Numerical investigation on Double Tube Counter Flow Heat Exchanger

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Abstract. In the current study, the investigation of heat transfer and fluid flow Characteristics of Pure water when pass through a double tube heat exchanger (DTHX). this investigation has been conducted across various Reynolds Number to gain insights into their performance also conducted a computational fluid dynamics (CFD) simulation using the ANSYS-FLUENT 22 R1 software. Result obtained was validated by comparing to empirical correlation data found in the existing literature. The investigation considered various operating variable as Reynolds Number and temperature across the inner, and outer tubes. Specifically, the Reynolds Number of a range of 2500 to 5500 at 333 K, and 2500 at 303 K for the respective tubes. Key findings are that friction factor is increase by 6.38% as compared to correlation (Blasius) in existing literature. And Nusselt number (Nu) increase by 40.84% as compared to correlation at the Reynolds Number (Re) of 2500. The heat transfer coefficients (hi) were increased by 8.30% as compared to existing literature.

Keywords: Computational Fluid Dynamics (CFD), Blasius Correlation, Concentric, Double Tube Heat Exchanger.

1. Introduction

Heat Exchanger is device in which transaction of heat takes place between two fluids Subhani et al. [1] CFD analysis was employed to predict outlet temperatures in parallel and counter flow heat exchangers based on fluid medium's inlet velocity and temperature. CFD is a science utilizing numerical methods to solve the governing equations for fluid flow, heat transfer, and mass transfer. Outlet temperatures were used to determine the overall heat transfer coefficient. Sridhar et al. [2] A comparative analysis was done between counter and parallel flow heat exchanger. CFD and thermal analysis are performed on the heat exchanger using various fluids (hot water, R134A, R22, R600A) and different heat exchanger materials. 3D models are created in Pro/Engineer, and the analysis is conducted in Ansys. Ahmad et al. [3] The study utilized computational fluid dynamics (CFD) to analyze a heat exchanger with parallel and counterflow systems. It examined factors like temperature, velocity, pressure drop, turbulence kinetic energy, and heat exchanger length. Results showed that the temperature of cold water on the shell side increased along the heat exchanger's length. Dhoria et al. [4] The aim of this project is to analyse temperature drops using CFD software and theoretical analysis. The study focuses on examining the variations in temperature as a function of inlet velocity and inlet temperature. Parallel and counter flow heat exchanger models were designed and simulated, and CFD analysis was employed to determine outlet temperatures. Bhattacharjee et al. [5] The design of a double pipe in tube heat exchanger has been challenging due to limited experimental data on fluid flow behavior and heat transfer. This project aims to enhance understanding by varying parameters such as temperatures and pipe/coil diameters to determine fluid flow patterns. The objective is to gain quantitative insights into the heat transfer process in double pipe heat exchangers. Boda et al. [6] The purpose of this review study is to outline developments in parallel and counter flow heat exchangers based on a survey of the literature. The goal is to investigate different alterations made to improve performance. Researchers used software, design approaches, tube shape adjustments, and the second law of thermodynamics to construct heat exchangers. Heller A et al. [7] This work examines the CFD simulation of a parallel/counter-parallel flow heat exchanger used to treat hypothermia. The goal is to determine its thermal performance as part of a fluid warmer. The 3D model has three regions: Infuscate, Hot Water, and a Solid Region (wall). This design has an elbow piece at the end to achieve the required counter-parallel flow pattern. Krasniqi D et al. [8] This paper presents dynamic models that depict the variation of hot and cold fluid temperatures along the heat exchanger's length. The objective is to establish relationships between inlet/outlet temperatures and heat transfer rate. These dynamic models enable optimization and control of the heat exchanger, facilitating predictions of how changes in independent variables will impact the system's outputs. Pathak R et al. [9] This study examines and optimises a counter flow heat exchanger under various operating situations. CFD analyses use simulations to investigate temperature, pressure, velocity, and turbulence profiles. The efficacy, overall heat transfer coefficients, pressure dips, and velocity variations of the are calculated. To determine the optimal operating conditions, entropy and exergy evaluations are done with different flow rates and inner pipe materials. The analyses show that the maximum temperature difference and efficacy are reached with copper at low flow rates, while the maximum temperature difference for the hot fluid is found with steel at high flow rates. Furthermore, at high flow rates, copper exhibits the highest rate of heat transfer and overall heat transfer coefficient, but also the highest rates of entropy formation. Basava Poornima C et al. [10] The work investigates Pr 3+: PPbKANPr glasses for visible lasers and optical amplifiers. Glasses were made using the melt-cast method. FTIR and Raman techniques were used to study vibrational modes. Yadav S. et al. [11] This paper introduces a micro-TEG system that employs a micro combustion concept. Bhukya MN et al. [12] The research describes a novel PV inverter topology for optimal solar power use. It contains a new MPPT method that uses an artificial neural network to identify shading patterns, a SIMO converter, and a multilayer inverter. The MPPT system's performance is examined under partially shadowed situations. Vijayakumar Y et al. [13] ZnO thin films, doped/co-doped with Al, Fe, were deposited using optimized spray pyrolysis. XRD, TEM, and Raman spectroscopy characterized the films, revealing polycrystalline nature with a Wurtzite structure. Singh B et al. [14] This research provides a detailed analysis of aluminium metal matrix composites (AMMCs), focusing on their current state and future potential. Yue L et al. [15] To solve the issues of volume change and unstable structures in tin and antimony-based anode materials for sodium ion batteries, a thermochemical method is presented. Goud JS et al. [16] The study takes temperature and humidity ratio changes into consideration as driving forces for heat and mass transmission, as well as surface convection, radiation, and internal heat impacts. Reddy PV et al. [17] Tube hydroforming (THF) is widely used in manufacturing complex automobile parts. Internal pressure, axial feeds, material characteristics, and processing conditions are all critical parameters in the process. Design by simulation seeks to find an optimal and cost-effective procedure by modifying these factors to produce defect-free goods. Francis V et al. [18] FFF is a 3D printing process that deposits semi-molten thermoplastic material layer by layer according to a CAD model. FFF is commonly used for rapid tooling and prototyping, and with advancements in printable materials, it is also utilized for direct end-use applications. Misra RK et al. [19] The behavior of fabricated bogie frame structures in railway locomotives varies between un-heat-treated and heat-treated conditions, leading to susceptibility to cracks. Quantifying and analysing this variation is crucial for assessing the samples made of the same material under both conditions. Singh L et al. [20] CFD used to analyse parallel and counterflow shell and tube heat exchanger, studying temperature, velocity, pressure, and length. The cold-water temperature increased along the heat exchanger's length. Verma M et al. [21] Geopolymer concrete (GPC) is a sustainable and environmentally friendly alternative to conventional concrete [22]. It forms a geopolymer bond, unlike regular concrete, which forms a calcium silicate hydrate bond. The geopolymer bond does not contain water in its final state.

