International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 10 Issue: 10 | Oct 2023 www.irjet.net p-ISSN: 2395-0072

CFD Investigation of Compact Heat Exchanger Having Different Fins with Nanofluid Titanium Dioxide

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Abstract - *Plate fin heat exchangers have established themselves as indispensable components in various industries, from automotive to aerospace, owing to their superior performance. Despite their significance, this technology has largely remained proprietary. Driven by industrial demands and international constraints, our country has embarked on an extensive research program to unlock the potential of plate fin heat exchangers, of which this thesis is a vital component. Critical issues revolving around materials, manufacturing techniques, and design principles continue to be pivotal in the widespread adoption of plate fin heat exchangers. However, the crux of their success lies in understanding the heat transfer and flow friction characteristics of plate fin surfaces, an area where a scarcity of experimental data persists, with existing correlations offering limited insights. This thesis makes a dual-pronged contribution to this field: It introduces a groundbreaking approach that combines computational and experimental data to formulate heat transfer and flow friction correlations. It presents a novel set of correlations tailored for plain rectangular, offset strip, and wavy fin surfaces – geometries that find extensive application in diverse industries. Conducting experiments to measure heat transfer over plate fin surfaces is often costly and challenging. Full-scale numerical simulations, like Direct Numerical Simulation (DNS), demand computing resources beyond the means of most heat exchanger designers. In light of these constraints, the approach outlined in this thesis offers a practical solution. General trends are computed using Computational Fluid Dynamics (CFD), while a few essential constants are derived from experimental data. Plain rectangular, offset strip, and wavy fins are among the most prevalent fin types in cryogenic, aerospace, and similar sectors. The heat transfer and flow friction correlations presented in this thesis hold the promise of broader applicability compared to existing correlations, marking a significant stride towards the advancement and democratization of plate fin heat exchanger technology.*

***Key Words*: Heat Exchanger, Nanofluid, Fins, CFD, Thermal Properties**

1. INTRODUCTION

Heat exchangers play a pivotal role in various industries and everyday applications by efficiently transferring thermal energy between two or more fluids or substances. One innovative and effective design enhancement employed in many heat exchangers is the use of fins. Fins are extended surfaces attached to the primary heat transfer surface, such as a pipe or a wall, with the primary objective of enhancing heat transfer rates. In this discussion, we will explore two common types of finned heat exchangers: plane fins and wavy fins. These fin configurations are employed to optimize heat transfer in various contexts, from cooling systems in electronics to large-scale industrial processes. Plane fins are one of the most fundamental and straightforward forms of extended surfaces used in heat exchangers. These fins are flat, typically rectangular, and are attached perpendicular to the base surface. They are found in a multitude of applications, ranging from household radiators to compact heat exchangers within automotive engines.

Heat transfer can be occurred via three main modes: conduction, convection (free or forced), and radiation. Also, heat transfer can be promoted by artificial approaches while it also occurs naturally from or to a thermodynamic system due to buoyancy forces. Moreover, heat transfer occurs between all live and inanimate things. All the living things are subjected to heat transfer between their body and the surroundings via one or more of the above-mentioned modes.

