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HEAT TRANSFER ENHANCEMENT USING NANO FLUID PARTICLE

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ABSTRACT

Heat transfer devices have been used for conversion and recovery of heat in many industrial and domestic applications. Over five decades, there has been concerted effort to develop design of heat exchanger that can result in reduction in energy requirement as well as material and other cost saving measures by functioning in most efficient and effective way serving our purpose. Heat transfer enhancement techniques generally reduce the thermal resistance either by increasing the effective heat transfer surface area or by generating turbulence. These techniques are classified as active and passive techniques. The active technique requires external power while the passive technique does not need any external power.

Our project is on enhancing thermal properties using nanofluids. A colloidal mixture of nano-sized particles in a base fluid, called nanofluids, tremendously enhances the heat transfer characteristics of the original fluid, and is ideally suited for practical applications due to its marvelous characteristics.

In our experiment, the nanofluid consists of water and CuO, water and ZnO flowing through counter flow shell and tube heat exchanger. About 50 nm diameter of CuO, ZnO nanoparticles was used in this analysis and found that overall heat transfer coefficient and convective heat transfer coefficient of nanofluids were higher than those that of base fluid at same inlet temperature and mass flow rate.

KEYWORDS: CuO, ZnO, Heat Transfer, Nanofluid, Shell-and-Tube Heat Exchanger, Thermal Conductivity

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1. INTRODUCTION

For several industrial applications, one of the most challenging parts is designing of energy efficient and improved methods in heat transfer rate. New technological developments are increasing the thermal loads and require faster cooling. The traditional methods in increasing the cooling rate (use of fins, mini/micro channels, baffles etc.) are already stretched to a great extent. Today, the automobile industry continuously faces the challenges to obtain best automobile design in the aspects of performance, fuel consumption, safety, etc.

The advancement of nanotechnology, nanofluids can be thought of as a coolant in heat exchangers. Nanofluids are liquid with suspensions of nanoparticles with at least one of their principal dimensions smaller than 50 nm. From previous investigations, nanofluids have been found to possess enhanced thermo physical properties such as thermal conductivity, thermal diffusivity and viscosity. Convective heat transfer coefficients of nanofluids are greater, compared to those of base fluids like ethylene glycol or water due to the increase in particle volume fraction, temperature and higher thermal conductivity of the nano particle that is dispersed in the fluid.

An experimental investigation was carried out to determine the effect of various concentrations of nano-dispersion (CuO,ZnO) mixed in water as base fluid on heat transfer characteristics of double pipe heat exchanger for counter flow arrangement.

A satisfactory agreement between numerical results and experimental results were observed. The effect of different particle shapes on the overall heat transfer coefficient, heat transfer rate, and entropy generation of shell and tube heat exchanger were studied and concluded by carrying out experiment.

2. LITERATURE SURVEY

Suspension of nano particles like Al, Zn, Si, Cu etc. in base fluids are called nanofluids. Nanofluid is the new challenge for thermal science provided by nanotechnology. These nanofluids have unique features different from conventional solid liquid mixtures. They contain mm or micrometer sized particles of metals and non-metals. Due to their excellent physical and chemical characteristics they find wide applications in enhancing heat transfer.

Research Paper

Sarit Kumar Das, Stephen U.S. Choi & Hrishikesh E. Patel [1] presented a paper on "Heat Transfer in Nanofluids-A Review". In this paper they presented an exhaustive review of nanotechnology study and suggest a direction for future developments in nanotechnology. The conclusion drawn in this paper is that nanofluids show great promise for use in cooling and related technologies. They observed maximum enhancement (□160%) with 1% volume fraction with multi-walled carbon nanotubes dispersed in engine oil.

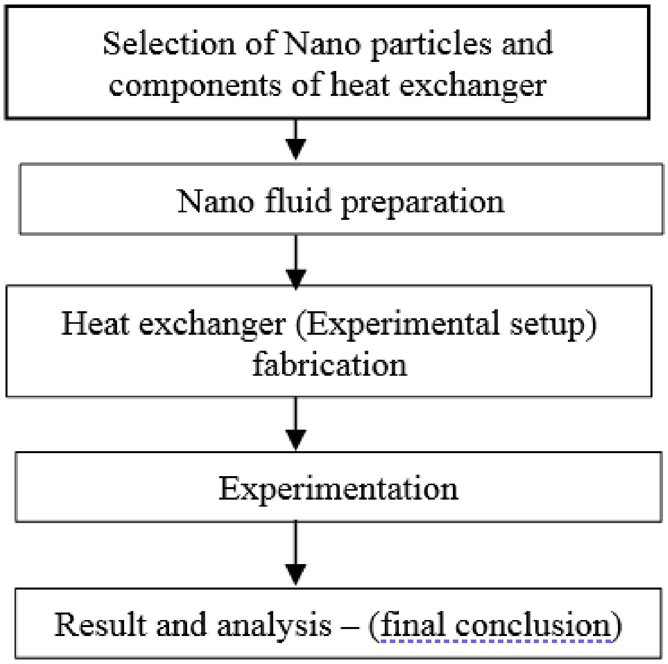
Elena V. Timofeeva, Wenhua Yu et. al. [2] presented a paper on "Nanofluids for Heat Transfer: An Engineering Approach". In this paper the factors contributing to the fluid cooling efficiency were discussed first, followed by a review of nanofluid engineering parameters and a brief analysis of their contributions to basic thermo-physical properties.