2. Material and Methods

2.1 Design and Data Deduction for DTHX

The arrangement of the double pipe heat exchanger can be modified into series and parallel configurations to meet specific requirements for pressure drop and mean temperature difference [23-26]. This type of heat exchanger is commonly used for sensible heating and cooling of process fluids when a smaller heat transfer area is sufficient. It is particularly suitable for high-pressure applications.

Table 1 Technical specification of DTHX.

Sr No.	Parts of DTHX	Dimension in mm
1	Innermost pipe inner diameter	32
2	Innermost pipe outer diameter	40

3	Outermost pipe inner diameter	54
4	Outermost pipe outer diameter	60
5	Inner pipe length	1500
6	Outer pipe length	1250

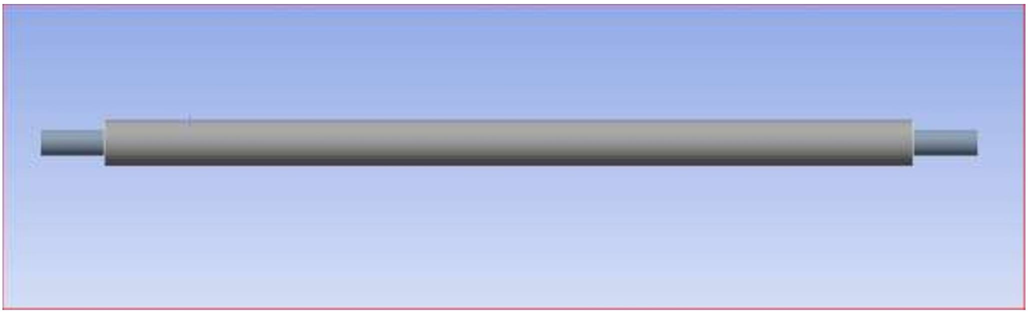

Figure 1 Design Modular Geometry of Double tube heat exchanger.

