International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || Volume 04 - Issue 04 || April 2019 || PP. 01-06

Comparative Analysis of Heat Transfer Characteristics of various Nano – Fluids in Shell & Tube Heat Exchanger

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Abstract: Modern technological progress in the fields of, transportation, medical, electronics and HVAC systems have resulted in a extreme need for a performance enhanced heat transfer system. Heat transfer by means of a flowing fluid is most used and the thermal properties of liquids play a decisive role in heating as well as cooling applications in industrial processes. Thermal conductivity of a liquid is an important physical property that decides its heat transfer performance. Conventional heat transfer fluids have inherently poor thermal conductivity which makes them inadequate for ultra high heat transfer applications.

Nano fluids are a new class of liquids whose properties are controllable by the addition of nano-particles. A great deal of attention has been drawn to their enhanced heat transfer characteristics relative to that of a pure fluid. This paper deals with synthesis of 3 various Nano Fluids and comparing their heat transfer capabilities experimentally using a shell and tube heat exchanger setup and attempt is made to suggest applications for enhanced heat transfer. Al_2O_3 Nano fluid is compared with Nano fluid containing carbon dots derived from Aloe vera and it is been found that carbon. Aloe vera yield more heat transfer.
Keywords: Al_2O_3 Nano particles, Heat Transfer Enhancement, Heat Exchanger, Carbon Dots.

I. INTRODUCTION

In this world of increasing energy demand, exhaustion of fossil fuels and environmental concerns, leads to search of energy saving technologies. Researchers have long been in claiming various heat transfer techniques for fast and more efficient heat transfer. Improvements to make heat transfer equipment more energy efficient would need to focus on enhancement in heat transfer rate by using Heat Transfer Fluids (HTF) such as water, mineral oil and ethylene glycol. However, the poor heat transfer properties of these common fluids are a key obstacle to the high compactness and effectiveness of heat exchangers. The essential initiative is to seek the usage of special solid particles having thermal conductivities several hundreds of times higher than those of conventional fluids.

Nano fluid is envisioned to describe a fluid in which nanometer-sized particles are suspended in conventional heat transfer basic fluids. Since the solid nano particles with typical length scales of 1–100 nm with high thermal conductivity are suspended in the base fluid (low thermal conductivity), have been shown to enhance effective thermal conductivity and the convective heat transfer coefficient of the base fluid. [1] Several published literature have mainly focused on the prediction and measurement techniques in order to evaluate the thermal conductivity of nano fluids. Many known nano fluids used for industrial purposes include metallic or non metallic nano particles such as Al2O3, CuO, Cu, SiO, TiO etc.

This paper concentrates on synthesis of a new variety of nano particle namely; carbon dots derived from Aloe Vera and compare its thermal properties with known nano fluids using a shell and tube heat exchanger. Thermal properties such as overall heat transfer coefficient, Heat Transfer Rate and Efficiency Improvement are determined and compared.

II. LITERATURE SURVEY

The use of particles of nanometer dimension was first continuously studied by a research group at the Argonne National Laboratory few decade ago. Researcher ***Choi.U.S (1995)*** was probably the first one who called the fluids with particles of nanometer dimensions ‘nano-fluids’. Compared with suspended particles of millimeter-or-micrometer dimensions, nano fluids show better stability and rheological properties, dramatically higher thermal conductivities. [2]

Yimin Xuan and Qiang Li (1999), presented a procedure for preparing a nano fluid which was a suspension consisting of nano phase powders and a base liquid. The hot-wire apparatus was used to measure the thermal conductivity of nano fluids with suspended copper nano-phase powders. Some factors such as the volume fraction, dimensions, shapes and properties of the nano particles were discussed. [3]

C.T.Nguyen et.al (2008) carried out an experimental investigation studying the heat transfer performance of the water-Al_2O_3 (36nm particle size) nano fluid inside a liquid evacuated impinging jet system destined to the cooling of high-power electronic components. It was found that the use of a nano fluid can provide a heat transfer enhancement of as much as 72% when compared to water. Results from erosion tests have shown that nano fluids have the potential to cause premature wear of mechanical components due to erosion. [4]

Weerapun Daungthongsuk and Somchai Wongwises (2007) had published articles for determining thermal conductivity of nano fluids using both experimental approach and mathematical approach. They have listed out many formulae for calculating Nusselt number and heat transfer coefficient. They have quoted ***Xuan et al.*** who had proposed the thermal Lattice Boltzmann model to display the flow features and heat transfer process of Cu–water nanofluid flowing inside a channel. The important advantage of this method was that it took the molecular dynamics into account and bridged the gap of microscopic or macroscopic phenomena of the nanofluids. [5]