P. Keblinski, S.R. Phillpot, S.U.S. Choi & J.A.Eastman [3] presented a paper on "Mechanism of Heat Flow in Suspensions of Nano-sized Particles (nanofluids)". In this paper they explained different mechanisms of heat flow in nanofluids. They explained Brownian motion of the particles, molecular level layering of the liquid at the liquid/particle interface, the nature of heat transport in the nanoparticles, and the effects of nanoparticle clustering.

Seok Pil Jang and S.U.S.Choi [4] presented a paper on "Role of Brownian Motion in the Enhanced Thermal Conductivity of Nanofluids". In this paper they devised a theoretical model that accounts for the fundamental role of dynamic nanoparticles in nanofluids. The model not only captures the concentration and temperature dependent conductivity but also predicts strongly size-dependent conductivity.

S.U.S.Choi and J.A.Eastman[5] presented a paper on "Enhancing Thermal Conductivity of Fluids with Nanoparticles". They provided information related to technology for production of nanoparticles and suspensions and theoretical study of thermal conductivity of nanofluids..

3. METHODOLOGY



4. NANO FLUID

4.1 Sonication

Sonication is the act of applying sound energy to agitate particles in a sample, for various purposes. Ultrasonic frequencies (>20 kHz) are usually used, leading to the process also being known as Ultrasonication or ultra-Sonication.

Sonication has numerous effects, both chemical and physical. The chemical effects of ultrasound are concerned with understanding the effect of sonic waves on chemical systems, this is called sonochemistry. The chemical effects of ultrasound do not come from a direct interaction with molecular species. Studies have shown that no direct coupling of the acoustic field with chemical species on a molecular level can account for sonochemistry or sonoluminescence

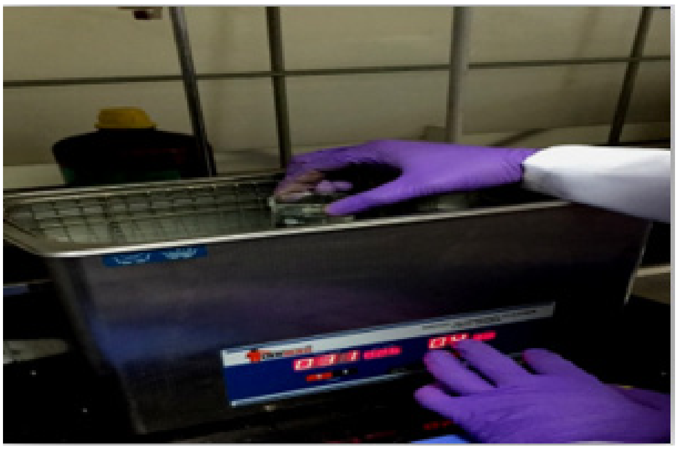


Figure 1

4.2 X Ray Diffraction

XRD is an effective method for identifying the phases present in unknown polycrystalline powders. The analysis is performed by comparing the diffraction pattern collected from an unknown sample with the diffraction patterns of known compounds. The automated process is called Search/Match (S/M) analysis. XRD is an important technique in the manufacture of ceramic materials. It provides phase analysis of materials throughout the manufacturing process, from raw materials to products. Several refractory powders were front packed into standard round aluminum specimen holders and leveled with a glass slide. No special effort was made to control the preferred orientation in the grains. Standard θ/2θ data were collected using a Rigaku Mini Flexbenchtopdiffractometer.

Figure 2

4.3 Transmission electron microscopy

TEM is a microscopy technique in which a beam of electrons is transmitted through a specimen to form an image. The specimen is most often an ultrathin section less than 100 nm thick or a suspension on a grid. An image is formed from the interaction of the electrons with the sample as the beam is transmitted through the specimen. The image is then magnified and focused onto an imaging device, such as a fluorescent screen, a layer of photographic film, or a sensor such as a charge-coupled device.