2.1 Meshing of DTHX

These elements, such as triangles or hexahedra, discretize the domain and allow the numerical solution of governing equations. Proper meshing is crucial for accurately modelling flow characteristics and boundary conditions, ensuring accurate and reliable CFD simulations**.** Meshing specifications are below:

- No of elements 514801
- Skewness 0.54
- Orthogonal quality 0.95

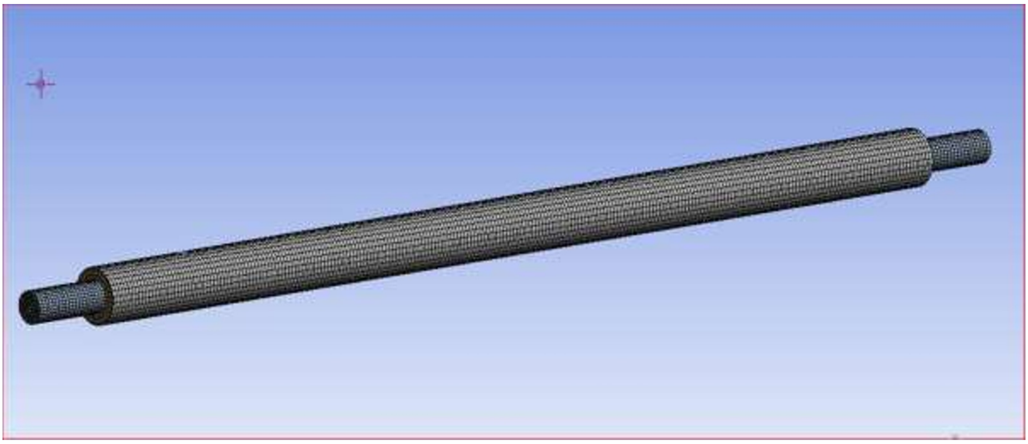

Figure 2 Meshing of DTHX IN ANSYS 2022 R1.

2.1 Data Deduction for Nanofluids and Pure Water

The computed variables and parameters are used to analyse the friction factor and Nu number in the DTHX are used [27]. These variables provide detailed insights into the data results.

It is possible to compute the heat transfer rate of hot, cold fluid, and normal fluids as follows:

$$\dot{Q}_h = \dot{m}_h \cdot c_h (T_{\text{ho}} - T_{\text{hi}}) \ldots\ldots\ldots\ldots\ldots \text{(1)}$$

$$\dot{Q}_c = \dot{m}_c \cdot c_c(T_{\text{ci}} - T_{\text{co}}) \ldots\ldots\ldots (2)$$

The following formula can be taken to express the heat quantities for the DTHX's cold, and hot fluid sides:

$$\dot{Q}_h = \dot{Q}_c \ldots\ldots\ldots (3)$$

The following formula [8] is used to evaluate the average heat transfer rate between the three fluids ($\dot{Q}_{avg}$):

$$\dot{Q}_{avg} = (\dot{Q}_h + \dot{Q}_c)/2 \ldots\ldots\ldots (4)$$

The Darcy-Weisbach equation is used to determine the Darcy friction factor for each tube in the DTHX.

$$\text{f} = \frac{2X\Delta P.D_{hy}}{\rho_{f}.L_f.v_f^2} \ldots\ldots\ldots (5)$$

The Nu and f correlation by Blasius [5].

$$\text{Nu}=0.0215\text{Re}^{0.8}\,\text{Pr}^{0.4}\ (\text{Re}\geq 2000) \ldots (6)$$

$$\text{f}=0.3164/\text{Re}^{1/4} \ldots\ldots\ldots (7)$$

2.2 Numerical CFD modelling in DTHX

In the pursuit of unveiling the enigmatic heat transfer and fluid flow characteristics of the remarkable DTHX (Double Tube Heat Exchanger), the governing equations find solace through the meticulous application of a finite volume discretization method.

The study employed a FVM with a (RNZ)k-ε turbulence model for simulating turbulent flows, accounted for conjugate heat transfer, used a pressure-velocity coupling method with the SIMPLE algorithm, applied a standard pressure discretization scheme, and utilized second-order upwind schemes to solve momentum and energy equations [28-30]. This comprehensive numerical approach allowed for investigation of the fluid flow characteristics and heat transfer within the DTHX, taking into consideration the complex interplay between heat transfer and fluid flow.

