ENHANCEMENT OF HEAT TRANSFER COEFFICIENT IN A U-BEND DOUBLE PIPE COUNTER FLOW HEAT EXCHANGER USING EG-WATER BASED SIC NANOPARTICLES IN COMPARISON WITH SIC+FE3O4 HYBRID NANOFLUID .

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Abstract

One of the passive techniques, to enhance the heat transfer is by using nanofluids. A nanofluid is a fluid containing nano meter-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nano particles in a base fluid. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nanotubes. Hybrid nanoparticles are a different class of nanoparticles prepared by mixing of two or more different types of nanoparticles in the base fluid. In this work, heat transfer enhancement of Double Pipe Heat Exchanger with U bend is experimentally analysed using SiC and SiC-Fe3O4 Hybrid nanofluid considering 30:70 Ethylene Glycol (EG) Water mixture as base fluid, varying the volume concentration from 0.01% to 0.08%. The thermo physical properties of nanofluids are experimentally determined. The experiments are performed at an operating temperature of 450C at different flow rates varying from 6 lpm to 14 lpm. The comparative study of enhancement of heat transfer, increase in pressure drop and overall thermal performance is evaluated. The results show that for both nanofluids, the heat transfer coefficient and pressure drop increase with the increase of volume concentration and with the increase of Re. However, SiCnanofluid and Hybrid nanofluid exhibit almost same thermal performance.

Key Words: Counterflow heat exchanger, Hybrid nanofluid, Heat transfer coefficient

Introduction:A heat exchanger is a device used to transfer heat between two or more fluids due to temperature difference between those fluids. The main function of the heat exchanger is either to remove heat from a hot fluid or add heat to a cold fluid. Thermal properties of fluid play a significant role in exchanging heat. The heat transfer enhancement is very important to achieve significant energy and cost savings. Heat transfer enhancement techniques are commonly used in areas such as process industries, heating and cooling in evaporators, thermal power plants, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles, etc.

Different types of heat transfer enhancement techniques are as follows:

Passive techniques

These techniques generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. They promote higher heat transfer coefficients by disturbing or altering the existing flow behavior which leads to increase in the pressure drop and effective heat transfer area in case of extended surfaces. Heat transfer augmentation by this technique can be achieved by using:

- Different types of inserts
- Rough surfaces

- Extended surfaces
- Coiled tubes
- Additives for fluids
- Swirl flow devices

Active techniques : These are more complex from the use and design point of view as the method requires some external power input to cause the desired flow modification and improvement in the rate of heat transfer.

- Mechanical aids
- Surface vibration
- Electrostatic fields
- Fluid vibration
- Injection
- Suction

Compound techniques: A compound augmentation technique is the one where more than one of the above-mentioned techniques is used in combination with the purpose of further improving the thermo-hydraulic performance of a heat exchanger. Conventional fluids such as Water, Engine oil and Ethylene Glycol are normally used as heat transfer fluids. Conventional fluids have lower heat transfer performance; as a result it effects the performance enhancement and compactness of the heat exchangers. Since, a solid metal has more thermal conductivity than a base fluid, suspending metallic solid fine particles into the base fluid is expected to improve the thermal conductivity. The recent advancement in material technology has made possible to improve heat transfer by suspending Nano-sized articles in base fluids.

A nanofluid is engineered by dispersing metallic or non-metallic Nano powders with a typical size less than 100 nm in the base fluid such as water, oil and ethylene glycol. Nano particles have much larger relative surface area and a high potential for heat transfer enhancement when compared with micro-sized particles.

The main reasons for dispersing Nano particles in the base fluids are listed as follows:

- Increases the effective thermal conductivity of the base fluid.
- Increases the surface area and heat capacity of the base fluid.
- The interaction and collision among particles, fluid and the flow passage surface are intensified.
- The mixing fluctuation and turbulence of the fluid are intensified.
- The dispersion of nanoparticles flattens the transverse temperature gradient of the fluid.

Methods of Nanofluidpreparation:Nano particles with an average size of ≤ 50nm have been used to prepare the nanofluid with EG-Water as the base fluid. One of is the difficulty of uniform dispersion in the base fluid and the sedimentation of Nano particles with time. Presently three methods are available for nanofluid preparation.