R.Velraj et.al (2012) had summarized a brief overview to address the unique features of nanofluids, such as their preparation, heat transfer mechanisms, conduction and convection heat transfer enhancement etc. They have concluded their experimental and theoretical work on pool boiling and applications of nanofluids. [6]

M.Karnan et.al (2016) had done initial research in Aloe vera Derived Activated High-Surface-Area Carbon nano particles. But they have proposed use of aloe vera derived carbon for electrical applications such as super capacitors. [7]

III. SYNTHESIS OF NANO FLUIDS

a. Synthesis of Al_2O_3 Nano Fluid:

In this experiment, Aluminum nitrate nonahydrate ($Al(NO_3)_3.9H_2O$) and Urea ($CO(NH_2)_2$) were used as starting precursor and fuels. 3.75g of $Al(NO_3)_3.9H_2O$ was added into 100 ml of distilled water and dissolve to prepare homogeneous solution using magnetic stirrer. Then, 1.25 g of urea was added to this solution under ultrasonication. After that, the mixture was heated to 80°C and kept at this temperature for 30 min to allow dissolution of the precipitate. The prepared solution was then transferred into a 100 ml Teflon-lined stainless autoclave, sealed and maintained at 150°C for 2 h in an oven. After the reaction, the autoclave was cooled down naturally to room temperature. The obtained product was collected through centrifugation, washed several times with ultra-pure water and ethanol and finally dried in a vacuum oven at 150°C for 24 h.

b. Synthesis of Carbon dots from Aloe Vera:

Carbon dots were synthesized using locally available natural sources i.e., Aloe Vera by hydrothermal treatment in a single step. In a typical synthesis, 5gm. of Aloe Vera was added to 100 ml of Millipore water. Then the mixture was transferred into a 100 ml Teflon lined autoclave and heated at 260 °C for 3 hours. Then carbon dots were collected by removing large particles through centrifugation at 15000 rpm for 20 minutes. Then the supernatant was filtered through 0.2 µm filter to remove any micron sized particles. Water dispersed CQDs were used for further characterizations.

IV. SEM ANALYSIS OF SYNTHESIZED C- DOT FROM ALOE VERA

Scanning Electron Microscope (SEM) analysis was carried out to determine the actual size and shape of the prepared Carbon Dots (CDs). The SEM image clearly shows that the synthesized CDs are well spread in water with a spherical shape and fine size distribution of about 30 nm in diameter shown in figure below

SEM measurements also revealed that the shape of the CDs is spherical in nature and the diameters are between 5-9 nm as shown in figure. The formation of C-dots is clearly confirmed by the appearance of spherical and agglomerated formations.

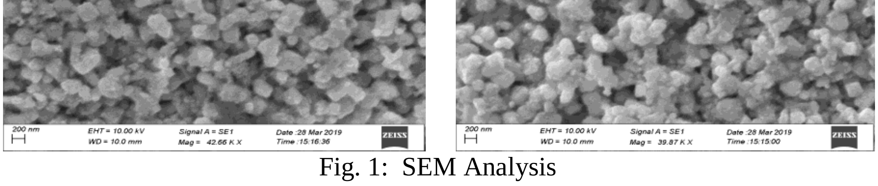

Fig. 1: SEM Analysis

V. EXPERIMENTAL SETUP

a. **Shell and Tube Heat Exchanger:** Outer shell of the heat exchanger is made from galvanized iron sheet of 18gauge thickness for a size of 15cm x 15cm x 22cm.The capacity of shell is 5 litre.
b. **Copper Coil:** The tube part of heat exchanger is copper coil which is rolled from 6mm diameter copper tube of pitch circle diameter 9cm containing 9 turns. The total length of the copper coil is 3.5m. This is placed in the above mentioned shell

