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Design And Analysis of A Concentric TTHEX (Triple Tube Heat Exchanger) for Better Heat Transfer with Enhanced Thermal Performance Using Computational Fluid Dynamics

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Abstract

For the goal of improving thermal efficiency, mathematics and computationally fluid dynamics assessments of several designs of a circumferential TTHEX (triple tube heat exchanger) were done. A total of five designs have been used to check its thermal performance for the same boundary conditions at various concentration ratios ofgraphenenanoplatelets–platinumnanofluid for this The momentum boundary condition with no slip is set for solid walls whereto achieve adiabatic conditions, the heat flows is for an outside lateral wall is set to zero, while the inner tube walls and baffles are coupled. In the computational domain, fluency software is often used to estimate fluid's heat transfer characteristics. The system of equations is continuously solved using the SIMPLE algorithm and finite volume formalism. Because the swirling impact on the turbulent boundary layer has more precision than the normal k-epsilon model, the RNG k-epsilon model is used for turbulent flow, and the second order optimization algorithm is utilized for movement energetic turbulent and its distribution function. Results show that TTHEX with inclined baffle at 75^o gives a maximum outlet temperature for nanofluid of 20.77^{o}K for ø = 0.1, which is 21.71% greater than without baffle, 33.56% greater than straight baffles and 20.58% greater than baffles inclined at 60^o. The heat transfer rate of 17.98% higher than without baffle, 27.79% higher than straight baffle and 17.04% higher than baffles inclined at 60^o, while the maximum overall heat transfer coefficient of 0.9832 for ø = 0.1 have been observed. Hence concentric TTHEX with inclined ribs at 75^o recommended for better heat transfer.

Keywords: Concentration ratio, heat transfer rate, Nano-fluid, Triple tube heat exchanger, Thermal performance.

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Introduction

A heat exchangers are devices or electronic device that transfers heat among two fluids in coming in contact. Heat exchangers are used in a variety of ways in our daily lives. Boilers, capacitors, air conditioners, and chilled columns, for examples, all use condenser microphones and distillation columns. Exchangers are also employed in the automotive industry in the form of radiators and cooling coil within engines. Heat exchangers are also commonly employed in the chemical and industrial industries to transfer heat across two liquids in a single or two phases.

Triple-tube heat exchangers are introduced to solve the disadvantages of double-tube heat exchangers by passage of the extra flow and increase of heat transfer area per unit length. The three fluid, heated, cool, and ordinary, were piped to the heat exchanger form three different containers, as indicated in Figure 1. The innermost pipe contains ice water, the medium tubing has hot water, and the outermost annulus contains regular water.

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Conflict of interest: None

Features of triple concentric tube heat exchanger

- A smooth indented inner profile ensures easy cleaning.
- Turbulence is created at low water velocities to enhance the heat transfer in the tube.
- Fouling on the tube surface is minimized.

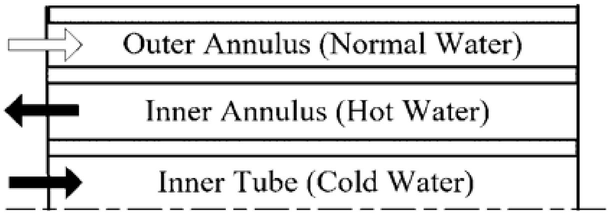


Figure 1: Flow directions of three fluids of the triple concentric pipe heat exchanger

- A wide range of diameters & types are available.

Application of triple tube concentric Heat exchanger

Triple concentric tube heat exchangers are used for various applications such as

- In the Food processing industries
- For the Pasteurization of viscous food products (milk, cream, pulpy orange juice, apple mash etc.)
- For the Sterilization of microorganisms such as fungi, bacteria, viruses, spore etc.
- For the Cooling of industrial machinery
- For Energy conversion and
- For the Refrigeration.

Preparation of graphenenanoplatelets–platinum nanofluid

According to the H. Yarmand *et al.* 2016 the graphenenanoplatelets–platinum (GNP) is not naturally hydrophilic and it can't be dispersed in distilled water directly. This functionalization process helps to introduce functional groups such as hydroxyl and carboxyl groups on the surface of GNP as shown in figure 2. Acid treatment process may used to conduct by dispersing GNP in a 3:1 ratio of H_2SO_4 and HNO_3 solution for 3 hours under bathultrasonication. After 3 hour, these GNPs should wash several times by DI water and then dried in an oven at the temperature of 70 °C for more than 24 hours.

