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Comparison of heat transfer enhancement of aluminum oxide nano-fluids with graphite nano – fluids with and without twisted tapes

V. Vedhagiri Eswaran.[a], Dr. G.Ramadoss [b], N. Subramaniam[c],
[a]Principal, Kongu Polytechnic College, [b]Principal, Shivani College of Engineering & Technology,
[c]Head of the Dept, Kongu Polytechnic College

Abstract- Heat transfer characteristics of the graphite and the aluminum oxide (Al_2O_3) nano powders were experimentally studied in detail by converting them as the nano fluid with water as the base fluid. Also, the insert of twisted tapes inside the tubes has also brought some change in the heat transfer rate. The tapes are twisted to right as well as the left side and experimental investigations were made on it. For both the nano fluids namely graphite and aluminum oxide respectively, experiments are carried out with three different concentrations. On comparing the heat transfer characteristics of the graphite and aluminium oxide nano fluid, it is found that the heat transfer characteristics of the aluminum oxide with twisted tapes towards right has shown a higher conductivity level.

Keywords- shell and tube heat exchanger, nano fluids, thermal conductivity, heat transfer co-efficient, twisted tapes.

1. Introduction

A shell and tube heat exchanger is the most common type of a heat exchanger used in most oil refineries, and in industries where heat transfer takes place at extreme high pressure. It is just because of its robust application. A shell and tube heat exchanger consists of a shell with a bundle of tubes installed in it. A baffle is nothing but a plate which is placed inside the shell and that prevents the cross flow the fluid through the shell side. The tubes can be of several types: plain, longitudinally finned etc. counter current heat exchangers are most widely used because it has a higher log mean temperature difference level than the ordinary one. Most of the industries use only multiple pass heat exchangers than the single pass because of its disadvantages such as easily breakable and high cost.

1.1. Selection of Material

It is necessary to build a tube with material with higher heat transfer conductivity such as copper. According to Claussius statement, heat always transfers to the high temperature to the lower temperature, the fluid with higher temperature level are allowed to flow through the tube side area. Also the tube material that we choose should be able to withstand all sorts of a condition such as temperatures, pressures, pH etc. Also it should be strong and corrosive resistant. Materials such as copper alloys, stainless steel, carbon steel, non-ferrous copper alloy, nickel, haste alloy and titanium are good enough to use. On the contrary, poor choice of the materials will result in leakage and it may lead to the pressure drop of the fluid.

1.2. Nano Fluids

Nano fluid is nothing but a fluid nano-meter sized particle called nanoparticles. These nano particles are immersed in the base fluids such as water, kerosene etc. it has been a known fact that the solid particles have better heat transfer characteristics than the liquid and their suspension in the base fluid makes them attractive to use towards heat transfer fluids. Nano fluids are also used as coolants in automobiles and other electronic devices.

The thermal conductivity is one of the important parameters for the heat transfer enhancement, some researches may undergo in the thermal conductivity of nanofluids as well. All results in the enhancement of the heat transfer on the addition of the nanoparticles on the base colloidal solution.

The objective of the present paper is to compare the heat transfer ability of the graphite and the aluminum oxide nano fluids with and without internals in the tube. Also the design of the internals is also varied as right and the left twist.