Continuity Equation:

$$\frac{\partial \rho}{\partial t} + \text{div}(\rho u) = 0 \ldots\ldots\ldots (8)$$

Momentum Equation:

$$\frac{\partial(\rho u)}{\partial t} + \text{div}(\rho u \mathbf{u}) = -\frac{\partial p}{\partial x} + \text{div}(\mu \,\text{grad}\, u) + \left[-\frac{\partial\left(\overline{\rho u'^2}\right)}{\partial x} - \frac{\partial\left(\overline{\rho u'v'}\right)}{\partial y} - \frac{\partial\left(\overline{\rho u'w'}\right)}{\partial z} \right] \ldots\ldots\ldots (9)$$

Energy Equation:

$$\frac{\partial(\rho E)}{\partial t} + \text{div}\,(\rho E \mathbf{u}) = \text{div}\,(k \text{grad}\ T) + \left[-\frac{\partial\left(\overline{\rho u'E'}\right)}{\partial x} - \frac{\partial\left(\overline{\rho v'E'}\right)}{\partial y} - \frac{\partial\left(\overline{\rho w'E'}\right)}{\partial z} \right] \ldots\ldots\ldots (10)$$

Turbulence Model:

A k-ε turbulence model, mostly employed in engineering applications, was used to model the heat transfer and fluid turbulence characteristics. To accurately capture heat transfer near solid surfaces with high temperature gradients, an enhanced wall-temperature wall-treatment was incorporated into the modelling approach. Malalasekera W. et al. [5]

Equation for k

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}[\rho k u_i] = \frac{\partial}{\partial x_j}\left[\alpha_k \mu_{eff} \frac{\partial k}{\partial x_j}\right] + G_k + G_b - \rho\varepsilon + S_k \ldots\ldots\ldots (11)$$

Equation for ε

$$\frac{\partial}{\partial t}(\rho\varepsilon)+\frac{\partial}{\partial x_i}(\rho\varepsilon u_i)=\frac{\partial}{\partial x_j}\left[\alpha_\varepsilon\mu_{eff}\frac{\partial\varepsilon}{\partial x_j}\right]+C_{1\varepsilon}\frac{\varepsilon}{k}(G_k+C_{3\varepsilon}G_b)-C_{2\varepsilon}\rho\frac{\varepsilon^2}{k}-R_\varepsilon+S_k \ldots\ldots (12)$$

where; $G_k=-\rho\overline{u_i'u_j'}\frac{\partial u_j}{\partial x_i}, R_\varepsilon=\frac{C_\mu\rho\xi^3(1-\xi/\xi_0)}{1+\psi\xi^3}\frac{\varepsilon^2}{k}, G_b=g_i\frac{\mu_t}{\rho P_t}\frac{\partial\rho}{\partial x_i}, C_{3\varepsilon}=$ $\tanh\left|\frac{v}{u}\right|, S_k=\xi\varepsilon$

The empirical coefficients used in equations of k and ε have specific values:

$C_{1\varepsilon} = 1.42$, $C_{2\varepsilon} = 1.68$ and $\alpha_k = \alpha_\varepsilon \approx 1.393$.

2.3 Boundary condition at inlet of DTHX

The detailed specification of heat exchanger is given below in table 2.

Table 2 Boundary Condition input to DTHX.

parameter	*Inner pipe*	*Outer pipe*
temperature	333k	303k
Reynolds number	2500-5500	2500
velocity	.224-2.24m/s	.448m/s
Turbulence model	k-epsilon	k-epsilon

3. Result and Discussion

It includes discussions on temperature profiles, pressure drop, heat transfer coefficient, and fluid velocity distribution [31-32]. The results are compared with theoretical or experimental data, providing insights into the performance, efficiency, and limitations of the heat exchanger design. The discussion often includes explanations, interpretations, and potential improvements or optimizations for the heat exchanger system.

3.1 Friction factor for Double tube heat exchanger

The friction factor in pipe flow represents the resistance to flow caused by pipe surfaces. It is a dimensionless quantity used to estimate pressure drop and head loss. The friction factor depends on parameters such as pipe roughness, Reynolds number, and relative roughness. It is essential for calculating pressure drop and determining pumping power in various applications involving fluid flow through pipes. Key findings are that friction factor is increase by 6.38% as compared to Blasius correlation.

In pipe flow, pressure drop refers to the decrease in pressure along the pipe due to flow resistance. Friction factor, a dimensionless parameter, represents the resistance caused by pipe walls. It depends on factors like roughness, Reynolds number, and relative roughness. The friction factor is used in equations like Darcy-Weisbach to accurately estimate pressure drop in pipe flow, aiding in system design and analysis.