Literature summary

Chen, (2022) Investigate the thermophysical properties of a vertically residual heating triple-tube heating element with non-uniform fin configuration and sizes *Seyed,* (2021) Work on fluid layer flowing in a triple tubular heat exchanger: power and thermal efficiency *M Malavasi* (2021) Using a parameters estimation method, investigate the temperature characterization of three tube heat exchangers*Mehdi,* (2021) To assess the heat transfer coefficients, a neural net was integrated with environment technique *Mehdi,* (2021) Estimate the heat transfer characteristics of a corrugated quintuple exchangers that works with water nanofluid that used a neural net. *Seyed,* (2021) Individual and combination examination of topological factors influencing the melting behavior of a three temperature exchangers *P Tanish,* (2021) Heat Is transferred in a Concentric Three Concentric Tube Heat exchanger: An Experimental Investigation *Sumit,* (2020) Improving the hydrodynamic performances of a nanofluid

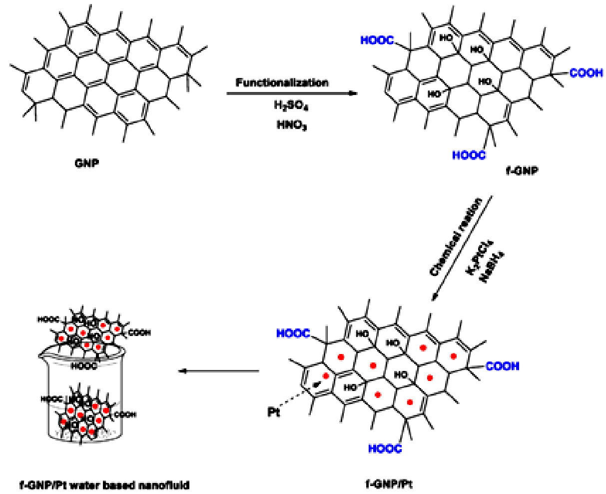


Figure 2: Procedure to prepare graphenenanoplatelets–platinum nanofluid[H. Yarmand *et al.* 2016]

flow in a double tubular heat exchanger is a current project *Tuyen,* (2020) A liquid-to-suction quintuple heat exchanger's thermoelectric features and optimization *Hossein,* (2019) Numerical simulation was used to conduct a thermal investigation of a triple - helical grounded exchangers *Nima,* (2019) Analyzing the effectiveness of a grapheme-operated corrugated triple-tube heating element *Navin,* (2019) Thermal and hemodynamic performances of a threefold fluid heating element with various passages and rows was investigated. *P. C. Mukesh,* (2019) A review on triple tube heat exchangers *Jasim,* (2018) PCM melted in energy storage technologies is expedited thanks to an unique fin design in a penthouse apartment heat exchanger. *Maulik,* (2017) An introduction to triple concentric tubular heat exchanger *Ravi,* (2017) In an inner diameter of the double pipe, heat transmission, friction coefficient, and efficiency of Fe_3O_4 hybrid nanofluid *Valerio,* (2017) A cylindrical tube heat exchanges exchange's thermal resistance can be predicted numerically *Nora,* (2017) In both stable and unstable modes, the thermodynamics behaviour of a triple tubular heat exchanger is studied. *Dilpak*(2016) A Triple Concentric Tube Heat Exchange's Topology and Heat Transfer Analysess *Radulescu,* (2016) Heat transport when double and triple cylindrical heat exchanger is studied *Senthil,* (2016) Triple Circles Tubes Heat Transfer Numeric Analysis Dimpled Tube Geometry *Gomaa,* (2015) A thread exchangers was investigated experimentally and numerically *Sarafraz,* (2015) In a double-pipe exchangers, improvement of thermal convection using biologically nanofluids *Reddy,* (2014) For a double tube heat exchanger, the overall heat transfer and frictional factors of an ethylene glycol hybrid nanofluid TiO2 nanofluid were investigated experimentally *Sanjay,* (2014) Thermo-hydraulic behavior of a thread heat transfer was investigated experimentally *Birol,* (2013) A thread residual heating thermal energy storage system is numerically evaluated *Pierre,* (2013) A Triple Concentric Tube Heat Evaporator Incorporated into a Wood-Based Atmospheric Air for Power Dwelling units: An Experimental Investigation

Zan Wu, (2013) With a double helical heating element, total pressure and rate of heat transfer of freshwater and nano - fluids *Jahanmir*(2012) Performance evaluation of Twisted bundle heat exchangers by CFD *Zhao,* (2012) Developments Thermoelectric design and simulation of concurrent 3 heat exchangers using a new integral-mean temperature difference method *Sinziana,* (2012) Establish Heat Transfer Coefficient Solver for a Triple Concentric-tube Heat Exchanger in Transition Regime *Weerapun,* (2009) Work on TiO_2–water nanofluids heat transfer performance and pressure gradient characteristics with a double counter flow heat exchanger *Ediz,* (2010) In a triple circular tube, research is being done on average heat transfer efficiencies and axially temperature profile*Nema,* (2006) Improved milk fouling simulations in a helix three tubular heat exchanger is being worked on *Ediz,* (2005) In a three tubular heat exchanger, the average heat transfer statistics are determined. According to the preceding pieces of literature, there has been and continues to be a lot of work done to improve the efficiency of triple heat exchanger tube. The majority of the study focuses on shell and tube, dual and treble tubular heat exchanger, and nano - fluids, able to react quickly, and other fluids. By modifying the design and various geometrical factors, different Empirical, Numeric, and Computer simulation assessments were optimized to evaluate the temperature dependent behaviour. As a result, there is opportunity to work in this industry.

