units which find application in conditioning and preserving items. A colloidal mixture of nano particles in a base fluid tremendously enhances the heat transfer characteristics of the original base fluid and is ideally suited for practical application due to its marvelous characteristics.
Keywords – Aluminium Oxide, Copper Oxide, Distilled Water, LMTD, PVD

I. INTRODUCTION

The impact of global warming on Earth became the pressing need for research and development to reduce its effect. Inefficient thermal fluid system always increase the green house gases so, there is a need to design energy efficient heat transfer system as well as study for enhancing the thermal capability if conventional fluids, which will contribute to better energy management.

I.1. NANO FLUIDS

Thermal conductivity of solids is in orders of magnitude greater than that of the dispersion of solid particles in a given fluid is bound to increase its thermal conductivity. However, dispersion of millimeter and micrometer sized particles are prone to sedimentation, clogging, erosion of pipes and channels and high pressure drops which kept away from the practical use. These fluids are engineered colloidal cluster of nano particles in a base fluid. This is due to the fact that nano particles have adaptive surface area, less particle momentum, high mobility and better suspension.

I.1.1. COPPER NANO FLUIDS

Copper based nano fluids are prepared using copper oxide nano powder. When a particular amount of nano powder is added to the distilled water and mixed well using a stirrer. 10 nm diameter nano particles produce much larger increase in k than 30 nm diameter nano particles.

Thioglycolic acid improves dispersion behaviour. 'K' value is enhanced due to smaller particle size.

I.1.2. ALUMINIUM NANO FLUIDS

Aluminium based nano fluids are prepared using aluminium oxide nano powder. Behaviour is similar to copper based nano fluids. When oxide impurities are present, thermal conductivity has is relatively high due to improved dispersion. Thermal conductivity ratio appears to be non linear with volume percentage.

II. COMPARISON SUMMARY

Table1. COMPARISON OF Cu AND Al NANO PARTICLES

COPPER	ALUMINIUM
1. Uniform distribution of particles, separated from each other. 2. No clustering of particles. 3. Average particle size varies from 25 nm. 4. The specific surface areas of these particles are 12 m^2/g.	1. Distribution of particles is not uniform. 2. Clustering of spherical particles together in well defined singles. 3. Average particle size varies from 18 nm. 4. The specific surface area of these particles are 40-60 m^2/g.

According to studies heat transfer increase with decreased particle size and specific surface area.

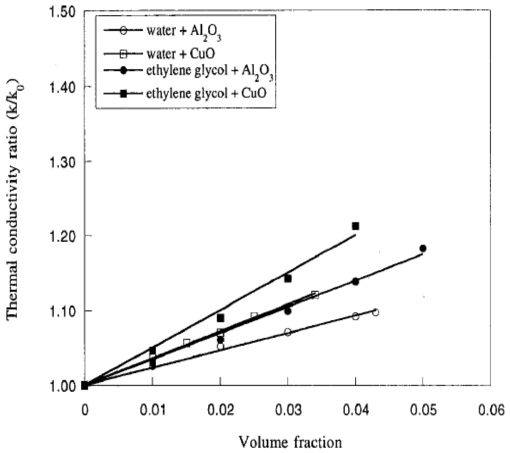

Fig1. Comparison Chart

II.1. SYSTEM OF NANO FLUIDS

Theoretically all solid nano particles with high thermal conductivity can be used as additives of nano fluids. Commonly used nano particles are:

1. Metallic particles (Cu, Al, Fe, Au, Ag)
2. Non metallic particles (Al_2O_3, CuO, TiO_2, SiC)
3. Carbon nano tubes
4. Nano droplets

The base fluids commonly used are water, oil, acetone, decene, ethylene glycol. Generally the thermal conductivity of solid is typically higher than that of liquids.

Nano fluids dispersing solid nano particles such as metal, non metal particles and carbon nano tubes are being widely investigated. A new kind of nano fluids dispersed with nano droplets was reported such type of nano emulsion fluids passes long term stability and can be easily mass produced. Although potential of nano droplets in enhancing thermal conductivity of nano fluids is doubtful, the development of nano emulsion fluid may open a direction for thermal-fluid studies. The nano fluids refer to a new kind of composite materials containing of nano additives and base fluids. The additives may be metal or non metal particles, nano fibers, nano rods or nano droplets.

