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Investigation on performance of bio synthesized copper nano fluid in helical coil and shell type heat exchanger

H. Ravi Kulkarni [a], C. Dhanasekaran [b], P. Rathnakumar [a], Edwin Geo Varuvel [c], S. Sivaganesan [b], M. Anantachar [a]

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Abstract

Tulsi leaf extracts has been used to produce biosynthesized copper nanoparticles. This biosynthesized nanoparticle is used for the preparation of nanofluid. The performance of nanofluid in a helical coil heat exchanger was studied for heat transfer rate and analyzed using standard correlation at the laboratory of NIT, Raichur. The fluid inlet temperature of the coil was 60°C and temperatures of fluid inside a shell of 32°C were maintained. A dean number in the range of 1000 – 10,000 was set on the shell side. The inlet fluid flow was constant at the coil. Thermal analysis has been carried out considering flow rate, overall heat transfer coefficient, and inlet and outlet temperature. When compared to the base fluid, using bio-synthesized Nanoparticles improved the heat transfer coefficient.

Introduction

Heat exchanger plays a vital role in heat transfer between fluid and fluid as well as fluid and solids. Different types of heat exchangers were available where heat transfer takes place with or with direct contact of fluid. In most thermal applications, improving heat transfer is critical. In recent years the heat exchangers have been the frontier in improving their performance and there is steady progress in improving heat transfer rate in active or passive ways. The bottleneck observed in heat exchangers i.e. lower heat transfer coefficient fluid is used in these systems. A solution to overcome this problem is replacing the conventional fluid with nanofluid. The addition of nanoparticles to fluid has been shown to enhance the fluid's heat transfer properties. Because of issues with Nano size particle suspension, different Nanoparticles have been used depending on their heat transfer application.

Choi et.al was the first to demonstrate the capabilities of this new class of nanofluids. Nanofluids are colloidal suspensions of nano-sized (5–100nm) 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. Khoshvaght et al. experimented with laminar flow conditions with 0.1 & 0.3 percent Cu of the copper nanoparticle has observed that enhancement in thermal performance, Reynolds number, heat transfer, and pressure drop with increasing nanoparticle concentration. T. Srinivas et. al. conducted experiments for 0.3, 0.6, 1, 1.5 & 2 percent concentration of Al2O3, TiO2, CuO/Water under Turbulent & Laminar flow condition. When comparing the three nanofluids, the 2 percent wt. CuO nanofluid had the best heat transfer. When compared to water, CuO nanofluid increases heat transfer by 32.7 percent. Milad Rakhsha et al. CuO/Water 0.10 percent concentration is used for the

experimental analysis under Turbulent & Laminar flow. CuO nanofluid discovered that with centrifugal force, the higher the velocity and Nusselt number, the easier it is to reach the outer surface of the helical tubes. Vinita. et.al. analyzed the nanoparticle volume fraction profiles and concluded that the nanoparticle volume fractions decline for the value of volume concentration.

Helically coiled tubes are superior to straight tubes in a few studies. Curved tubes have been proposed as a method for improving heat transfer and are widely used in a variety of mechanical applications. We used a helical coil heat exchanger for this investigation. The nanofluids lead to an increased thermal conductivity and finally to a heat transfer enhancement in heat exchangers. Hence an experiment on performance of bio synthesized copper nano fluid in helical coil and shell type heat exchanger was conducted at NIT Raichur.

Section snippets

Experimental apparatus

The experimental setup involving two-part viz. helical coil side heat exchanger (HCSHE) and shell side of heat exchanger (SSHE). The main components of HCSHE are helical coil, hot reservoir, pump, control valve, and heater coil. The helical coil having a dimension of 130mm and a pitch of 30mm with 7 no of turns. The helical coil is made of the copper tube having a thickness of 1.7mm with an outer diameter of tube12.7mm. The total length of the tube is 2600mm. The insulated hot reservoir is …

Preparation of nano fluid

Broth extraction

The drying of Tulsi leaf was done using solar dryer maintained at a temperature of 40°C for 48h. Before drying Tulsi is thoroughly cleaned using distilled water. In a mixer, the Tulsi leaves are churned in small powder. Cryogenic ball milling reduces the powder to nanoparticles. The obtained powder is passed through a set of 20 mesh sieve (840μm) to get a uniform size. The method of synthesis used was a top-down approach. Then the 10g of uniformly sized powder is taken into…

Experimental procedure

Initially, the experiment was conducted for trail reading using DI- water on both sides of Shell and Helical coil heat exchanger. The electrical power of 240V is supplied through dimmer stat to heating coil in the hot reservoir and controlled by a thermostat to stop the electrical supply at a set temperature of 60°C and this temperature is measured and displayed through thermocouple and digital temperature indicator respectively. The Deionized (DI) water in a hot reservoir is maintained at…

Data reduction

The following equation have been used

Cold water (Q_{cold}) $\mathbf{Q_{Cold}} = \mathbf{m} * \mathbf{Cp} * \mathbf{\Delta T}$

Hot water (Q_{Hot}) $\mathbf{Q_{Hot}} = \mathbf{m} * \mathbf{Cp} * \mathbf{\Delta T}$

Average heat Flow (Q_{avg}) $\mathbf{Qavg} = \frac{\mathbf{Qcold+Qhot}}{\mathbf{2}}$

Reynolds Number (Re) $\mathbf{Re} = \frac{\mathbf{4m}}{\mathbf{\pi d \mu}}$

Nusselt Number (Nu) $\mathbf{Nu} = \frac{\mathbf{h*d}}{\mathbf{k}}$

Dean Number (De) $\mathbf{De} = \mathbf{Re}\sqrt{\frac{\mathbf{d}}{\mathbf{D}}}$

Pressure Drop (Δp) $\mathbf{\Delta p = \rho * g * h}$

Friction Factor (f) $\mathbf{f = \frac{\Delta p}{\left(\frac{1}{2}\right)\rho v^2\left(\frac{D}{L}\right)}}$

Thermal Performance Factor (η) $\boldsymbol{\eta = \left(\frac{\left(\frac{Nu_{nf}}{Nu_w}\right)}{\left(\frac{f_{nf}}{f_w}\right)^{\left(\frac{1}{3}\right)}}\right) * \delta^{0.003}}$ …

Results

Laminar and turbulent flow tests were carried out with dean numbers ranging from 1000 to 10,000 when compared to the base fluid. The Fig. 6, Fig. 7 Depicted the effect of Nusselt Number with Dean Number for various concentration volume of nanoparticle. Nusselt number increases with increase in Dean Number for various concentrations of nanoparticle (i.e. 0.01, 0.03 & 0.05% of the concentration of nanofluid). It was observed that heat transfer was enhanced with the use of biosynthesized copper…

Conclusion

- The performance of heat transfer and Friction Factor characteristics were studied using copper/DI water nanofluid in an HCSHE.…
- An experimental setup was validated and it was found that the setup was in agreement with the standard correlation…
- Heat transfer characteristics were measured for the set up with DI water and 0.01, 0.03 & 0.05% of the concentration of nanofluid. It was observed that heat transfer was enhanced with the use of biosynthesized copper nanofluids.…
- The results indicated that the…

…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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