Objective

Triple tubular heat exchanges must be constructed for a variety of scenarios. This following are the project's main objectives..

- Researching various thermal exchanges and their mathematical relationships.
- Create several computer simulations of triple concentric tubular heat exchanger, such as heat exchangers with baffling, straight baffles, and inclination bemuses.
- Perform computational fluid dynamics study on all triple concentric tube heat exchanger designs at varied nano - fluids concentrations.
- To evaluate the outcomes of all treble tubular heat exchanger designs.

Methodology

Mathematical Analysis Of Concentric Triple Tube Heat Exchanger

The current study involved in chilling has undertaken a statistical modeling of concentrictreble tubular heat exchanger. In the inflatable raft, cool fluids flow and outer tube at a temperature of $T_{c1(in)}$ andexits at temperatures $T_{c1(out)}$ where $T_{c2(out)}$ in the inner tube and outer tube, respectively. The heated fluid that must be cooling entering thetreble tubular heat exchanger through the inner annular at a temperature of $T_{h(in)}$ and exits at a temperature of $T_{h(out)}$ as shown in figure no. 3.

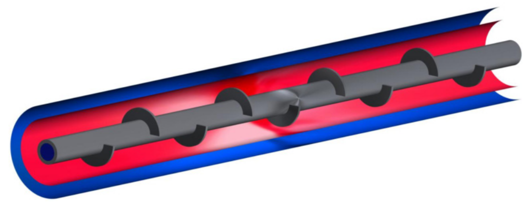


Figure 3: Arrangement of fluid flow in triple tube heat exchanger

The temperature difference modelling in a three tube heat exchanger is different for cases in which the hot fluid flows in much the same way as the cooling water and cases where another heat flux flows with in reverse way. As a result, the formulas for all these two distinct configurations are examined independently.

There are some assumptions have been considered for simplicity[29]

- The system is at steady state.
- Both fluids are incompressible.
- Fluid properties are constant.
- Phase change does not occur at any point in the heat exchanger.
- The heat exchanger is insulated from the surroundings.

Heat transfer rate of the hot nanofluid, cold fluid and normal fluid

$$q_{nf} = \dot{m}_{nf} \cdot c_{p,nf}\left(T_{nf,in} - T_{nf,out}\right)$$

$$q_{cold} = \dot{m}_{cold} \cdot c_{p,cold}\left(T_{cold,out} - T_{cold,in}\right)$$

$$q_{normal} = \dot{m}_{normal} \cdot c_{p,normal}\left(T_{normal,out} - T_{normal,in}\right)$$

Overall heat transfer coefficient of the concentric triple tube heat exchanger

$$U = \frac{q_h}{A_{cross,inner} \times LMTD_{avg}}$$

$$LMTD_{avg} = \frac{LMTD_{hot\ \&\ cold} + LMTD_{hot\ \&\ nf}}{2}$$

$$LMTD_{hot\ \&\ cold} = \frac{\Delta T_1 - \Delta T_2}{ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}$$

And

$$LMTD_{hot\ \&\ nf} = \frac{\Delta T_3 - \Delta T_4}{ln\left(\frac{\Delta T_3}{\Delta T_4}\right)}$$

Where

$$\Delta T_1 = T_{hot,in} - T_{cold,out}$$

$$\Delta T_2 = T_{hot,out} - T_{cold,in}$$

$$\Delta T_3 = T_{hot,in} - T_{nf,out}$$

$$\Delta T_4 = T_{hot,out} - T_{nf,in}$$

Circumferential tube heat exchanger exchanger efficiency

$$Effectiveness = \frac{q_h}{q_{max}}$$

Bulk mean temperature of cold fluid

$$T_{b,cold} = \frac{T_{cold-1,in} + T_{cold-1,out}}{2}$$

Bulk mean temperature of hot fluid

$$T_{b,hot} = \frac{T_{hot,in} + T_{hot,out}}{2}$$

Liner velocity

Liner velocity of nano fluid

$$v_{nf} = \frac{\dot{m}_{nf}}{\rho_{nf} A_{cross\ mid}}\ m/sec$$

Liner velocity of cold water

$$v_{cold} = \frac{\dot{m}_{cold}}{\rho_{cold} A_{cross\ inner}}\ m/sec$$

Liner velocity of normal water

$$v_{normal} = \frac{\dot{m}_{normal}}{\rho_{normal} A_{cross\ outer}}\ m/sec$$

Reynolds number

Reynolds No. of nanofluid

$$R_{e,nf} = \frac{\rho_{nf} v_{nf} D_{mid}}{\mu_{nf}}$$

Reynolds No. of cold water

$$R_{e,cold} = \frac{\rho_{cold} v_{cold} D_{inner}}{\mu_{cold}}$$

Reynolds No. of normal water

$$R_{e,normal} = \frac{\rho_{normal} v_{normal} D_{out}}{\mu_{normal}}$$

Calculation of Nusselt no. of nanofluid

$$Nu_{nf} = \frac{h_{nf} D_{h,nf}}{k_{nf}} = 0.023 R_{e,nf}^{\ 0.8} \times Pr_{nf}^{\ 0.4}$$