2. Experimental Setup

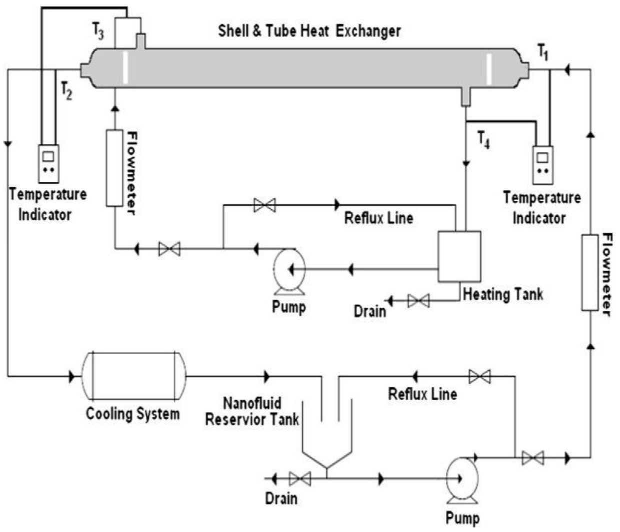
The experimental setup consists of a pump, a water storage tank of capacity 175 lit, water heater, shell and tube heat exchanger, thermocouples at the entry and the exit to measure the inlet and the outlet temperature. The thermocouples were calibrated by PT100 type and the error in them is less than 0.1 LC. The thermocouples 1 and 2 are used to measure the inlet temperature and the exit temperature of the nano fluid and on the contrary the thermocouple 3 and 4 measures the inlet temperature of the base fluid. In order to get accurate experimental results, first of all equipment is made stable by passing the water through the shell as well as the tube side of the heat exchanger.

The experimental setup consists of a shell with 51mm inside diameter and the tube bundle consisting of 6 tubes with 8mm outside diameter, 1mm thickness, and 518mm length and the tube pitch is 8mm. the baffle spacing are 15% and 129.5 mm respectively.

The heat exchanger as well as the pipe is strongly wound by a thermal insulation tape. Two series of solution in prepared such as aluminium oxide-water, graphite-water where water flows through the shell side in both the cases. To prepare stable nano fluids, ultrasonic vibrations were made to pass through it to prevent the agglomeration of the nano particles.

The nano fluids are prepared with different particle concentration such as 0.1%, 0.2%, 0.3% respectively. It is done to investigate the effect of the nanoparticles concentration on the heat transfer performance if the nano fluids.

Twisted tapes: To develop flow hydro-dynamically, twisted tapes are inserted in the heat transfer test tube .The twisted tapes tested in experiments with twist ratio (y/D = 3.0) and two different twists (Left twist and right twist with a clearance of 0.0357mm. The schematic figure of twisted tape insert is given in Fig.2. The twisted tape insert attachments are manufactured according to fix the twisted tapes separated from the tube wall and attached onto the twisted tapes to prevent contact of inserts with the tube inner surface. The twisted tapes with teflon attachments contained in the experimental study are shown in Fig. 3.



The twisted tapes inserts

3. Results and discussions

The accuracy of the experimental system was tested with distilled water before measuring the convective heat transfer of nano fluids. Then the experimental study was carried out with graphite nano fluids with and without twisted tapes at different concentrations and at different flow rates. After completing this experiments, the system is cleaned with distilled water and the experimental study was carried out with Aluminum oxide nano fluids with and without twisted tapes at different concentrations and at different flow rates. Based on the experimental values the various properties like logarithmic mean temperature difference, thermal conductivity of nano particle mixtures at different concentration (0.1% , 0.2% and 0.3% by volume), viscosities at different temperatures, specific heats, reynolds number, prandle number, nusselt number and overall heat transfer coefficient. The readings were taken at different flow rates and at different concentrations of graphite water nano mixtures and the same was compared with Aluminum oxide nano fluids system.

Based on the calculations, the following graphs were plotted between the values of Reynolds Number at different concentrations of graphite and at different flow rates with and without twisted tapes and the same was compared with the Aluminum Oxide nano fluids.

Figs.1-15 represent the overall heat transfer coefficient of the Aluminum oxide and Graphite/water nanofluids versus Reynolds and for various volume concentrations respectively. From the results, the overall heat transfer coefficient of Aluminum Oxide nanofluids with Right twist increases significantly with Reynolds number when comparing with the Graphite Nano fluids . For both fluids the overall heat transfer coefficient at a constant Nusselts number increases with nanoparticle concentration compared to the base fluid. As clearly shown in Fig.1-15, the maximum enhancement of the overall heat transfer coefficient of Aluminum Oxide nanofluids occurs at 0.3% volume concentration and at 5 lpm flow rate the enhancement approximately 48%. At this Reynolds number the enhancement of the overall heat transfer coefficient at 0.1%, 0.2% & 0.3%, nanoparticle volume concentrations are about 25.98%, 45.5% and 61.3%, respectively.

