Mathematical and CFD Assessment of Double Tube Heat Exchanger having Three Different Designs

Shushil Kumar[1], Jeetendra Mishra[2], Shamir Daniel[3]

[1]Shushil Kumar, Thermal Engineering, Truba Institute of Engineering & Information Technology, Bhopal, MP, India
[2]Jeetendra Mishra, Assistant Professor, Thermal Engineering, Truba Institute of Engineering & Information Technology, Bhopal, MP, India
[3]Shamir Daniel, Assistant Professor, Thermal Engineering, Truba Institute of Engineering & Information Technology, Bhopal, MP, India
[1]kumarshushil741@gmail.com, [2]jeetendra.mishra10@gmail.com, [3]shamirdaniel3004@gmail.com

* Corresponding Author: Shushil Kumar

Abstract:*In the present work computational fluid dynamics analyses have been performed for double tube heat exchanger at different Reynolds number, total three designs such as smooth tube, spherical element, double helical baffle at constant pitch have been used. For this analysis of double tube heat exchangers water and Ag-MoS_2 (Silver-molybdenum disulfide) are used as heat transfer fluid, where Ag-MoS_2 flow in inner tube as a hot fluid and water in outer tubeas cold fluid, the inlet velocity of cold fluid was taken as 0.59 m/sec at 300 K and the inlet velocity of hot fluid was varied from 0.2, 0.35, 0.5 and 0.65 m/sec at 350 K.Result showed that maximum temperature drop of 13.936 Kelvin for hot fluid at 0.4886 kg/sec mass flow rate for double helical baffles heat exchanger and the maximum temperature rise of 10.377 Kelvin for cold fluid at 1.5879 kg/sec mass flow rate for double helical baffles heat exchanger.*

Keywords:*Double tube heat exchanger, thermal performance, Reynolds number, heat exchanger, computational fluid dynamics (CFD), mathematical analysis etc*.

I. Introduction

A heat exchangers are devices that uses a working fluid and a works surfaces with different temperatures to transport thermal energy (enthalpy) between two or even more environment. Heat transfer can happen between solid surfaces and liquids, solid particles and liquids, and so forth. Air pre heater, evaporators, tube heat exchanger, condensers, chillers, and automotive radiator are all example of heat transfer. A sensible heat exchangers is one in which no phase transition happens in any of fluid in the exchange. Internal thermal sources of energy, such as heating systems and nuclear fuel elements, could be present in the exchanger.Within the exchangers, such as in fire heats, boilers, and fluidized bed exchanges, combustible& chemical reactions can occur [21].
Mechanical devices are utilized in agitated vessels, scraped surface exchanges, and continuous stirred - tank reactors, among other exchangers. Conduction is the most common type of heat transfer in a recuperation's dividing wall. In a heated tube heat exchanger, on the other hand, the heat pipe not only serves as a dividing wall, but it also aids heat transmission through condensing, evaporating, and conductivity of the fluid inside of the heat pipe. If the fluids are immiscible, the separate wall can be removed, and the fluid interfaces can serve as a heat transfer, as in a direct-contact heat transfer.
The design and thermally analyses the double tube heat exchanger are the objective of this research. a two-pipe system Heat transfer (also known as "double pipes") are distinguished by a constructing form that gives the heat exchange a U-shaped appearance. The term "dual pipe" originally referred to a heat transfer that consisted of a pipes inside a piping system, usually of straight-leg design with no bending. The current U-shaped structure became the industry norm due to the use of removable bundles assembly and the capacity to withstand differential temperature increases while eliminating the usage of expansion joints (typically the exchanger's weak point).

The hairpin exchanger's capacity to manage higher tube side pressures at a lesser cost than some other removable-bundle exchanges is one of its advantages. This is partly due to a lack of passes partitions at the tube sheets, which makes the gasket design procedure more difficult. At tube side pressure of 825 bar, current mechatronics technology allows the construction of trustworthy, removable bundles, hairpin multi-tubes (12,000 psi).

Convection phenomenon withineach fluid and conductivity through the walls separating two fluid are the most common methods of heat exchange in an exchanger. It's easier to deal with a total heat transfer coefficients U when analyzing exchangers because it accounts for these effects on heat exchange. The magnitude of the temperature differential at a given place in an exchanger determines the heat transfer rate between both fluids at that location, which varies along the heat transfer. Working with the logarithm means temperature difference (LMTD), which is an equivalent average temperature distinction between the two fluids throughout the entire heat exchanger, is usually convenient for analyzing heating elements.

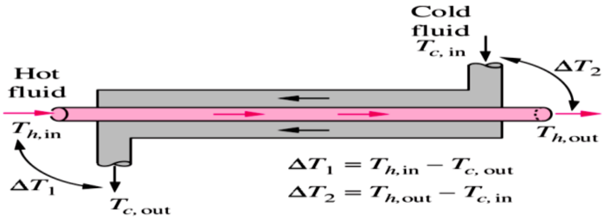


Figure 1: Counter Flow Heat Exchanger

The double tube heat exchanger is the basic heat exchanger, consisting of two concentric pipe of various diameters as seen in figure1. In a double tube heat exchanger, one fluid flow through the smaller pipe and the other via the annular space between two pipe.In the double tube heat exchanger following three categories of flow arrangements are possible:

1) Parallel flow.
2) Counter flow.
3) Cross flow.

The counter flow heat exchanger is consider for present work which shown in figure 1.Two flowing fluids are separate by a solid wall in a heat exchanger. By circulation, heat is transmitted from of the hot fluid to the walls, through the wall by conductivity, and back to the cold fluid by convection. The convective thermal efficiency normally incorporate any effects of radiation[Bahman Zohuri 2017].

II. LITERATURE REVIEW

Asadi et al. (2021) [1] The goal of this work is to quantitatively analyze the impacts of turbulence-inducing elements in the double pipe Heat Exchanger with varied shapes (HEX). The flow of water is tumultuous and it is considered a working fluid. In addition, commercial software has been used to perform CFD simulations using the finite volume method. The different geometry, such as smooth tube, corrugated tube, tubular with spherical components, and tubular with axial fins, are analyzed in the first chapter. Following that, the heat transfer properties of two different hybrid nanoparticles, Ag-MoS2 and Fe3O4-SiO2, are compared. Finally, the optimal configuration for incorporating Ag MoS2 hybrids nanomaterials to improve heat transfer performance was chosen.The double tube heating element with spherical elements provides the best heat transfer performance, according to the data. Furthermore, in the optimized model with Ag-MoS2 1 percent, raising the Reynolds number from 4000 to 13,000 improves the convective heat transfer coefficient by 62.21 percent.

Chao Luo &Ke Wei Song (2021) [2] For a double-tube heat exchanger, a new twisted annulus between two counter-twisted oval tubes is presented. The annuli's oval tubes have the same twist pitch but twist in different directions. The thermal and hydraulic effectiveness of the annuli is numerically reported for various aspect ratios and twist ratios. The findings show that in the twisting annular, a good secondary flow is formed, which can greatly improve heat transmission. The maximal Nu and f of the twisting annuli are 157 percent and 118 percent higher than those of the straight annuli, respectively. In the analyzed range of geometry parameters, the thermal efficiency factor has the highest value of 1.98.Correlations of Nu and f as a function of Re, twist ratio, and element size are suggested, with variations of less than 10% and 8%, respectively.

MortezaHangi et al. (2021) [3] The optimum configuration is subjected to a full parametric study to investigate the impact of relevant operations and geometric characteristics. The heat transfer coefficient of DPHXs is improved by increasing the number of helical periods and helical fins on the tube and annulus sides. For the best arrangement, the effects using an alumina–water nano - fluid flowing in the pipe wall is explored. Due to more uniform nanoparticles distribution, the rate of total heat transfer enhancement is observed to be higher in configurations with more intensive mixing. To determine the exergy efficiency of DPHXs with various configurations, an exergetic analysis is performed. For the mentioned system, the effect of various operational and geometric characteristics on efficiency is explored.

Nidal H. Abu-Hamdeh et al. (2021) [4] Using the finite volume method, the heat exchange performances and fluid flow characteristics of a helical micro double-tube heat exchanger (HMDTHX) were numerically investigated. For Reynolds numbers of 50, 100, 150, and 200, the tube length was considered to remain constant at 30 mm, and 12 different configurations were modelled by altering the turning amount and pitch length (P). The results showed that putting any helix angle in the straight pipe improved heat transmission. It did, however, have an optimal point that changed depending on Reynolds number (Re). In all situations, rising Re resulted in an increase in the overall heat transfer coefficient (OHTC), pressure drop, and pumps energy.Overall, increasing P lowered OHTC, pressure drop, and pumping power, all of which had various max points among P = 0.5 and 3. For Re = 200 and P = 2, the maximum overall heat transfer coefficient (OHTC) enhancement was 45 percent. Finally, by examining the velocities contours, it was discovered that a secondary flow via the HMDTHX existed, which was influenced by centrifugal force and improved fluid flow turbulence and heat transfer.

QingangXiong et al. (2021) [5] The influence of conical and fusiform tube heat exchanger in double-pipe heat exchangers (DPHE) on heat transmission and turbulence layouts was established in this study. In the double heat transfer with circular or rectangular tube configurations, a total of 21 configurations, including conical and fusiform tabulator inserts, are modeled at four Reynolds number levels (Re = 4000, 7000, 10000, and 13000) on the tube side. The finite-volume approach is used to discretize the disturbance flow equations utilizing the realizable k– model using Fluent software. The results show that when a heat exchanger with a circular inner pipe is used, the maximal convective heat transfer coefficient is reached.

S. Padmanabhan et al. (2021) [6] Several strategies were developed to achieve the required heat transfer rate while maintaining a cost-effective pumping capability within the heat exchanger's stated design and duration. Helical inserts are one of the most popular and effective ways of improving exchangers. Inserts with a helical shape. The effectiveness of an ANSYS CFX tool for twin tube heat exchangers with helical insert would be investigated in this article. The heat transfer and temperature distribution along the pipes will be compared to a heat exchanger with helical inserts in a comparative study.

S.M. Zakir Hossain et al. (2021) [7] A unique hybrids shells and double pipes exchangers was created and used to improve the heat transition process in this study. Instead of employing simple tubing, double pipes were used to increase the heat transmission surface. The streams passed thru the annulus, exchanging heat with two fluids sandwiched between them. Simulations were used to test the device's performance. For several flow patterns, such as co-current, counter-current, insulated, and non-insulated configuration, the simulation findings were validated with experimental data in steady-state conditions.. Depending on the function of central heating, heat exchangers worked with three fluids, such as two hot fluids and a cold fluid (H-C-H) or vice versa (C-H-C). The results showed that the temperature differences forecasts were in good agreement with the experimental data in terms of magnitude and trends.