4.4 Preparation of Nanofluids

We are taking two nano fluid CuO fluid and ZnO fluid .Lets see the copper fluid preparation. Initially to measure the quantity of 4g(1L) nano particle containing CuO (50nm) in the ratio of 0.04% it adding with distilled water .The base fluid is being half an hour dissolved by using ultra sonication.

Next see the Zinc fluid preparation to measure the quantity of 4g(1L) nano particle containing ZnO (40nm) in the ratio of 0.04% it adding with distilled water .The base fluid is being half an hour dissolved by using ultra sonication.

CuO 0.04% +Base fluid 99.96% =CuO Nano fluid (100%)
ZnO 0.04% +Base fluid 99.96% =ZnO Nano fluid (100%)

5. HEAT EXCHANGER EXPERIMENTAL SETUP

The main components used to fabricate the setup are:

- Thermocouple
- Temperature controller
- Heater
- Fluid tank
- Copper tube
- PVC pipe

5.1 Thermocouple

A Thermocouple is a sensor used to measure temperature. Thermocouples consist of two wire legs made from different metals. The wires legs are welded together at one end, creating a junction. This junction is where the temperature is measured. When the junction experiences a change in temperature, a voltage is created. The voltage can then be interpreted using thermocouple reference tables to calculate the temperature.

There are many types of thermocouples, each with its own unique characteristics in terms of temperature range, durability, vibration resistance, chemical resistance, and application compatibility. Type J, K, T, & E are "Base Metal" thermocouples, the most common types of thermocouples. Type R, S, and B thermocouples are "Noble Metal" thermocouples, which are used in high temperature applications.

Figure 3

5.2 Controller

As the name implies, a temperature controller - often called a PID controller is an instrument used to control temperature. The temperature controller takes an input from a temperature sensor and has an output that is connected to a control element such as a heater or fan.

To accurately control process temperature without extensive operator involvement, a temperature control system relies upon a controller, which accepts a temperature sensor such as a thermocouple or RTD as input. It compares the actual temperature to the desired control temperature, or set point, and provides an output to a control element.

Figure 4

5.3 Heater

A heating element converts electrical energy into heat through the process of resistive or Joule heating. Electric current passing through the element encounters resistance, resulting in heating of the element. Unlike the Peltier effect, this process is independent of the direction of current flow.

Figure 5

5.4 Fluid tank

The Fluid Tank is a block used to store large amounts of fluids (eg. fuel, oil, water, and lava, also gases). It can also store fluids for different intermediate operations. You can stack them to get bigger Fluid Tanks.

Figure 6

5.5 Copper tube

Copper tubing is most often used for supply of hot and cold tap water, and as refrigerant line in HVAC systems. There are two basic types of copper tubing, soft copper and rigid copper. Copper tubing is joined using flare connection, compression connection, or solder. Copper offers a high level of corrosion resistance

Figure 7

5.6 Pipe

A pipe is a tubular section or hollow cylinder, usually but not necessarily of circular cross-section, used mainly to convey substances which can flow — liquids and gases (fluids), slurries, powders and masses of small solids.

Figure 8

6. ASSEMBLY SETUP

A setup of the experimental apparatus is shown in fig. we fixed two tank one is fluid storage input tank,another is fluid storage output tank. 80mm pvc pipe connected for cooling water circulation Then to connect the two tanks between U shape copper tube inside of pvc pipe.We maintain constant temperature in input storage fluid tank so we fixed heater with controller.we need to measure the hot water and cold water temperature so we fixed thermocouples in input and output. All thermocouple connected with separate controllers for noting temperature. The output fluid again circulate input storage tank by using pump.