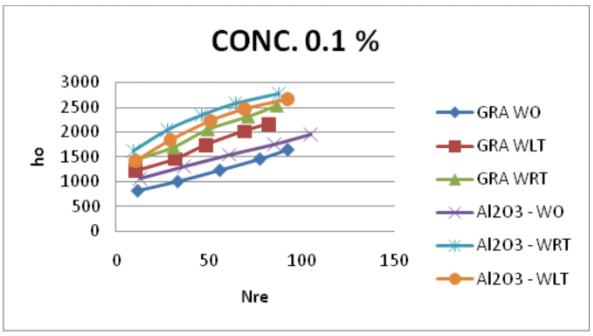


Fig 1 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 1 lpm and 0.1 concentration.

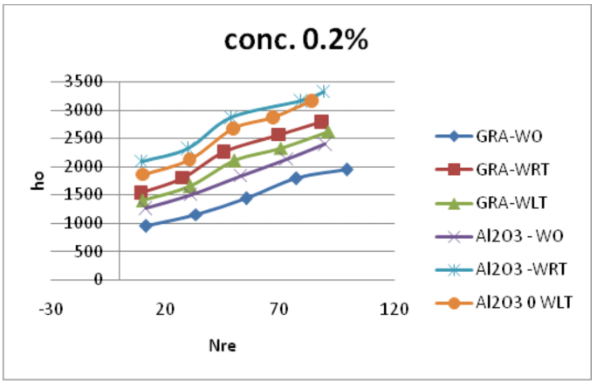


Fig 2 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 1 lpm and 0.2 concentration.

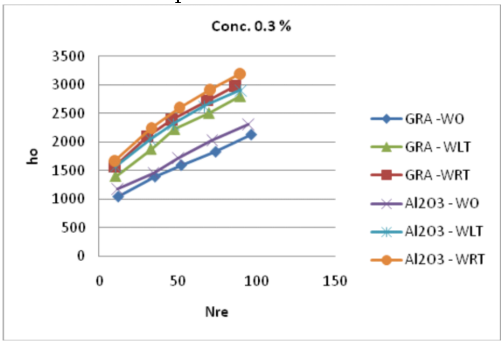


Fig 3 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 1 lpm and 0.3 concentration.

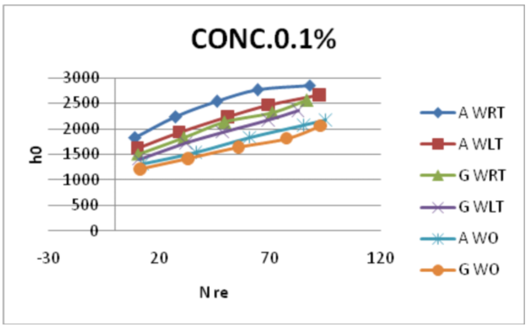


Fig 4 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 2 lpm and 0.1 concentration.

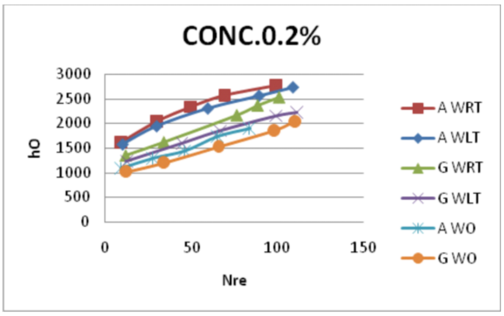


Fig 5 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 2 lpm and 0.2 concentration.

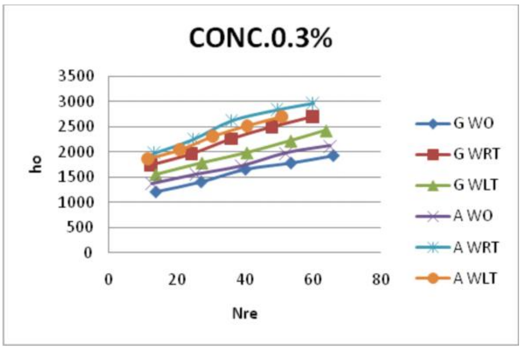


Fig 6 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 2 lpm and 0. 3 concentration.