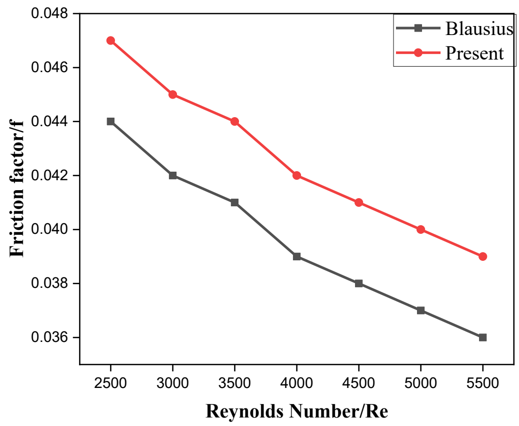

Figure 3 Variation in inner pipe fiction factor (f) with Inner Reynolds Number (Re).

3.2 Nusselt Number for Double tube heat exchanger

It is an indicator of the effectiveness of convective heat transfer and is commonly used in analysing fluid flow and heat transfer phenomena**.** Nusselt number (Nu) increase by 40.84% as compared to Blasius correlation at a certain Reynolds Number (Re) of 2500.

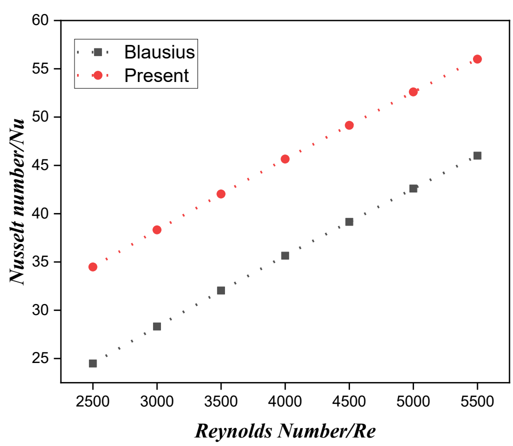

Figure 4 Variation in inner pipe Nusselt Number (Nu) with Inner Reynolds Number (Re).

3.3 Heat Transfer Coefficients for Double tube heat exchanger

Heat transfer coefficients in a double tube heat exchanger represent the effectiveness of heat transfer between the hot and cold fluids. They quantify the rate of heat transfer per unit area and temperature difference. Higher heat transfer coefficients indicate more efficient heat exchange [33-35]. Factors that influence these coefficients include fluid properties, flow rates, surface conditions, and the geometry of the heat exchanger. Accurate determination of heat transfer coefficients is essential for designing and optimizing the performance of double tube heat exchangers**.** The heat transfer coefficients (h_i) were increased by 8.30% as compared to existing literature.

Nu is a dimensionless parameter used in heat transfer to quantify the convective heat transfer effectiveness relative to conductive heat transfer. It represents the ratio of convective heat transfer to conductive heat transfer and is influenced by fluid properties, flow conditions, and surface characteristics. The Nusselt number is crucial in heat transfer analysis, design, and optimization of various systems. Figure 5 has shown about the variation in inner pipe Heat transfer coefficients (h) with Inner Reynolds (Re).

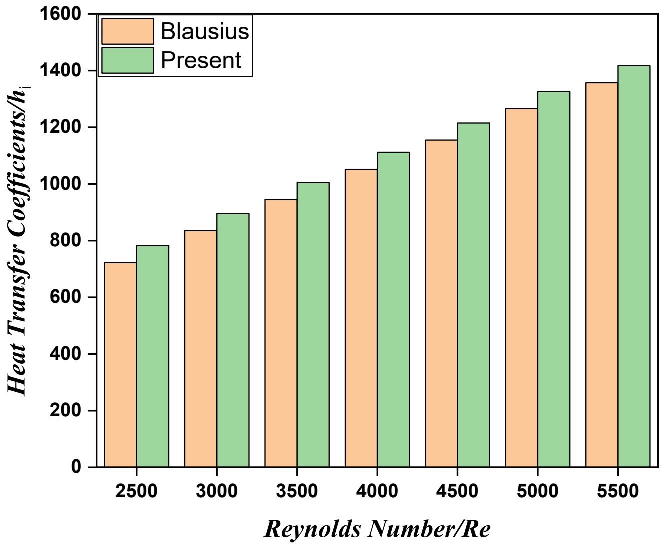

Figure 5 Variation in inner pipe Heat transfer coefficients (h) with Inner Reynolds (Re).

