implementation is complicated by their tendency to damage mechanical pumps and valves, as well as clog flow passages due to particle settling. Recent developments in nanotechnology and related manufacturing techniques have made possible the production of far smaller 'Nano-sized' particles. Such particles greatly reduce the damage to flow loop components while providing cooling benefits. Hence, an additive proposed in this work is Nanoparticles.

A Nanofluid is a three-phase fluid that includes a solid phase (nanoparticles), the liquid phase (base fluid), and the interfacial phase. Much equipment like the boilers, cooling towers, and cogeneration systems make use of Nanofluids. The scope for research in the use of Nanofluids has boomed as it delivers favorable characteristics in thermal and electrical conductivities. The colloidal mixture of Nanoparticles of size 1 to 100nm would be dispersed in water by different methods. Typical examples of nanoparticles are made of metals, oxides or carbides, while base fluids are generally water, ethylene glycol or oil. The Nanofluid has thermophysical properties different from that of the base fluid. In general, the thermal conductivity of Nanofluids is higher than the base fluid thereby increasing the heat transfer rate. The extent of heat transfer enhancement on using Nanofluids depends mainly on the type of nanoparticles, size of nanoparticles and concentration of nanoparticles in base fluid.

Tiwari and others [4] used a plate heat exchanger to study the performance of Nanofluids containing CeO_2, Al_2O_3, TiO_2, and SiO_2 for the highest overall heat transfer rate by varying volumetric flow rates and in a specific range of concentrations. TiO_2 and CeO_2 nanoparticles had better heat transfer characteristics at lower volume concentrations whereas Al_2O_3 and SiO_2 nanoparticles shown higher heat transfer characteristics at the higher volume concentrations.

Albadr and others [7] used a shell and tube heat exchanger to experimentally study heat transfer with water as the base fluid and Al_2O_3 as the nanoparticle in the coolant. They used Al_2O_3 in varying concentrations and found that the addition of nanoparticles to water increased properties such as thermal conductivity, the viscosity of the Nanofluid. The friction factor increased with the increase in the concentration of nanoparticles. At a particle volume concentration of 2% Aluminum oxide Nanofluid gave significantly higher heat transfer characteristics.

2. Objective

- To enhance the heat transfer co-efficient of fluids exchangers, by increasing the thermal conductivity of the coolant thereby its operating efficiency, which play a key role in the overall running cost of a plant.
- To observe the variation of certain parameters with increase in concentration of Nano fluids.

3. Methodology

3.1. Experimental setup

The setup for the experimentation consists of a laboratory scale double pipe heat exchanger with stainless steel as the material of construction and length of about 0.8m. The peripherals would include two tanks, pumps, flowmeter (rotameter) to maintain different flow rates, temperature sensing instrument, coil heat exchangers to regulate the temperature of fluid, valves to control the flow rates and heat tolerant pipes for transportation of fluids.

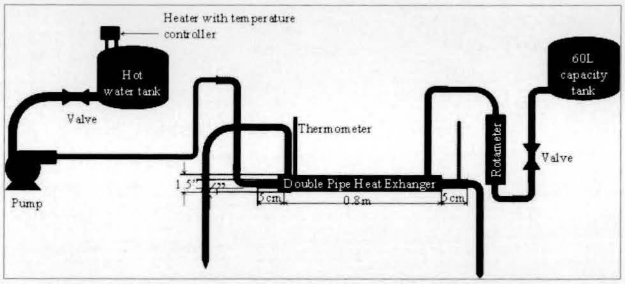

Fig. 1. Block diagram of the experimental setup.

Two tanks with the hot and cold fluid is maintained one at the experimental high temperature and the other at room temperature respectively, which would be the inlet temperatures of the two fluids. The flow rate of both fluids is set with the help of valves and rotameters. After a steady state is achieved the outlet temperatures on both sides is recorded. The same experiment is repeated for different flow rates and different inlet temperatures. The hot fluid is water in all the cases. The cold fluid is also water at first which would be used as a reference to the subsequent fluids i.e. Nano fluids with varying concentration. Graphs of heat transfer coefficients vs. flow rates; the inlet temperature of hot fluid is plotted for the comparative analysis of various streams.