Design: *CREO software

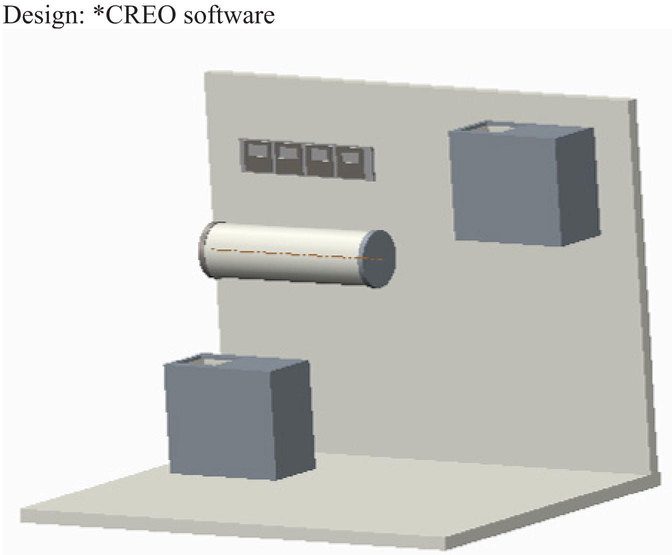


Figure 9

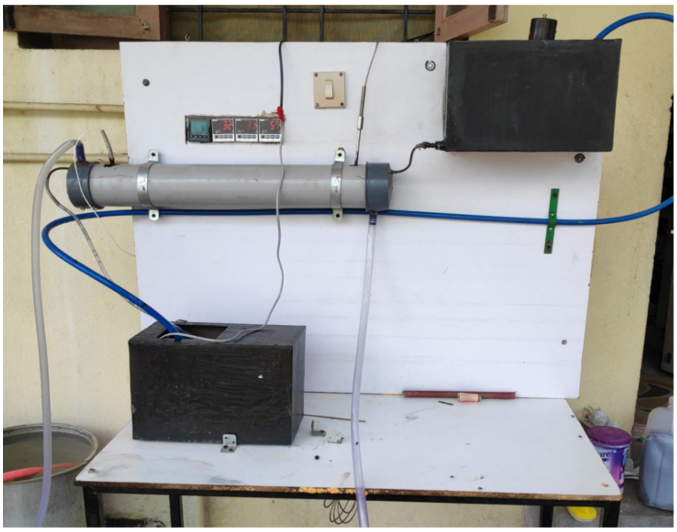


Figure 10

7. PROCEDURE

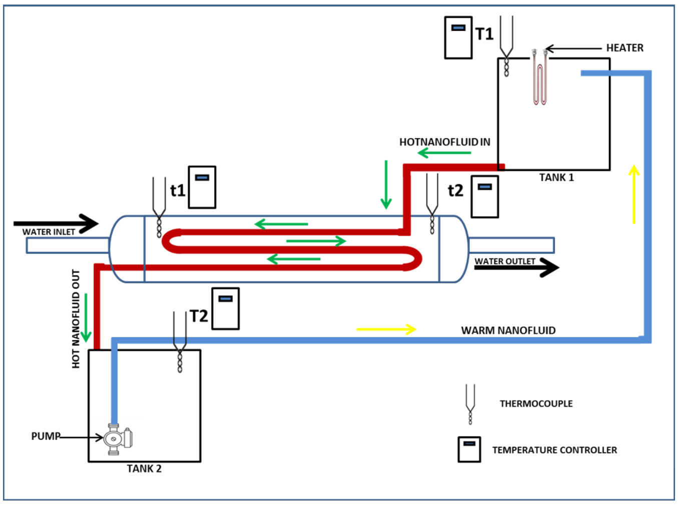
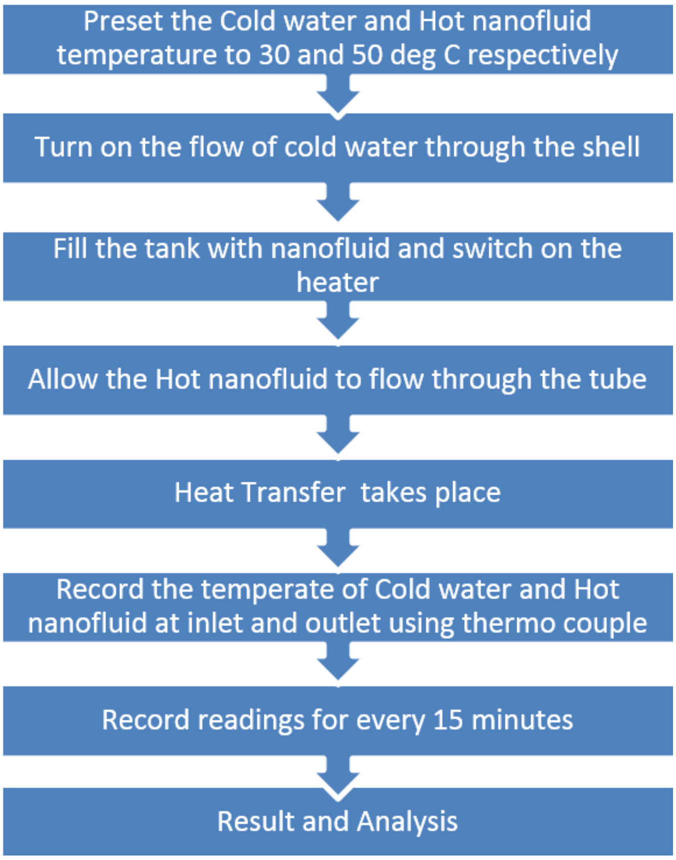