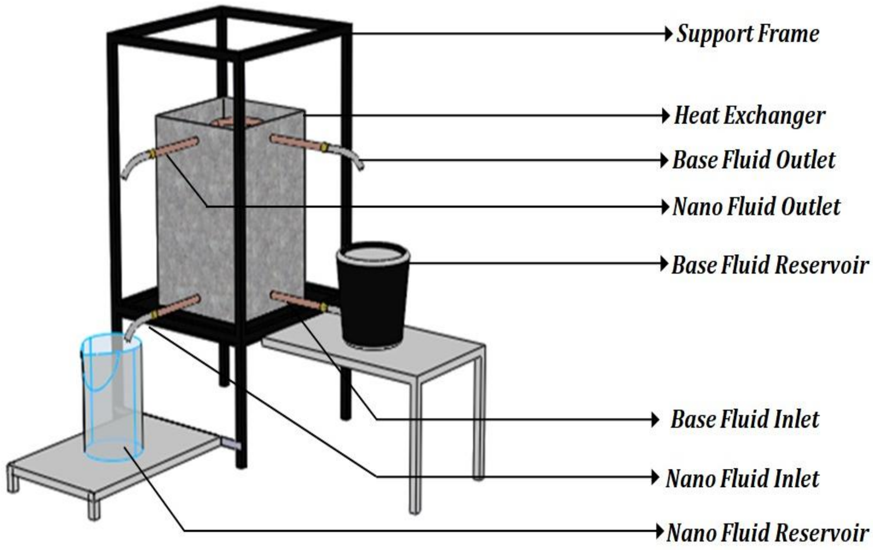

Fig. 2: Experimental Setup

c. **Insulating Rope**: The heat exchanger is insulated by using 6mm diameter asbestos fabric rope to minimize the heat loss to the atmosphere.
d. **Base Fluid Reservoir:** A tank of 8 litre capacity is placed on the stove. This vessel is used for storing water which is the base fluid.
e. **Measuring Beaker**: A cylindrical glass beaker measuring 750ml capacity is used for storing heat transfer fluid up to 500ml mark.
f. **Circulation Pump:** Electrical circulation pump of 220v and 5Hz of maximum capacity of 40lit/hr is used and a 12v DC circulation pump is used for supplying base fluid to the shell.
g. **Supporting Frame:** Supporting frame is fabricated using mild steel L angle to support the heat exchanger, base fluid and heat transfer fluid reservoir. L angle is joined using arc welding method.
h. **Accessories:** Hot water hose of 8mm diameter is used for required length. This can withstand temperature of 150^0 C. Threaded brass nipples connected to the copper coil using flare nut.

VI. EXPERIMENTAL PROCEDURE

Base fluid (water) is taken in room temperature and filled in base fluid reservoir of 8 litre capacity. This reservoir is placed over the stove and water is heated up to 90°C − 95°C. The heated water is made to fill inside the shell of the heat exchanger by the circulation pump. Once the water is filled inside the shell, the heat transfer fluid is circulated through the copper coil. The flow rate of base fluid and heat transfer fluid is measured. Inlet and outlet temperature of both fluids are measured using digital temperature and noted. The procedure is repeated and readings are tabulated until steady state condition is reached. The same procedure is repeated by changing heat transfer fluid such as Al_2O_3 Nano Fluid and Carbon Dots derived from Aloe Vera.

S. NO	BASE FLUID	HEAT TRNSFER FLUID
1	Water	Water
2	Water	Al_2O_3 – Water (3.00 gm/Litre)
3	Water	Al_2O_3 – Water (1.50 gm/Litre)
4	Water	Carbon. Aloe Vera (50.0 gm/1Litre)

Table 1: Nano Fluids Used

VII. EXPERIMENTAL READINGS

S. NO	Fluid Details		Base Fluid Temperature		HTF Temperature	
	Base Fluid	HTF	Inlet Temp	Outlet Temp	Inlet Temp	Outlet Temp
			T_{hi} (°C)	T_{ho} (°C)	T_{ci} (°C)	T_{co} (°C)
1	Water	Water	94	72	32	36
2	Water	Al_2O_3 – Water (3.00 gm/Litre)	95	87	39	72
3	Water	Al_2O_3 – Water (1.50 gm/Litre)	92	83	34	70
4	Water	Carbon Dots	93	83	34	78

VIII. NUMERICAL ANALYSIS

To calculate physical properties of nanofluids, we use formulas which are available in the literature as follows:

$$\rho_{nf} = (1-\varphi)\rho_f + \varphi.\rho_{np}$$

Where ,

ρ_{nf} – Density of Nanofluid
ρ_f – Density of Base fluid
ρ_{np} – Density of Nano Particles
φ – Volume Fraction

$$C_{pnf} = \frac{(1-\varphi)(\rho c_p)_f + \varphi(\rho c_p)_{np}}{\rho_{nf}}$$

Where ,

C_{pnf} – Specific Heat of nanofluid
C_{pf} – Specific Heat of Base fluid
C_{pnp} – Specific Heat of Nano Particles [8]

Following LMTD method for Shell and Tube Heat Exchanger, LMTD, Heat Transfer Rate, Overall Heat Transfer Coefficient and Exchanger Efficiency is calculated using formulae given below and results are tabulated.

$$LMTD, \Delta T_m = \frac{\Delta T_i - \Delta T_o}{ln\, {}^{\Delta T_i}/_{\Delta T_o}}$$

