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Experimental Validation and Verification of using Nanofluid in Shell and Tube type Heat Exchanger

[#1]Vaibhav Lokhande, [#2]Mayuresh Khedekar

[1]vaibhavlokhande1993@gmail.com,
[2]mayureshkhedekar31@gmail.com

[#12]Department of Mechanical Engineering

Alard Charitable Trust's Alard College of Engineering & Management

ABSTRACT

Cooling is indispensable for maintaining the desired performance and reliability in wide variety of products like cars, computers and high power laser systems. Whenever there is an increase in heat load and heat fluxes caused by high power and small size in these products, cooling is one of the technical challenges faced by the industries like microelectronics, transportation, manufacturing, etc. There are many single-phase liquid cooling techniques such as micro channel heat sink and two-phase liquid cooling techniques like heat pipes, thermosyphones, direct immersion cooling and spray cooling. Development of the nanomaterials and nanotechnology has made it possible to structure a new type of heat transfer fluid formed by suspending small particles called as Nanoparticles of Diameter<100 nm. In conventional base fluids like water and ethylene glycol Stephen U. S. Choi coined the term NANO FLUID to refer the thermal properties superior to those of their base fluids. Due to rapid fluid mixing effect, the energy transport inside the nano fluids is strengthened by modifying the temperature profiles. Experimental data indicates that particle size, volume fraction and properties of the nanoparticles influence the heat transfer characteristics of nano fluids. This paper shows the research work on mini heat exchanger using Al2O3 (which is a water based nano fluid).

Keywords: NANO FLUID, Heat pipes, Al2O3.

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I. INTRODUCTION

Heat exchanger using nanofluid is a device in which the heat transfer takes place by using nano fluid. In this the working fluid is nanofluid. Nanofluid is made by the suspending nano particles in the fluid like water, ethylene glycol and oil, etc.

1.1 Introduction to Nano Fluids

Nanofluid, first suggested by StephenU.S. Choi of Argonne National Lab in 1995, innovative working fluid for heat transfer created by dispersing highly thermal conducting solid particles smaller than 50 nanometers in diameter in traditional low thermal conducting heat transfer fluids such as water, engine oil, and ethylene glycol.

1.2 Introduction to Heat Exchanger

It is an equipment which transfer the energy from a hot fluid to a cold fluid, with maximum rate and minimum investment and running costs. The heat transfer in a heat exchanger usually involves convection on each side of fluid and conduction through the wall separating the two fluids.

1.3 Why we use nanofluid?

The main goal or idea of using nanofluids is to attain highest possible thermal properties at the smallest possible concentrations (preferably<10nm) in hot fluids. A nanofluid is a mixture of water and suspended metallic nano particles. Since the thermal conductivity of metallic solids are typically orders of magnitude higher than that of fluids it is expected that a solid/fluid mixture will have higher effective thermal conductivity compared to the base fluid only.

II. LITERATURE REVIEW

[1] L.B mapa et al: Measured enhanced thermal conductivity of Cu- Water based Nano fluid using a shell and tube heat exchanger. Where the dimensions of heat

exchanger is 240X24X0.25mm, using 37 tubes. The outcome of analysis is rate of heat transfer is increases with increasing flow rate and also its concentration. By nanoparticle dispersed into de-ionized base fluid a better enhancement is achieved.

[2]. J.Koo et al: Investigated the nano particle collision and deposition in the surface wall with the help of micro channel heat sink. Which has the dimension of 1cm X 100 micrometer X300 micrometer; water-Cu and Cuethylenena nofluid are through micro channel heat sink. They are investigated the base fluid should posses high prandtle number and get enhanced heat transfer rate by minimize particle – particle, particle-wall collision. Viscous dissipation is important of narrow channel because Nusselt number high for high aspect ratio.

[3]. Shung-Wen Kang et al: Studied about the relation between thermal resistance- size of nanoparticle with the help of 211 micrometer X 2187 micrometer sized and deep grooved circular pipe and heat pipe maintain 40 temperature. They are finalized thermal resistance is directly proportional to the size of the nanparticle. Maximum reduction of the thermal resistance by using 10nm sized particle. Because particle size is increasing the walltemperature also increases. So small sized particle suitable for enhanced heat transfer rate. Thermal resistance is decreases with the increasing heat and concentration of nanoparticles.