Ahmad Vaisi et al. (2020) [8]The empirical effects of continuously and discontinuous twisted tapes turbulators (perforated and non-perforated) on heat exchange, friction coefficient, and thermal properties in the double heating systems is described in this study. 9 holes with various geometries, such as triangles, square, rectangles, circular, and diamonds with triangle arrangements, have been formed on tabulator flat surfaces using discontinuity twisting tapes. Working fluids are now on the side of the inner tube, and the annular space is hot and cold liquid, respectively, in the Reynolds range of 5500–10000.The discontinuity tabulator has a better effect on the heat transmission and pressure drop than the continuously turbulator, according to experimental results. When comparison to the continuously turbulator, the discontinuity tabulator without the need for a hole does have an enhancement in heat transmission of 8.2% and a reduction in pressure loss coefficients of 9.8%.

Anas El Maakou et al. (2020) [9] The thermo-fluid properties of a double pipe heat exchanger (DPHX) with split longitudinal fins (SLF) on the annular side are investigated in this work. SLF tubes are a variation of ordinary longitudinally finned tubes (LF) that allow for several surfaces interruption to breach the boundary condition and offer an interruption fluids passageway along the flow length. The experiment is carried out with a fluids with a high Prandtl number (engine oil) and changing thermally parameters.For configurations with a fin splitting intervals around 0.333 and 0.166 m, three-dimensional computational fluid dynamics (CFD) simulations have been performed under laminar flow regime. Based on flowing fluid, heat transfer rate, and needed pumping power, a comparison of the SLF configurations to the reference LF arrangement is undertaken.

J.D. Moya-Rico et al. (2020) [10] The purpose of this work was to investigate the effect of different configurations of spaced evenly twisted tape elements (TTEs) put into a smooth double tube heat exchanger on thermal properties performances (DTHX). A 60° brix solutions of sugar and water was employed as the Heat Transfer Fluid to mimic the behaviour of high-viscosity food-industry fluids (HTF). A total of 320 experiments were conducted, with the flow velocity (Reynolds number) and TTE configuration being varied. The findings of nine distinct configuration, including various twisted tape element pitching and free-space lengths, are shown. Finally, using minimum variance methods, the data out of each case were correlated for Nusselt number and drag coefficient.

III. METHODOLOGY

Heat exchangers are typically used for extended periods of time with little variation in their operational conditions. As a result, steady-flow systems can be modelled. Each fluid's mass flow rate remains constant, as do fluid parameters like as velocity and temperature at every inlet or outlet. The velocity and altitudes of the fluid streams vary little or not at all, resulting in low kinetic and possible energy changes.

A fluid's specific heat varies with temperature. However, it can be considered as a consistent at a certain average value within a specific temperature range with very little loss of accuracy. Heat conduction all along tube's axis is usually minimal and can be dismissed. Finally, the heat exchanger's outside surface is considered to be fully insulating, resulting in no heat transfer to the surround medium and also only heat exchange between both the fluid layers.

As can be observed in equations 1 and 2, the rate of heat transfer from the hot fluid must be equal to the cold fluid.

$$\dot{Q}_h = \dot{m}_h C_{pc}(t_{h,out} - t_{h,in}) \quad (1)$$

$$\dot{Q}_c = \dot{m}_c C_{pc}(t_{c,out} - t_{c,in}) \quad (2)$$

When analyzing heat exchangers, it's common to combine the products of the flowrate and the fluid's heating value into a single number. The heat capacity rates is a number that is defined for both hot and cold fluids stream as illustrated in equations 3.

$$C_h = \dot{m}_h C_{ph} \text{ and } C_c = \dot{m}_c C_{ph} \quad (3)$$

The heat transfer rate required to raise the temperature of a flowing fluid by 1°C as it runs through a heat exchanger is known as the heat capacity rate of a flowing fluid. The heat transfer rate is shown in Equations 4 and 5.

$$\dot{Q}_c = C_c(t_{c,out} - t_{c,in}) \ (4)$$

$$\dot{Q}_h = C_h(t_{h,out} - t_{h,in}) \ (5)$$

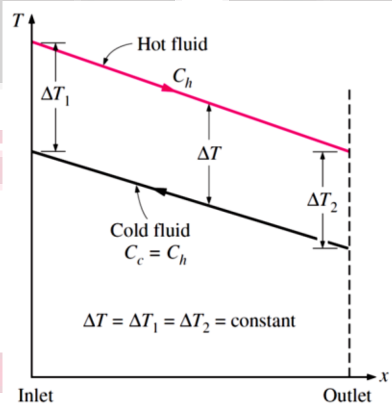


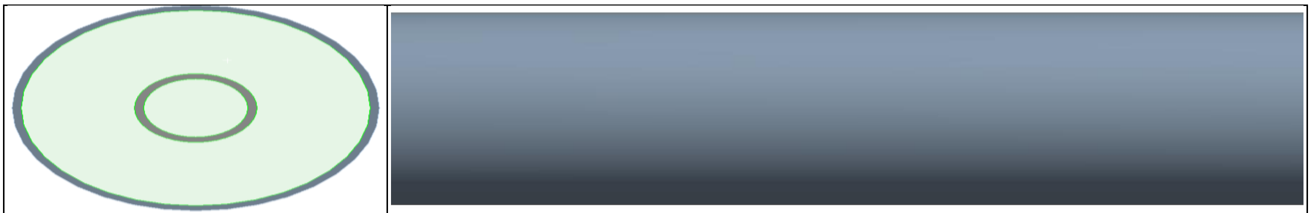
Figure 2: Temperature variation of two fluids that have the same mass flow rate and the same specific heat

In a heat exchanger, the heat transfer rate equals the heat capacity rate of either fluid multiplied by the change in temperature of that fluid. It's important to note the only times the temperature increase of a cold fluid equals the drop in temperature of a heat flow is that when the heat capacity rates of the fluid layers are equal, as illustrated in Figure 2.

In the present work total three designs such as smooth tube, spherical element, double helical baffle at constant pitch have been used.

1. CAD model of double tube heat exchanger for smooth tube:

The three dimensional CAD model of double tube heat exchanger for smooth tube is created with the help of design modular of ANSYS workbench. The inner tube diameter is 20 mm, for hot fluid, while the diameter for outer tube is 60 mm. The length of heat exchanger is 1500 mm as shown in figure 3.



(a) Face side	(b) length side

Figure 3: CAD model of double tube heat exchanger for smooth tube; (a) Face side (b) length side

2. CAD model of double tube heat exchanger with spherical element:

With the CAD of the design module of the ANSYS workbench, a three-dimensional CAD model of a double pipe heat exchanger with spherical elements is generated in the current work. For heat flow, the inner tube diameter is 20 mm, while the outside inner diameter is 60 mm with a length of 1500 mm and a spherical element with R-40 and a pitch of 100 mm as shown in figure 4.

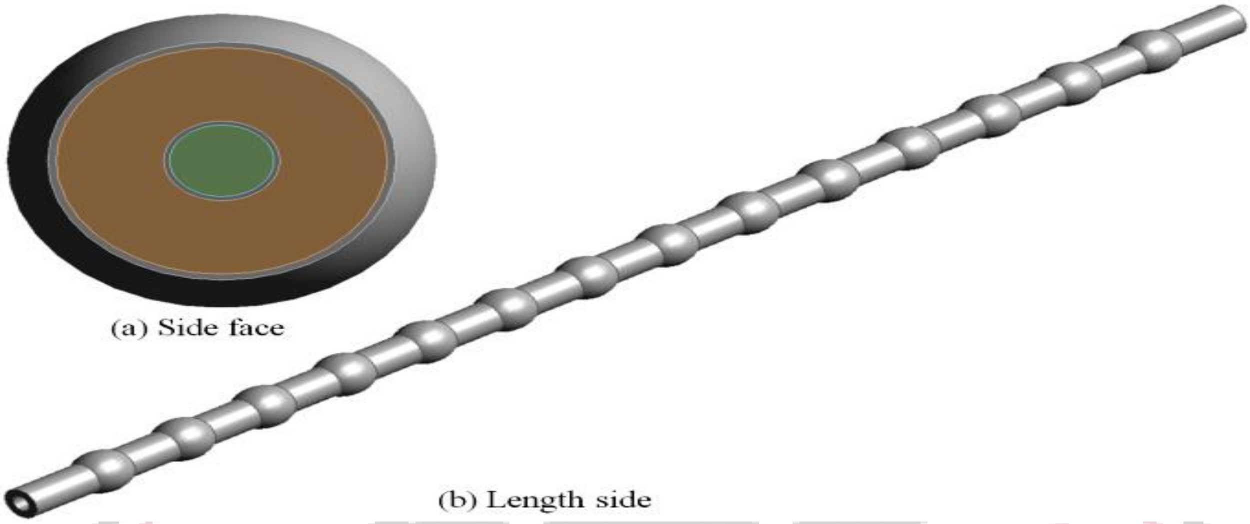


Figure 4: CAD model of double tube heat exchanger with spherical element; (a) Face side (b) length side

3. CAD geometry of double tube heat exchanger with double helical baffles:

With the help of ANSYS workbench's design module, a three-dimensional CAD model of a double tubular heat exchanger with the double helical baffling was generated. For hot fluid, the inner diameter is 20 mm, while the outer side tube diameter is 60 mm with a length of 1500 mm and a helical baffles with such a size of 2 mm x 3 mm and a pitch of 100 mm as shown in figure 5.

