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Augmentation of Heat Transfer in Shell and Coil Type Heat Exchanger Using Nano Fluid

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ABSTRACT

The heat transfer efficiency of most thermal devices can be enhanced by increasing it. Some process sectors, such as power plants and automobiles, require heat transfer enhancement in either heating, cooling, or evaporation on equipment such as air conditioning, radiators, freezers, and condensers. The approaches that are accessible can be divided into two categories: passive and active techniques. The goal of the study was to use passive strategies to improve heat transmission in a twin pipe heat exchanger. Water and titanium dioxide nano-fluid are examples of nanofluid.

Keywords : Heat Transfer, Nanofluid, Water and Titanium Dioxide Nano-Fluid

I. INTRODUCTION

Heat exchangers increase the exchange of heat between liquids of various temperatures while preventing them from mixing. These heat exchangers have become a vital necessity in today's culture because they have no negative effects on the environment. Tables 1–3 show that the cost of extracting energy is also lower and more conservative In most thermal applications, improving heat transport is critical. There are two approaches for increasing the heat transfer rate: active and passive. Heat exchangers are a critical component in a variety of modern contexts, including cooling systems, power plants, and treatment facilities, and continual efforts are made to improve their heat transfer efficiencies. While there has been steady progress in improving the performance of heat exchangers by addressing development and format issues in recent decades, the poor heat transfer properties of the working liquids used in these systems have remained a significant exhibition constraining factor for these systems. Adding high-thermal-conductivity nanoparticles to these cooling liquid fluids appears to enhance their capabilities. The heat transmission coefficients of solids are higher than those of fluids. The development of smaller particles, known as nanoparticles, has defeated the negative hydrodynamic effects of solid particles in liquids. Suspension of nano-sized particles in a liquid has been shown to significantly improve the liquid's heat transfer capabilities while avoiding the problems associated with suspension of bigger particles, such as halting up and settling in a heat exchanger.

Choi and et.al. [1] were the first to demonstrate the capabilities of this new class of fluids, dubbed nano fluids. Nano fluids are colloidal suspensions of nano-sized (5–100 nm) particles in a base liquid, according to the definition. They observed a significant increase in thermal conductivity values, which could lead to an increase in the heat transfer exhibitions of the fluid stream. Since then, research has continued to document the effects of various nanoparticles in various base fluids. [4] When used in heat transfer applications, helical coiled tubes have been shown to be superior to straight tubes in a few studies.l Because of the geometry of the tube, centrifugal force causes auxiliary stream advancement, which increases heat transmission. [2] Various studies have been carried out in order to increase the stability of nanofluids and to prevent two phenomena that are fundamental to their stability, such as aggregation and sedimentationIn late decades while there has been consistent advancement in improving the performance of heat exchangers by tending to their development and format issues, the poor heat transfer properties of the working liquids utilized in the heat exchangers have still stayed a significant exhibition constraining element for these sys- tems. Adding of nano particles with high thermal conductivity into these cooling liquid fluids appears to expand their abilities since.

Touloukian and Ho (1970). Based on their theoretical studies, Hamilton and Crosser (1962) and Wasp (1977) developed thermal conductivity models for two-phase mixtures. Sohn and Chen (1984) looked at the thermal conductivity of a solid-fluid mixture moving at low speeds. The thermal conductivity was shown to increase with increased shear rate at greater flow rates (higher peclet number). Masuda et al. (1993) investigated the feasibility of suspending submicroscopic particles in standard heat transfer fluids to change their characteristics.

Solids have higher heat transfer coefficients than fluids. The advancement of littler particles, of nano-sizes, has beaten the neg- ative hydrodynamic impacts of solid particles in the liquid. Suspen- sion of nano-sized particles in a liquid have been seen to essentially upgrade heat transfer properties of the liquid while being skilled at neither stopping up nor settling in a heat exchan- ger application, basic issues related with suspension of larger size particles.

Choi and et.al. [1] Were the first to exhibit the capability of this new variety of fluids, known as nano fluids. Nano fluids by defini- tion are colloidal suspensions of nano-sized (5–100 nm) particles in a base liquid. They watched huge upgrade in thermal conductiv- ity esteems that might prompt an expansion in the heat transfer exhibitions of the fluid stream. From that point forward, research has kept on reporting the impacts of different nano particles in dif- ferent base fluids. [4]The few examinations have demonstrated that helical coiled tubes are better than straight tubes when uti- lized in heat transfer applications. The centrifugal power because of the shape of the tube brings about the auxiliary stream advance- ment which improves the heat transfer.[2] Various examinations have been done to improve the steadiness of nanofluids and to pre- vent two phenomena which are basic to the stability of nanofluid.