Nusselt number of chilled water calculations:

$$Nu_{cold} = \frac{h_{cold} D_{h,cold}}{k_{cold}} = 0.023 \times R_{e,cold}^{\ 0.8} \times Pr_{cold}^{\ 0.4}$$

Nusselt number of typical water calculations:

$$Nu_{normal} = \frac{h_{normal} D_{h,normal}}{k_{normal}} = 0.023 R_{e,normal}^{\ 0.8} Pr_{normal}^{\ 0.4}$$

Heat transfer coefficient for GNPs, Normal and cold water

$$h_{nf} = \frac{k_{nf} . Nu_{nf}}{D_{hnf}}\ W/_{m^2 . k}$$

Heat transfer coefficient for cold water:

$$h_{cold} = \frac{k_{cold} . Nu_{cold}}{D_{h,cold}}\ W/_{m^2 . k}$$

Heat transfer coefficient for Normal water:

$$h_{normal} = \frac{k_{normal} . Nu_{normal}}{D_{h,normal}}\ W/_{m^2 . k}$$

Darcy-Weisbach factor for Newtonian fluids

$$f_D = \frac{64}{Re}$$

Blasius friction factor for turbulent flow in circular tubes

Blasius developed an expression of friction factor in 1913 for $2100 < Re < 10^5$

$$f_{Blasius} = \frac{0.0791}{Re^{0.32}}$$

The expression for pressure drop through both sides

Pressure drop for GNPs

$$\Delta p_{nf} = 4 f_{nf} \frac{L}{D_2} \rho_{nf} \frac{{\mu_{nf}}^2}{2}$$

Pressure drop for cold

$$\Delta p_{cold} = 4 f_{cold} \frac{L}{D_1} \rho_{cold} \frac{{\mu_{cold}}^2}{2}$$

Pressure drop for normal

$$\Delta p_{normal} = 4 f_{normal} \frac{L}{D_3} \rho_{normal} \frac{{\mu_{normal}}^2}{2}$$

Computational Fluid Dynamics Analysis

Computational fluid dynamics is the analysis of systems involving fluid flow, heat transfer by use of computer based simulation. This technique is very powerful and extent a wide range of industrial application areas. Thecomputational fluid dynamics used to solve a wide variety of problems such as fluid flow in various domains, aerodynamics of aircraft, Heat exchangers, IC engines etc. The current study uses Ansys fluent to perform computational fluid dynamics simulation on a circumferential three tubular heat exchanger. The governing equations such as continuity equation, momentum equation, and energy equations are used to perform this computational analysis.

Algorithm Used For Computational Fluid Dynamics Analysis

Governing Equations

For the CFD analysis, the governing partial differential equations, in steady state form,

The governing equations can be solved via computational models under the following conditions:

- The nanofluid is believed to be homogeneous and in a stable state.
- Turbulent and incompressible flow are terms used to describe flow.

Conservation of Mass or Continuity Equation

The conservation equations formula, often known as that of the conservation equations, is written in the form:The axial coordinate is x, and the fluid velocity is u.

Momentum Conservation Equations

Conservation of momentum in an inertial reference frame is described by

$$\frac{\partial(\rho_{nf}.u_{i,}u_j)}{\partial x_i} = -\frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_j}\left\{\mu_{nf}\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)\right\} + \frac{\partial}{\partial x_j}\left(-\rho_{nf}.\overline{u_i'}.\overline{u_j'}\right)$$

Energy Equation

$$\frac{\partial(u_i.T)}{\partial x_i} = \frac{\partial}{\partial x_j}\left\{(\Gamma+\Gamma_t)\frac{\partial T}{\partial x_j}\right\}$$

Where:

T= Temperature

Γ = Molecular thermal diffusivity

Γ_t = Turbulent thermal diffusivity

Where:

Pr = Prandtl number

$$\Gamma = \frac{\mu_{nf}}{\rho_{nf}.Pr}$$

Table 1: Dimensions of Ribbed concentric TTHEX

Parameter	*Value (mm)*
Rib heights H	9 mm
Rib pitches λ	50 mm
heat exchanger length L	500 mm
thickness of the walls (t_b)	2.77 mm
diameters of the inner tubes	13.51 mm
diameters of intermediate tubes	45.26 mm
outer tube diameter	70.66 mm
Ribs thickness (t_R)	2 mm
material of both tubes and ribs	Aluminum
Thermal conductivity	200 W/mK