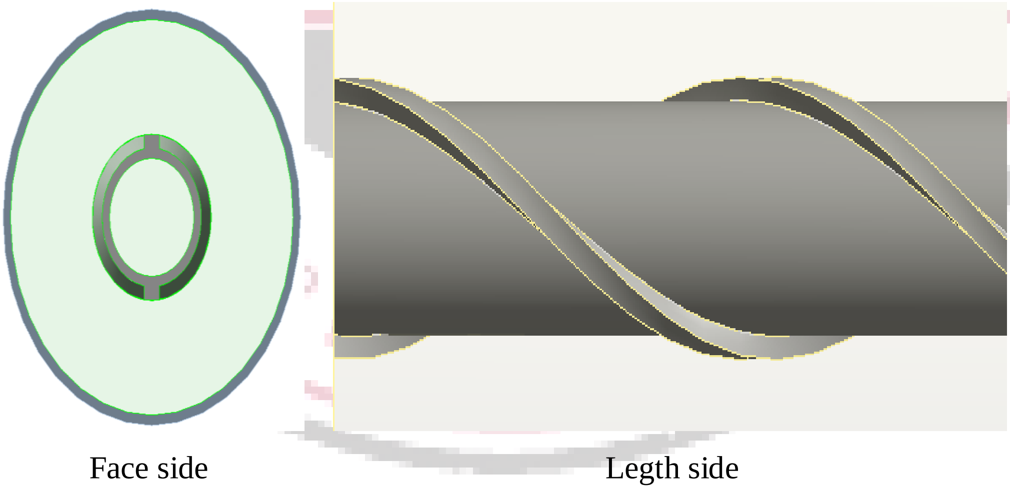


Figure 5: CAD geometry of double tube heat exchanger with double helical baffles

IV. RESULT ANALYSIS

To improve the thermal efficiency of several design of the double tube heat exchanger, mathematical and numerical hydrodynamic analyses were undertaken in this study. To predict the thermal performance, three designs were used: smooth tube, spherical element, double helical baffles, and convective heat transfer for inflatable raft as Ag-MoS_2, and cold fluid as liquid water flowing in outer annular space, with cold stream inlet velocity of 0.59 m/sec and inlet temperature of 300K. The velocities of the hot fluid input is 0.2, 0.35, 0.5, and 0.65 m/sec at inlet temperature of 350K.

.

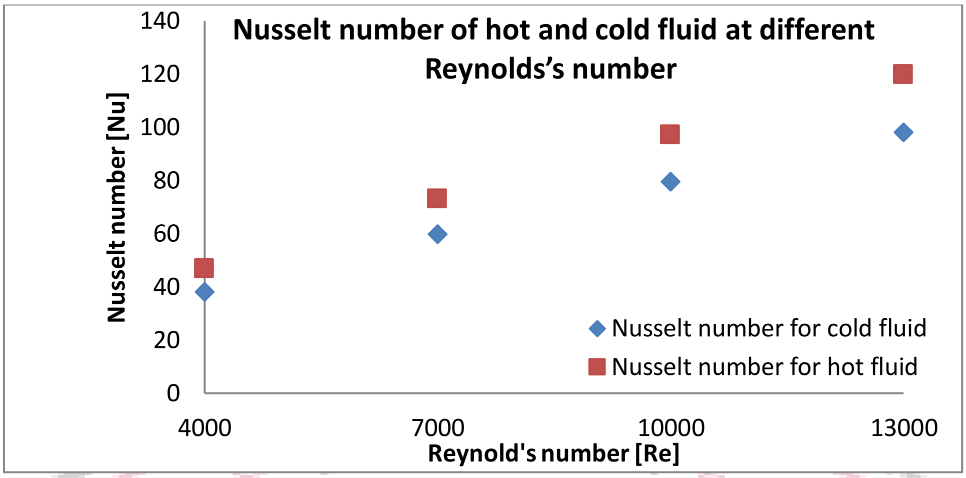


Figure 6: Nusselt number of hot and cold fluid at different Reynolds's number

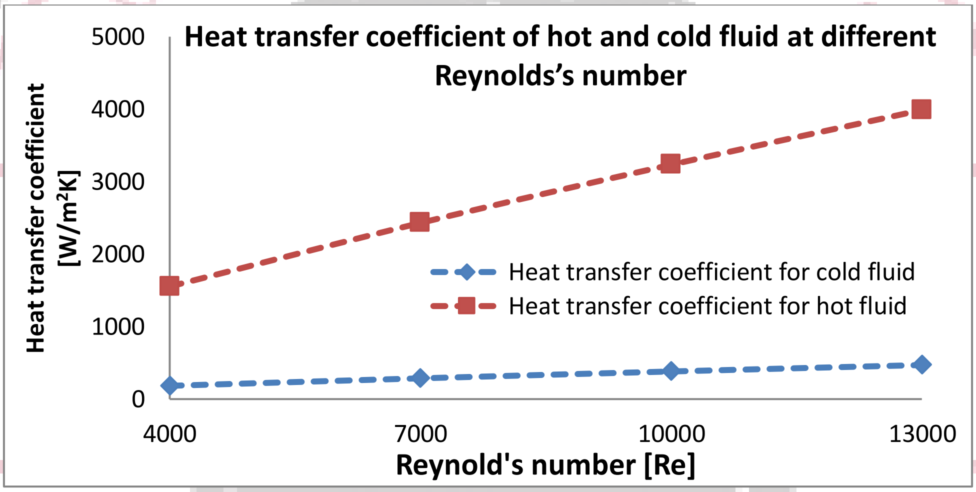


Figure 7: Heat transfer coefficient of hot and cold fluid at different Reynolds's number

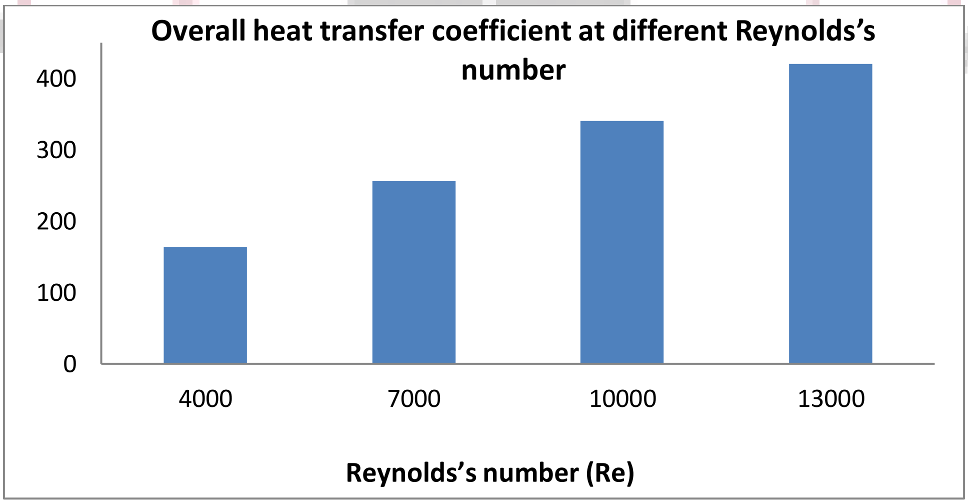


Figure 8: Overall heat transfer coefficient at different Reynolds's number

Computational fluid dynamics analysis for double pipe heat exchanger for smooth tube:

The intake temperatures of hot and cold fluid are 350 K and 300 K, respectfully, after performing computational fluid dynamics study of a twin pipe heat exchanger for tube bundle wherein cold liquid passes at 0.59 m/sec and hot fluid flows at 0.2 m/sec. The hot fluid temperature drops to 343.283 K at the output, while the cold stream temperature increases to 302.972 K, as illustrated in the contoured figure 9.

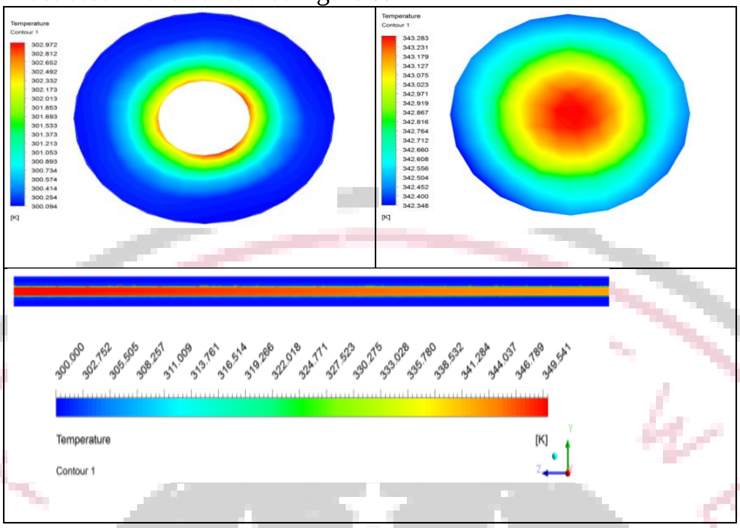


Figure 9: Temperature distribution for double pipe heat exchanger for smooth tubeat 0.2 m/sec(a) cold fluid at outlet (b) hot fluid at outlet(c) heat exchanger mid plane

After performing computational fluid dynamics analysis of double pipe heat exchanger for smooth tube where cold fluid flows at 0.59 m/sec and hot fluid at 0.35 m/sec, the inlet temperature of hot and cold fluid are 350 K, and 300 K respectively. The hot fluid temperatures at outlet is drop upto 344.106 K and the cold fluid temperature rise upto 302.979 K as shown in figure 10.

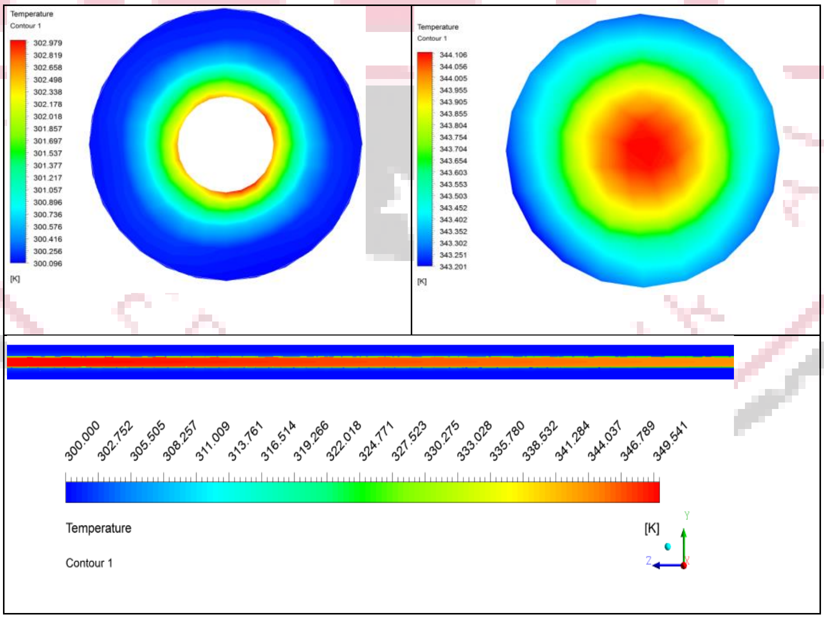


Figure 10: Temperature distribution for double pipe heat exchanger for smooth tubeat 0.35 m/sec(a) cold fluid at outlet (b) hot fluid at outlet(c) heat exchanger mid plane

After performing computational fluid dynamics analysis of double pipe heat exchanger for smooth tube where cold fluid flows at 0.59 m/sec and hot fluid at 0.5 m/sec, the inlet temperature of hot and cold fluid are 350 K, and 300 K respectively. The hot fluid temperatures at outlet is drop upto 344.759 K and the cold fluid temperature rise upto 303.007 K as shown in figure 11.

