Journal of Manufacturing Engineering, September 2023, Vol. 18, Issue. 3, pp 100-103

EFFICIENCY ENHANCEMENT OF HEAT TRANSFER FLUIDS BY USING CARBON DOTS NANOPARTICLES DERIVED FROM ALOE VERA

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ABSTRACT

Modern technological progress in transportation, medical, electronics and HVAC systems has resulted in an extreme need for a performance-enhanced heat transfer system. Heat transfer employing a flowing fluid is most used, and the thermal properties of liquids play a decisive role in heating and cooling applications in industrial processes. The 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, making them inadequate for ultra-high heat transfer applications. Nanofluids are a new class of liquids whose properties are controllable by adding nanoparticles. A great deal of attention has been drawn to their enhanced heat transfer characteristics relative to that of pure fluid. This paper synthesizes three various Nano Fluids and experimentally compares their heat transfer capabilities using a shell and tube heat exchanger setup. An attempt is made to suggest applications for enhanced heat transfer. Al2O3 Nanofluid is compared with Nanofluid containing carbon dots derived from Aloe vera, and it has been found that carbon. Aloe vera yields more heat transfer.

Keywords: *Nanoparticles, Heat Transfer Enhancement, Heat Exchanger, Carbon Dots.*

1. Introduction

In this world of increasing energy demand, exhaustion of fossil fuels and environmental concerns leads to the search for energy-saving technologies. Researchers have long claimed 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, these common fluids' poor heat transfer properties are a crucial obstacle to heat exchangers' high compactness and effectiveness. The essential initiative is to seek the usage of particular solid particles with several hundred times higher thermal conductivity than conventional fluids. Nanofluid is envisioned to describe a fluid in which nanometer-sized particles are suspended in conventional heat transfer basic fluids. Since the solid nanoparticles with typical length scales of 1–100 nm with high thermal conductivity are suspended in the base fluid (low thermal conductivity), they have been shown to enhance the 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 to evaluate the thermal conductivity of nanofluids. Many known nanofluids used for industrial purposes include metallic or non-metallic nanoparticles such as Al2O3, CuO, Cu, SiO and TiO. This paper synthesizes a new variety of nanoparticles, namely carbon dots derived from Aloe Vera, and compares its thermal properties with known nanofluids using a coil heat exchanger. Thermal properties such as overall heat transfer coefficient, Heat Transfer Rate and Efficiency Improvement are determined and compared.

The use of particles of nanometer dimension was first continuously studied by a research group at the Argonne National Laboratory a few decades ago. Researcher Choi (1995) was probably the first one who called the fluids with particles of nanometer dimensions 'nanofluids'. Compared with suspended particles of millimeter-or-micrometer dimensions, nanofluids 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.

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Some factors, such as the volume fraction, dimensions, shapes and properties of the nanoparticles, were discussed. [3]

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

Weerapun Daungthongsuk and Somchai Wongwises (2007) determined nanofluids' thermal conductivity using both experimental and mathematical approaches. They have listed out many formulae for calculating the Nusselt number and heat transfer coefficient. They have quoted Xuan et al. 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) 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]. Karnan et al. (2016) did initial research in Aloe vera Derived Activated High-Surface-Area Carbon nanoparticles. Nevertheless, they have proposed the use of aloe vera derived carbon for electrical applications such as supercapacitors [7].

2. Experimental Details

2.1 Synthesis of Al_2O_3 Nano Fluid:

In this experiment, Aluminum nitrate nanohydrate ($Al(NO_3)_3.9H_2O$) and Urea ($CO(NH_2)_2$) were used as starting precursors and fuels. 3.75g of $Al(NO_3)_3.9H_2O$ was added into 100 ml of distilled water and dissolved to prepare a homogeneous solution using a 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 the 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 two hours 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.

2.2 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. A typical synthesis added 5gm. of Aloe Vera 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 a 0.2 µm filter to remove micron-sized particles. Water-dispersed CQDs were used for further characterization.

2.3 SEM Analysis of Synthesized C- Dot From Aloe Vera

Scanning Electron Microscope (SEM) analysis was carried out to determine the prepared Carbon Dots (CDs) size and shape. 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 1. SEM measurements also revealed that the shape of the CDs is spherical, and the diameters are between 5-9 nm, as shown in the figure. The appearance of spherical and agglomerated formations confirms the formation of C-dots.