2. LITERATURE SURVEY

Rafał Andrzejczyk et. al. [1], The authors aim to demonstrate improved heat transfer efficiency by using wire coil inserts to induce turbulent flow in the boundary layer and by blowing air into the pipe's annulus. They utilize the Wilson plot method to estimate heat transfer coefficients (HTC) for various heat exchanger configurations. The study primarily focuses on experimental data for HTC and pressure drops. Establishing an extensive experimental database for HTC and pressure drops. Analyzing the impact of different flow conditions, such as water mass flow rate and void fraction, on heat transfer and hydraulic performance. **J.I. Córcoles et. al [2],** In this study, 3-D simulations analyzed the impact of geometry in eight spirally inner corrugated tubes within a double pipe heat exchanger under turbulent flow (Re=25×103). This research explored various combinations of pitch and height in a 3-D inward corrugated tube model, a novel approach for a double pipe heat exchanger. The model included the entire heat exchanger geometry, resembling real-world applications. Grid independence analysis used a 3-D unstructured tetrahedral mesh and the Realizable k−ε turbulence model. **Hussein H. Habeeb et. al [3]**, In an experimental analysis of a vertical double pipe heat exchanger, the study introduced bubble generation through air injection using an air diffuser with numerous small holes at the bottom of the inner hot tube. The setup included a small compressor with an air flow meter and a boiler with a temperature controller to heat the hot fluid. Inlet and outlet temperatures were monitored with digital thermocouples. Tests were conducted in both parallel and counter flow configurations, varying the flow rates of the cold fluid and air injection. **Chirag Maradiya et. al [4],** The paper provides a comprehensive review of passive heat transfer devices and their relative merits for a wide variety of industrial applications. It discusses heat transfer enhancement techniques that reduce thermal resistance by increasing the effective heat transfer surface area or generating turbulence. The effectiveness of these techniques is evaluated using the Thermal Performance Factor (TPF), which is a ratio of the change in heat transfer rate to the change in friction factor. Various types of inserts, such as counter double twisted tape and combined twisted tape with wire coil, are used in heat transfer enhancement devices. **Alam, Tabish et. al. [5],** This paper aims to review techniques for enhancing heat transfer in heat exchanger devices, such as solar air heaters and turbine cooling blades, using single-phase heat transfer fluids. It also covers recent developments like Electrohydrodynamic (EHD) and Magnetohydrodynamics (MHD). Heat transfer enhancement can be achieved through active and passive methods. Active methods require external power, while passive methods involve surface modifications or the insertion of swirl devices in the flow. **Orhan Keklikcioglu et. al. [6],** Heat transfer enhancement methods can be categorized as passive or active. Active methods require external power, while passive methods improve thermohydraulic performance without additional energy input. Passive methods are commonly used in both experimental and numerical studies to enhance heat transfer and reduce costs. These methods include components like twisted tapes, coiled wires, and nozzle turbulators placed in the fluid flow path. **Hussein H. Hamed et. al. [7],** This experimental study investigates the impact of using compound techniques (passive and active) on the performance of a double pipe heat exchanger. The study focuses on both parallel and counter flow configurations and compares the outcomes with and without the passive (packing) method. The heat transfer of the heat exchanger is evaluated in terms of cost and size. The results show that employing both techniques together enhances the performance parameters of the heat exchanger by about 15%, while using the active method alone improves it by 25%. **Mehdi Bahiraei et. al. [8],** The research aims to enhance the thermal efficiency of a triple-tube heat exchanger (TTHE) by using crimped-spiral ribs and nanofluid. The crimped-spiral rib is placed on the top of the internal tube, and the hot fluid within the ribbed side is a water-alumina nanofluid, while the other fluids are pure water. The study utilizes numerical solutions and the two-phase mixture method, with turbulent flow modeled using the Reynolds Stress Model (RSM). The use of nanofluid significantly improves the overall heat transfer coefficient (U), heat transfer rate, effectiveness, and performance index. **Shankara Murthy.H. M et. al. [9],** The paper examines the impact of passive techniques on heat transfer enhancement, friction factor, and thermal performance in a double-tube heat exchanger with various turbulator configurations and Alumina nanofluid as a coolant. The findings revealed that bubble generation had a significant impact on various parameters, leading to positive effects on heat transfer rate, effectiveness, number of transfer units, and overall heat transfer coefficient. Additionally, it was noted that exergy loss was influenced by this bubble generation process within the heat exchanger. **Hozaifa A. Mohamed et. al. [10],** The research aims to enhance the convective heat transfer coefficient in double pipe heat exchangers by mixing water with copper oxide (CuO) nanoparticles. The study examines the effects of nanofluid volume concentrations, flowrates, and inlet temperature on the Nusselt number, finding that nanoparticles significantly enhance the convective heat transfer coefficient inside