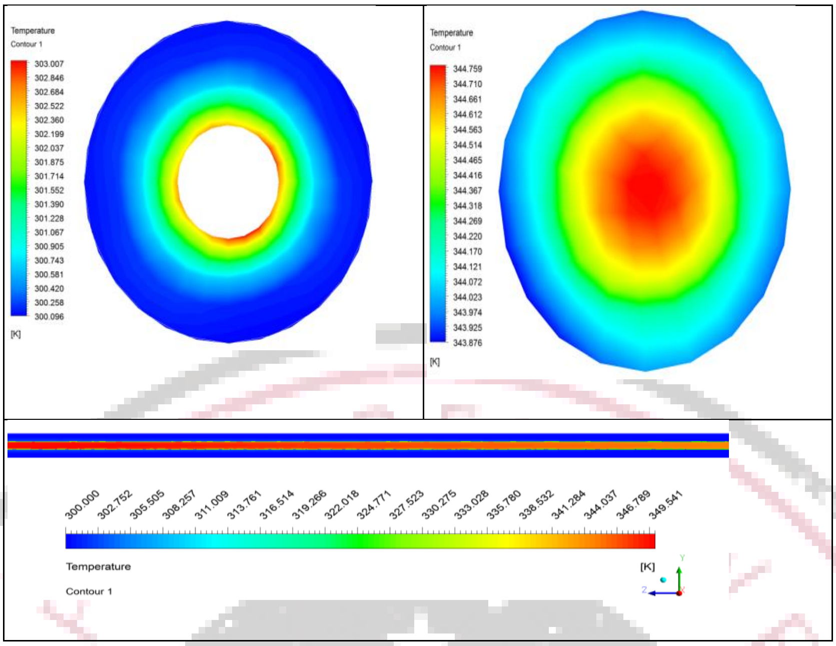


Figure 11: Temperature distribution for double pipe heat exchanger for smooth tubeat 0.5 m/sec(a) cold fluid at outlet (b) hot fluid at outlet(c) heat exchanger mid plane

After performing computational fluid dynamics analysis of double pipe heat exchanger for smooth tube where cold fluid flows at 0.59 m/sec and hot fluid at 0.65 m/sec, the inlet temperature of hot and cold fluid are 350 K, and 300 K respectively. The hot fluid temperatures at outlet is drop upto 345.446 K and the cold fluid temperature rise upto 303.226 K as shown in figure12.

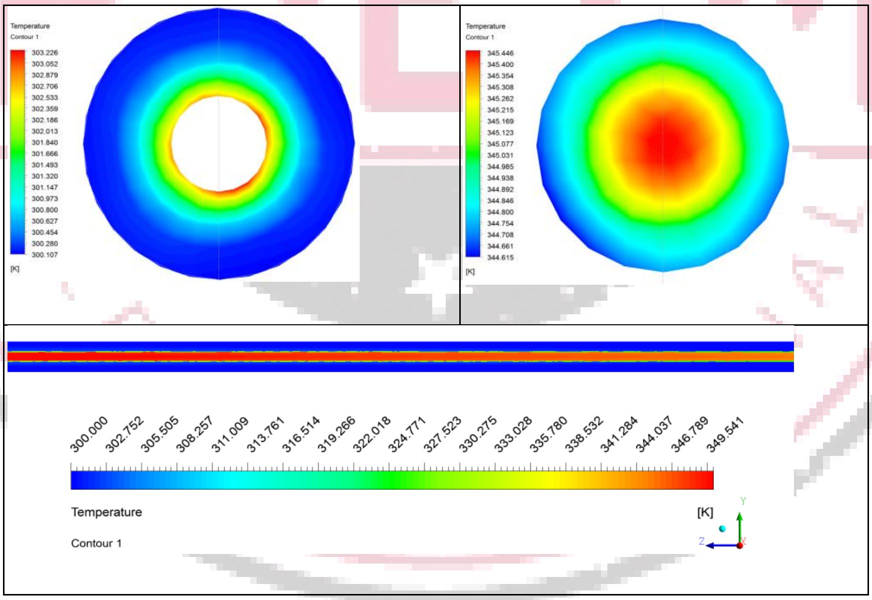


Figure 12: Temperature distribution for double pipe heat exchanger for smooth tubeat 0.65 m/sec(a) cold fluid at outlet (b) hot fluid at outlet(c) heat exchanger mid plane

Computational fluid dynamics analysis for double tube heat exchanger with spherical element

After performing computational fluid dynamics analysis of double pipe heat exchanger with spherical element where cold fluid flows at 0.59 m/sec and hot fluid at 0.2 m/sec, the inlet temperature of hot and cold fluid are 350 K, and 300 K respectively. The hot fluid temperatures at outlet is drop upto 338.363 K and the cold fluid temperature rise upto 304.586 K as shown in figure13.

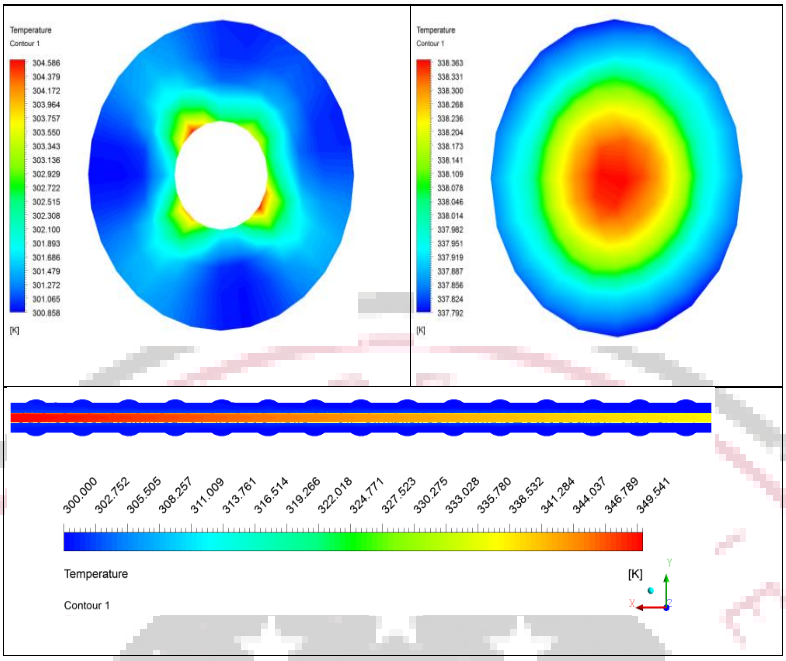


Figure 13: Temperature distribution for double pipe heat exchanger with spherical element at 0.2 m/sec(a) cold fluid at outlet (b) hot fluid at outlet(c) heat exchanger mid plane

After performing computational fluid dynamics analysis of double pipe heat exchanger with spherical element where cold fluid flows at 0.59 m/sec and hot fluid at 0.35 m/sec, the inlet temperature of hot and cold fluid are 350 K, and 300 K respectively. The hot fluid temperatures at outlet is drop upto 341.415 K and the cold fluid temperature rise upto 304.915 K as shown in figure14.

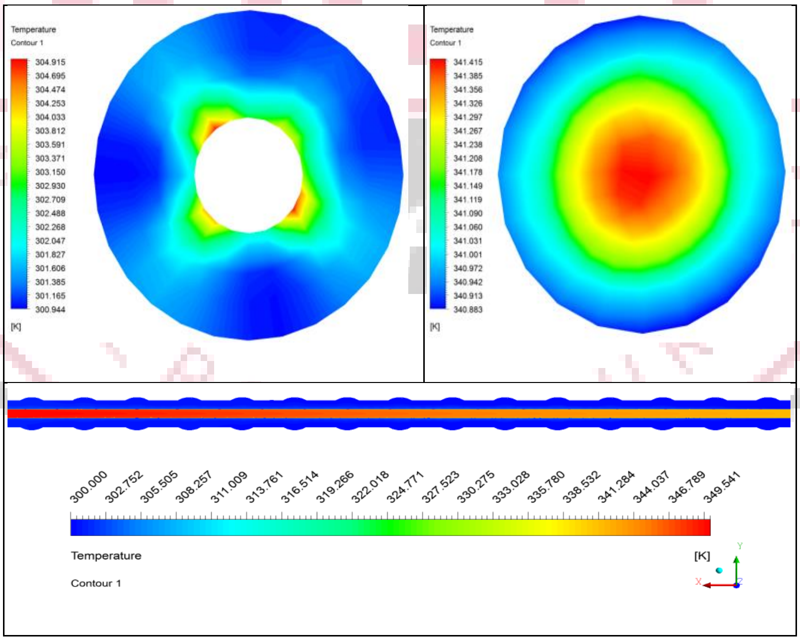


Figure 14: Temperature distribution for double pipe heat exchanger with spherical element at 0.35 m/sec(a) cold fluid at outlet (b) hot fluid at outlet(c) heat exchanger mid plane

After performing computational fluid dynamics analysis of double pipe heat exchanger with spherical element where cold fluid flows at 0.59 m/sec and hot fluid at 0.5 m/sec, the inlet temperature of hot and cold fluid are 350 K, and 300 K respectively. The hot fluid temperatures at outlet is drop upto 343.654 K and the cold fluid temperature rise upto 305.552 K as shown in figure 15.