Figure 11



8. OBSERVATION

8.1 Observations Of Base Fluid

S.No	Time (min)	Hot Fluid Inlet Temp t1 (°c)	Hot Fluid Outlet Temp t1 (°c)	Mass Flow Rate of Base Fluid(g/s)
1	15	50	44	8
2	30	50	39	
3	45	50	40	
4	60	50	40	
5	75	50	41	

Table 1 : Hot Base fluid

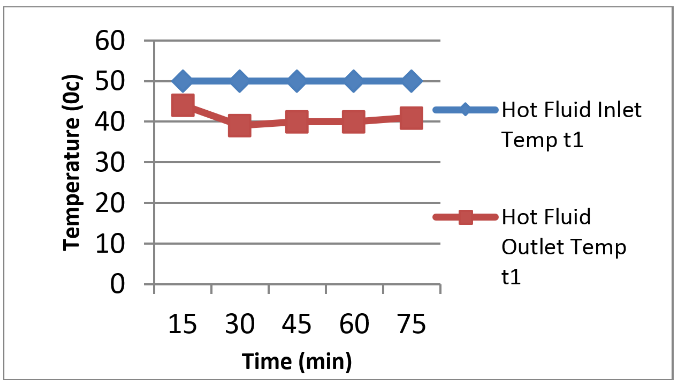


Chart: 1

S.No	Time (min)	Cooled Water Inlet Temp T1(°c)	Cooled Water Outlet Temp T2(°c)	Mass Flow Rate of Water(g/s)
1	15	30	31	20.2
2	30	30	33	
3	45	30	33	
4	60	30	32	
5	75	30	33	

Table 2: Cold Water

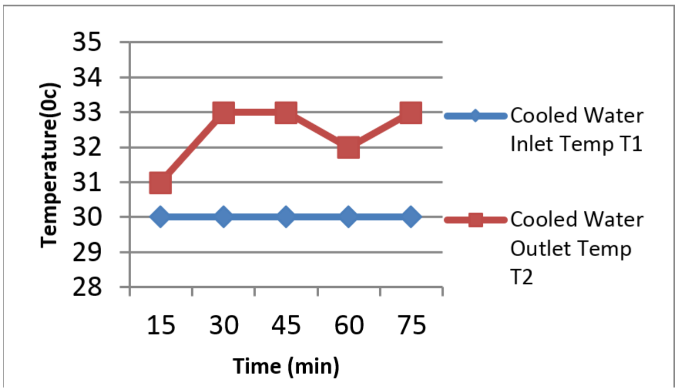


Chart: 2

8.2 Observations Of Cuo Nano Fluid

S.No	Time (min)	Hot Fluid Inlet Temp t1 (0c)	Hot Fluid Outlet Temp t1 (0c)	Mass Flow Rate of Water(g/s)
1	15	50	40	11
2	30	50	46	
3	45	50	48	
4	60	50	45	
5	75	50	46	

Table 3: Hot Cuo Nano Fluid

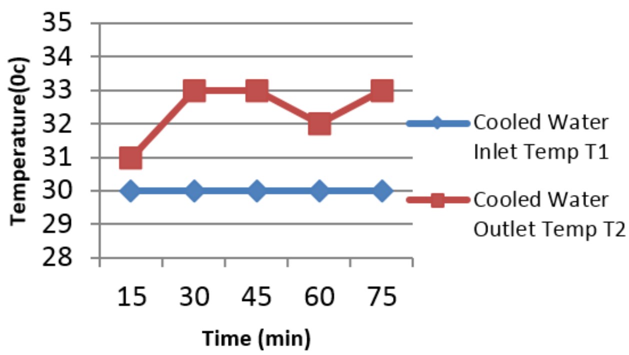


Chart: 3

S.No	Time (min)	Cooled Water Inlet Temp T1(0c)	Cooled Water Outlet Temp T2(0c)	Mass Flow Rate of Water(g/s)
1	15	30	35	24.3
2	30	30	35	
3	45	30	36	
4	60	30	36	
5	75	30	33	