III. PREPARATION

Preparation of nano fluids is the key step in the use of nano particles to improve the thermal conductivity of fluids. Two kinds of methods have been employed in producing nano fluids. One in a single step method and other in a two step method. The single step method is the process combining the preparation of nano particles with the synthesis of the nano fluids, for which nano particles are directly prepared by physical deposition (PVD) technique or liquid chemical method, In this method the process of drying, storage, dispersion and transportation of nano particles are avoided, so the agglomeration of nano particles are minimized and stability of fluid is increased. But a disadvantage of this method is that only low vapour fluids are compatible with the process, which limits the application of this method.

Two step methods for preparing nano fluids is a process by dispersing nano particles in to base liquids. Nano particles, nano fibres or nano tubes used in this method are first produced as a dry powder by inert gas condensation, chemical vapour deposition, mechanical alloying or other suitable techniques, and nano sized powder than dispersed into fluid in a processing stage. This step isolates the preparation of the nano fluids from the preparation of nano particles. As a result agglomeration of nano particles may take place. Agglomeration will only result in the settlement and clogging of the micro channels, but also decreases the thermal conductivity. Simple technique such as ultrasonic agitation or the addition of the surfactants is often used to minimize particle aggregation and improve dispersion behavior.

III.1. STABILITY OF NANO FLUIDS

Nano fluids are not a simple mixture of liquid and solid particles. Nano particles tend to aggregate with the time elapsed for its surface activity. The agglomeration of nano particles result not only the settlement and clogging of micro channels but also the decreasing of thermal conductivity of nano fluids.

Peng et al studied the factors that influence the stability of nano fluids and the test result showed that the most important factors that affect the stability of suspension were the nano particle concentration, dispersant, viscosity of base fluid and pH value. The variety, diameter, density of the nano particle and ultrasonic vibration also influence the stability of nano fluids.

In general, methods such as change of pH value, addition of dispersants, treatment on surface of nano particles and ultrasonic agitation have been used to improve stability of nano fluids. Although the methods mentioned above were used to improve stability of nano fluids, only several days or months stable time of nano fluids was reported effective and simple methods that can keep long term stability of the nano fluids are not available so far.

III.2. THERMAL CONDUCTIVITY

Thermal conductivity is an important parameter for enhancing heat transfer performance of a heat transfer fluid. To measure the thermal conductivity of nano fluids the convective heat transfer technique is used. Convective heat transfer refers to heat transfer between a fluid and a surface

due to the macroscopic motion of the fluid relative to the surface. The surface can be a solid wall or an interface with another liquid.
Since thermal conductivity of solid nano particle is much higher than that of fluids, the suspended particles are expected to be able to increase the thermal conductivity and the heat transfer performance.

III.3. INFLUENCE OF NANO PARTICLES

Nano particles, the additive of nano fluids, play an important role in changing the thermal transport properties of nano fluids. The investigation about nano particles mainly focus in the effect of their volume fraction, thermal conductivity, morphology and Brownian movement. Most investigation revealed that the thermal conductivity of nano fluids increase anomalously with the increase in the volume fraction of nano particles. The thermal conductivity of Cu/Distilled water increases non linearly with volume fraction of Cu nano particles.
The experimental results showed that the enhanced thermal conductivity ratio increases with the increase of volume fraction of aluminium oxide nano particles in nano suspension. The measured thermal conductivity is anomalously of nano tubes loading their augment to the enhanced thermal conductivity is due to the nature of heat conduction in nano particle suspension, and an organize structure at the solid liquid interface the non linear phenomenon can be ascribed to both the size and shape of nano particles.
The shape of nano particles can influence the enhancement of thermal conductivity of nano fluids. The high enhancement of effective thermal conductivity can be achieved when the shape of nano particles deviated much from the spherical one. The analysis of the experiment data suggested that the dominant mechanism of thermal conductivity enhancement in nano fluids strongly depends on the particle aspect ratio i.e. the ratio of major axis to the minor axis of the particle. The effect of the Brownian motion could be the predominant for spherical nano particles. The diffusive heat conduction mechanism will gradually take over the dominance as the aspect ratio increases.

III.4. INFLUENCE OF BASE FLUIDS

Besides the influence of nano particles, thermal conductivity, temperature and viscosity of the base fluids also effect the enhancement of thermal conductivity of nano fluids. However, research on the effect of base fluids is relatively less reported. It has been indicated that suspension using the same nano particles, enhanced thermal conductivity ratio is reduced with increasing thermal conductivity of the base fluid. The measured thermal conductivity enhancement decreased with increase in suspension in both nano fluid system. The difference in the particle aspect ratio, which have important effects on both the direct relationship between viscosity and thermal conductivity of nano fluids. However, the viscosity of base fluid has significant effect on stability of nano fluids.