Method 1:Nanofluid is prepared by direct mixing of the Nano particles to the fluid (water) and stirred for certain duration. This procedure of preparation is not stable and has sedimentation of Nano particles which can be observed after one hour so we add surfactance or by changing the fluid nature by adding acid or base fluid to nanofluid

Method 2: By changing the pH of nanofluid.All our Nanofluids having pH of around 8, pH 7 above fluids called as bases. So we are adding strong acid (H_2SO_4) drop by drop to maintain ph around 7.H_2SO_4 is added to Nanofluid and pH altered from 7.8 to around 7. Then the mixture is stable for a considerable duration of time (more than 5 hours) however, the Nanofluid may cause corrosion of the test section while in operation.

Method 3: Use of surfactants to the base liquid.Addition of small quantities of surfactants to the base fluid helps sustain dispersion of Nano particles. To achieve uniform dispersion of Nano particles and sustain the fluid for longer duration from sedimentation, stirring the mixture for 12 to 16 hour duration is adopted.

- Poly oxy ethylene sorbitinmonoliate (Tween 800)
- Sodium Dodecyl Benzene Sulfonate (SDBS)
- Sodium Dodecyl Benzene Sulfonate has been used as surfactant in the preparation of Nanofluids.

Need for Hybrid Nano fluids Hybrid nanofluid is a new nanotechnology fluid that is synthesized by dispersing two different nanoparticles into conventional heat transfer fluid. Recently, researchers have indicated that

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hybrid nanofluids can effectively substitute the convectional coolant especially those working at very high temperatures.

Literature review:

Most of the research available in the literature has focussed on the , and etc. as nanofluid with water as the base fluid. There observed to be almost very limited literature on the application of Silicon Carbide and hybrid Nano particles with EG- water as base fluid in heat transfer applications. The range of volume concentration considered in the present research is from 0.01% to 0.08%, on which limited research is reported. Thus, based on the literature review the objective of the present work is set as follows:

Scope of work: In this present study, it is proposed to perform experimental investigations on the enhancement of heat transfer coefficient using SiCand hybridnanofluids, at concentrations of 0.01, 0.02, 0.04, 0.06 and 0.08% in a U-bend double pipe heat exchanger for counter flow arrangement.

Objectives:

- To experimentally study the enhancement of heat transfer using Fe3O4 nano particles in comparison with hybrid nano particles Fe3O4-SiC in the base fluid as Ethylene glycol and water as base fluid with proportion of 30:70 using different concentration in u bend double pipe heat exchanger arrangement for counter flow.
- To study and compare the pressure drop in heat exchanger with EG-Water and Fe3O4, hybrid nanofluids.
- To compare the relative performance of the both hybrid and Fe3O4 nanoparticles by evaluating thermal performance factor.

Methodology:

- To prepare the Iron Oxide and hybrid nanofluids at various concentrations using two-step process.
- To determine the thermal conductivity and viscosity of nanofluid experimentally.
- To validate the experimental setup with water as working fluid.
- To repeat the experiment with Ethylene Glycol and Water in the ratio of 30:70 by volume as hot fluid.
- To repeat the experiment with Iron Oxide nanofluid at different volume fractions.
- To repeat the experiment with Iron Oxide and Silicon Carbide hybrid nanofluid at different volume fractions.
- To compare experimental data with that of existing correlations and infer from the results.

Overall Comparison of experimental friction factors of SiC and SiC-Fe3O4 hybrid with Reynolds number of nanofluids at various concentrations

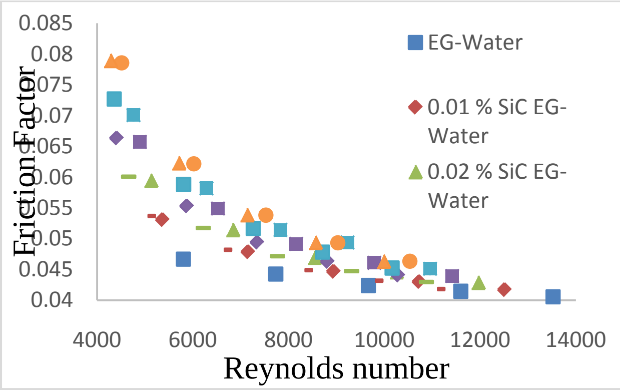

Fig.1. Comparison of experimental friction factors with Reynolds number at various concentrations of nanofluids

Fig.1 shows the variation of experimental friction factor with Reynolds number for different concentrations of nanofluids. The results show friction factor is increased from 6.75 % to 27.35 % for SiCnanofluids at volume concentrations of 0.01 % to 0.08%. For the same volume concentrations, hybrid nanofluids show an increase from 1.62 % to 21.35 %.