Table 4: Cold Water

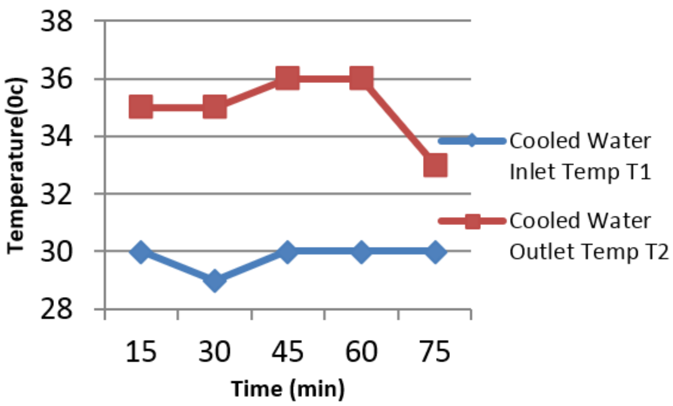


Chart: 4

8.3 Observations Of Zno Nano Fluid

S.No	Time (min)	Hot Fluid Inlet Temp t1 (0c)	Hot Fluid Outlet Temp t1 (0c)	Mass Flow Rate of Water(g/s)
1	15	50	42	10
2	30	50	45	
3	45	50	44	
4	60	50	43	
5	75	50	43	

Table 5: Hot ZnO Nano fluid

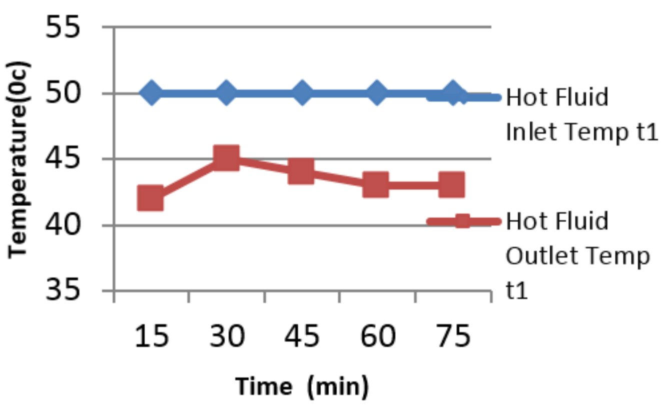


Chart: 5

S.No	Time (min)	Cooled Water Inlet Temp T1(0c)	Cooled Water Outlet Temp T2(0c)	Mass Flow Rate of Water(g/s)
1	15	30	32	22.3
2	30	30	31	
3	45	30	31	
4	60	30	33	
5	75	30	32	

Table 6: Cold Water

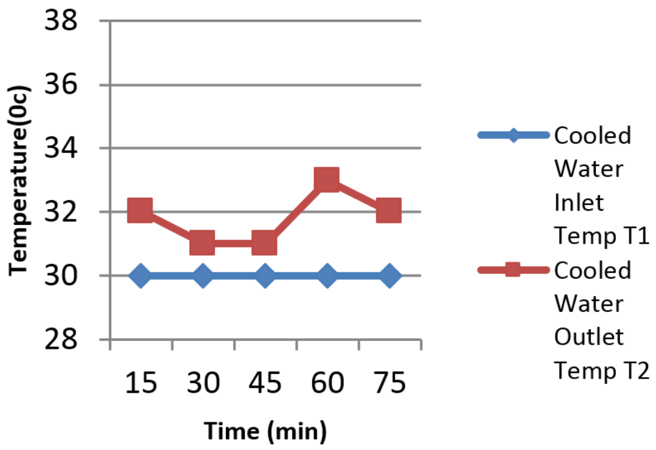


Chart: 6

9. CALCULATIONS

The convective heat transfer coefficient of base fluid flowing through inner copper tube of the test section is estimated by following procedure.

The heat transfer rate of nano fluid (hot fluid) was estimated using the following.

$Q_{nf} = m_{Hnf} \times C_{pnf} \times \ (t_1\text{-}t_2)$
$Q_{nf} = 4.115\times10^{-3}\ \ m^3/s$
$Q_{nf} = AV$
Mean velocity
$V= Q_{nf} / (\prod/4)\times d^2$
$= 4.115x10\text{-}^3 / (0.785x4^2)$
$\mathbf{V=3.27x10^{-4}\ m/s}$

The Reynolds number of the nano fluid (hot fluid) was estimated using the following equation
$Re = \rho VD/ \mu = VD/ (nU)$ Where,
nU(dynamic viscosity)
$= 3.27x10^{-4}\ x\ 5/0.921\ x\ 10^{-6}$
Re = 1775.24

The nusselt number of the nano fluid was estimated using the following equation
$Nu = 0.0296\ \ Rex^{0.8}\ \ Pr^{0.33}$
$Nu = 0.0296\ x\ 1775.24^{0.8}\ x\ 5.234^{0.33}$
Nu = 20.31

Finally convective heat transfer coefficient of nanofluid (hot fluid) was estimated by following equation

$Nu = h_{nf}\, d/K$

$h_{nf} = 20.31x0.63965/4$

h_{nf} =3.25 W/m²K

The Friction factor of the nano fluid was estimated using the following equation

$f=(1.58 \ln Re -3.82)^{-2}$

$f=(1.58 \ln 1775.24 -3.82)^{-2}$

f = 0.016

The heat transfer rate of cold water was estimated using the following.