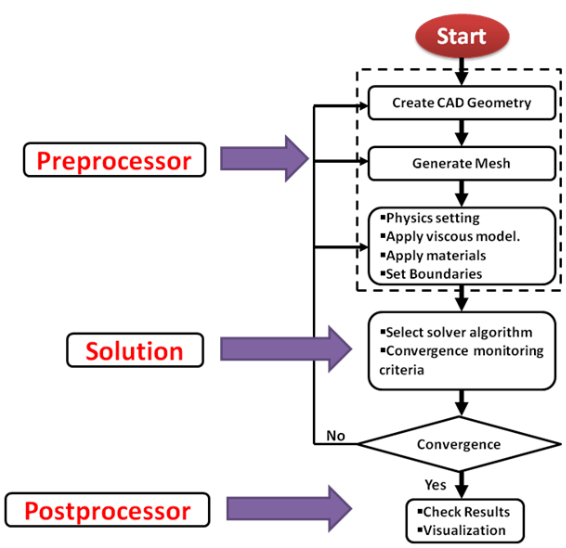


Fig ure 4: Algorithm used for Computational fluid dynamics analysis

$$\Gamma_t = \frac{\mu_{nf,t}}{\rho_{nf}.Pr_t}$$

***k* − *ε*model:**

The turbulence kinetic energy '*k*' and its rate of dissipation 'ε is obtained from the following transport equations:

$$\frac{\partial(\rho_{nf}.\varepsilon u_i)}{\partial x_i} = \frac{\partial}{\partial x_j}\left(\alpha_\varepsilon.\mu_{eff}.\frac{\partial \varepsilon}{\partial x_j}\right) + C_{1\varepsilon}\frac{\varepsilon}{k}(G_k) - C_{2\varepsilon}\rho_{nf}\frac{\varepsilon^2}{k} - R_\varepsilon$$

$C_{1\varepsilon}$= 1.42 (constant) and

α_ε = 1.39 (constant) [10]

For the present study the kinetic energy '*k*' may by written as

$$\frac{\partial(\rho_f.\varepsilon u_i)}{\partial x_i} = \frac{\partial}{\partial x_j}\left(\alpha_k.\mu_{eff}.\frac{\partial k}{\partial x_j}\right) + G_k - \rho\varepsilon$$

Where:

α_k

= 1.39 (constant) [10]

G_k

= Generation rate of turbulent KE due to mean velocity gradients

$$G_k = -\overline{\rho u_i' u_j'}\frac{\partial u_j}{\partial x_i}$$

Hear the inverse of effective prandtl number for ε and k are defined by α_ε and α_k and

μ_{eff}= effective viscosity of fluids

$\mu_{eff} = \mu_{nf} + \mu_{t,nf}$

Where

μ_{nf} = viscosity of nanofluid and

$\mu_{t,nf}$= Turbulent eddy viscosity for nanofluid

$$\mu_{t,nf} = \rho C_\mu \frac{k^2}{\varepsilon}$$

Where

C_μ= constant (0.0845) [10]

The RNG k-epsilon model is used for turbulent flow. Because this model has the ability to consider the effect of swirling flows on turbulence with higher precision as compared to the standard k-epsilon turbulence model.

The turbulence kinetic energy: Turbulence kinetic energy *k* is the kinetic energy per unit mass of the turbulent fluctuations u_i'The SI unit of k is $J/kg = m^2/s^2$

$$K \stackrel{\text{def}}{=} \frac{1}{2}\overline{u_i'u_i'} = \frac{1}{2}\left(\overline{u_x'^2} + \overline{u_y'^2} + \overline{u_z'^2}\right) = \frac{3}{2}\overline{u'^2}$$

Total entropy production rate:

$S_t = S_h + S_f$

Where

S_t= total entropy generation

S_h= Thermal entropy production rate

S_f = Frictional entropy production rate

$$S_f = \frac{\mu}{T}\left\{2\left[\left(\frac{\partial v_x}{\partial x}\right)^2 + \left(\frac{\partial v_y}{\partial y}\right)^2 + \left(\frac{\partial v_z}{\partial z}\right)^2\right] + \left(\frac{\partial v_x}{\partial y} + \frac{\partial v_y}{\partial x}\right)^2 + \left(\frac{\partial v_x}{\partial z} + \frac{\partial v_z}{\partial x}\right)^2 + \left(\frac{\partial v_y}{\partial z} + \frac{\partial v_z}{\partial y}\right)^2\right\}$$

And

$$S_h = \frac{\beta}{T^2}\left[\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2 + \left(\frac{\partial T}{\partial z}\right)^2\right]$$

The global entropy generation rate is an integral of the local entropy generation rate in the whole domain of the fluid and may be expressed as

$$S = \int S dv\ (W/K)$$

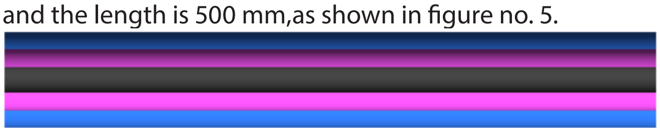
The total rate of exergy destruction depends on the total entropy generation rate and can be expressed by

$$X_d = T_0 . S_t$$

T_0= Ambient temperature

CAD model of concentric triple tube heat exchanger

In this work, we present three-dimensional Cad files of a concentric triple tube heat exchanger both with and without baffles. With a straight baffle having a pitch 50 mm & baffle height 9 mm, baffles inclined at 45^O, 60^O& 75^O are created with the help of the design modular of the ANSYS workbench. The inner tube diameter is 13.51 mm, the intermediate tube diameter is 45.26 mm, the outer tube diameter is 70.66 mm, and the length is 500 mm,as shown in figure no. 5.