3.2. Preparation of zinc oxide nano particles

Three methods for preparation of ZnO nanoparticles were adopted.

3.2.1 Method 1: Sol-Gel method

Zinc granules were dissolved in concentrated HCl solution to give $ZnCl_2$, followed by reaction with Na_2CO_3 to give precipitation in the form of zinc carbonate. Further zinc carbonate was washed with water and precipitates were dissolved in acetic acid to get zinc acetate. In the presence of methanol zinc acetate on reaction with NaOH gives ZnO nanoparticles.

3.2.2 Method 2: Precipitation method

A 0.2M solution of zinc sulphateheptahydrate was reacted by addition of NH_4OH at constant rate to precipitate ZnO. The precipitate was dried to obtain ZnO nanoparticles. Zinc oxide Nano particles were also synthesized using zinc nitrate and potassium hydroxide.[1]

The samples obtained from the precipitation techniques were then analyzed using the SEM (Scanning Electron Microscope) and the XRD (X-Ray Diffraction).

4. Results

4.1. Nano particle characterization

The characterization of the samples through the SEM analysis shows that the nanoparticles prepared from the precipitation technique are of sizes in the range of 30 to 50nm. The particle size obtained from precipitation technique is of lowest range compared to particles prepared from other methods.

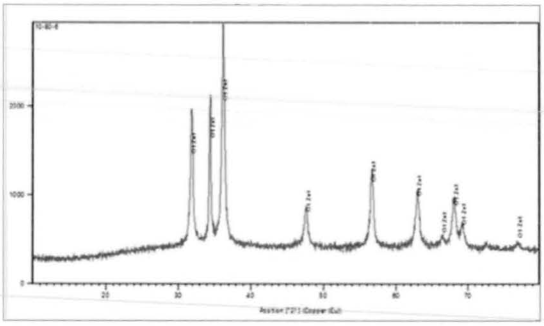

Fig. 2. XRD analysis of the sample synthesized.

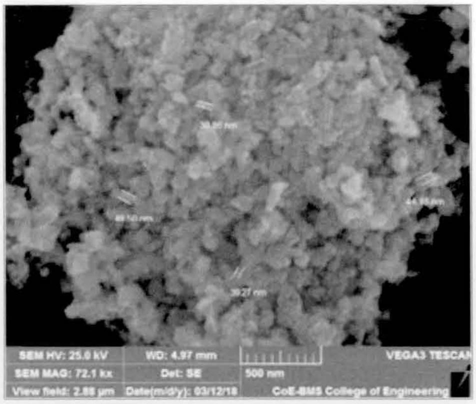

Fig. 3. SEM image of the sample synthesized.

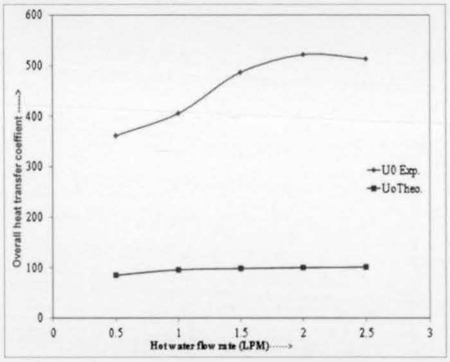

Fig. 4. Variation of heat transfer coefficient with hot water flow rate at hot water inlet temperature of 70°C

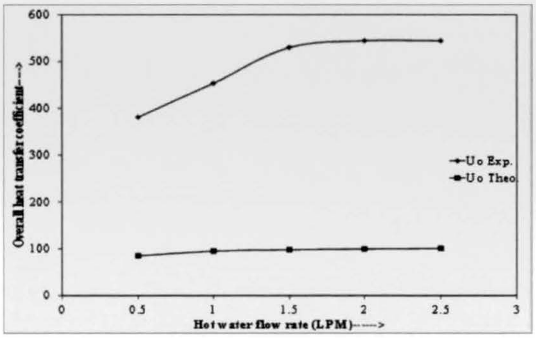

Fig. 5. Variation of heat transfer coefficient with hot water flow rate at hot water inlet temperature of 60°C.