$Q_{nf} = m_{nf}\, Cp_{nf}\ (t_1-t_2)$

Q_{nf} =9.09×10-3 m^{-3}/s

Q_{nf} =AV

Mean velocity

$V=Q_{nf}$ /(∏/4)×d2

$=9.09x10^{-3}/(0.785x80^2)$

V=1.8x10-6 m/s

The Reynolds number of the nanofluid (hot fluid) was estimated using the following equation

$R_e = \rho\ VD/\ \mu$ =VD/ nU

Where, nU(dynamic viscosity)

$= 1.8x10^{-6}$ x $84/0.8315x10^{-6}$

Re=181.84

The nusselt number of the nano fluid was estimated using the following equation

$Nu=0.0296\ Rex^{0.8}\ Pr^{0.33}$

$Nu=0.0296$ x $181.84^{0.8}$ x $3.193^{0.33}$

Nu=2.79

Finally convective heat transfer coefficient of nanofluid (hot fluid) was estimated by following equation

$Nu= h_{nf} d/K$

h_{nf} = 2.78x0.6357/80

h_{nf} =0.022W/m²K

The Friction factor of the nano fluid was estimated using the following equation

$F = (1.58\ l_n\ Re -3.82)^{-2}$

$f=(1.58\ l_n 181.84 -3.82)^{-2}$

f=0.052

The Logarithmic mean temperature difference "LMTD"of the nano fluid was estimated using the following equation

LMTD = (ΔT1-ΔT2)/In(ΔT1/ΔT2)

LMTD = (18-14)/In(18/14)

LMTD = 15.92 ⁰C

10. RESULTS AND ANALYSIS

10.1 Fluid Reynolds number for hot nano fluid and cold water

S .No	Fluid	Reynolds Number	
		Re (Hot nano fluid)	Re (Cold water)
1	Water	1775.24	181.84
2	ZnO Nano fluid	2998.47	207.91
3	CuO Nano fluid	4482.52	232.08

10.2 Fluid Nusselt number for hot nano fluid and cold water

S .No	Fluid	Nusselt Number	
		Nu(Hot nano fluid)	Nu(Cold water)
1	Water	20.31	2.79
2	ZnO Nano fluid	22.57	2.92
3	CuO Nano fluid	24.84	3.53

10.3 Fluid Heat Transfer cofficient for hot nano fluid and cold water

S .No	Fluid	Heat transfer Coefficient(W/m2K)	
		h(Hot nano fluid)	h(Cold water)
1	Water	3.25	0.017
2	ZnO Nano fluid	3.54	0.019
3	Cuo Nano Fluid	4.31	0.023

10.4 Fluid Friction factor for hot nano fluid and cold water

S .No	Fluid	Friction factor	
		f(Hot nano fluid)	f(Cold water)
1	Water	0.016	0.052
2	ZnO Nano fluid	0.013	0.047
3	CuO Nano fluid	0.012	0.044

10.5 Logarithmic mean temperature difference

S. No	Time (min)	LMTD ⁰C		
		Water	ZnO Nanofluid	CuO Nanofluid
1	15	16.26	12.33	14.79
2	30	12.56	15.64	16.73
3	45	13.19	16.09	16.26
4	60	13.61	13.77	14.81
5	75	13.69	17.16	15.32