a) Without baffle

b) Straight baffle

c) Baffle inclined at 45^O

d) Baffle inclined at 60^O

e) Baffle inclined at 75^O

Figure 5: CAD model of concentric TTHEXfor different designs: a) without baffle, b) Straight baffle, c) Baffle inclined at 45^O, d) Baffle inclined at 60^O, e) Baffle inclined at 75^O

Meshing is a critical operation in computational fluid dynamics analysis in this process CAD geometry is divided into large numbers of small pieces called mesh. The total no of nodes generated in the present work is 3918427, and total no. of elements is 3059523 as shown in figure 6. Types of element generated in this meshing is tet4, Hex8, and Wed6, with element size, is 0.5 mm

Meshing: The total no of nodes generated in the present work is 3918427, and the total no. of elements is 3059523, as shown in figure 7. Types of elements generated in this meshing are tet4, Hex8, and Wed6, with element size, is 0.5 mm

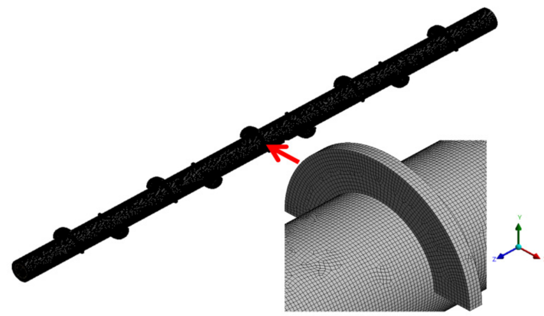


Figure 6: Meshing of concentric tube TTHEX with straight baffles

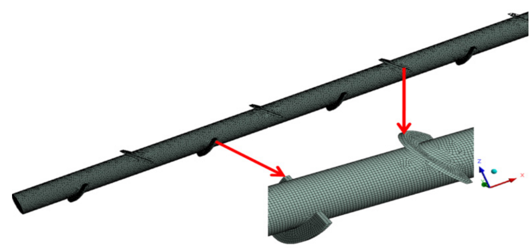


Figure 7: Meshing of concentric tube TTHEX with inclined baffles at 75^O

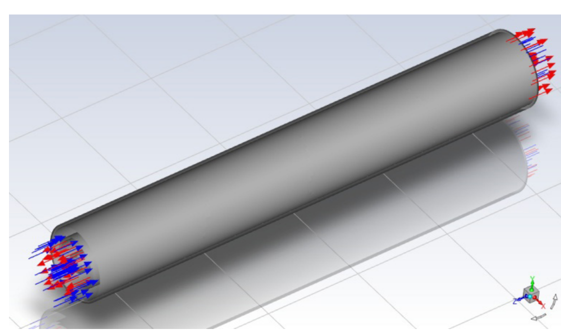


Figure 8: Boundary conditions of concentric tube TTHEX with straight baffles

Boundary conditions:

- To determine the temperature distribution need to on the energy equation.
- For turbulence, the RNG k-epsilon model is utilized so because swirled effects on turbulence has a better precision than the regular k-epsilon models.
- The fluid flow is graphite nanoplatelets–platinum nanofluid in concentrations of 0.0 (clean water), 0.02, 0.06, and 0.1, with an aluminum heat transfer pipe.
- Because the outer layer of a tube heat exchanger is totally insulated, there is no temperature difference between both the outer tube and the atmosphere; therefore, the outside wall heat flux is set to zero to achieve adiabatic conditions.
- For heat interactions among fluids and pipes, the interior and intermediary tubes walls with ribs are connected.
- At temperatures of 283K and 291K, a cold and normal fluid input with a mass flow rate of 0.1 Kg/sec is used.
- Nano fluid inlet having Reynolds number of 5000 and mass flow rate of 0.020322 Kg/Sec at concentration rate of 0.0, 0.023905 Kg/Sec at concentration rate of 0.02, 0.031886 Kg/Sec at concentration rate of 0.06 & 0.032463 Kg/Sec at concentration rate of 0.1 at inlet temperature of 343K
- Because the fluid that flows within the heating element is the atmosphere, the gauge pressure again for output governing equations must be set to zero.
- The rest of the surface is handled as a solid wall with no slip circumstances.
- Pressure velocities coupled connected technique for temperature The translational energies instability, power, and thermal diffusivity are calculated using the SIMPLE technique and the second derivative advection schemes.
- The Fluent solver is used for CFD analysis.