3.4 Temperature Contour for Double tube heat exchanger

Temperature contours in a heat exchanger represent the visualization of temperature distribution across its surfaces. They are generated using computational simulations and show variations in temperature levels through color-coded or contour line displays. Temperature contours provide insights into heat transfer efficiency, thermal gradients, and aid in the design, optimization. In this inner tube temperature decrease to 318K and outer fluids temperature increase to 310K from 303K. Figure 6 has shown about the static temperature contour of DTHX.

Figure 6 Static Temperature Contour of DTHX.

3.5) Pressure Contour for Double tube heat exchanger

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Pressure contour in a double heat exchanger shows the distribution of pressure across its surfaces, providing insights into pressure variations, flow restrictions, and aiding in evaluating performance and optimization of the exchanger.

Figure 7 Static Pressure Contour of DTHX.

3.6 Velocity contour for Double tube heat exchanger

Velocity contour in a double tube heat exchanger represents the visualization of fluid velocity distribution across its surfaces. It provides insights into the flow behavior, velocity gradients,

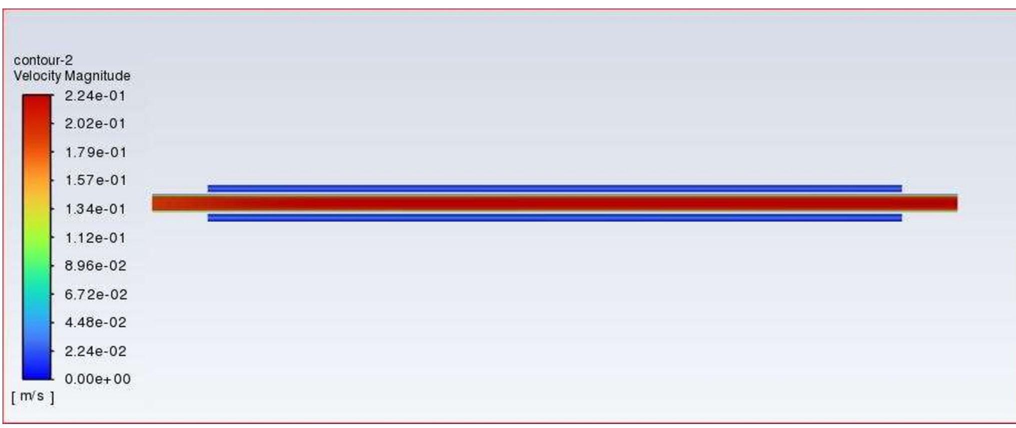

Figure 8 Velocity Magnitude of DTHX.

4. Conclusion

Through the simulation, it has observed that the intricate interplay between the hot and cold fluids, revealing the effectiveness of heat exchange. The analysis has shed light on the heat transfer coefficients, pressure drops, and temperature distributions within the heat exchanger. By understanding these key factors, engineers can optimize the design and operation of double tube heat exchangers, maximizing their thermal efficiency and ensuring effective heat transfer between fluid streams. The investigation considered various operating variable as Reynolds Number and temperature across the inner, and outer tubes. Specifically, the Reynolds Number of a range of 2500 to 5500 at 333 K, and 2500 at 303 K for the respective tubes. Conclusion in this regard is listed below:

1. friction factor is increase by 6.38% as compared to correlation (Blasius) in existing literature
2. Nusselt number (Nu) increase by 40.84% as compared to correlation at the Reynolds Number (Re) of 2500.
3. The heat transfer coefficients (h_i) were increased by 8.30% as compared to existing literature.

References:

1. Subhani SC, Sravani P. The Systematic Comparision on Analysis of Parallel Flow and Counter Flow Heat Exchanger by using CFD and Practicle Methods. Int. J. Mod. Trends Sci. Technol., no. 2021 Dec.
2. Sridhar KO, Bicha K. Comparative Analysis of Parallel and Counter Flow Heat Exchangers. International Journal of Scientific Engineering and Technology Research. 2017 Feb;6(4):638-44.
3. Ahmed F, Sumon MM, Fuad M, Gugulothu RA, Mollah AS. Numerical simulation of heat exchanger for analyzing the performance of parallel and counter flow. WSEAS Trans Heat Mass Transfer. 2021;16:145-52.
4. Dhoria SH, Kumar EM, Yeswanth IV, Jayanti L. CFD analysis on concentric tube heat exchanger in parallel and counter flow direction. J. Eng. Res. Appl. 2018;8(06).
5. Bhattacherjee D. CFD Analysis of Double Pipe Counter Flow Heat Exchanger. International Journal of Engineering Research & Technology (IJERT)(Oct, 2020) ISSN.:2278-0181.
6. Alkorbi, A. S., Kumar, K. Y., Prashanth, M. K., Parashuram, L., Abate, A., Alharti, F. A., ... & Raghu, M. S. (2022). Samarium vanadate affixed sulfur self doped g-C3N4 heterojunction; photocatalytic, photoelectrocatalytic hydrogen evolution and dye degradation. International Journal of Hydrogen Energy, 47(26), 12988-13003.
7. Boda MA, Deshetti SS, Gavade MA. Design and Development of Parallel-Counter Flow Heat Exchanger. International Journal of Innovative Research in Advanced Engineering. 2017;4(2):29-35.
8. Heller A. CFD Simulation of the Thermal Performance of a Parallel Counter-Parallel Flow Heat Exchanger for the Treatment of Hypothermia.
9. Gupta, T. K., Srivastava, A. K., & Srivastava, V. S. (2021). Microstructural and tensile behaviour of hybrid MMC Al7075/SiC/B4C produced by mechanical stir casting. Materials Today: Proceedings, 47, 4107-4113.
10. Krasniqi D, Selimaj R, Krasniqi M, Filkoski R. Thermal Dynamic Analysis Of Parallel And Counter Flow Heat Exchangers.
11. Pathak R, Geete A. Thermal performance analyses of concentric pipe counter flow heat exchanger at different operating conditions by CFD. i-Manager's Journal on Mechanical Engineering. 2018 Nov 1;9(1):1.
12. Basavapoornima C, Kesavulu CR, Maheswari T, Pecharapa W, Depuru SR, Jayasankar CK. Spectral characteristics of Pr3+-doped lead based phosphate glasses for optical display device applications. Journal of Luminescence. 2020 Dec 1;228:117585.
13. Yadav S, Sharma P, Yamasani P, Minaev S, Kumar S. A prototype micro-thermoelectric power generator for micro-electromechanical systems. Applied Physics Letters. 2014 Mar 24;104(12).
14. Xu, H. J., Qu, Z. G., & Tao, W. Q. (2014). Numerical investigation on self-coupling heat transfer in a counter-flow double-pipe heat exchanger filled with metallic foams. Applied Thermal Engineering, 66(1-2), 43-54.
15. Srivastava, A. K., Nag, A., Dixit, A. R., Tiwari, S., & Srivastava, V. S. (2019). Parametric study during abrasive water jet turning of hybrid metal matrix composite. In Advances in Manufacturing Engineering and Materials: Proceedings of the International Conference on Manufacturing Engineering and Materials (ICMEM 2018), 18–22 June, 2018, Nový Smokovec, Slovakia (pp. 72-84). Springer International Publishing.
16. Bhukya MN, Kota VR, Depuru SR. A simple, efficient, and novel standalone photovoltaic inverter configuration with reduced harmonic distortion. IEEE access. 2019 Apr 4;7:43831-45.
17. Srinivasan, K., Porkumaran, K., & Sainarayanan, G. (2009, August). Improved background subtraction techniques for security in video applications. In 2009 3rd International Conference on Anti-counterfeiting, Security, and Identification in Communication (pp. 114-117). IEEE.
18. Vijayakumar Y, Nagaraju P, Yaragani V, Parne SR, Awwad NS, Reddy MR. Nanostructured Al and Fe co-doped ZnO thin films for enhanced ammonia detection. Physica B: Condensed Matter. 2020 Mar 15;581:411976.
19. Siavashi, M., & Miri Joibary, S. M. (2019). Numerical performance analysis of a counter-flow double-pipe heat exchanger with using nanofluid and both sides partly filled with porous media. Journal of Thermal Analysis and Calorimetry, 135, 1595-1610.
20. Singh B, Kumar I, Saxena KK, Mohammed KA, Khan MI, Moussa SB, Abdullaev SS. A future prospects and current scenario of aluminium metal matrix composites characteristics. Alexandria Engineering Journal. 2023 Aug 1;76:1-7.
21. Yue L, Jayapal M, Cheng X, Zhang T, Chen J, Ma X, Dai X, Lu H, Guan R, Zhang W. Highly dispersed ultra-small nano Sn-SnSb nanoparticles anchored on N-doped graphene sheets as high performance anode for sodium ion batteries. Applied Surface Science. 2020 May 15;512:145686.