[4] Shuichi Tori: Investigated convective heat transfer coefficient of diamond based nanofluid by using heat tube apparatus. Specification of tube is 4.3mm,4mm outer and inner diameter respectively, and applied 100W power uniformly. They are showed the heat transfer coefficient is increases with increasing concentration and Reynolds numbertofn Nano fluid, but at the same time increased the pressure drop with increasing concentration of nano particle.

[5]. S.J Kim et al: Investigated formation of porous layer and wet ability of nanofluid using critical heat flux experiment and SEM images. They are used three different types of nanoparticles with different diameters such as Al2O3 (110-220nm) SiO2(20-40nm) Zno(110- 210nm). They are showed boiling is main factor to affect the heat transfer rate of nanofluid. Due to nucleate boiling nanoparticle deposited on wall, so the porous layer is formed on the wall. Porous layer directly consequence for creating wettablity, cavity and roughness of surface wall. So heat transfer rate decreased due to boiling of nanofluid.

[6]. PaisamNaphon et al: Investigated the thermal efficiency of heat pipe using titanium –alcohol Nanofluid, heat pipe dimensions are 60mm and 15mm length and outer diameter respectively. The Thermal efficiency increases with increasing tilt angle within 600 angle and concentration of nanoparitcle.

[7]. Anilkumar et al: Studied the heat transfer enhancement of fin, using Al2o3- water nano fluid analyzed using CFD. Reyleigh number increases due to Brownain motion, ballistic phonon transport, and clustering and dispersion effect of nanoparticle. At high Rayleigh number flow rate at center circulation is increasing, so temperature is drop from center of fin. Volume of the circulation increases the velocity at centre is increases as the result of increasing the solid fluid heat transportation. Low aspect ratio fin is suitable for heat transfer enhancement, because heat affected zone is less

[8]. Yu-Tung Chen: Investigated the thermal resistance of heat pipe using Al2O3 water nanofluid, heat pipe made as 200cmX3mm length and thickness respectively. Heat resistance is increases with increasing concentration of nano fluid up to 50ppm. Due to wet ability of nanoparticle various geometry wick is created on heat pipe.

[9]. Eed Abdel Hafez Abdel-hadi et al: Investigate the heat transfer analysis of vapour compression system using Cuo-R134a Nano fluid, test section made of copper horizontal tube and heat is applied 10-40 Kw/m Heat flux concentration and size particle is important factor to enhance the heat transfer rate of nanofluid. Heat transferrate increases with increasing heat flux, upto 55% of concentration of nanofluid and upto2.5nm sized particles.

III. EXPERIMENTAL ANALYSIS

- **EXPERIMENT PROCEDURE**

1. Fill the tank with water and place the electric heater in it.
2. Switch on the electric heater the and let the temperature of water reach 80°C.
3. Fill nanofluid/water at room temperature in the second tank.
4. Ensure the inlet and outlet valves of the shell are open.
5. Switch on the water pump of the hot fluid tank and let the hot water circulate continuously in the shell at a constant inlet temperature of 80°C.
6. After achieving constant inlet temperature of 80°C of the hot water in the shell, turn on the water pump of the nanofluid/water which is at room temperature in the second tank.
7. Give suitable time for heat transfer to occur between hot fluid and cold fluid.
8. Note down the readings on temperature sensor of the inlet and outlet ports of the nanofluid/water which is flowing through the tubes.
9. Calculate heat transfer rate by using equation (Q) = $m \times Cp \times (\Delta T)$.

- **OBSERVATION/READING**

1. Temperature reading of Hot water and Cold water in °C

Table No. 1 – Temperature of hot and cold water

SR. NO.	HOT WATER (T_{hot})		COLD WATER (T_{cold})	MASS FLOW RATE (kg/sec)	
	T_{inlet}	T_{outlet}	T_{inlet}	T_{outlet}	
1	60.7	59.1	28.2	33.9	0.6389

2	57.4	55.5	29.6	35.1	0.6389
3	56.2	54	31.8	37.2	0.6389
AVERAGE	58.1	56.2	30.2	35.4	0.6389

2. Temperature reading of Hot water and Nanofluid- AL_2O_3in°C

Table No. 2 – Temperature of hot water and nanofluid

SR. NO.	HOT WATER (T_{hot})		$AL_2O_3(T_{Al2O3})$		MASS FLOW RATE (kg/sec)
	T_{inlet}	T_{outlet}	T_{inlet}	T_{outlet}	
1	60.7	48	29.5	45	0.7667
2	57.4	47.5	36.4	43.1	0.7667
3	56.2	50.6	39.8	40.6	0.7667
AVERAGE	58.1	48.7	35.23	42.9	0.7667