Overall Comparison of experimental pressure drop of SiC and SiC-Fe3O4 hybrid nanofluids with Reynolds number at various concentrations

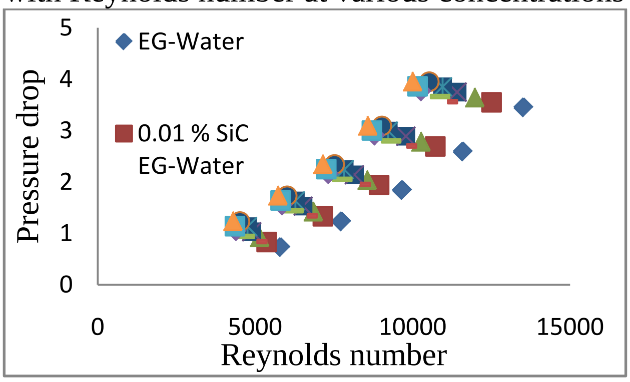

Fig.2 Comparison of experimental pressure drop with Reynolds number at various concentrations of nanofluids

Fig.2 shows the variation of pressure drop with Reynolds number for different concentrations of nanofluids. The results show pressure drop is increased from 7.33 % to 113.61 % for SiCnanofluids at volume concentrations of 0.01 % to 0.08 %. For the same volume concentrations, hybrid nanofluids show an increase from 52.63 % to 126.78 %.

Overall Comparison of experimental pressure drop of SiC and SiC-Fe3O4 hybrid nanofluids with flow rate at various concentrations

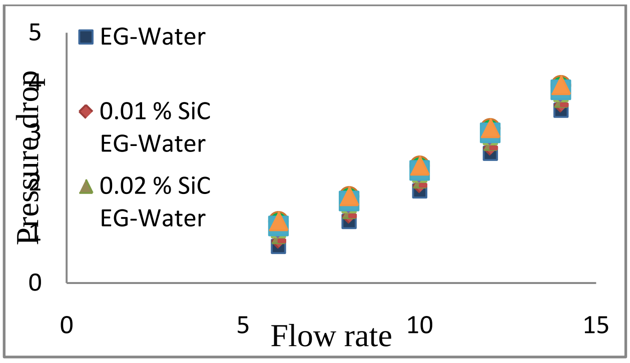

Fig.3comparison of experimental heat transfer coefficients with flow rate at various volume concentrations of nanofluids

Fig.3 shows the variation of pressure drop with flow rate for different concentrations of nanofluids. The results show pressure drop is increased from 6.80 % to 34.02 % for SiCnanofluids at volume concentrations of 0.01 % to 0.08 %. For the same volume concentrations, a hybrid nanofluid shows an increase from 7.48 % to 34.70 %.

Thermal Performance Index: The trade-off behavior between pressure drop and heat transfer enhancement induced complexity to the system. Thus, to study the combined effect of heat transfer enhancement and increase in pressure drop, thermal performance index is defined as from M.M.Sarafaraz

$$\eta = \left(\frac{Nu_{nf}}{Nu_{bf}}\right)\left(\frac{f_{nf}}{f_{bf}}\right)^{\frac{1}{3}} \quad ...... (8.8)$$

Thermal Performance Index of SiCnanofluids

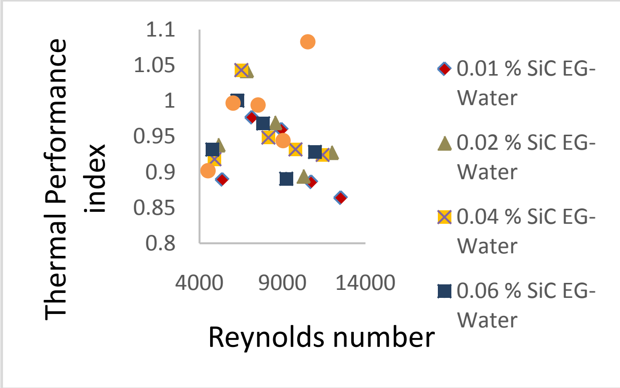

Fig.4 Comparison of Thermal performance index with Reynolds number at various volume concentrations of SiCnanofluids

Fig.4 shows the variation of thermal performance index if SiCnanofluids at various concentrations with respect to Reynolds number. The highest value of thermal performance index is observed at 0.08 % SiC which is 1.0829 at Reynolds number overall range of 10530.The maximum average thermal performance index is observed to be 1.042, 1.043, 1.0829 for the volume concentrations of 0.02, 0.04 and 0.08 % respectively.