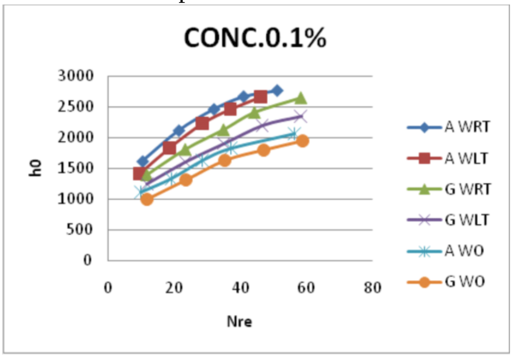


Fig 7 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 3 lpm and 0.1 concentration.

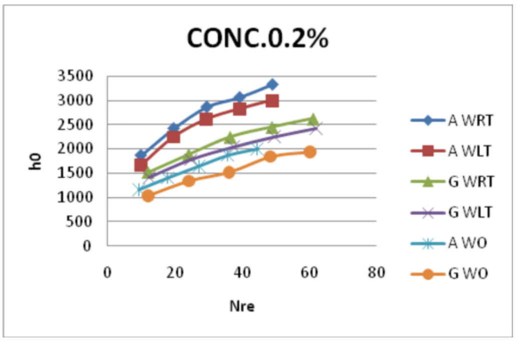


Fig 8 1Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 3 lpm and 0.2 concentration.

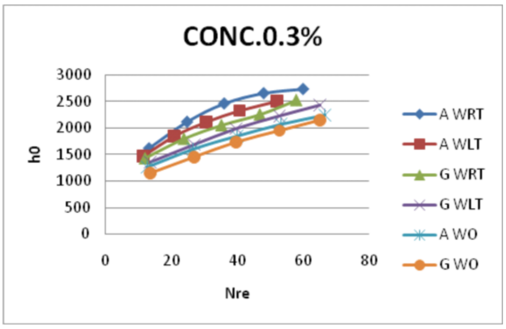


Fig 9 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 3 lpm and 0.3 concentration.

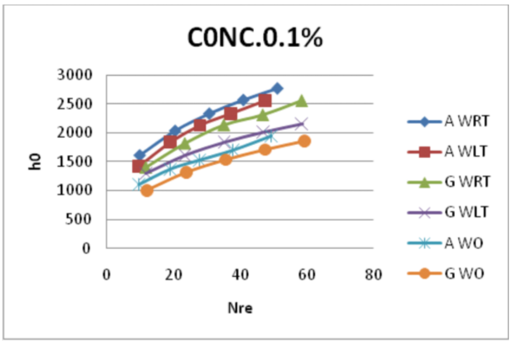


Fig 10 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 4 lpm and 0.1 concentration.

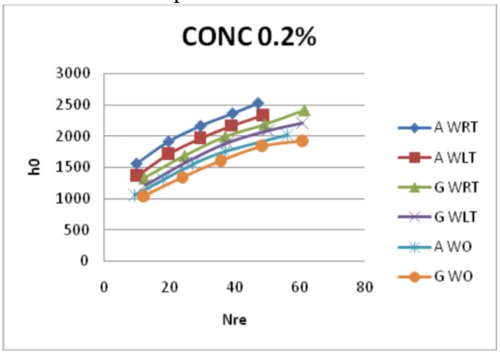


Fig 11 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 4 lpm and 0.2 concentration.

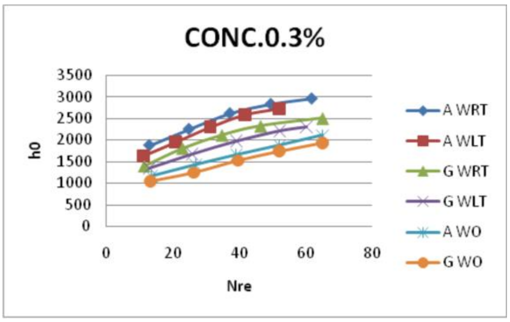


Fig 12 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 4 lpm and 0.3 concentration.