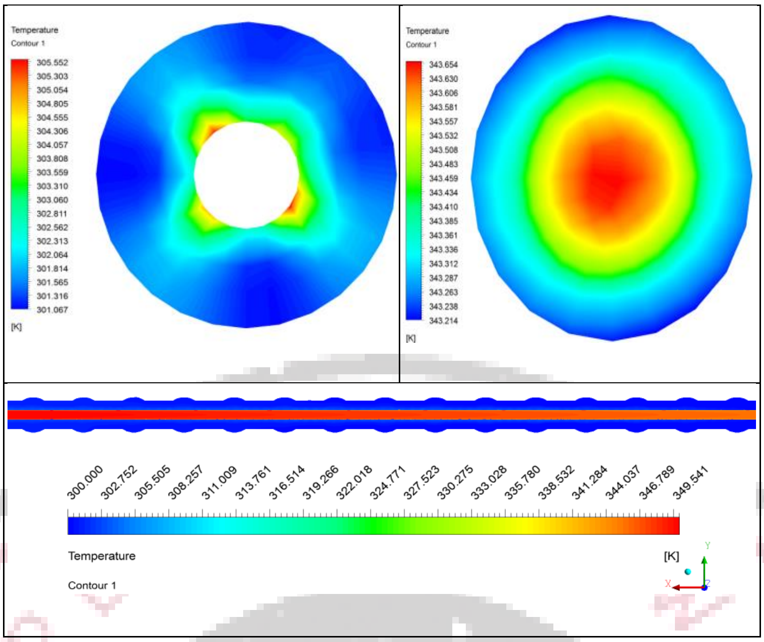


Figure 15: Temperature distribution for double pipe heat exchanger with spherical element at 0.5 m/sec(a) cold fluid at outlet (b) hot fluid at outlet(c) heat exchanger mid plane

After performing computational fluid dynamics analysis of double pipe heat exchanger with spherical element where cold fluid flows at 0.59 m/sec and hot fluid at 0.65 m/sec, the inlet temperature of hot and cold fluid are 350 K, and 300 K respectively. The hot fluid temperatures at outlet is drop upto 344.953 K and the cold fluid temperature rise upto 305.907 K as shown in figure 16.

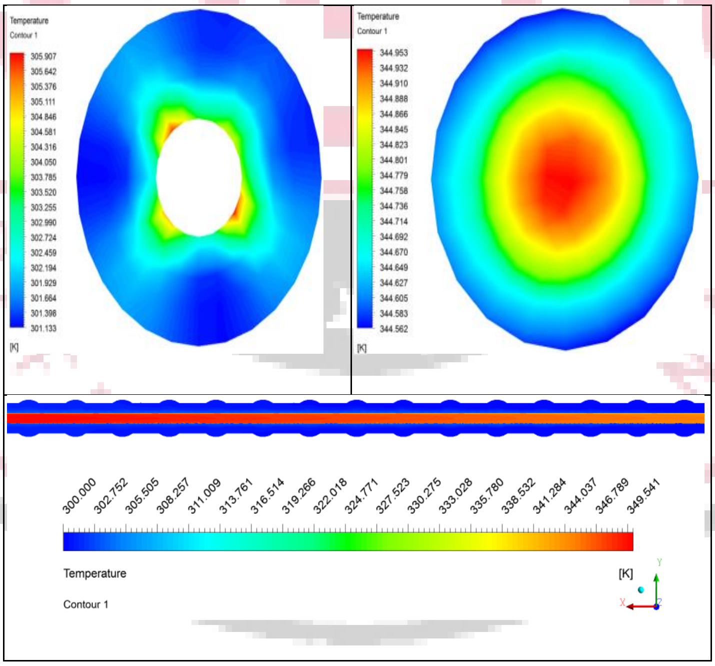


Figure 16: Temperature distribution for double pipe heat exchanger with spherical element at 0.65 m/sec(a) cold fluid at outlet (b) hot fluid at outlet(c) heat exchanger mid plane

Computational fluid dynamics analysis for double tube heat exchanger with double helical baffles

After performing computational fluid dynamics analysis of double pipe heat exchanger with double helical baffles where cold fluid flows at 0.59 m/sec and hot fluid at 0.2 m/sec, the inlet temperature of hot and cold fluid are 350 K, and 300 K respectively. The hot fluid temperatures at outlet is drop upto 336.064 K and the cold fluid temperature rise upto 306.391 K as shown in figure 17.

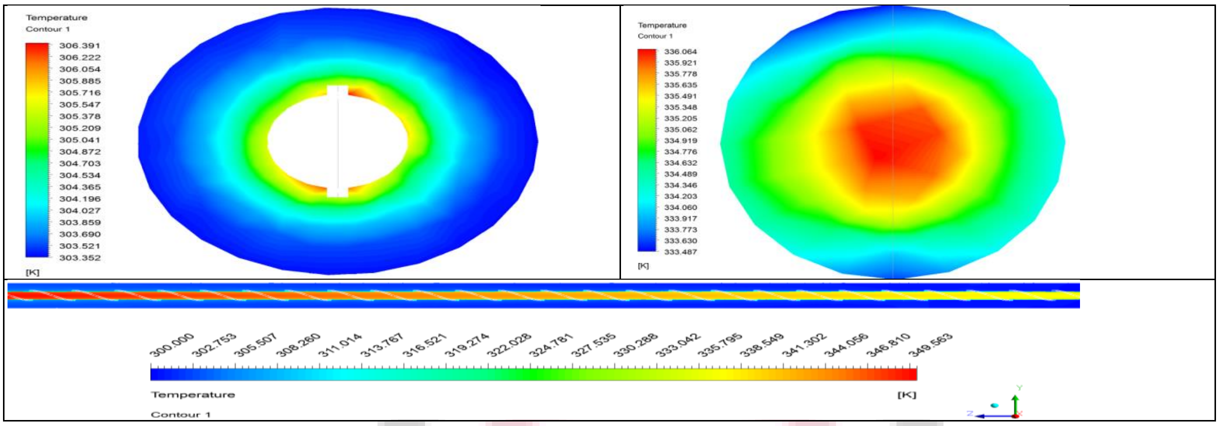


Figure 17: Temperature distribution for double pipe heat exchanger with double helical baffles at 0.2 m/sec (a) cold fluid at outlet (b) hot fluid at outlet(c) heat exchanger mid plane

After performing computational fluid dynamics analysis of double pipe heat exchanger with double helical baffles where cold fluid flows at 0.59 m/sec and hot fluid at 0.35 m/sec, the inlet temperature of hot and cold fluid are 350 K, and 300 K respectively. The hot fluid temperatures at outlet is drop upto 339.047 K and the cold fluid temperature rise upto 307.443 K as shown in figure18.

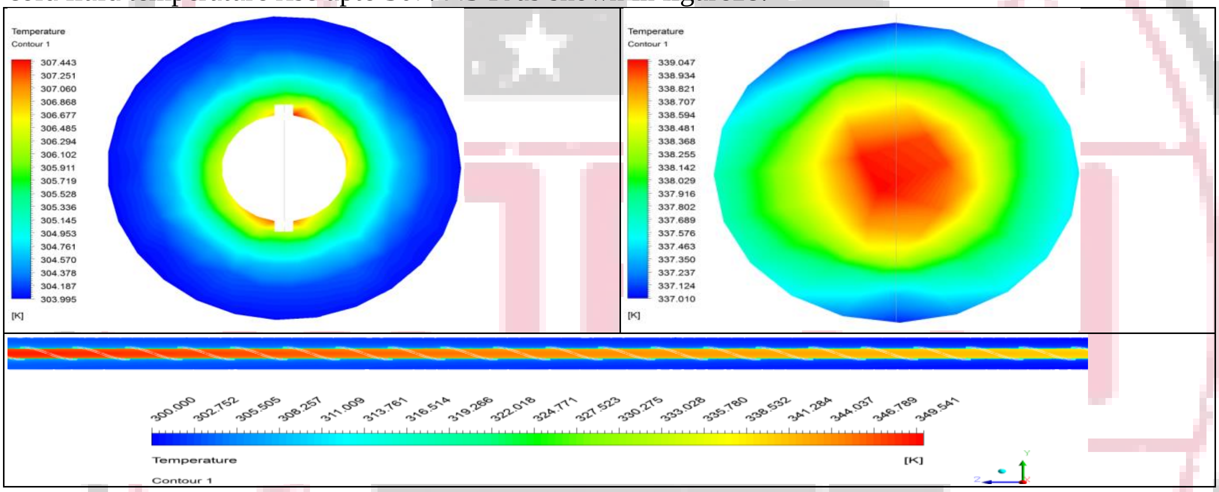


Figure 18: Temperature distribution for double pipe heat exchanger with double helical baffles at 0.35 m/sec (a) cold fluid at outlet (b) hot fluid at outlet(c) heat exchanger mid plane

After performing computational fluid dynamics analysis of double pipe heat exchanger with double helical baffles where cold fluid flows at 0.59 m/sec and hot fluid at 0.5 m/sec, the inlet temperature of hot and cold fluid are 350 K, and 300 K respectively. The hot fluid temperatures at outlet is drop upto 341.82 K and the cold fluid temperature rise upto 309.175 K as shown in figure 19.

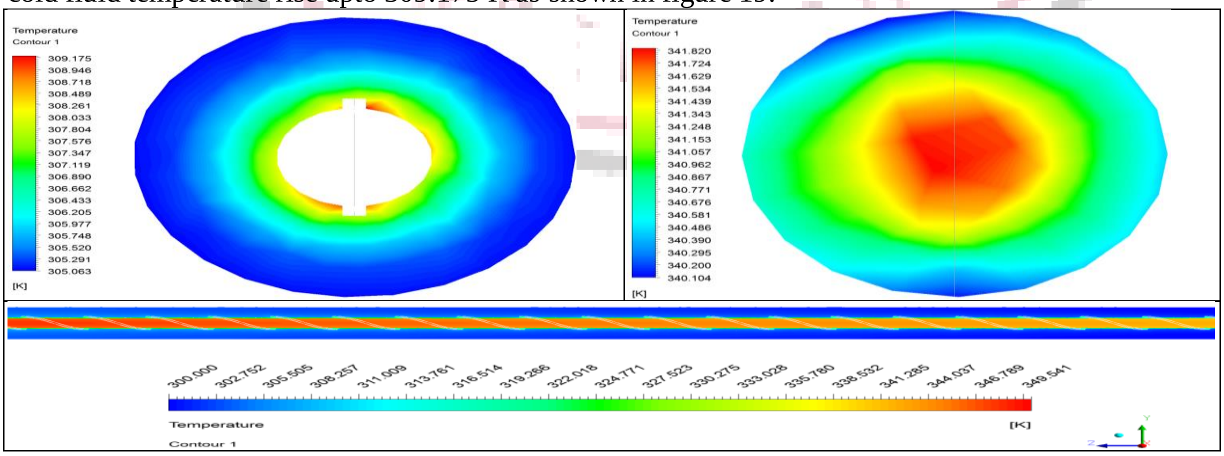


Figure 19: Temperature distribution for double pipe heat exchanger with double helical baffles at 0.5 m/sec (a) cold fluid at outlet (b) hot fluid at outlet(c) heat exchanger mid plane

After performing computational fluid dynamics analysis of double pipe heat exchanger with double helical baffles where cold fluid flows at 0.59 m/sec and hot fluid at 0.65 m/sec, the inlet temperature of hot and cold fluid are 350 K, and 300 K respectively. The hot fluid temperatures at outlet is drop upto 343.399 K and the cold fluid temperature rise upto 310.377 K as shown in figure 20.

