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A Review on Triple Tube Heat Exchanger for Optimizing Heat Transfer Rate

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Abstract - *In recent years, the performance of thermal control systems has improved in many ways thanks to developments in control theory and information technology. Efforts have been made to produce more efficient heat exchangers using various methods to improve heat transfer. The triple concentric tube heat exchanger is better than the double concentric tube heat exchanger. The three concentric tube heat exchanger consists of three tubes of different diameters connected concentrically. Most previous studies used two liquids for different arrangements. Cold fluids flow from the inner tube and outer ring and hot fluid from the inner ring. This article presents the proposed methodology, computational fluid dynamics and the representation of the mathematical relationship.*

Key Words: CFD, heat exchanger, temperature, TTHE, Tube.

1. INTRODUCTION

Over the past decade, the growing demand for energy has led many scientists to conduct extensive research on the optimal use of energy to overcome this problem. Improving the efficiency of thermo fluidic devices is one of the solutions to achieve this goal. One of the most used thermal equipment is the double tube heat exchanger, which is widely used in various industrial applications, so increasing its efficiency is beneficial for energy saving. Three-tube heat exchangers are introduced to solve the disadvantages of double-tube heat exchangers by passing excess flow and increasing the heat exchange area per unit of length.

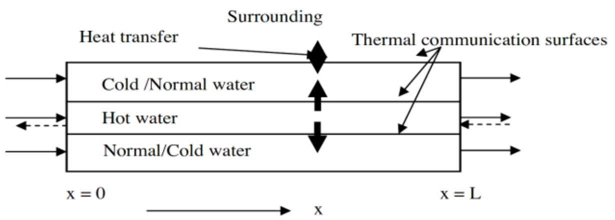

Fig -1: Flow directions of three fluids for N–H–C and C–H–N configurations of the triple concentric pipe heat exchanger

In the figure above, a concept of a triple concentric tube heat exchanger, as shown in figure 1. The three liquids, namely hot liquid, cold liquid and normal liquid, are pumped to the heat exchanger from three different tanks, as shown in Fig.1. Normal liquid flows through the innermost tube, hot liquid flows through the inner ring, and cold liquid flows through the outer ring. This arrangement of the flow of different liquids is called the N-H-C heat exchanger configuration, as shown in Figure 1. The flow of fluids can be reversed to provide parallel counter-current flow arrangements. Basically, a triple concentric tube heat exchanger consists of 3 tubes placed concentrically in each other. We have therefore called these tubes the inner tube, the intermediate tube and the outer tube. The heat exchanger consists of an inner tubular space, an inner ring and an outer ring. The efficiency offered by a triple tube heat exchanger is higher than that of a double tube heat exchanger. Heat exchangers are used for air conditioning, heating applications, power generation, waste heat recovery and chemical treatment

2. LITERATURE REVIEW

Navin Raja Kuppusamy& Lee Poh Seng [1] The hybrid cooling system has become a promising thermal management system for data centers due to its ability to constantly dissipate heat from various electronic components. Fluid cooling and air cooling can be used to cool the active component or the passive component. The results critically assessed the trade-off between TFHEX's heat transfer capability and its pressure drop, i.e. the required pump power. This can be a benchmark for data center engineers to choose the appropriate TFHEX configuration for hybrid cooling.

M. Bahiraei, N. Mazaheri, A. Rizehvandi [2] The current publication attempts to numerically study the hydrothermal properties and energy performance of a hybrid nanofluid containing grapheme-nano-platinum composite powder in a triple-tube heat exchanger with inserted fins. The nanofluid flows from the inner ring side, while the cold fluid and normal fluid flow from the tube side and the outer ring side respectively. In terms of energy efficiency, the heat exchanger with the smallest fin height and the smallest fin pitch with the highest nanoparticle concentration is recommended, as the performance index in this case is higher than that of others cases.

J.D. Moya-Rico at el. [3] This work presents an artificial neural network (ANN) model that can accurately predict heat transfer rate and pressure drop in a triple concentric tube (TTHX) heat exchanger with corrugated and uncorrugated inner tubes and which incorporates a liquid typically found in the food industry. The best training algorithm is Bayesian control. The results of the ANN agree well with the experimental data, with an absolute mean relative deviation of less than 1.91% for the heat transfer coefficient and less than 3.82% for the pressure drop.

Radouane Elbahjaoui , Hamid El Qarnia [4] This paper presents a thermal performance analysis of triple concentric tube latent heat storage systems filled with a commercial phase change material (PCM: RT50). Triple concentric tube storage tanks with PCM are connected to a flat collector. A fluid that acts as a heat transfer fluid circulates in the solar collector and receives solar thermal energy. This is then transferred to the PCM by forced convection and stored in memory as latent heat.