Result Discussion

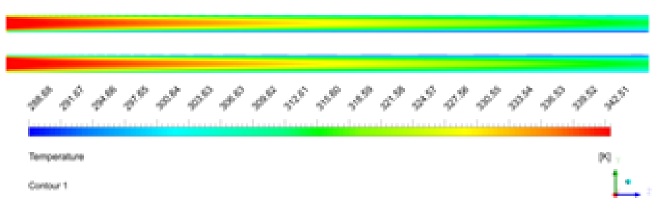


Figure 9: Temperature distribution along the entire length in middle tube for concentric TTHEX (triple tube heat exchanger)without baffle at φ = 0.1%

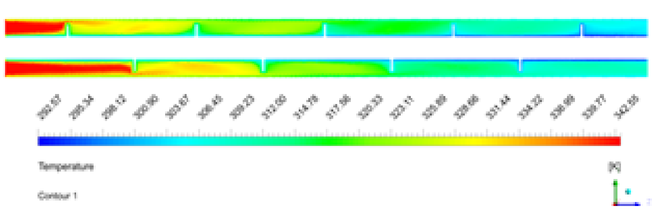


Figure 10: Temperature distribution along the entire length in middle tube for concentric TTHEX (triple tube heat exchanger)with straight baffle at φ = 0.1%

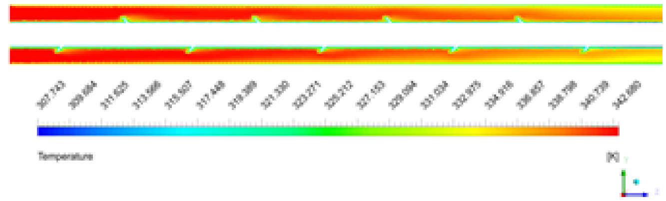


Figure 11: Temperature distribution along the entire length in middle tube for concentric TTHEX (triple tube heat exchanger)with 45° inclined baffle at 0.1%

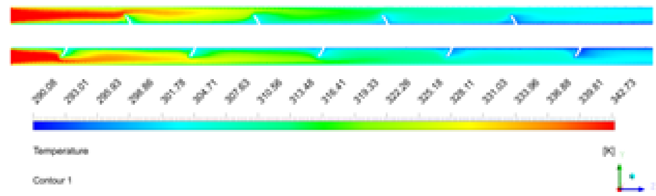


Figure 12: Temperature distribution along the entire length in middle tube for concentric TTHEX(triple tube heat exchanger) with 60° inclined baffle at 0.1%

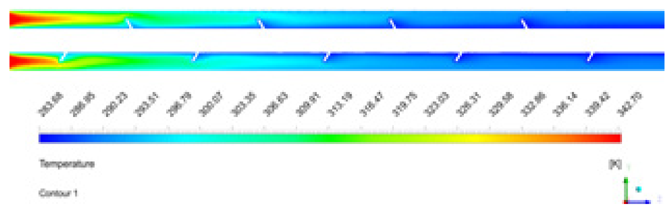


Figure 13: Temperature distribution along the entire length in middle tube for concentric TTHEXwith 75° inclined baffle at 0.1%

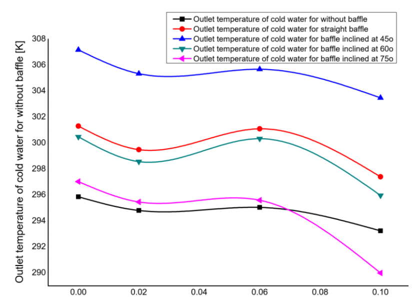


Figure 14: Comparative results of outlet temperature of cold water for concentric TTHEX (triple tube heat exchanger)at various configuration and concentrations

The temperature gradient over the whole length of the center tubing for circumferential three pipe heat exchanger as depicted in figure no. 09 to 13 was computed using computational fluid dynamics. The temperature dropped from 343 K to 288.68 K for without baffle, 292.57 K for the straight baffle, and 307.74 K for baffle inclined at 45°, 290.08 Kfor baffle inclined at 60°& 283.68 K for baffle inclined at 75°. It also observed that the maximum outlet temperature for nanofluid of 20.77 °K for ø = 0.1which is 21.71% greater than without baffle, 33.56 % greater than straight baffles, and 20.58% greater than baffles inclined at 60° (Figures 14 to 22).

