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# EXPERIMENTAL INVESTIGATION ON THE HEAT TRANSFER PERFORMANCE OF IRON OXIDE AND SILICON CARBIDE NANOFLUIDS

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***ABSTRACT –***

Increase in the heat transfer performance of traditional base fluids is obtained by adopting one of the passive heat transfer enhancement techniques, by adding additives to the base fluid. These fluids are commonly known as nanofluids which are obtained by suspension of nano-meter-sized solid particles in the base fluid. Hybrid nanofluids are the one which enhances the performance of base fluid better than the single component nanofluid due to the suspension of more than one type of nanoparticles in the base fluid. In the present investigation the heat transfer performance of iron oxide ($Fe_3O_4$) and Silicon Carbide(SiC) nanofluid suspended in 40:60 volume ratio of Ethylene Glycol and Water mixture, is determined at an operating temperature of 45°C. Experimental investigation of the thermophysical properties are performed, and the heat transfer performance of the nanofluids is determined under turbulent conditions using a Double Pipe Heat Exchanger (DPHE) with U-bend. Experiments are carried out in a turbulent regime for the nanoparticle volume concentrations ranging from 0.02% to 0.08% for flow rates ranging from 6 to 14 lpm. Results indicate that the SiC nanofluid exhibited better thermo-physical properties and heat transfer characteristics when compared with $Fe_3O_4$ nanofluids.

**KEYWORDS:** nanofluid, thermophysical properties, heat transfer enhancement, volume concentration

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## 1. INTRODUCTION

The major challenge in the field of heat transfer is to enhance the performance of heat transfer fluids. Enhancement of the heat transfer performance can be achieved either by active or passive techniques. Active techniques include variation in the geometrical design, increasing the flow rate which in turn increases the pumping power whereas the passive techniques include insertion of twisted tapes or suspension of nanometre-sized solid particles to the base fluid also called nanofluids coined by Choi [1]. Vasu et al. [2, 3] conducted analytical research to develop correlations for the thermophysical properties and Nusselt number of water-based $Al_2O_3$, Cu, CuO and $TiO_2$ nanofluids. Researchers have conducted studies to determine the effect of base fluids like Glycerol-water [4], Propylene glycol-water [5-7] on the heat transfer performance of different nanofluids. To improve the heat transfer enhancement most of the researchers have conducted a study on the improvement in the design of heat exchangers [8-10]. Experiments were conducted by many researchers [11-15] using SiC nanoparticles in different base fluids which include water EG and mixtures of EG and water in various proportions. in all their experimentations SiC nanofluids exhibited better heat transfer characteristics than the base fluid. The literature available [16-19] on the heat transfer performance of $Fe_3O_4$ nanofluids also suggests that its heat transfer performance is also better than the base fluid. But based on the literature survey it was understood that very limited research is available on $Fe_3O_4$ & SiC nanofluids with EG-Water as base fluid at a low volume concentration (below 0.1%). Hence in the present study, the thermo-physical properties and the heat transfer performance of $Fe_3O_4$ & SiC nanofluids are experimentally determined at low volume concertation of 0.02, 0.04, 0.06 and 0.08%.

## 2. PREPARATION OF HYBRID NANOFLUIDS:

$Fe_3O_4$ and SiC nanoparticles of 30nm and 50nm size respectively are procured from Nano Amor, Texas, USA. The nanofluids are prepared using a two-step method which includes suspension of nanoparticles in the base fluid and preparing a stable solution using the sonication process. To obtain the stability of the nanofluid a pH value of 7 is maintained. The mass of nanoparticles to be suspended in the base fluid for the particle concentration considered in the analysis is calculated using Eq.1.

ISSN PRINT 2319 1775 Online 2320 7876

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$$\phi = \frac{\frac{m_{np}}{\rho_{np}}}{\left(\frac{m_{np}}{\rho_{np}} + \frac{m_{bf}}{\rho_{bf}}\right)} \times 100 \quad (1)$$

The prepared nanofluids are stirred continuously for 24 to 36 hrs to attain stability. The nanofluids were stable for more than 60 hours after sonication. The stability of $Fe_3O_4$ and SiC nanofluids is measured using Zeta Potential. All the nanofluids considered for the analysis exhibited the Zeta potential values greater than ±30mV indicating better stability of the nanoparticles in the colloidal solution.

The thermophysical properties of the nanofluids are determined experimentally and the accuracy and range of the instruments used are given in Table 1.