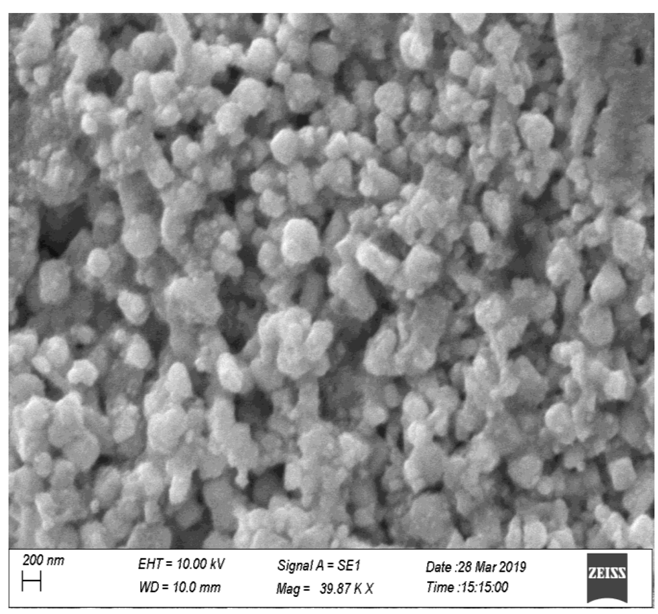

Fig. 1 SEM Analysis of Carbon Dots.

The experimental setup is assembled as presented in Fig. 2 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 the base fluid and heat transfer fluid is measured. Both fluids' inlet and outlet temperatures are measured using digital temperature and noted. The procedure is repeated, and readings are tabulated until a 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.

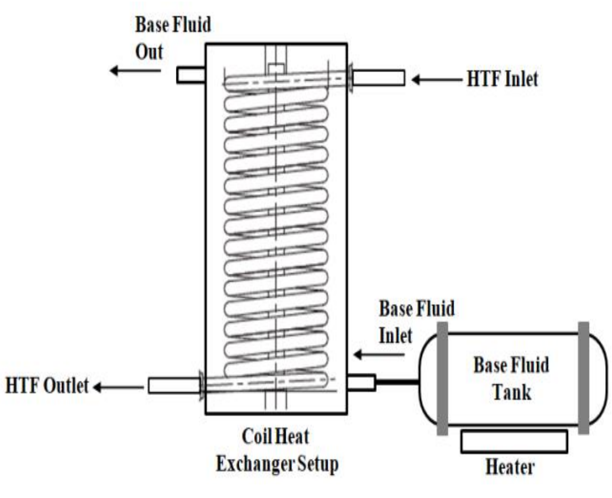

Fig. 2 Experimental Setup

Table 1 Nano Fluids Used

S. No	Base Fluid	Heat Transfer Fluid
1	Water	Water
2	Water	Al_2O_3 – Water (1.50 gm/Litre)
3	Water	Carbon. Aloe Vera (50.0 gm/1Litre)

Table 2 Temperature Readings

Fluid Details		Base Fluid Temperature		HTF Temperature	
Base Fluid	HTF	Inlet Temp	Outlet Temp	Inlet Temp	Outlet Temp
Water	Water	94°C	72°C	32°C	36°C
Water	Al_2O_3 – Water	92°C	83°C	34°C	70°C
Water	Carbon Dots	93°C	83°C	34°C	78°C

To calculate the 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 the LMTD method for Shell and Tube Heat Exchanger, LMTD, Heat Transfer Rate, Overall Heat Transfer Coefficient and Exchanger Efficiency is calculated using the formulae below and the results 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

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

Where,

A − Surface Area of Copper Coil

3. Results and Discussions

After thorough experimental investigation and comparison, we find that Nano fluid prepared from Carbon Dots derived from Aloe-Vera improves the system's heat transfer rate and efficiency. However, Aluminium oxide nanoparticles of 1.5g/lit absorb more heat than 3g/lit because the surface area to volume ratio is higher in the first case. It proves that the volume fraction, shape, dimensions and properties of the nanoparticles affect the thermal conductivity of nanofluids.

Table 3 Experimental Findings

Fluid Details		LMTD	Heat Transfer Rate	Overall Heat Transfer Coefficient	Efficiency
Base Fluid	**HTF**	**ΔT_m (°C)**	**Q (J/kg)**	**U (J/kg°C)**	**H (%)**
Water	Water	38.99	2894.54	844.35	38.70
Water	Al_2O_3 – Water	30.09	4760.21	1799.13	62.02
Water	Carbon Dots	21.88	7690.08	3997.72	74.57

4. Conclusion

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

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

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