Birol Basal & Ahmet Unal [5] In order to improve storage performance, a new thermal energy storage system is proposed in this study consisting of a triple arrangement of concentric pipes. The rationale for the present proposal is that an annular layer of PCM, which is in contact with the coolant of the inner and outer surfaces, provides a larger heat transfer surface. For this purpose, a numerical study is carried out using the enthalpy method.

3. PROPOSED METHODOLOGY

The main objective of the proposed work is to improve the performance development of TTHE through analytical methods, CFD analysis and heat exchanger testing.

We will study the TTHE countercurrent analysis method derived from Ediz Batmaz. This gives us an idea of the heat transfer rate and efficiency.

A) Total heat transfer coefficients in a counter-current arrangement.

B) Axial distribution of the temperature of the liquids in the counter-current group.

We use a basic method to calculate the total heat transfer coefficients and the length of the three concentric tube heat exchanger. The triple tube heat length is mathematical in this work and CFD analyzes should be performed.

3.1 Computational Fluid Dynamics

Usually abbreviated to CFD, it is a branch of fluid mechanics that uses numerical analysis and algorithms to solve and analyze fluid flow problems. Computers are used to perform the necessary calculations to simulate the interaction of liquids and gases with surfaces defined by boundary conditions with fast supercomputers, better solutions can be obtained. Ongoing research is leading to software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. The initial experimental validation of this software is carried out using a wind tunnel, the final validation being carried out by large-scale tests, eg. Flight tests. The fundamental basis of nearly all CFD problems are the Navier-Stokes equations, which define any single-phase fluid flow (gas or liquid, but not both). These equations can be simplified by removing the terms describing the viscous effects to further simplify the Euler equations by removing the terms describing the vortices to get all the potential equations. Finally, these equations can be linearized for small disturbances in subsonic and supersonic flows (non-transonic or hypersonic) to obtain linearized potential equations. In general, the geometry is simplified for CFD studies. Mesh is the discretization of the area in small volumes, the equations are solved using iterative methods. The modeling begins with the description of the boundary and initial conditions of the rule and leads to the modeling of the entire system.

4. MATHEMATICAL RELATION

The heat transferred of the hot fluid through the inner annulus is calculated as follows:

$$Q_h = m_h C_h (T_{hi} - T_{ho})$$

While the heat transferred of the cold fluid in the inner tube is calculated as:

$$Q_c = m_c C_c (T_{co} - T_{ci})$$

The heat transferred of the normal fluid in the outer annulus is calculated as:

$$Q_n = m_n C_n (T_{no} - T_{ni})$$

The heat balance between the chilled, normal and hot fluid for the triple concentric-tube presumes the establishment and determination of the heat flow transferred and the heat flows received as follows:

$$Q_h = (Q_c + Q_n)$$

The average heat transfer rate Q_{av} is determined between the three fluid sides as:

$$Q_{av} = \left(\frac{Q_h + Q_{cn}}{2}\right)$$

Where Q_{cn} is the aggregate of the chilled and normal tap fluid heat transfer rate as:

$$Q_{cn} = (Q_c + Q_n)$$

The heat transfer coefficient of the inner annulus h_{in} is calculated from:

$$Q_h = h_{in} A\ LMTD_{av}$$

The average log-mean temperature difference between the three fluids is LM T D_{av}

$$LMTD_{av} = \frac{LMTD_{hc} + LMTD_{hn}}{2}$$

Where is the log-mean temperature difference between hot and chilled fluid while is the log-mean temperature difference between hot LM T D_{hc} and normal LM T D_{hn} tap fluid.

The Reynolds number and Nusselt number are determined as:

$$Re = \frac{\rho v D_{hy}}{\mu}$$

$$Nu = \frac{h D_{hy}}{k}$$

Where D_{hy} is defined as the hydraulic diameter, which calculated as:

$$D_{hy} = (D_{2\,i} - D_{1\,o})$$

The friction factor of the inner annulus of the triple concentric-tube is calculated as:

$$f_{in} = \frac{2\Delta P_{in} D_{hy}}{\rho l v^2}$$

The effectiveness of the triple tube heat exchanger is calculated as:

$$\varepsilon = \frac{Q_{av}}{Q_{max}} = \frac{Q_{av}}{(m\ c)_{min}(T_{h\,i} - T_{c\,i})}$$

The heat transfer per unit pumping power of the triple tube heat exchanger is calculated as:

$$\left({}^{Q}/_{P_p}\right) = \frac{m_h c_h \Delta T_h}{(m_h\ \Delta P_{in}/\rho_w) + (m_n\ \Delta P_o/\rho_w)}$$

5. CONCLUSION

It is expected that after completing all types of analysis, such as mathematical analysis and CFD, there will be a productive result. The three-tube heat exchanger offers maximum heat exchange area and provides better heat transfer rate and performance with different friction factors. The proposed methodology, computational fluid dynamics and the representation of the mathematical relationship presented in this article are used.

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