Thermal Performance Index of SiC-Fe3O4 hybrid nanofluids

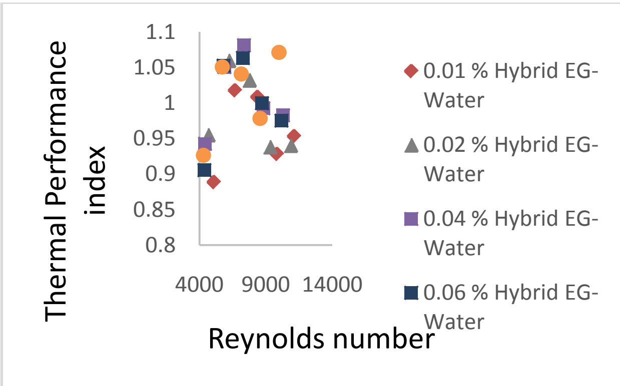

Fig.5 Comparison of Thermal performance index with Reynolds number at various volume concentrations of SiC-Fe3O4 hybrid nanofluids

Fig.5 shows the variation of thermal performance index if SiC-Fe3O4 hybrid nanofluids at various concentrations with respect to Reynolds number. The highest value of thermal performance index is observed at 0.04 % SiC-Fe3O4 hybrid nanofluid which is 1.081 at Reynolds number over a range of 7340. The maximum average thermal performance index is observed to be 1.081, 1.071, 1.063, and

1.032 for the volume concentrations of 0.04, 0.08, 0.06 and 0.02 % respectively.

Summary

- The average convective heat transfer coefficient increases with increase in volume concentration of nanofluid. The hybrid nanofluids experimental results shows higher heat transfer coefficient than Silicon Carbide nanofluids.

- The experimental friction factor is increased with increase in volume concentration of nanofluids.

- Comparing with all nanofluids, the maximum enhancement of heat transfer coefficient is 42.06% when SiCnanofluid is used whereas for hybrid nanofluid the maximum enhancement is 47.28%.

- The maximum average value of thermal performance index is observed at 0.08 % SiC which is 1.082 whereas for hybrid nanofluid the maximum average value is 1.081 at 0.04 % concentration.

Conclusions: In the present work, U-bend double pipe heat exchanger is used to study the heat transfer enhancement at various concentrations of Silicon Carbide (SiC) and Silicon Carbide-Iron Oxide nanofluids at different flow rates. The hot nanofluid is allowed to pass through the inner tube, while cold water at constant flow rate passed through the annulus. Under these conditions, experiments are performed various concentrations of 0.01, 0.02, 0.04, 0.06, and 0.08% of SiC and SiC-Fe_3O_4 hybrid particles mixed in EG-Water in the turbulent regime. From the data analysis of the experimental observations, the following conclusions are drawn.

- The thermal properties such as, thermal conductivity and viscosity of single particle nanofluid and hybrid nanofluid present higher values than base fluid. The Viscosity of SiCnanofluids is enhanced from 8.19 % to 28.68 % for 0.01 % to 0.08% volume concentrations at an operating temperature of 45oC. The viscosity of hybrid nanofluid is enhanced from 16.39 % to 36.06% for 0.01 % to 0.08% volume concentration at an operating temperature of 45oC.

- For the same volume concentration and at an operating temperature of 45oC, Sic thermal conductivity is enhanced from 22.9 % to 31.62 % whereas for hybrid nanofluid the enhancement is from 23.55 % to 32.87 %.

- The enhancement of viscosity and thermal conductivity is observed to be comparatively more for hybrid nanofluid compared to that of SiCnanofluid, at the same operating temperature and at the same volume concentrations. Because of iron oxide present in the hybrid mixture has slightly greater than silicon carbide.

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