IV. EXPERIMENTAL DESIGN

IV.1. MATERIALS USED

- Copper pipe
- Steel cylinder
- Ball valves
- Distilled water
- Aluminium oxide nano powder
- Copper oxide nano powder
- Thermocouple
- Temperature indicator
- Water heater
- Pump

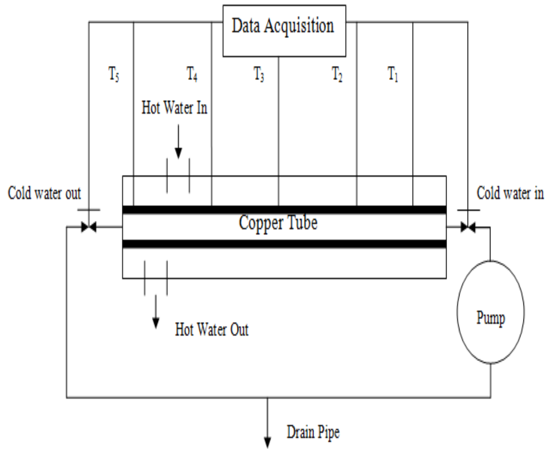

Fig2. Convective heat transfer system

The apparatus consists of a concentric tube heat exchanger. The energy is obtained from a heater and it flows through the outer pipe. And cold water flows through the inner copper tube. The cold water is kept in room temperature and hot water temperature is set to desired temperature for the experiment to be done. The hot water can be submitted at any one end in such a way that the heat exchanger is enabled and this can be done by suitable valve operation.

Heat exchanger is a device in which heat is transferred between two fluids that are at different temperatures. Heat exchangers are typically classified according to flow arrangement and type of construction. The simplest heat exchanger is one for which the hot and cold fluid move in the same or opposite directions in a concentric tube. In this arrangement both the fluids enter at opposite direction and double pipe heat exchanger is used when one or either of the fluids enters at high pressure and the water is circulated in the system along a motor and is controlled by valves. Water is circulated under high pressure and initially the experiment is done using distilled water. After the results the experiment is done using nano fluids containing CuO and Al_2O_3.

Since water containing nano fluids which flow through the copper pipes, the hot water inside the tube help to conduct the heat from the hot to cold fluid and hence it would be an enhancement in the overall heat transfer. The system pumps the nano fluids at a desired flow and then by using various thermocouples mounted on the cylinder readings are got through a temperature indicator.

IV.2. SPECIFICATIONS

- Inner Tube (Copper)
- Inner Diameter (d_i) = 5.75 mm
- Outer Diameter (d_o) = 6 mm
- Outer Tube (Mild Steel)
- Inner Diameter (d_i) = 157 mm
- Outer Diameter (d_o) = 160 mm
- Length of heat exchanger (L) = 300 mm

IV.3. SETTLING OF NANO PARTICLES

Settling time for CuO and Al_2O_3 are calculated at specific time intervals so that heat generated is calculated in nano particles before they settle down. Distilled water us used and the particles are stirred and are allowed to settle down.

IV.4. EXPERIMENT USING DISTILLED WATER

Distilled water is used to conduct the experiment, where 200 ml of it is mixed in the system. Readings are taken using various thermocouples. Temperatures of hot and cold water are taken and then amount of heat transfer is calculated and considered to be reference value and compared with CuO and Al_2O_3.

IV.5. EXPERIMENT USING COPPER OXIDE IN DISTILLED WATER

Copper oxide nano powder is added with distilled water to form a solution and then the solution is used to conduct the experiment. Nearly 0.5 grams of powder are added into the solution and is then stirred well and poured into the experimental setup.

IV.6. EXPERIMENT USING ALUMINIUM OXIDE IN DISTILLED WATER

Aluminium oxide nano powder is added with distilled water to form a solution and then it is used to conduct the experiment. Nearly 0.5 grams of powder are added into the solution. The solution is then stirred well and used to conduct the experiment.