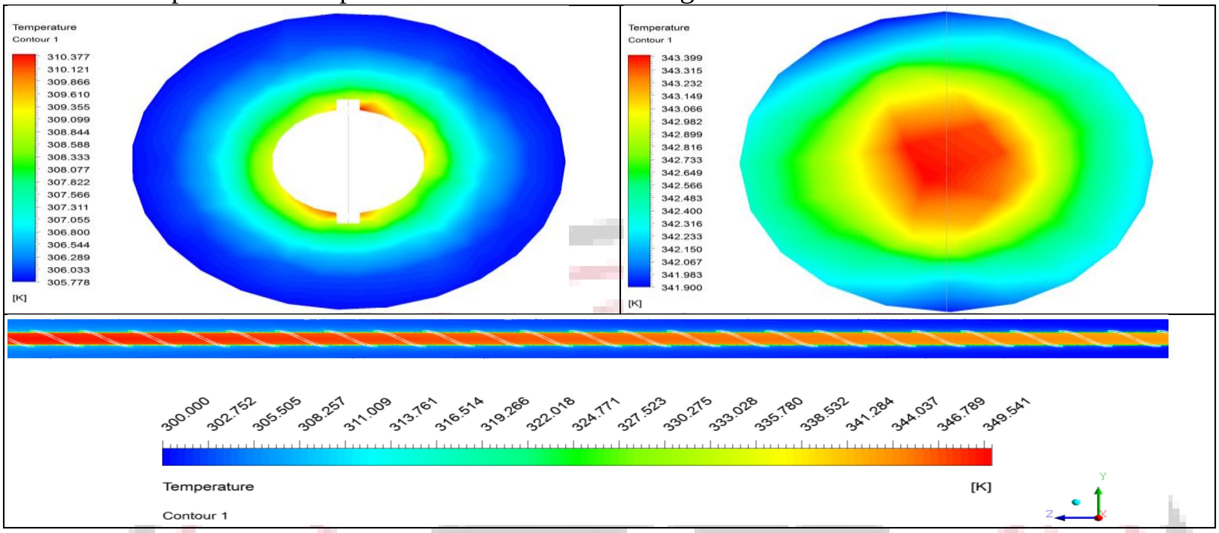


Figure 20: Temperature distribution for double pipe heat exchanger with double helical baffles at 0.65 m/sec (a) cold fluid at outlet (b) hot fluid at outlet(c) heat exchanger mid plane

Comparative results of temperature at hot outlet for different design of double tube heat exchanger

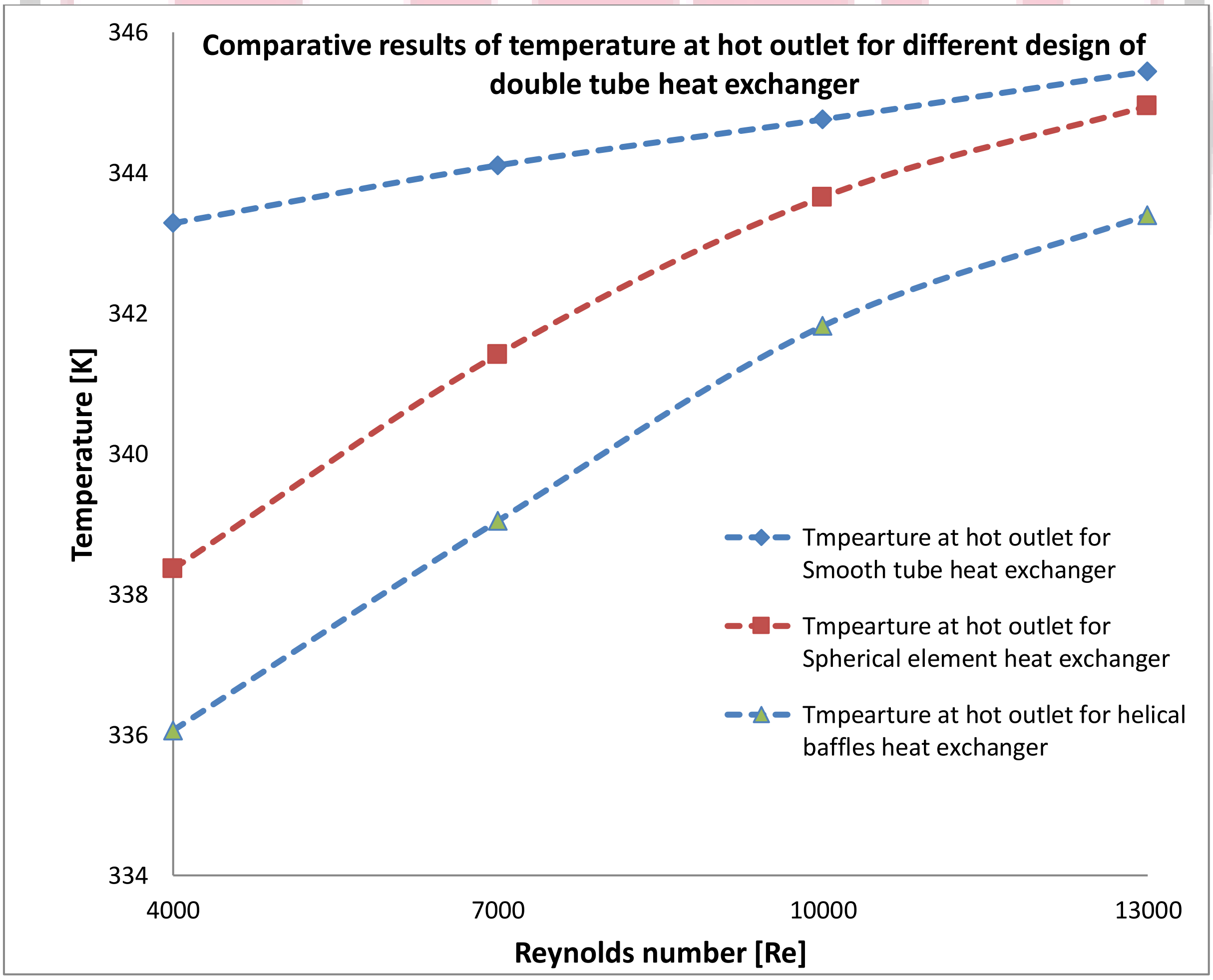


Figure 21: Comparative results of temperature at hot outlet for different design of double tube heat exchanger

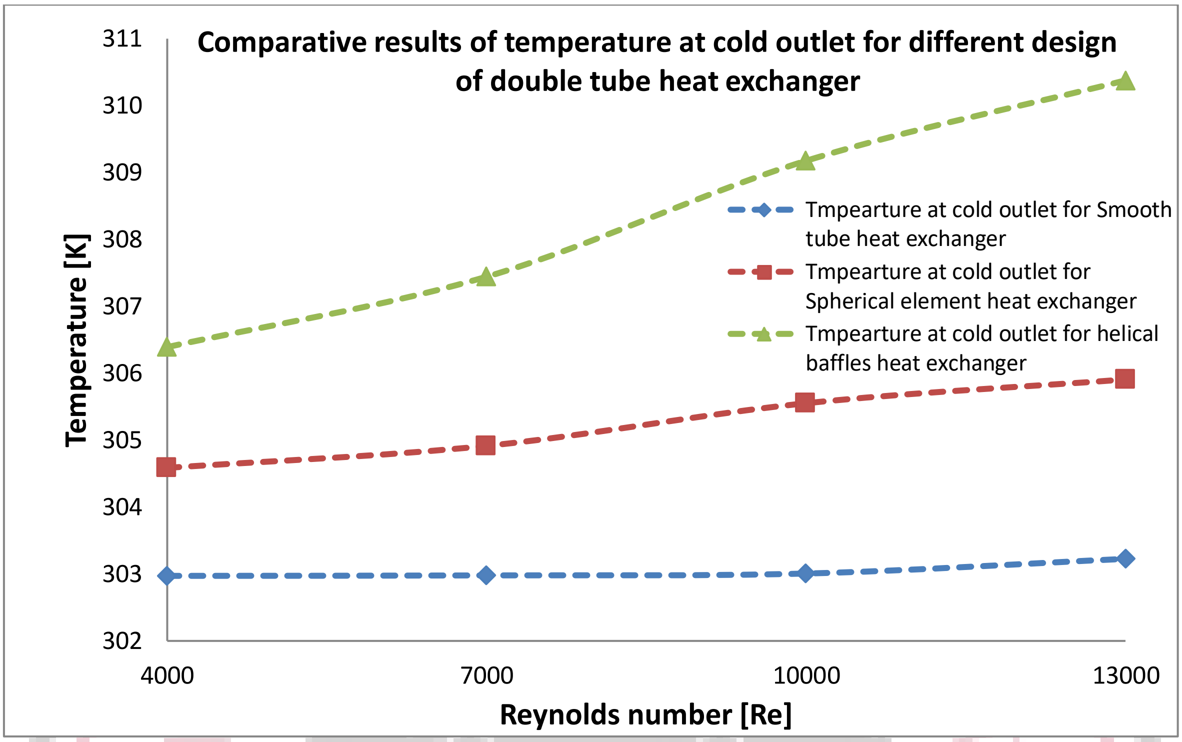


Figure 22: Comparative results of temperature at cold outlet for different design of double tube heat exchanger