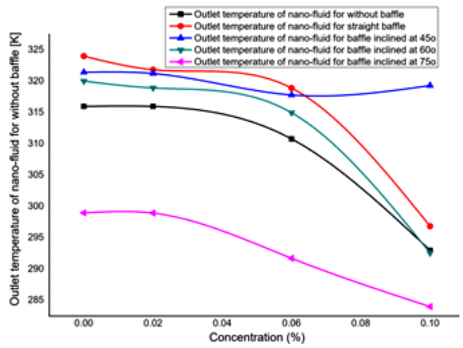


Figure 15: Comparative results of outlet temperature of nanofluid for concentric TTHEX (triple tube heat exchanger) at various configuration and concentrations

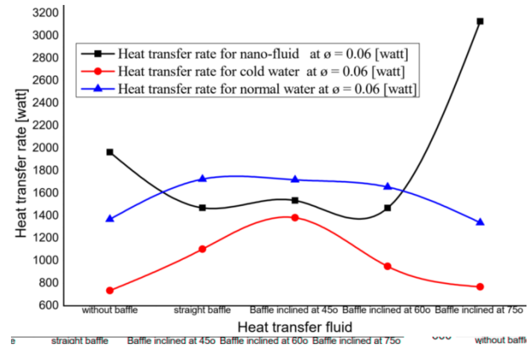


Figure 19: Comparative results of heat transfer rate for different design of TTHEX at ø = 0.02

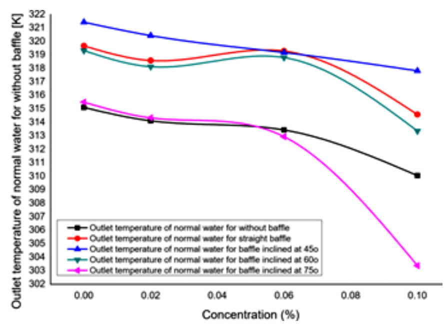


Figure 16: Comparative results of outlet temperature of normal water for concentric TTHEX (triple tube heat exchanger)at various configuration and concentrations

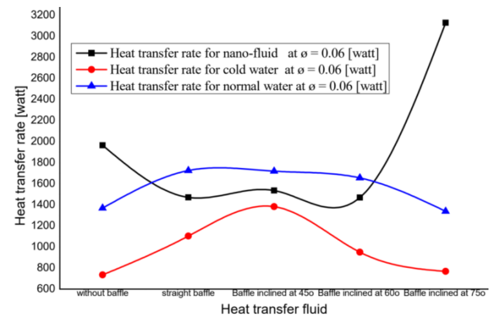


Figure 20: Comparative results of heat transfer rate for different design of triple tube heat exchangerat ø = 0.06

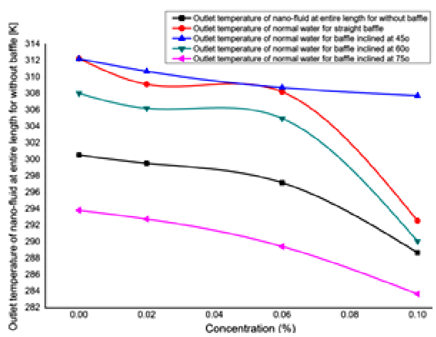


Figure 17: Comparative results of outlet temperature of nanofluid at entire length for concentric triple tube heat exchanger at various configuration and concentrations

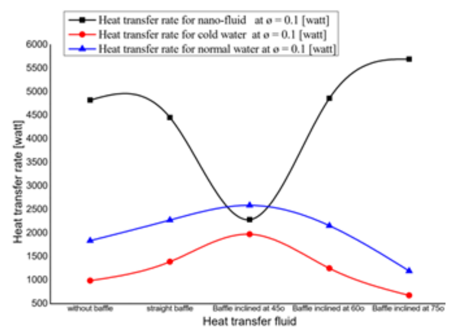


Figure 21: Comparative results of heat transfer rate for different design of TTHE at ø = 0.1

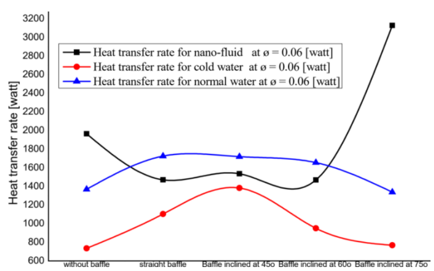


Figure 18: Comparative results of heat transfer rate for different design oftriple tube heat exchanger at ø = 0.0

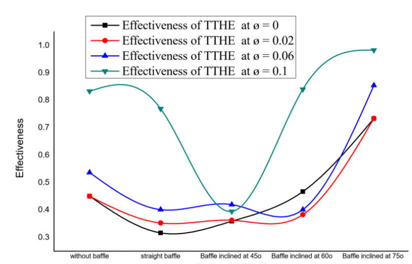


Figure 22: Effectiveness of the various design oftriple tube heat exchanger at different concentration

Conclusion:

The computational fluid dynamics simulation of a circumferential three pipe heat exchanger with inclination baffle revealed the following results at 75^{O} gives maximum outlet temperature for nanofluid of 20.77^{o} K for ø = 0.1 which is 21.71% greater than without baffle, 33.56 % greater than straight baffles and 20.58% greater than baffles inclined at 60^{o}. The heat transfer rate of 17.98% higher than without baffle, 27.79% higher than straight baffle and 17.04% higher than baffles inclined at 60^{o}, while the maximum overall heat transfer coefficient of 0.9832 for ø = 0.1 have been observed. As a result, a concentric triple tube heat exchanger with slanted ribs was developedat 75^{O} recommended for better heat transfer.

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