**Table 1**. Range and Accuracies of Instruments used for measuring thermo-physical properties

| **Parameter** | **Instrument** | **Range** | **Accuracy** |
|---|---|---|---|
| Density | Anton Paar | 0.0011 to 0.9999g/cm$^3$ | ±0.001% |
| Specific heat | Mittal heat capacity apparatus | 0.5 to 4 MJ/m$^3$°C | ±0.005% |
| Viscosity | DV2T Brookfield Viscometer | 0.2 to 3000cp | ±0.1%. |
| Thermal Conductivity | Tempos thermal property analyzer | 0.2 to 2 W/mK | ±10% |

Due to the uncertainty in the measured values, there will be an uncertainty in the calculated values of Reynolds number, heat transfer coefficient and friction factor which are determined using the method adopted by Azmi et al.[20]. The maximum uncertainty percentages obtained for Reynolds number, heat transfer coefficient and friction factor are 0.22%, 0.89% and 0.52% respectively. The heat transfer performance of $Fe_3O_4$ and SiC nanofluids is experimentally investigated using a counter flow double pipe heat exchanger with U-bend. A detailed description of the experimental setup and the data analysis is presented in Kanthimathi et al.[21].

ISSN PRINT 2319 1775 Online 2320 7876

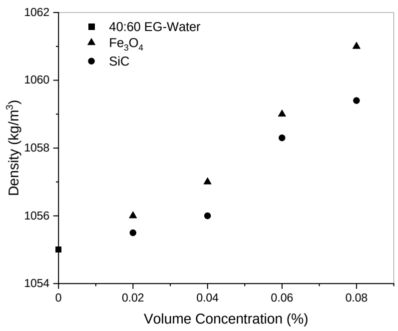
Research paper  UGC CARE Listed (Group -I) Journal Volume 8, Issue 2, 2019

## 3. RESULTS AND DISCUSSION

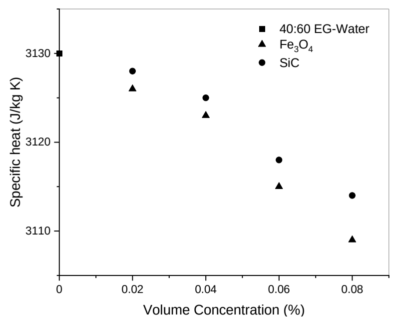
### 3.1 Thermo-Physical Properties:

The density of $Fe_3O_4$ and SiC nanofluids with 40:60 EG-Water as base fluid is represented in Figure 1(a). The enhancement in the density of $Fe_3O_4$ nanofluids is ranging from 1.44% to 2.11% and that of SiC nanofluids ranging from 1.24% to 2.05%.

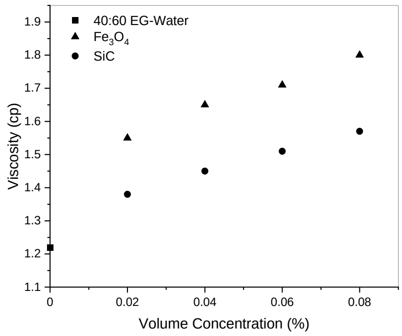
Specific heat of 40:60 EG-Water based $Fe_3O_4$ and SiC nanofluids decreased with increasing volume concentration and the percentage decrease for $Fe_3O_4$ nanofluids is ranging from 0.12 to 0.67% whereas SiC nanofluids are ranging from 0.06 to 0.51% as shown in Figure 1(b).



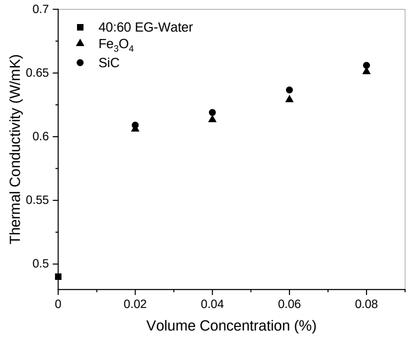

(a) Density




(b) Specific Heat




(c) Viscosity




(d) Thermal Conductivity

Figure 1. Thermo-Physical Properties of 40:60 EG-Water based $Fe_3O_4$ and SiC nanofluids

Viscosity and thermal conductivity of $Fe_3O_4$ and SiC nanofluids with 40:60 EG-Water as base fluid increased with the increase in volume concentration. The enhancement in the viscosity of $Fe_3O_4$ nanofluids is varied from 27.04 to 47.54% and that of SiC nanofluids ranging from 13.11 to 28.68% as shown in Figure 1(c). The enhancement in the thermal conductivity of $Fe_3O_4$