The corresponding peaks of the graph obtained through XRD analysis of those of pure zinc Oxide[16].

4.2. Heat transfer with water

The experimentation of water as coolant with varying hot water flow rates gave the following results.

Figures 4 and 5 shows the variation of the overall heat transfer with the inlet flow

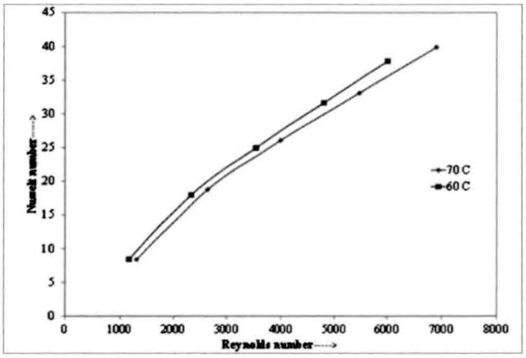

Fig. 6. variation of nusselt number with reynolds number at different hot water inlet temperatures.

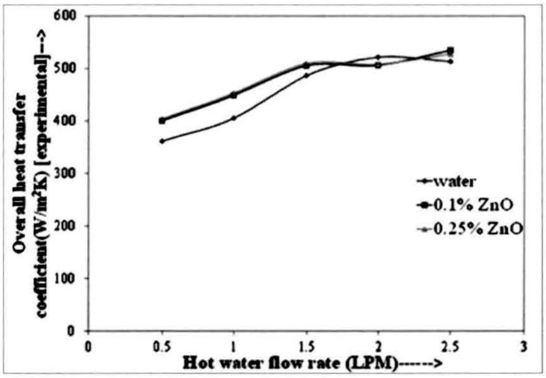

Fig. 7. Experimental values of overall heat transfer coefficient at 70°C of hot water inlet.

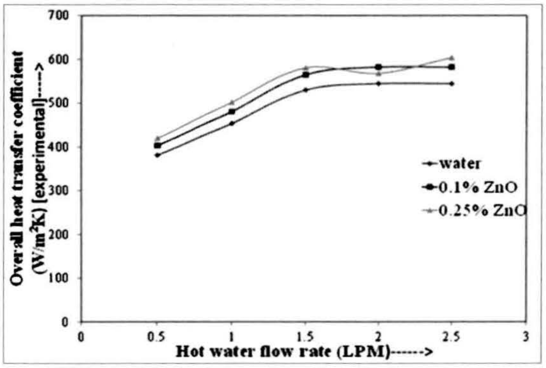

Fig. 8. Experimental values of overall heat transfer coefficient at 60°C of hot water inlet.

rate of hot water. The high resistance of stainless steel, leakages, scaling and other factors contributes to the difference in the experimental and theoretical overall heat transfer coefficients. The overall heat transfer coefficient initially increases significantly then becomes more constant. Also, at same flow rates and different hot water inlet temperature the values of the overall heat transfer coefficients are very close.

In the fig. 6 it is seen that the Reynolds number comparatively changes more with temperature as compared to that of Nusselt number. The graph seems to shift a little to the right with increase in temperature.

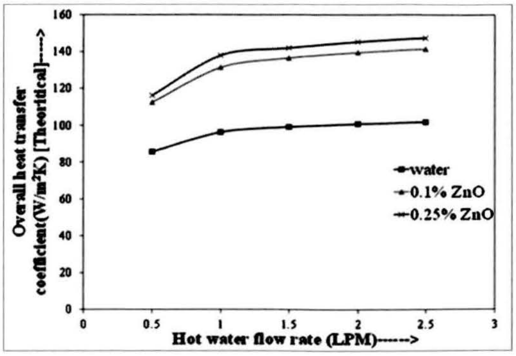

Fig. 9. Theoretical values of overall heat transfer coefficient at 70°C of hot water inlet.