22. Goud JS, Srilatha P, Kumar RV, Kumar KT, Khan U, Raizah Z, Gill HS, Galal AM. Role of ternary hybrid nanofluid in the thermal distribution of a dovetail fin with the internal generation of heat. Case Studies in Thermal Engineering. 2022 Jul 1;35:102113.
23. Reddy PV, Reddy BV, Rao PS. A numerical study on tube hydroforming process to optimize the process parameters by Taguchi method. Materials Today: Proceedings. 2018 Jan 1;5(11):25376-81.
24. Francis V, Garg S, Saxena KK, Jain PK, Lade J, Kumar D. Effect of chemical and heat treatment on 3D printed parts: Nanoparticles embedment approach. Advances in Materials and Processing Technologies. 2022 Nov 30;8(sup4):2277-88.
25. Arun, V., Singh, A. K., Shukla, N. K., & Tripathi, D. K. (2016). Design and performance analysis of SOA–MZI based reversible toffoli and irreversible AND logic gates in a single photonic circuit. Optical and quantum electronics, 48, 1-15.
26. Swarna, K. S. V., Vinayagam, A., Ananth, M. B. J., Kumar, P. V., Veerasamy, V., & Radhakrishnan, P. (2022). A KNN based random subspace ensemble classifier for detection and discrimination of high impedance fault in PV integrated power network. Measurement, 187, 110333.
27. Misra RK, Porwal R, Saxena KK, Godara SS. Effect of post weld heat treatment on mechanical properties of MIG welded mild steel. Advances in Materials and Processing Technologies. 2022 Sep 30;8(sup2):489-503.
28. Manohar, T., Prashantha, S. C., Nagaswarupa, H. P., Naik, R., Nagabhushana, H., Anantharaju, K. S., ... & Premkumar, H. B. (2017). White light emitting lanthanum aluminate nanophosphor: near ultra violet excited photoluminescence and photometric characteristics. Journal of Luminescence, 190, 279-288.
29. Singh L, Yahya MM, Singh B, Sehgal S, Saxena KK, Mohammed KA. Investigation of the Effects of Overlapping Passes on Friction Stir Processed Aluminum Alloy 5083. Metal Science and Heat Treatment. 2023 Dec 20:1-5.
30. Saxena, A., Kumaraswamy, A., Dwivedi, S. P., Srivastava, A. K., & Maurya, N. K. (2020). Experimental and computational investigation on dynamic fracture toughness (J1d) behavior of multi-pass SMA armor steel weldments. Theoretical and Applied Fracture Mechanics, 106, 102502.
31. Ashwini, S., Prashantha, S. C., Naik, R., & Nagabhushana, H. (2019). Enhancement of luminescence intensity and spectroscopic analysis of Eu3+ activated and Li+ charge-compensated Bi2O3 nanophosphors for solid-state lighting. Journal of Rare Earths, 37(4), 356-364.
32. Tripathi, G. P., Agarwal, S., Awasthi, A., & Arun, V. (2022, August). Artificial Hip Prostheses Design and Its Evaluation by Using Ansys Under Static Loading Condition. In Biennial International Conference on Future Learning Aspects of Mechanical Engineering (pp. 815-828). Singapore: Springer Nature Singapore.
33. Verma M, Meena RK, Singh I, Gupta N, Saxena KK, Reddy MM, Salem KH, Salmaan U. Investigation on the impact of elevated temperature on sustainable geopolymer composite. Advances in Mechanical Engineering. 2023 Sep;15(9):16878132231196402.
34. Kumar, C. P., Raghu, M. S., Prathibha, B. S., Prashanth, M. K., Kanthimathi, G., Kumar, K. Y., ... & Alharthi, F. A. (2021). Discovery of a novel series of substituted quinolines acting as anticancer agents and selective EGFR blocker: Molecular docking study. Bioorganic & Medicinal Chemistry Letters, 44, 128118.
35. Demir, H., Dalkilic, A. S., Kürekci, N. A., Duangthongsuk, W., & Wongwises, S. (2011). Numerical investigation on the single phase forced convection heat transfer characteristics of TiO2 nanofluids in a double-tube counter flow heat exchanger. International Communications in Heat and Mass Transfer, 38(2), 218-228.