Study of thermal effectiveness in shell and helically coiled tube heat exchanger with addition nanoparticles

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Abstract. Thermal effectiveness was performed as preliminary research in shell and coiled tube heat exchanger with addition of Al2O3 nanoparticles. In the present study, the effect of small concentration of Al2O3 nanoparticles analysis for steady state. Water is selected as the working fluid of cold fluid and refrigerant R-22 as hot fluid. The present work also includes the effect of nanoparticles on logarithmic temperature difference (LMTD), amount of heat absorbed by the water as a time series function. Based on the result, the effectiveness of water-Al2O3 nanoparticles as cold fluid shows good agreement on heat transfer parameter enhancement. The heat exchanger effectiveness increase until 2.2% compare to that of heat exchanger without Al2O3 nanoparticles. This phenomenon indicates an increases of heat transfer process inside heat exchanger. The application of water-Al2O3 nanoparticles on shell and coiled tube heat exchanger enhanced the convective heat transfer passively.

Keywords: shell and coiled tube heat exchanger, effectiveness, heat recovery, energy conservation

1. Introduction
Heat exchanger is a engineering equipment that integrates two major field which are heat transfer and fluid mechanics. This equipment has concept of maximizing the heat transfer and minimizing pressure losses between two working fluid that driven by temperature difference [1]. In the last few years, optimization of heat exchanger through corrugated surface engineering [1-6], increase the energy efficiency and conservation in building [7-11], thermal power plant, air conditioning system (HVAC) for domestic and commercial using [12, 13] and many others application are always became the main concern of recent researcher. Efficient energy system design in refrigeration and air conditioning includes utilization of heat exchanger recovery system. Counter flow indirect evaporative cooler as heat exchanger recovery device [14-15], optimization on mechanical subcooling system [16-18], application of heat exchanger recovery unit, floating condensing and other equipment to recover waste heat [19-20].
Shell and helically coiled tube heat exchangers are one of the most important heat exchangers used in heat recovery technology. The study of the thermal performance of these types of heat exchangers was extensively performed in the past years by [21-25]. [26] investigated the thermal performance and pressure drop of a helical coil heat exchanger with and without helical crimped fins. [27] experimentally investigated the effect of flow rates, inlet temperatures, coil diameter and pitch in shell and helically coiled tube heat exchangers. Special attention has been given to designing small but efficient on heat transfer. To accommodate this reason, a technique developed to suspended small part of nanoparticles to the basic fluid became nanofluid. Nanofluid increase the thermal conductivity of basic fluid and increase the heat transfer inside the heat exchanger [28-31]. There has rapid development of utilization heat recovery and nanoparticles associated with air conditioning. To resolve this problem, recent research propose the use of heat recovery as a thermal energy reservoir for utilizing condenser heat to enhanced the energy conservation. To apply the nanofluid (Al₂O₃-water) for practical heat transfer process, more studies on its flow and heat transfer feature are needed. To address the this purposes, an preliminary investigation throught out this research predicting of the effectiveness the utilization shell and helically coiled tube heat exchanger and nanoparticles as heat recovery system.

2. Experimental Apparatus And Method

The typical heat exchanger with its geometrical parameters is shown in Figure 1.

![Figure 1: Heat recovery dimension](image)

The fluid flow pump through a PVC tube by centrifugal pump from the storage tank to the test section at range 0.00167 up to 0.0002 m³/s. The volume concentration of nanoparticles is 0.1%. The water-alumina nanofluid was prepared using mechanical mixer (magnetic stirrer) and ultrasonic processor for dispersing nanoparticles uniformly.

The heat transfer process in the nearly counter-flow exchanger was studied with LMTD and effectiveness model. For the LMTD method, heat transfer equation can be written as:

\[ Q = U \cdot A \cdot \Delta T_{LMTD} \]

where \( U \), overall heat transfer coefficient; \( A \), surface area for heat transfer; \( \Delta T_{LMTD} \), log-mean temperature difference between two fluids inside the heat exchanger. For single-pass (parallel or counterflow) heat exchangers:
\[
\Delta T_{LMTD} = \frac{\Delta T_i - \Delta T_o}{\ln(\Delta T_i / \Delta T_o)}
\]

where \(\Delta T_i\) and \(\Delta T_o\) are the temperature differences between two fluids at inlet and outlet ends of either fluid in the exchanger. The LMTD method can be extended to complex flow arrangements, such as multiple-pass shell-and-tube exchangers by introduction of a correction factor \(F\). In this investigation the time series of LMTD value calculated from temperature data multiply by factor \(F\).

The shell and helically coiled tube heat exchanger in this experiment using refrigerant R-22 as the hot fluid which flows inside the tube and water as the cold fluid flows outside the tube or in the shell side heat exchanger. The hot refrigerant temperature was 90 ± 2.5°C and the cold water temperature was 30 ± 2.5°C. The refrigeration system using capillary tube as expansion device so that the volume flowrate through the heat exchanger has small deviation. Meanwhile the volume flowrate of cold fluid 0.00167 m³/s up to 0.0002 m³/s. The heat exchanger test section length of was 0.7 m. The test section was equipped with four k-type thermocouple placed at each of fluid inlet and outlet section for temperature measurement. Thermocouples were connected to a data logger for digitalized and recorded for 3600 s in computer memory.

3. Result and Discussion

Preliminary experiments were done using no nanofluid as cold fluid. This data was then used as a comparison to that of (Al₂O₃-water) nanofluid as fluid to be heated. The time series data were processing using equation 2 to find the logarithmic mean temperature different (LMTD).

![Figure 3](image_url)

**Figure 3.** The time series of LMTD of shell and helically coiled tube heat exchanger on volume flowrate (a) 0.00167 m³/s; (b) 0.00183 m³/s; (c) 0.0002 m³/s
Figure 3 shown, that the LMTD value of for heat exchanger equipped with water-alumina nanoparticles higher that water heat exchanger. The LMTD analysis is suitable form of average temperature difference between hot and cold fluid of heat exchanger. The nanoparticles inside the water has function as heat carrier between the wall and the fluid. This intensive interaction plays an important role in convective heat transfer. So that, data of water-alumina nanofluid has LMTD lower than pure water.

![Graph](image)

**Figure 3.** Comparison of effectiveness between water and water-alumina nanofluid with different time:
- (a) 400 s
- (b) 800 s
- (c) 1200 s

From figure 3, it is found that the LMTD value of for heat exchanger equipped with water-alumina nanoparticles higher than water heat exchanger. The nanoparticles inside the water has function as heat carrier between the wall and the fluid. This intensive interaction plays an important role in convective heat transfer. So that, data of water-alumina nanofluid has LMTD lower than pure water.

4. Conclusions
An experimental investigation on shell and helically coiled tube heat exchanger with addition of Al₃O₃ nanoparticles was carried out for time series LMTD analysis and effectiveness analysis for describing preliminary heat transfer characteristics. The result can be summarized that the addition of 0.1% Al₃O₃ nanoparticles has slight lower of time series LMTD value. The effectiveness for water-alumina better 2.2% compare to that of pure water as cold fluid inside heat exchanger.

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