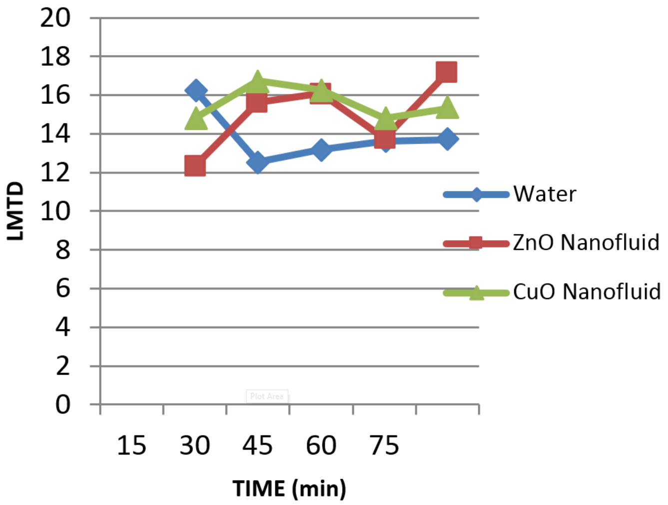


Chart: 7

11 APPLICATION

Experimentally and theoretically Nanofluids have been shown to possess improved heat transport properties and higher energy efficiency in a variety of thermal exchange systems for different industrial applications, such as transportation, electronic cooling, military, nuclear energy, aerospace etc. Nanofluid research could lead to a major impact in developing next generation coolants for numerous engineering and medical applications. The above applications are stated and briefly discussed.

11.1: Heat Transportation The mixture of ethylene glycol and water is almost a universally used vehicle coolant due to its lowered freezing point as well as its elevated boiling point. The thermal conductivity of ethylene glycol is relatively low compared to that of water, while the engine oils are much worse heat transfer fluids than ethylene glycol in thermal transport performance. The addition of nanoparticles and nanotubes to these coolants and lubricants to form nanofluids can the increase their thermal conductivity, and give the potential to improve the heat exchange rates and fuel efficiency. The above improvements can be used to reduce the size of the cooling systems or remove the heat from the vehicle engine exhaust in the same cooling system.. The dispersed CuO & Al2O3 nanoparticles and antifoam agents in the transmission fluid, and then, the transmission fluid was used in real time four wheel automatic transmissions. The results show that CuO nanofluids have the lowest temperature distribution at both high and low rotating speed and accordingly the best heat transfer effect.

11.2: Electronics cooling The power dissipation of IC (Integrated Circuits) and micro electronic components has dramatically increased due to their size reduction. Better thermal management and cooling fluids with improved thermal transport properties are needed for safe operation. Nanofluids have been considered as working fluids in heat pipes for electronic cooling application. Gold nanoparticles with a particle size of 17nm dispersed in water were used as a working fluid in a disk shaped miniature heat pipe. The result shows that the thermal resistance of the disk shaped miniature heat pipe is reduced by nearly 40% when nanofluids are used instead of de-ionized (DI) water. Kang et al [81] measured the temperature distribution and thermal resistance of a conventional grooved circular heat 15 pipe with water based nanofluids containing 1 to 50 ppm of 35nm silver nanoparticles. The result shows that at the same charge volume, the thermal resistance of the heat pipe with nanofluids is reduced by 10% to 80% compared with that of DI water at an input power of 30 to 60 W.

11.3: Military Applications Military hardware both mechanical and electrical devices dissipates a large amount of heat and consequently requires high heat flux cooling fluids having sufficient cooling capacity. Nanofluids have the capability to provide the required cooling capacity in such applications, as well as in other military applications, including submarines and high power laser.

11.4: Medical Application Nanofluids are now being developed for medical applications, including cancer therapy. Iron based nanoparticles can be used as delivery vehicle for drugs or radiation without damaging the neighboring healthy tissues by guiding the particles up the blood stream to the tumor locations with magnets. Nanofluids could be used to produce higher temperatures around tumors, to kill cancerous cells without affecting the nearby healthy cells .Nanofluids could also be used for safer surgery by cooling around the surgical region, thereby enhancing the patient's health and reducing the risk of organ damage.

Nanofluids are currently expensive, partly due to the difficulty in manufacturing them. The development of new synthesis methods is necessary to make nanofluids more affordable before they will see wide-spread applications.

12. CONCLUSION

An experimental analysis was carried out on a nanofluid through counter flow heat exchangers with prepared CuO and ZnO nano particles. Based on the observed results, the following conclusion were drawn. In this study it is found that the energy effectiveness high in CuO compared to ZnO nano particles.

Finally,it was concluded that the better heat transfer coefficient of CuO nano fluid and ZnO nano fluid higher compare to pure water. It could be included that, by using nano fluid the effectiveness of heat exchanger increased.

And also the weight concentration of nano particles in nano fluid also enhance heat transfer characteristics. Higher the nano particle by weight (amount) higher is the heat exchange between them.

13. ACKNOWLEDGEMENT

The project work is not a single handed effort and it is our team, whom we wanted to thank for standing with us under all circumstances. I would also like to express my gratitude towards our Mechanical department and on the whole towards the college for supporting us and believing in us.
Special thanks to our Guide: J P Ramesh

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