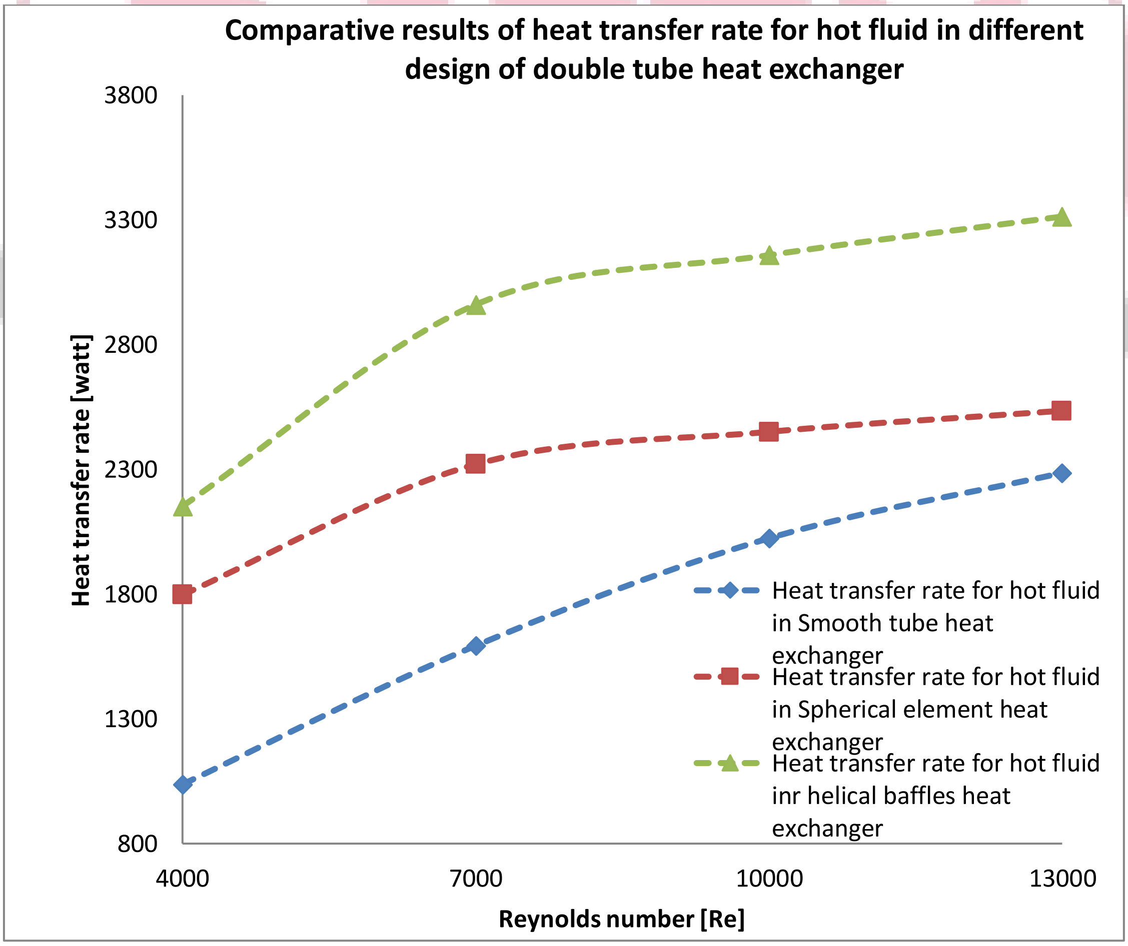


Figure 23: Comparative results of heat transfer rate for hot fluid in different design of double tube heat exchanger

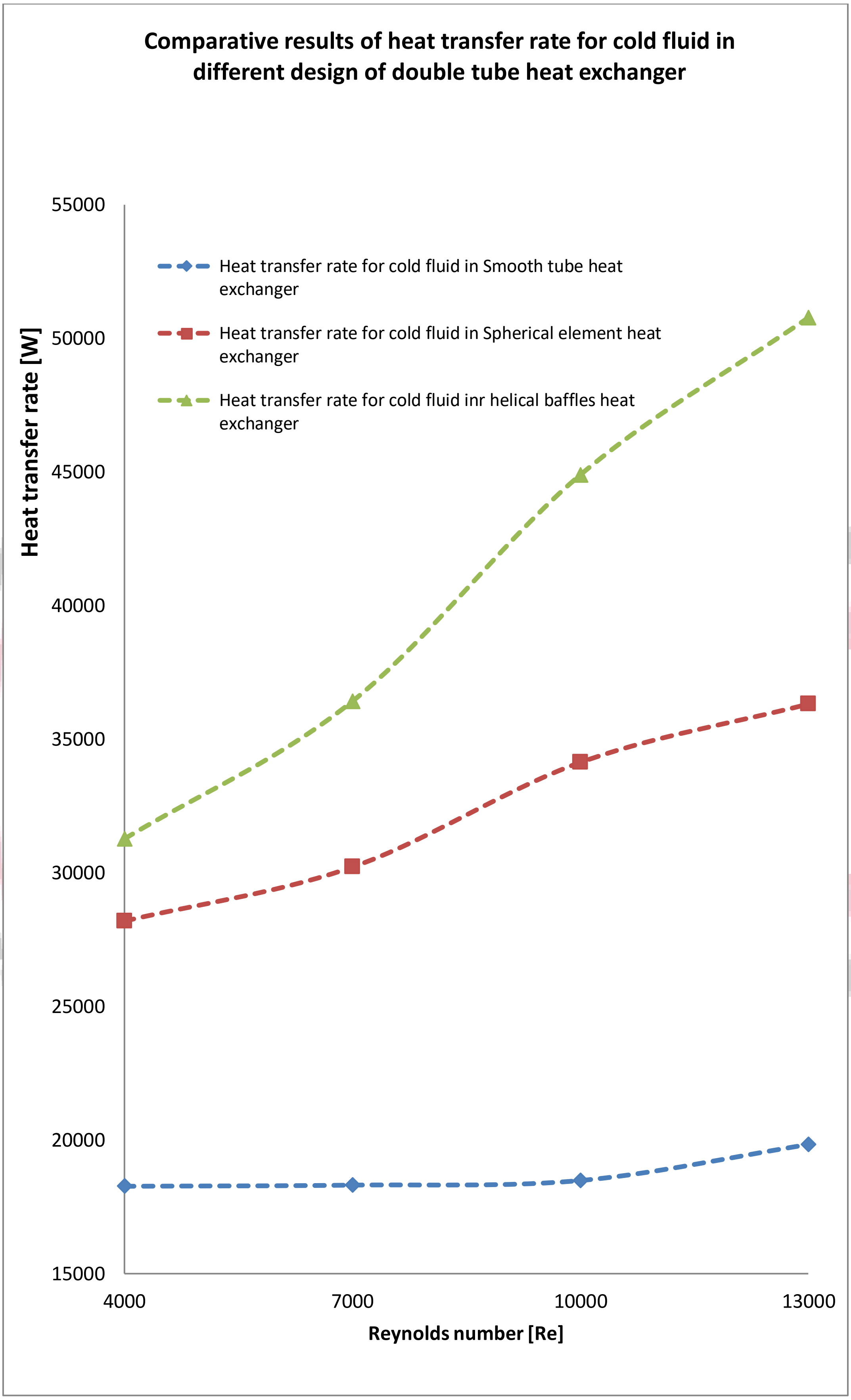


Figure 24: Comparative results of heat transfer rate for cold fluid in different design of double tube heat exchanger

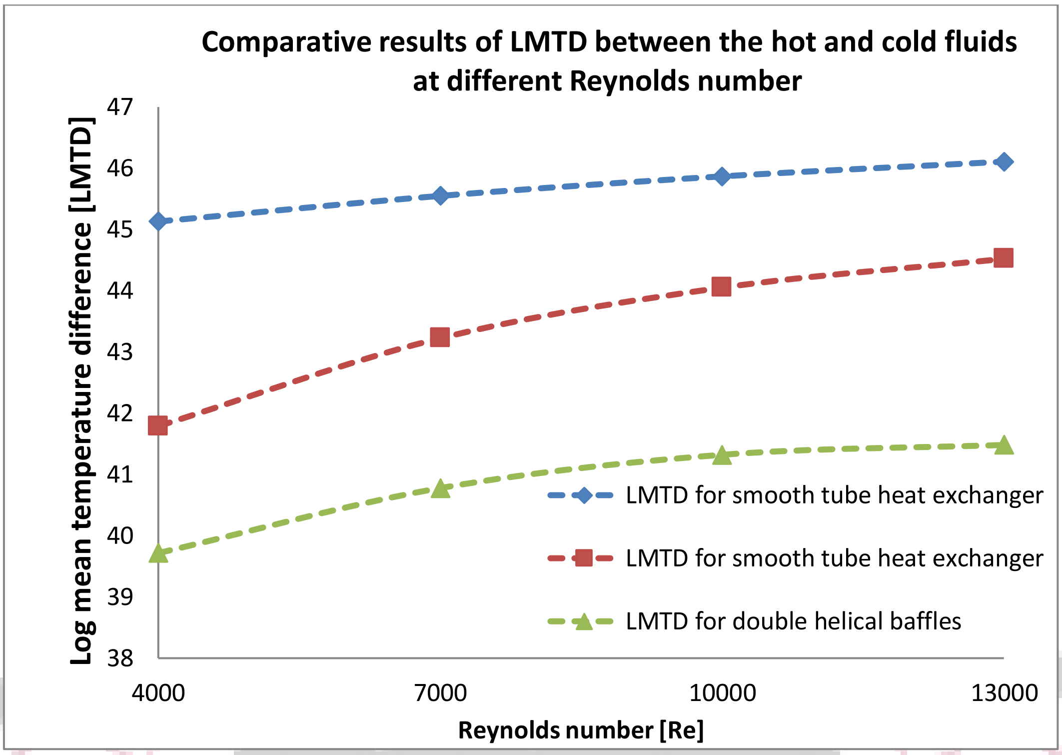


Figure 25: Comparative results of LMTD between the hot and cold fluids at different Reynolds number

The LMTD method is used to calculate the heat transfer rate in a heat exchanger. The logarithmic means temperature difference in temperature for considered a component decreases from 46.10 to 45.13 degrees Kelvin, 44.52-41.79 degrees Kelvin for spherical elements, and 41.48-39.72 degrees Kelvin for the double helical baffling at various Reynolds, as seen in the graph above.

V. CONCLUSION

In this study, computational fluid dynamics calculations for a double tube heat exchanger were performed at various Reynolds numbers using three distinct design ideas: smooth tubes, spherical elements, and double helical baffle at constant pitch. Water and Ag-MoS_2 (Silver-molybdenum disulfide) were used as heat transfer fluids in this study, with Ag-MoS_2 flowing in the inflatable raft as a hot fluid and water flowing in the outer tube. The cold fluid inlet velocity was set at 0.59 m/sec at 300 K, as well as the hot fluid inlet velocity are 0.2, 0.35, 0.5 and 0.65 m/sec at 350 K. The momentum energy turbulence and its rate of dissipation are calculated using the SIMPLE algorithms with a higher cognitive upwind strategy.From the aforementioned analysis, the following conclusions have been drawn.