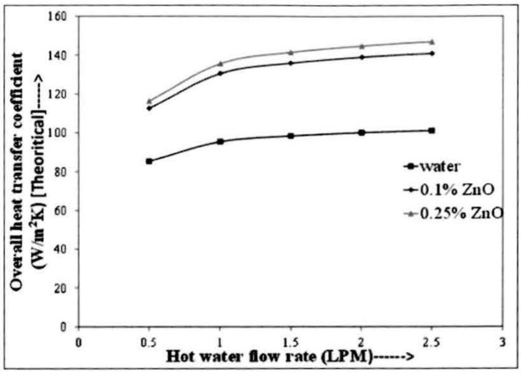

Fig. 10. Theoretical values of overall heat transfer coefficient at 60°C of hot water inlet.

4.3. Experimentation with zinc oxide nano fluid

(Ref fig .7. and 8)

The addition of zinc oxide nanoparticles to the base fluid increases the overall heat transfer coefficient. The jump in the experimental heat transfer coefficient from water alone as coolant to 0.1% Nano fluid was higher than that from 0.1% Nano fluid to 0.25% Nano fluid. The cooling effect of the Nano fluid is higher at the low flow rates of hot water and the difference in the values of overall heat transfer coefficient decreases with higher input hot water flow rates. The graphs of water as coolant and Nano fluids tend to converge at higher hot water flow rates. (Fig. 9 and 10)

The theoretical values of heat transfer coefficient seem to increase with increase in nanoparticle concentration in the base fluid. Again, the jump from the experimental heat transfer coefficient from water alone as coolant to 0.1% Nano fluid was higher than that from 0.1% Nano fluid to 0.25% Nano fluid. The

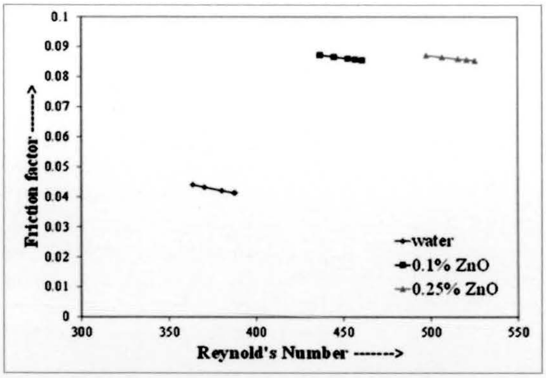

Fig. 11. Friction factor vs. Reynolds number with increasing nanoparticle concentration at 70°C of hot water inlet

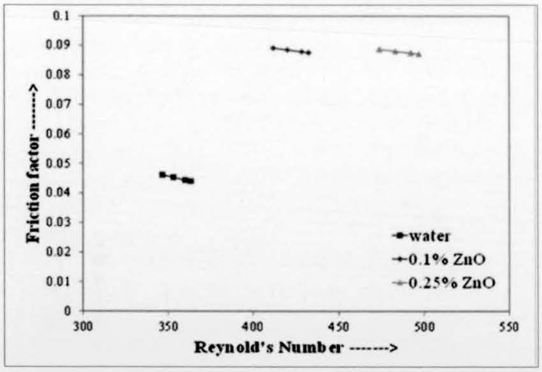

Fig. 12. Friction factor vs. Reynolds number with increasing nanoparticle concentration at 60°C of hot water inlet.

theoretical values of heat transfer coefficients of water and Nano fluids did not seem to converge at higher temperatures as in the case of the experimental values. (ref fig. 11 & 12)

The friction factor vs. Reynolds number graphs at the two inlet hot water temperatures shows that though the volumetric rate were the same at all times, the addition of Nanoparticles significantly increased the Reynold's number as the addition of nanoparticles increases the density to quite an extant. The values of Reynold's number and friction factor for a particular coolant vary over a very small range of values as the flow rate is practically the same and the variation in the values occur due to the change in the physical properties such as density, viscosity, etc. with temperature. The friction factorrange also shifts to higher values with increase inN_{Re}increase in nanoparticle concentration.