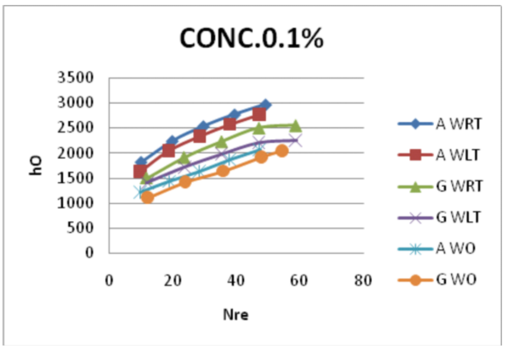


Fig 13 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 5 lpm and 0.1 concentration.

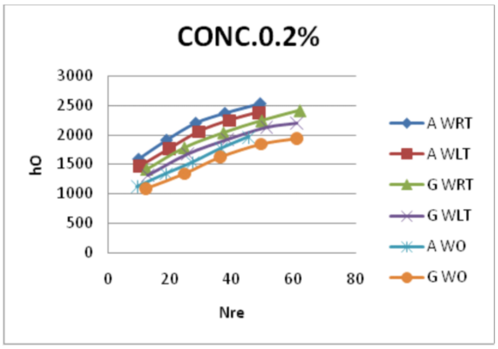


Fig 14 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 5 lpm and 0.2 concentration.

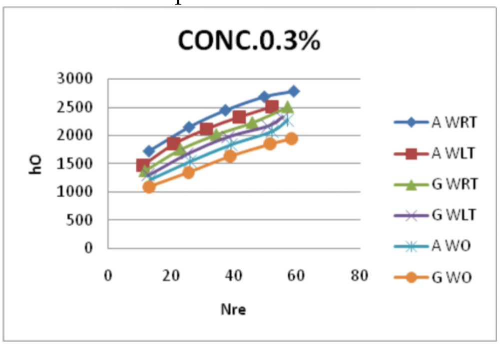


Fig 15 Variation of Reynolds number Vs Heat transfer co-efficent for Graphite, Al_2O_3 with and without internals at flow rate 5 lpm and 0.3 concentration.

Based on the experimental data the optimum volume concentration of Graphite particles as well as of Aluminum oxide in water are 0.3 vol.%, Generally the enhancement of convective heat transfer coefficient depends on increasing of the fluid thermal conductivity and decreasing of thermal boundary layer thickness. Thermal conductivity of the nanofluids increases with increasing of the volume concentrations. Decreasing of the thermal boundary layer thickness can be due to mobility of particles near the wall, migration of them to the center of tube, and reduction of viscosity at the wall region.

Convective heat transfer coefficient of nanofluids decreases with nanoparticle volume concentration at the concentrations higher than the optimum. This may be associated with the effect of high viscosity at the higher volume concentrations that causes in thickening of thermal boundary layer. In other words, at the higher volume concentrations the effect of increase of viscosity on the heat transfer coefficient is more than the effect of increase of thermal conductivity.

5. Conclusion

In the present experimental study heat transfer behavior of Aluminum Oxide and Graphite/water nanofluids in a shell and tube heat exchanger was investigated. The experiments were done for a wide range of Reynolds numbers, nanoparticle volume concentrations, and for different particle types.

The experimental results indicate that the heat transfer characteristics of nanofluids improve with Nusselt and Reynolds numbers significantly. Addition of nanoparticles to the base fluid enhances the heat transfer performance and results in larger heat transfer coefficient than that of the base fluid at the same Reynolds number.

Aluminum Oxide nano- fluids have the different optimum volume concentration in which the heat transfer characteristics show the maximum enhancement comparing with Graphite nano -fluids at all concentrations The nano-particle with less mean diameter has a lower optimum volume concentration.

At different nano-particle concentrations the heat transfer enhancement of are not the same. The nano-fluids posses better heat transfer behavior at the lower and higher volume concentrations. Competition of thermal conductivity and particle size of nano-particle may be the source of these differences for heat transfer performances.

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