Conclusion for smooth pipe double tube heat exchanger

1. After running a computational fluid dynamics analysis on a smoother pipe-double tubular heat exchanger with cold fluid flowing at 0.59 m/sec and heated fluid flowing at 0.2 m/sec. The temperatures of the hot fluid drops to 343.28 K at the outlet, whereas the temperature of the cold fluid rises to 302.97 K. The heat transfer rates for the hot and cold streams are 1037.45 and 17270.5 watt, respectively, with a log means difference in temperature of 45.1296.
2. After doing a computational fluid dynamics simulation on a smooth pipe twin tube heat exchanger with cold and hot fluid flowing at 0.59 and 0.35 m/sec,The temperatures of the hot fluid drops to 344.106 K at the outlet, while the temperature of the water rises to 302.979 K. The heat transfer rates for the hot and cold fluids are 1593 and 18313.5 watt, respectively, with a log mean difference in temperature of 45.548.
3.After doing a computational fluid dynamics simulation of a smooth pipe twin tubular heat exchanger with cold and hot fluid flowing at 0.59 and 0.5 m/sec, The temperatures of the heated fluid drops to 344.759 K at the outlet, while the temperature of the cold fluid rises to 303.007 K. The heat transfer rates for the hot and cold fluids are 2023.7 and 18485.7 watt, respectively, with a log mean difference in temperature of 45.87.
4.After running a computational fluid dynamics simulation on a smoother pipes twin tubular heat exchanger with cold and hot fluid flowing at 0.59 and 0.65 m/sec, The temperatures of the heat flux drops to 345.446 K at the outlet, while the temperature of the cold rises to 303.226 K. The heat transfer rates for the hot and cold fluids are 2285.89 and 19832 watt, respectively, with a log mean difference in temperature of 46.11.

Conclusion for spherical element double tube heat exchanger

1. After doing a computational fluid dynamics simulation of a twin tube heat exchanger with a spherical element and cooling coil flowing at 0.59 m/sec and hot fluid flowing at 0.2 m/sec. The temperatures of the hot fluid drops to 338.363 K at the outlet, while the temperature of the cold rises to 304.586 K. The heat transfer rates for the hot and cold fluids are 1797.35 and 28192.62 watt, respectively, with a log means temperature difference of 41.789.
2. After doing a computational fluid dynamics simulation of a twin tubular heat exchanger with a spherical element and cooling coil flowing at 0.59 m/sec and heated fluids flowing at 0.35 m/secThe temperature of the hot fluid drops to 341.415 K at the outlet, while the temperature of the cold fluid rises to 304.915 K. The heat transfer rates for the hot and cold fluids are 2320.3 and 30215.2 watt, respectively, with a log mean difference in temperature of 43.224.
3. After doing a computational fluid dynamics simulation of a twin tube heat exchanger with a spherical element and cooling coil flowing at 0.59 m/sec and hot fluid flowing at 0.5 m/sec. The temperatures of the hot fluid drops to 343.654 K at the outlet, whereas the temperature of the cold fluid rises to 305.552 K. The heat transfer rates for the hot and cold streams are 2450.37 and 34131.1 watt, respectively, with a log means difference in temperature of 44.049.
4. After doing a commercial cfd simulation of a twin tube heat exchanger with a spherical component and cooling coil flowing at 0.59 m/sec and hot fluid flowing at 0.65 m/sec. The temperature of the hot fluid drops to 344.95 K at the outlet, whereas the temperature of the cold fluid rises to 305.907 K. The heat transfer rates for the hot and cold streams are 2534.85 and 36313.5 watt, respectively, with a log mean difference in temperature of 44.502.

Conclusion for helical baffle double tube heat exchanger

1. After performing a commercial CFD simulation of a helical baffled double tubular heat exchanger with cold and hot fluids flowing at 0.59 and 0.2 m/sec. The temperature of the hot fluid drops to 336.064 K at the outlet, while the temperature of the cold fluid rises to 306.391 K. The heat transfer rates for the hot and cold fluids are 2152.434 and 31270.78 watt, respectively, with a log means difference in temperature of 39.717.
2. After doing a computational fluid dynamics simulation of a helical baffled double tubular heat exchanger with cold and hot fluid flowing at 0.59 and 0.35 m/sec, The hot fluid temp decreases to 339.047 K at the outlet, while the cold fluid temperature rises to 307.443 K. The heat transfer coefficients for cold and hot water are 2960.312 watt and 36418.15 watt, respectively, with a log mean difference in temperature of 40.777.
3. After doing a commercial CFD simulation of a helical baffle double tubular heat exchanger with cold and hot fluid flowing at 0.59 and 0.5 m/sec, The hot fluid temperature drops to 341.82 K at the outlet, while the cold stream temperature increases to 309.175 K. The heat transfer coefficients for hot and cold fluids are 3158.53 watt and 44892.72 watt, respectively
4. After performing a commercial CFD simulation of a helical baffledouble tubular heat exchanger with cold fluid flowing at 0.59 m/sec and hot fluid flowing at 0.65 m/sec, the mean temperature differential is 41.321. The temperature of the hot fluid drops to 343.399 K at the outlet, while the temperature of the cold fluid rises to 310.377 K. The heat transfer rates for the hot and cold fluids are 3313.379 and 50774.04 watt, respectively, with a log means difference in temperature of 41.482.

REFERENCES

[1] A. Asadi et al. (2021) “Numerical analysis of turbulence-inducing elements with various geometries and utilization of hybrid nanoparticles in a double pipe heat exchanger” Alexandria Engineering Journal 23 August 2021 https://doi.org/10.1016/j.aej.2021.08.074

[2] Chao Luo &Ke Wei Song (2021) “Thermal performance enhancement of a double-tube heat exchanger with novel twisted annulus formed by counter-twisted oval tubes” International Journal of Thermal Sciences 164 (2021) 106892 https://doi.org/10.1016/j.ijthermalsci.2021.106892..

[3] MortezaHangi et al. (2021) “Design improvement of compact double-pipe heat exchangers equipped with tube-side helical insert and annulus-side helical strip: Hydrothermal and exergy analyses”Applied Thermal Engineering 190 (2021) 116805 https://doi.org/10.1016/j.applthermaleng.2021.116805.

[4] Nidal H. Abu-Hamdeh et al. (2021) “A detailed hydrothermal investigation of a helical micro double-tube heat exchanger for a wide range of helix pitch length” Case Studies in Thermal Engineering 28 (2021) 101413 https://doi.org/10.1016/j.csite.2021.101413.

[5] QingangXiong et al. (2021) “3D Numerical Study of Conical and Fusiform Turbulators for Heat Transfer Improvement in a Double-Pipe Heat Exchanger”nternational Journal of Heat and Mass Transfer 170 (2021) 120995 https://doi.org/10.1016/j.ijheatmasstransfer.2021.120995.

[6] S. Padmanabhan et al. (2021) “Heat transfer analysis of double tube heat exchanger with helical inserts” Materials Today: Proceedings 10 January 2021 https://doi.org/10.1016/j.matpr.2021.01.337.

[7] S.M. Zakir Hossain et al. (2021) “Fabrication of a hybrid shell and double pipe heat exchanger by means of design and performance assessment” Chemical Engineering & Processing: Process Intensification 165 (2021) 108430 https://doi.org/10.1016/j.cep.2021.108430.

[8] Ahmad Vaisi et al. (2020) “Experimental investigation of perforated twisted tapes turbulator on thermal performance in double pipe heat exchangers” Chemical Engineering & Processing: Process Intensification 154 (2020) 108028 https://doi.org/10.1016/j.cep.2020.108028.

[9] Anas El Maakou et al. (2020) “Performance enhancement of finned annulus using surface interruptions in double-pipe heat exchangers” Energy Conversion and Management 210 (2020) 112710 https://doi.org/10.1016/j.enconman.2020.112710.

[10] J.D. Moya-Rico et al. (2020) “Experimental characterization of a double tube heat exchanger with inserted twisted tape elements” Applied Thermal Engineering 174 (2020) 115234 https://doi.org/10.1016/j.applthermaleng.2020.115234.

[11] J.I. Corcoles et al. (2020) “Numerical and experimental study of the heat transfer process in a double pipe heat exchanger with inner corrugated tubes” International Journal of Thermal Sciences 158 (2020) 106526 https://doi.org/10.1016/j.ijthermalsci.2020.106526.

[12] NazaruddinSinaga et al. (2020) “Second law efficiency analysis of air injection into inner tube of double tube heat exchanger” Alexandria Engineering Journal 30 October 2020 https://doi.org/10.1016/j.aej.2020.10.064.

[13] A. Khosravi et al. (2019) “Performance improvement of a double pipe heat exchanger proposed in a small-scale CAES system: An innovative design” Applied Thermal Engineering 162 (2019) 114315 https://doi.org/10.1016/j.applthermaleng.2019.114315.

[14] Ali Karimi et al. (2019) “The effects of tape insert material on the flow and heat transfer in a nanofluid-based double tube heat exchanger: Two-phase mixture model” International Journal of Mechanical Sciences 156 (2019) 397–409 https://doi.org/10.1016/j.ijmecsci.2019.04.009.

[15] C. Gnanavel et al. (2019) “Heat transfer augmentation by nano-fluids and circular fin insert in double tube heat exchanger – A numerical exploration” Materials Today: Proceedings 16 August 2019 https://doi.org/10.1016/j.matpr.2019.08.236.

[16] Cong Qi et al. (2019) “Experimental study on the flow and heat transfer characteristics of nanofluids in double-tube heat exchangers based on thermal efficiency assessment” Energy Conversion and Management 197 (2019) 111877 https://doi.org/10.1016/j.enconman.2019.111877.

[17] Ganesh Kumar Poongavanam et al. (2019) “Heat transfer and pressure drop performance of solar glycol/activated carbon based nanofluids in shot peened double pipe heat exchanger” Renewable Energy 140 (2019) 580e591 https://doi.org/10.1016/j.renene.2019.03.059.

[18] C. Gnanavel et al. (2019) “Heat transfer augmentation by nano-fluids and Spiral Spring insert in Double Tube Heat Exchanger – A numerical exploration” Materials Today: Proceedings 19 July 2019 https://doi.org/10.1016/j.matpr.2019.07.602.

[19] ImanBashtani&JavadAbolfazliEsfahani (2019) “ε-NTU analysis of turbulent flow in a corrugated double pipe heat exchanger: A numerical investigation” Applied Thermal Engineering 159 (2019) 113886 https://doi.org/10.1016/j.applthermaleng.2019.113886.

[20] Agung Tri Wijayanta et al. (2018) “Double-sided delta-wing tape inserts to enhance convective heat transfer and fluid flow characteristics of a double-pipe heat exchanger” Applied Thermal Engineering 145 (2018) 27–37 https://doi.org/10.1016/j.applthermaleng.2018.09.009.

[21] Edreis Edreis and A Petrov (2020) “Types of heat exchangers in industry, their advantages and disadvantages, and the study of their parameters’’ IOP Conf. Series: Materials Science and Engineering 963 (2020) 012027 IOP Publishing doi:10.1088/1757-899X/963/1/012027.