Table 1. Thermo physical properties of nanofluid.

S. No	Physical Properties	Water	Nanofluid		
			0.5	1.5	2.5
1.	Thermal Conductivity (W/mk)	0.6	0.61002	0.61005	0.610091
2.	Density (kg/m^3)	997	997.09 1	997.2 779	997.47
3.	Specific Heat (J/kgJ)	4179	4178.60	4177.78	4176.92
4.	Viscosity (kg/ms)	0.00765	0.0008	0.00081	0.00083

Table 2. Specification of Helical coil heat exchanger.

Sl. No	Dimension parameter	Dimension in m
1	Inner Diameter of coil	0.1046
2	Outer Diameter of Coil	0.13
3	Pitch	0.03
4	Inner diameter of tube	0.011
5	Outer diameter of tube	0.0127
6	Length of tube	2.6
7	Height of the shell	0.25
8	Inside diameter of shell	0.15

Table 3. Specifications of the experimental test setup.

S.No	Particular	Specification
1.	Water pump	0.5 HP
2.	Rotameter	1.2–12 LPM
3.	Test section Copper material	I.D.: 0.01 m, O.D.: 0.012 m, L = 1 m
4.	Insulation material	Asbestos rope
5.	Water tank	Mild steel
6.	U-tube manometer	Mercury

Nano fluid have piqued the interest of many academics, particularly in the field of thermal engineering. Curved tubes have been proposed as a means for improving heat transfer and are widely used in a variety of mechanical applications. [3] Nanofluids are colloids made up of nano-scale particles and a base fluid. They were considered because of their improvements in base-liquid heat transfer characteristics. He showed that adding a little amount (less than 1% by volume) of nanoparticles to regular fluids increases the thermal conductivity of the liquid by about two times. The use of a green synthesised nanofluid would be a step toward conserving the environment and maximising the use of natural resources.

Nanofluid preparation

Preparation of plant extracts

The azadirachta indica (neem) leaves were harvested, cleaned, and thoroughly washed with distilled water. To eliminate the moisture from the cleaned neem leaves, they are dried in a solar tunnel dryer at 400°C for two days. Using a mixer with a diameter of less than 180 mm, the dry leaves are crushed into powder. Cryogenic ball milling reduces the power to nano particles. The method of synthesis adopted was a top-down approach. Silver nanoparticles synthesised in an environmentally friendly manner.

Under continuous string, the extracts were combined with 100 ml of 1 mM aqueous silver nitrate solution. After thoroughly combining the leaf extracts with the precursor, the mixture was incubated at 310°C for 24 hours. The reduction of Ag+ to Ago is shown by a change in colour from colourless to brown. As a result, nanoparticle formation has occurred [5]. The solution has now been centrifuged for 30 minutes at 6000 rpm, followed by

To eliminate undesirable biological elements, soak pellets in deionized water.

The nanofluid was created using green nanoparticles, and the nanofluid's parameters are provided in the table. The morphology of nano particles was studied using a scanning electron microscope (carl Zeiss Microscopy EV10, Germany) with magnifications ranging from 1 to 30,000 times, acceleration voltage 0.2 to 30Kv, probe current 0.5pa to 5mA, X-ray analysis 8.5 mm AWD & 350 take off angle, pressure range 10 to 3000 Pa, and time range 5-60 min. According to the SEM image, the particles are smaller than 30 nm. Because nanoparticles' surfaces are naturally hydrophobic and prone to agglomeration in the absence A SEM image was taken of the sof surfactant. As a result, 1 percent polyvinyl pyrolidine was found to be effective. To determine the thermophysical characteristics of nanofluid, the following correlations were applied.

II. Experimental setup

De-ionized water is first put into the hot and cold reservoirs, and the values are set for parallel flow. Power is supplied to both the pump on the hot reservoir side and the pump on the cold reservoir side when the mains are turned on. The heater receives power as well. The regular water in the hot reservoir is heated with a 1500 W electric heater. The thermostat is set to 60 degrees Celsius. A dimmer-stat controls the heater's voltage, which is set to 150 V. A rotameter is used to establish the mass flow rate at 160 LPH at the hot fluid input. Both a digital temperature indicator and a thermometer are used to keep track of the temperature. Various sorts of fluids can be utilised for experiments in a cold reservoir. We utilised de-ionized water in this experiment. With 0.5 LPM adjustments, the mass flow rate is altered from 1.5 to 5 LPM. Near the cold reservoir, a radiator with a fan is installed. By using forced convection, it aids in the cooling of the water. The radiator's outlet is connected to the cold water reservoir, allowing the cooled fluid to be reused to extract heat (Figs. 1–7).