- **CALCULATIONS**

1) Heat transfer rate of cold water

Heat transfer rate of cold water (Q) = $m \times Cp \times (\Delta T)$

$\therefore$ Q_{cold}= $m \times Cp \times (Toutlet - Tinlet)$.......equation (1)

After substituting the values of cold water from Table No. 1 we get,

$\therefore Q_{cold} = 0.6389 \times 4.187 \times (35.4 – 30.2)$

$$\boxed{\therefore Q_{cold} = 13.91 \text{ KW}}$$

2) Heat transfer rate ofNanofluid – AL_2O_3

Heat transfer rate of Nanofluid - Al_2O_3 (Q) = $m \times Cp \times (\Delta T)$

$\therefore$ Q_{Al2O3} = $m \times Cp \times (Toutlet - Tinlet)$............equation (2)

After substituting the values of Nanofluid from Table No. 2 we get,

$\therefore$ Q_{Al2O3}= 0.7667 $\times$ 451.955 $\times$ (42.9-35.23)

$$\boxed{\therefore Q_{Al2O3} = 2657.76 \text{ KW}}$$

IV. RESULT

1) Heat transfer rate of Cold water found from equation (1) is,

Q_{cold}= 13.91 KW

2) Heat transfer rate of Nanofluid – AL_2O_3 Q_{Al2O3} = 2657.76 KW

3) To calculate the difference of heat transfer capacity between cold water and nanofluid we use equation,

$\therefore$ HT = $Qnanofluid - Qcold$

$\therefore$HT = 2657.76 - 13.91

$$\boxed{\therefore HT = 2643.85 \text{ KW}}$$

V. RESULT TABLE

Table No. 3 - Result

Sr. No.	**Liquid Type**	**Q (KW)**	**Difference (Q_{Al2O3}-Q_{cold})KW**
1.	Water	13.91	2657.76 – 13.91 = 2643.85
2.	Al_2O_3	2657.76	

VI. COEFFICIENT OF PERFORMANCE (COP)

In general, efficiency is given by the ratio of output to input. Thus, efficiency can be written as given below,

$$\therefore \eta = \frac{OUTPUT}{INPUT}$$

However, efficiency cannot be calculated for a heat pump, here Coefficient Of Performance (COP) is required. COP is the inverse function if efficiency.

$$\therefore COP = \frac{1}{\eta}$$

$$\therefore COP = \frac{INPUT}{OUTPUT}$$

VII.COP CALCULATIONS

1) **COP of cold water**

$$\therefore COP = \frac{T2 - T1}{T3 - T4}$$

$$\therefore COP = \left(\frac{35.4 - 30.2}{58.1 - 56.2}\right)^{-1}$$

$$\therefore COP = 0.3653$$

2) **COP of nanofluid**

$$\therefore COP = \frac{T6 - T5}{T7 - T8}$$

$$\therefore COP = \left(\frac{42.9 - 35.23}{58.1 - 48.7}\right)^{-1}$$

$$\therefore COP = 1.2256$$

VIII. ADVANTAGES

1. Less expensive as compared to Plate type coolers.
2. Can be used in systems with higher operating temperatures and pressures.
3. Pressure drop across a tube cooler is less.

4. Tube leaks are easily located and plugged since pressure test is comparatively easy.
5. Tubular coolers in refrigeration system can act as receiver also.
6. Using sacrificial anodes protects the whole cooling system against corrosion.
7. Tube coolers may be preferred for lubricating oil cooling because of the pressure differential.
8. High specific surface area and therefore more heat transfer surface between particles and fluids.
9. High dispersion stability with predominant Brownian motion of particles.
10. Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification.
11. Reduced particle clogging as compared to conventional slurries, thus promoting system miniaturization.
12. Adjustable properties, including thermal conductivity and surface wet ability, by varying particle concentrations to suit different applications.

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X. APPLICATIONS

- Electronic applications
- Transportation
- Industrial cooling applications
- Nuclear systems cooling
- Space and Defence
- Medical application
- Cooling of Microchips

XI. CONCLUSION

1. The heat transfer rate of nanofluid is greater than that of water has been proved by this experimental setup and the calculations taken.
2. It could be concluded that, by using nanofluid the effectiveness of heat exchanger will be increased.
3. Also heat transfer rate is drastically increased by using nanofluid.

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