Where,

ΔT_i – Inlet Temperature Difference
ΔT_o – Outlet Temperature Difference

$$Heat\ Transfer, Q = m_{nf}\ .c_{pnf}\ .[T_{co} - T_{ci}]$$

Where,

m_{nf} – Mass Flow Rate of Nano Fluid
C_{pnf} – Specific Heat of nanofluid

$$Overall\ Heat\ Transfer\ Coefficent, \mathrm{U} = \frac{Q}{A\Delta T_m}$$

Where,

A – Surface Area of Copper Coil

IX. RESULTS

S. NO	FLUID DETAILS		LMTD	HEAT TRANSFER RATE	OVERALL HEAT TRANSFER COEFFICIENT	EFFICIENCY
	BASE FLUID	HTF	ΔT_m (°C)	Q (J/kg)	U (J/kg°C)	η (%)
1	Water	Water	38.99	2894.54	844.35	38.70
2	Water	Al_2O_3 – Water (3.00 gm/Litre)	31.12	4499.22	1644.18	58.92
3	Water	Al_2O_3 – Water (1.50 gm/Litre)	30.09	4760.21	1799.13	62.02
4	Water	Carbon Dots	21.88	7690.08	3997.72	74.57

X. CONCLUSION

After thorough experimental investigation and comparison we find that Nano fluid prepared from Carbon Dots derived from Aloe-Vera improve the heat transfer rate and efficiency of the system. Aluminium oxide nano-particles of 1.5g/lit absorbs more heat than 3g/lit because surface area to volume ratio is more in the first case. This is proves that, the volume fraction, shape, dimensions and properties of the nano particles affect the thermal conductivity of nano fluids.

Nanofluids have great potentials to improve automotive and heavy-duty engine cooling rates by increasing the efficiency, lowering the weight and reducing the complexity of thermal management systems. The application of nanofluids in industrial cooling will result in great energy savings and emissions reductions. Additionally, these nano fluids can be used as coolant for the emergency core cooling systems (ECCSs) of both PWRs and boiling water nuclear reactors.

We propose that, Aluminium oxide Nano-fluids can be used for heat transfer application such as boilers and waste heat recovery. Carbon Dots from Aloe Vera can be used for electronics equipments cooling, HVAC application and in nuclear reactors. Carbon dots are superior in the sense that, since it is extracted from natural plant source, this is eco-friendly by providing least concern in environmental hazards.

XI. ACKNOWLEDGEMENT

The authors feel extremely grateful and wish to acknowledge the works of Dr.V.Renuga, Professor, Department of Chemistry, National College, Trichy and Mr.C.Neela Mohan, Research Scholar, Department of Chemistry, National College, Trichy, for their support and guidance in the field of Nanofluids and also for helping in synthesis of nano fluids used in this research.

XII. REFERENCES

[1]. Sadik Kakac, Anchasa Pramuanjaroenkij, "Review of Convection Heat Transfer Enhancement with Nano-fluids", International Journal of Heat and Mass Transfer, March (2009), Page no: 3187 − 3196
[2]. Choi U.S, "Enhancing Thermal Conductivity of Fluids with Nano particles." ASME FED (1995), Page No : 99 –103.
[3]. Yimin Xuan, Qiang Li, "Heat Transfer Enhancement of Nano-fluids", International Journal of Heat and Fluids flow, September (1999), Page No: 58 − 64.
[4]. C.T.Nguyen, G.Laplante, M.Cury, G.Simon, "Experimental Investigation of Impinging Jet Heat Transfer and Erosion Effect Using Al_2O_3-Water Nano-fluid", IASME International Conference on Fluid Mechanics and Aerodynamics, August 20−22 (2008).
[5]. Weerapan Daughongouk, Somchai Wongunises, "A Critical Review of Convection Heat Transfer of Nano-fluids", Elsevier – Renewable and Sustainable Energy Reviews, June (2005), Page No: 797 − 817.
[6]. Velraj Ramalingam, Shanthi.R ,Shamuga Sundaram Anandan , "Heat Transfer Enhancement Using Nano-fluids an Overview", International Journal of Thermal Science, 2012,Volume 16, Page No: 423 − 444.
[7]. M. Karnan, K. Subramani, N. Sudhan, N. Ilayaraja, and M. Sathish, "Aloe vera Derived Activated High-Surface-Area Carbon for Flexible and High-Energy Super-capacitors", ACS Applied Materials and Interfaces, November (2016), Page No: 35191 − 35202.

[8]. Hadighe Ashouri, Abbas Ghasemizad, "Numerical Simulation of Heat Transfer Improvement in the Diverted of Fusion Reactor by Using Al_2o_3 Nano-Fluids", Journal of Theoretical and Applied Physics, Volume 16 December (2018)

[9]. Samy Joseph Palm, Gilles Roy, Cong Tam Nguyen, "Heat Transfer Enhancement with the Use of Nano-Fluids in Radial Flow Cooling System Considering Temperature-Dependent properties". Elsevier – Applied Thermal Engineering, March (2006), Page No: 2209 − 2218

[10]. Wei Yu, and Huaqing, Xie, "A Review on Nano-fluids Preparations Stability Mechanism and Application, Journal of Nano Materials, July (2011), Volume 2012, Page No: 1 − 17.