When the temperature hits 60°C, a thermometer is used to record the entrance and output temperatures of hot fluid. Similarly, a thermometer is used to record the entrance and output temperatures of cold fluid. The digital temperature indicator is used to determine the temperature of the wall. The pressures at the inlet and outflow of the flow are measured using a u-tube manometer. In a tabular column, the obtained readings are tallied. The technique is repeated.

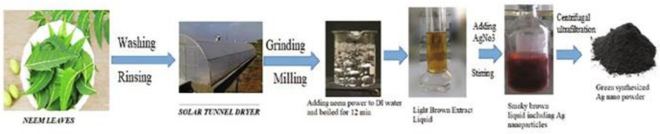

Fig. 1. Green synthesis of silver nano particles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 2. Nano fluid preparation

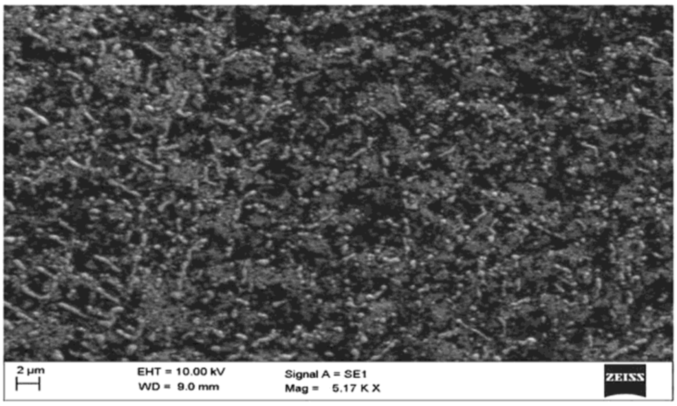

Fig. 3. SEM image of Nano particle

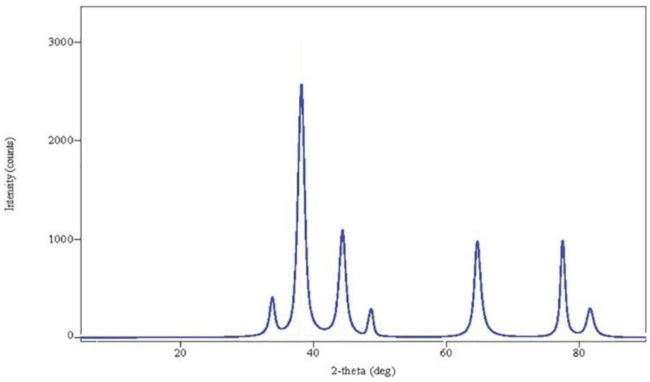

Fig. 4. XRD of green silver nanoparticles. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Data reduction

Analysis of heat exchanger is carried out using the following equation

Heat absorbed by cold water Q_c ¼ m_c × Cp_C × ðT_{in} — T_{out}Þ Heat rejected by hot water Q_h ¼ m_h × Cp_h × ðT_{in} — T_{out}Þ Area A ¼ pdl

Thermal Performance Factor

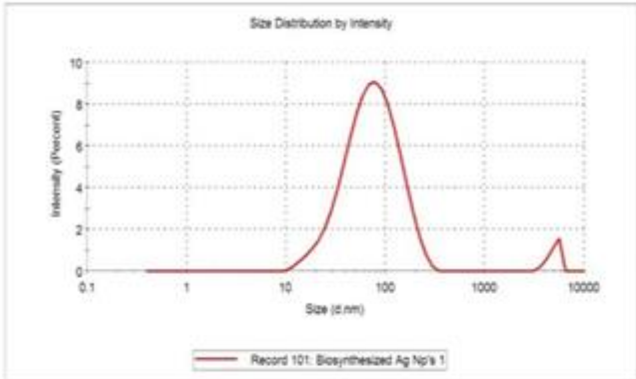

Fig. 5. Size distribution by intensity

III. RESULTS AND DISCUSSION

For heat transport studies, the experimental setup is confirmed using the Roger equation. The experiment was carried out with DI-water in a laminar flow setting, with a Dean Number of 500–2000. When the experimental data were compared to the theoretical values calculated using Roger's equation, it was discovered that they were quite close. Figure 8 shows a comparison of experimental values with the Roger equation. For volume control, experiments were carried out utilising nanofluid (agno3 –DI water).