5. Conclusion

A coolant is a substance that is used to reduce or regulate the temperature of a system. An ideal coolant has a high thermal capacity and low viscosity, is of low-cost, non-toxic, and chemically inert. A Nano particles neither cause nor promotes corrosion of the cooling system. The study of the Nano fluid Zinc oxide shows that the coolant possesses many ideal properties of a coolant. The zinc oxide Nano fluid increased the overall heat transfer coefficient but didn't prove to be of very high value at higher flow rates of hot water. The increase in the theoretical overall heat transfer coefficient varied from 39.01% at high hot water flow rate (turbulent region) to 31.43% at low hot water flow rate (laminar region) whereas the experimental overall heat transfer coefficient values were about 10.74% to 4.21% for a 0.1% concentration of ZnO. Also, the increase in the theoretical overall heat transfer coefficient varied from 44.88% at high hot water flow rate (turbulent region) to 35.83% at low hot water flow rate (laminar region) whereas the experimental overall heat transfer coefficient values were about 11.8% to 2.78% for a 0.25% concentration of ZnO. The overall heat transfer coefficient was in very close proximity of that obtained with water alone. Also, the nanofluid does not decompose easily even at higher temperatures. Zinc oxide possesses anti-bacterial and anti-fungal properties making it resistant to biological attacks as well. Despite the positive points there are certain drawbacks of zinc oxide as coolant as well. The Nano fluid tends to offer greater pressure drop and friction factors. If the instrument to measure the flow rate is a direct reading instrument such as the rotameter, the chances of getting an obscured reading are higher as the Nanofluid loses its transparency on addition of white zinc oxide Nanoparticles. With increase in concentration, the possibility of settling may increase and the confirmation of occurrence of settling is difficult due to lack of transparency. The research has a lot of scope in the development of the nano fluids and its application.

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Heat transfer enhancement in a double pipe heat exchanger using zinc oxide nanofluid*

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ABSTRACT

Keywords:
Nano fluid,
Heat Exchanger,
Heat Transfer Coefficient,
Zincoxide.

Water is majorly used as a coolant in both industries and vehicles but there are certain drawbacks associated with it. The extent to which heat can be absorbed is low and the range of the cooling operation is limited by the boiling and freezing points of water. Work is being done to compress these constrictions by using coolant with Zinc Oxide nanoparticles to enhance the overall heat transfer coefficient.

The work is intended to assess the variation in the degree of heat transfer by physical experimentation. For the experimentation purpose, a Double Pipe Heat Exchanger was fabricated. The nanoparticles selected were Zinc oxide and they were prepared in the laboratory by various methods. The samples were analyzed by using methods of Scanning Electron Microscopy (SEM) and X-ray powder diffraction. The range of 30-50 nm prepared nanoparticles was selected. Different concentration of nanoparticles was added in base fluid which decides the degree of heat transfer. Finally, on running the experiment an increase in the overall coefficient from 31.43% -44.88% (theoretical) and 2.78% - 11.8% (experimental) was observed.

1. Introduction

Heat exchanger is a device that is used to transfer heat from a hot fluid to cold fluid. There are different types of heat exchangers which are used in industries to utilize the heat energy and to make the whole process economically feasible. An efficient heat exchanger transfers heat at the maximum possible rate. The heat transfer rate enhancement can be made possible by two methods (1) optimizing the design of the heat exchanger and/or (2) optimizing the operational parameters. Design optimization needs consideration of functional and mechanical aspects of the specific case and optimization of the operational parameters demands repeatable results obtained through multiple experimentations. The operational methods of enhancement of heat transfer rate can be subdivided as (1) active methods and (2) passive methods. The examples of the active method are electrohydrodynamics, jets, sprays, ultra-sonication, synthetic jet heat transfer, and high amplitude vibration, and those of passive method is a surface coating, using Nanofluid, hydrodynamic cavitation, turbulence promoters, and mixers. A passive method using Nanofluid to enhance the rate of heat transfer is employed in the present research work.

Most of the heat exchangers used in various industries, automobiles, refrigeration units etc. make use of water as a coolant. Water is a volatile liquid which can be used over only a window of 0-80°C below the lower range water solidifies and exceeding the higher range the rate of evaporation is very high.

Solid particles generally possess far greater thermal conductivity than common heat transfer liquids. Mixing solid particles in a liquid can, therefore, enhance the cooling potential of the liquid by increasing the thermal conductivity of the suspended fluid. In the past, this goal was sought by using particles in a few 'millimeter' or 'micrometer' size particles. While these fluids do provide the aforementioned cooling benefit, their

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