ISSN PRINT 2319 1775 Online 2320 7876

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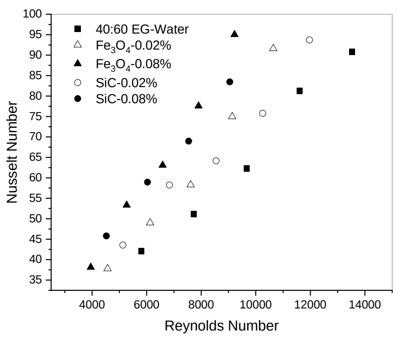
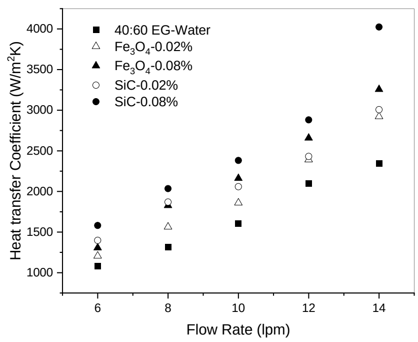
nanofluids varies from 23.67 to 32.85% and that of SiC nanofluids varies from 24.28 to 33.87% Figure 1(d).

### 3.2 Heat transfer performance:

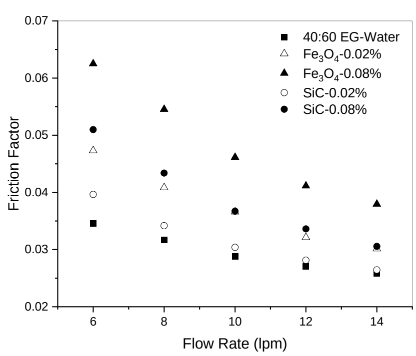
The Nusselt number of the $Fe_3O_4$ and SiC nanofluids increased with the increase in volume concentration and flow rate, but the comparison of Nusselt number with Reynolds number does not give a clear indication on the heat transfer performance of the nanofluids, because Reynolds number decreases with the increase in viscosity Figure 2(a). Hence the heat transfer coefficient of the nanofluids considered is compared with the flow rate of the nanofluid as shown in Figure 2(b). Heat transfer coefficient of the nanofluids increased with the increase of volume concentration and flow rate. The average enhancement in the heat transfer coefficient of $Fe_3O_4$/40:60 EG-Water varied from 17.96% to 25.28% and that of SiC/40:60 EG-Water varied from 28.26% to 54.58% as the volume concentration varied from 0.02 to 0.08%.



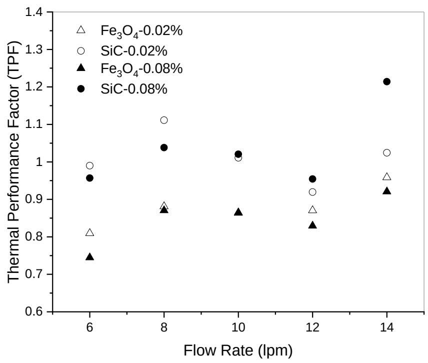

(a) Nusselt Number of nanofluids




(b) Heat Transfer Coefficient of Nanofluids




(c) Friction Factor of Nanofluids




(d) Thermal performance Factor

Figure 2. Heat Transfer performance of 40:60 EG-Water Based $Fe_3O_4$ and SiC Nanofluids

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The friction factor of the nanofluids considered in the analysis increase with the increase in volume concentration and decreased with the increase in flow rate of the nanofluid as shown in Figure 2(c). $Fe_3O_4$ nanofluids exhibited the highest enhancement in friction factor with an average percentage increase of 62.47% at 0.08% volume concentration. An increase in the heat transfer coefficient and friction factor is observed for both the nanofluids considered. Hence the thermal performance factor(TPF) is determined and is represented in Figure 2(d). It was observed that the TPF of SiC nanofluids is more than 1 at almost all flow rates and volume concentrations. Since SiC nanofluids have exhibited higher TPF values they are considered to be more suitable heat transfer fluids when compared to $Fe_3O_4$ nanofluids.

## 4. Conclusions:

The thermo-hydraulic performance of 40:60 EG-Water based $Fe_3O_4$ and SiC nanofluids is determined experimentally for the low volume concentrations ranging from 0.02 to 0.08% for the nanofluids flow rates of 6 to 14 lpm at an operating temperature of 45°C. SiC nanofluids have exhibited better thermophysical properties when compared with $Fe_3O_4$ nanofluids. Also, SiC nanofluids exhibited better heat transfer performance characteristics compared to $Fe_3O_4$ nanofluids with a maximum heat transfer enhancement of 71.8% at 0.085 volume concentration and 14 lpm flow rate when compared with the base fluid.

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