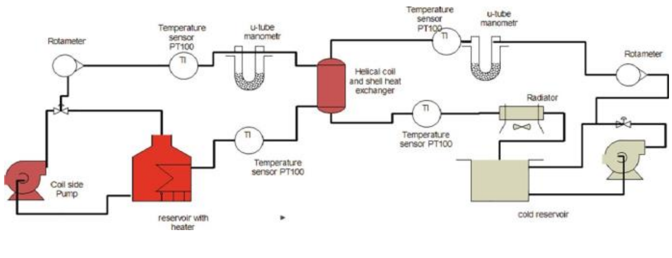

Fig. 6. line diagram of experimental setup

Fig. 7. Experimental setup

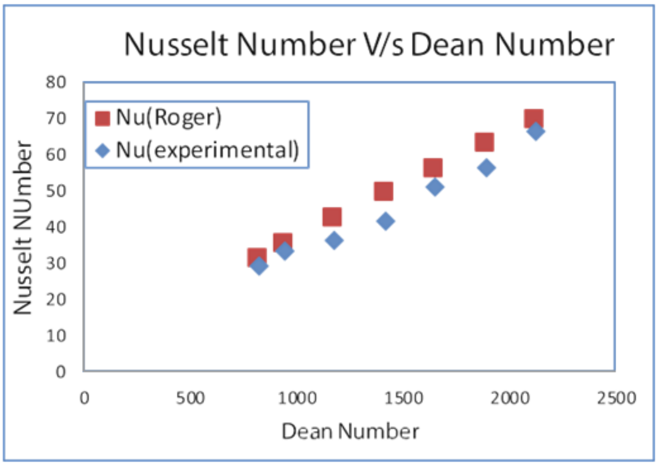

Fig. 8. Nusselt number V/s Dean Number (DI-water).

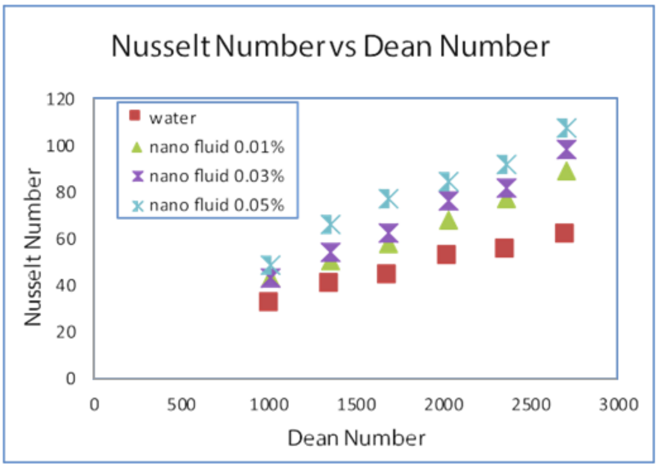

Fig. 9. Nusselt number V/s Dean Number

Concentration in the 0.01 percent to 0.05 percent range. Laminar flow tests were carried out with dean numbers ranging from 1000 to 3000. The graph Fig. 9 shows that the Nusselt number varies with time. Dean Number when compared with that of base fluid. From Fig. 10.

Increases in nano particle volume concentration and dean number improve convective heat transfer. The thermal conductivity of the disseminated nano particle in the base fluid improves heat transfer rate. In the past, various mechanisms have been presented. Because the swirl causes a disturbance at the coil surface, the residence time of nano fluid in the coil rises. The increased disturbance of the fluid at the coil surface is responsible for excellent fluid mixing and successful reconstruction of the thermal and hydrodynamic limit layer, resulting in a 32 percent increase in convective heat transfer. Nusselt number is increased by 65 percent as compared to DI water. Figure 11.

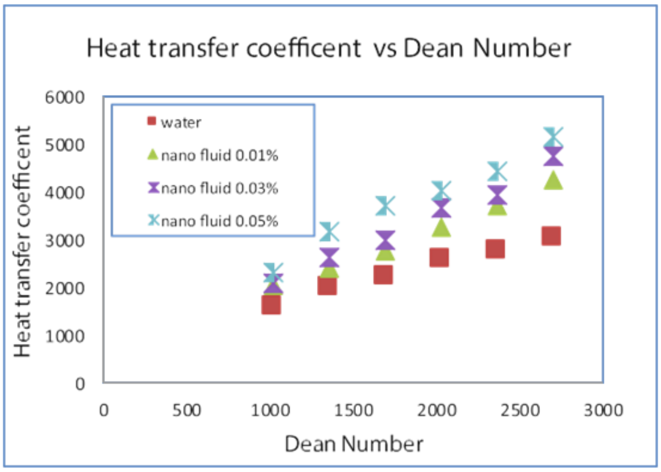

Fig. 10. Heat Transfer Coefficient V/s Dean Number.