V. DATA TABULATION

Table2. RESULTS OBTAINED FROM DISTILLED WATER

Serial No.	Cold Water		Hot Water		LMTD (^oC)	Heat Transfer (q) Watts	Overall heat transfer coefficient (U) $W/m^2 K$
	Inlet	Outlet	Inlet	Outlet			
1.	34	36	70	66	30	12.54	286
2.	34	38	80	77	39	19.89	293.4
3.	34	39	90	87	47	24.56	311.6

Table3. RESULTS OBTAINED FROM DISTILLED WATER AND COPPER OXIDE SOLUTION

Serial No.	Cold Water		Hot Water		LMTD (^oC)	Heat Transfer (q) Watts	Overall heat transfer coefficient (U) $W/m^2 K$
	Inlet	Outlet	Inlet	Outlet			
1.	34	38	70	65	32	14.54	290.3
2.	34	39	80	76	43	22.13	296.4
3.	34	40	90	85	51	28.32	323.6

Table4. RESULTS OBTAINED FROM DISTILLED WATER AND ALUMINIUM OXIDE SOLUTION

Serial No.	Cold Water		Hot Water		LMTD (^oC)	Heat Transfer (q) Watts	Overall heat transfer coefficient (U) $W/m^2 K$
	Inlet	Outlet	Inlet	Outlet			
1.	34	36	70	67	31	12.13	289
2.	34	38	80	77	40	20.79	298.4
3.	34	39	90	86	48	25.66	314.5

VI. CALCULATIONS

Following calculations are done:

- LMTD = $(dT_i - dT_o)/ \ln(dT_i/dT_o)$ (^oC)

$$dT_i = Th_i - Tc_i$$

$dT_o = Th_o - Tc_o$
$dT_o = 2\ ^oC$
$dT_i = 4\ ^oC$
$LMTD = (4 - 2)/ \ln (4/2)$
$= 30\ ^oC$

- Heat Transfer (q) = $mc_p\Delta T$ (W) = 12.54 W
- Overall Heat Transfer Coefficient (U) = q/(A x LMTD) = 286 W/m^2K
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VII. CONCLUSION

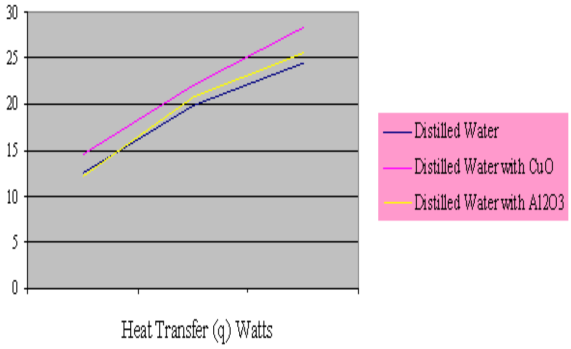

Fig3. Heat transfer plot

After result calculations are made which shows that there is 4% increase in overall heat transfer when copper oxide containing nano fluid is compared with the distilled water whereas aluminium oxide containing fluid does not show any difference in heat transfer characteristics. From the graph, copper oxide nano fluid has greater heat transfer characteristics when compared to distilled water and aluminium oxide. It shows that nano fluid have better carrying capacity than conventional fluids. Thus, use of nano fluids will also reduce the size of the system and increase efficiency, thus replacing conventional fluids with nano fluids for better results.

REFERENCES

[1] C.H. Li, G.P. Peterson, Experimental investigation of temperature and volume fraction variations on the effective thermal conductivity of nanoparticle suspensions (nanofluids), *Journal of Applied Physics, 99,* (2006), 084314.

[2] Y. Xuan, Q. Li, Investigation convective heat transfer and flow features of nanofluids, *Journal of Heat Transfer, 125,* (2002), 151–155.

[3] S. Lee, S.U.S. Choi, S. Li, J.A. Eastman, Measuring thermal conductivity of fluids containing oxide nanoparticles, *Trans. ASME, Journal of Heat Transfer, 121,* (1999), 280– 289.

[4] Y. Xuan, Q. Li, Heat transfer enhancement of nanofluids, *International Journal of Heat Fluid Flow, 21,* (2000), 58–64.

[5] Y. Xuan, W. Roetzel, Conceptions for heat transfer correlation of nanofluids, *International Journal of Heat Mass Transfer, 43,* (2000), 3701–3707.

[6] Sidi El Be´caye Maı¨ga, Samy Joseph Palm, Cong Tam Nguyen, Gilles Roy, Nicolas Galanis, Heat transfer enhancement by using nanofluids in forced convection flows, *International Journal of Heat and Fluid Flow, 26,* (2005), 530–546.

‘[7] Sadik Kakaç, Anchasa Pramuanjaroenkij, Review of convective heat transfer enhancement with nanofluids, *International Journal of Heat and Mass Transfer, 52,* (2009), 3187–3196.

[8] S.M.S. Murshed, K.C. Leong, C. Yang, Enhanced thermal conductivity of TiO_2-water based nanofluids, *International Journal of Thermal Sciences, 44,* (2005), 367–373.