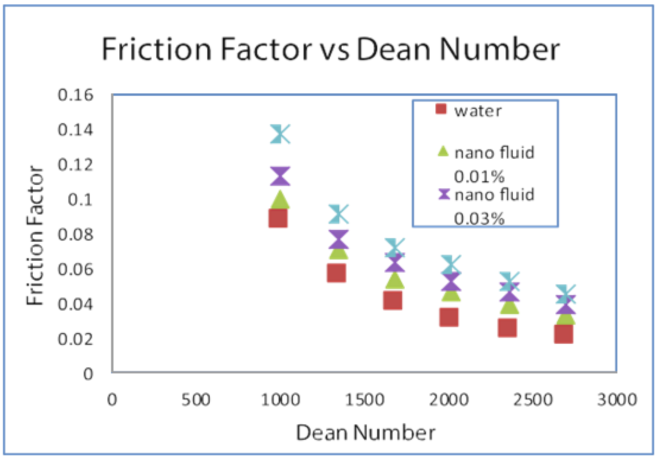

Fig. 11. Friction Factor V/s Dean Number.

Among them, the Brownian mechanism is most suited for justification of increased thermal conductivity. Brownian motion is the random, unpredictable movement of small particles in a fluid as a result of continuous bombardment by molecules from the surrounding media. The test investigation clearly shows that increasing the volume concentration of nanoparticles and the Dean Number improves heat transmission. Swirl is primarily responsible for the increased convective heat transfer in a tube flow. Before nanofluids are employed in commercial heating and cooling units, it is critical to count the pressure drop and friction factor in the test section. The pressure drop across the test portion is measured using a U-tube manometer during the experiment to analyse the flow properties of nanofluid. In comparison to Di water, the pressure drop and friction factor in nano fluid has no noticeable increase from the experimental value.

Thermal performance analysis

The thermal performance factor of a system for net energy gain must be greater than one. Under laminar flow conditions, the variance in thermal performance factor against Dean Number is larger than one for varied concentration ratios of nano- fluid. In a heat exchanger, the thermal performance factor is used to assess the impact of heat transfer rate and pressure. The graph Fig. 12 shows that as the volume concentration increases, the thermal performance factor decreases significantly. The graph above shows that reducing the concentration of nanofluid used is doable in terms of energy savings.

IV.CONCLUSION

Using a wide variety of particle volume concentrations, an experimental examination was carried out to explore the heat transfer and Friction Factor properties of AgNo3/DI water With a 0.05 percent volume concentration of nanofluid in a helical coil heat exchanger (0.01 percent , to 0.05 percent). The usage of these nanoparticles has boosted the rate of heat transmission while reducing pressure drop. The Nusselt number rises as the Reynolds number and the concentration of nanoparticles rise. The interaction of nanoparticle Brownian motion and micro-convection of the nanoparticles in the base fluid causes the boundary layer thickness to thin.

As the concentration of micro particles increases, so does the Friction Factor.

AgNo3/DI water nanofluid, the highest thermal performance factor value of 1.2 was discovered. The thermal performance of AgNo3/DI water nano fluid at 0.05 percent concentration is improved, according to the findings of the experiments. The value of the thermal performance factor drops slightly as the Dean Number rises.

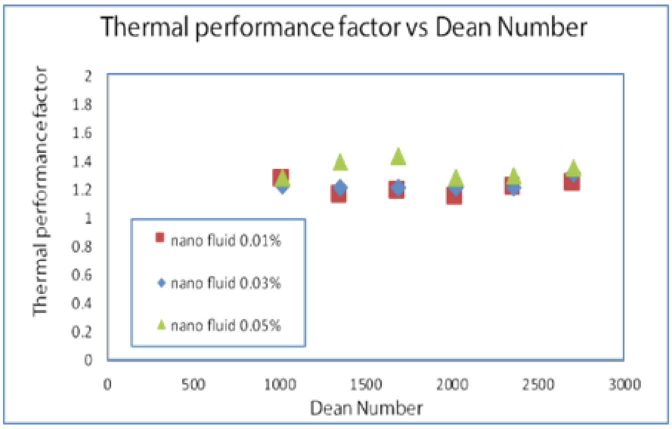

Fig. 12. Thermal performance factor V/s Dean Number

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