the tube. Increasing the number of twisted tape inserts enhanced thermal performance by increasing contact surface area, residence time, swirl intensity, and fluid mixing due to multi-longitudinal vortices. **Ponshanmugakumar Arunachalam et. al. [11],** This study aims to enhance the thermal performance of a heat exchanger tube by investigating two factors: (i) using twisted tapes in various configurations, and (ii) employing Cu-nanoparticles at different concentrations as the working fluid. Results showed that the tube with twisted tapes exhibited superior thermal performance compared to a plain tube. This improvement was attributed to continuous swirling flow and multi-longitudinal vortices along the test tube, facilitated by the presence of twisted tape inserts. **C. Gnanavel et. al. [12],** The paper investigates heat transfer enhancement in a double pipe heat exchanger using passive techniques such as nano-fluids and twisted tape inserts with rectangular cuts on their ribs. The study focuses on the thermal performance of various nanofluids, including titanium dioxide, beryllium oxide, zinc oxide, and copper oxide, in laminar to turbulent flow conditions. The results of the numerical study are compared, and the best nanofluid for heat transfer enhancement is suggested. **M.E. Nakhchi et.al [13],** The paper presents numerical simulations analysing the turbulent flow and thermal performance of fluid flows inside heat exchangers with perforated louvered strip inserts, showing that the recirculation flow through the holes of the inserts improves heat transfer. The study also investigates the effects of double mounted louvered strips on the flow characteristics, finding that using double perforated louvered strips with specific slant angles can significantly enhance heat transfer. **Rimah S. Al Aridi et. al. [14],** The paper discusses the use of trapezoidal vortex generators (VGs) in a Concentric Tube Heat Exchanger (CTHE) for heat transfer enhancement. Computational Fluid Dynamics (CFD) analysis is conducted using ANSYS Fluent to study the effects of VGs in different locations within the CTHE.Four designs are analysed, including a with no VGs and three cases with VGs placed in different locations. Results show that VGs are effective in all locations, with the highest improvement observed in case 1, where the heat transfer ratio is enhanced by 97% and the thermal enhancement factor is increased by 210% compared to the case with no VGs. **J.D. Moya-Rico et. al. [15],** This paper aimed to investigate how different configurations of regularly spaced twisted tape elements (TTEs) inserted into a smooth double tube heat exchanger (DTHX) influence thermo-hydraulic performance. To mimic high-viscosity food-industry fluids, a 60° brix solution of water and sugar served as the Heat Transfer Fluid (HTF). The study comprised 320 experimental tests that varied flow velocity (Reynolds number) and TTE configuration. Nine different configurations were tested, involving various TTE pitches and free-space lengths. **S. Padmanabhan et. al. [16],** Improving the thermal efficiency of heat exchangers has a direct impact on the materials used, energy obtained, and cost savings. This enhancement is particularly valuable in applications requiring thermal transfer processes, as it can significantly increase heat efficiency and the economic viability of the design and operation. Double tube heat exchangers, with their small diameters, are well-suited for high-temperature and high-pressure applications. While they are cost-effective, they tend to have relatively high pressure drops. To address this, various techniques have been developed to achieve the required heat transfer rate while maintaining economical pumping capabilities within the heat exchanger's design parameters. **Chen Heng et. al. [17],** In this paper, the focus is on H-type finned tube heat exchanger elements, which are known for their ability to maintain high heat transfer capacity, possess self-cleaning properties, and enable the recovery of waste heat from flue gases in boiler renovations. The research employs an experimental open high-temperature wind tunnel system to investigate the heat transfer and pressure drop characteristics of H-type finned tube banks. The study explores the impact of several parameters, including fin width, fin height, fin pitch, and air velocity, on various aspects of heat transfer and pressure drop. Specifically, the research examines fin efficiency, convective heat transfer coefficient, integrated heat transfer capacity, and pressure drop concerning these parameters. **Awais Muhammad et. al. [18],** This paper reviews heat transfer enhancement and pressure loss reduction in compact heat exchangers using vortex generators (VGs). It explores VG type, shape, design, and attack angle effects on heat transfer and pressure loss. Longitudinal vortices generated by VGs reduce wake regions, enhance turbulence, and improve flow mixing, with effects dependent on Reynolds number. Delta winglet VGs outperform rectangular types, and downstream placement is more effective. The paper also discusses microscopic vortex formation analysis using flow visualization techniques. **M. Awais et. al. [19],** This study used numerical analysis to explore how interrupted surfaces affect compact heat exchangers (CHXs). They found that incorporating delta winglet vortex generators (DWVGs) can enhance heat transfer and pressure drop in CHXs. The study considered various factors, including the number of vortex generator rows (N), attack angles (θ), configurations, tube arrangements (inline and staggered), and tube shapes (circular, oval, and rectangular). They determined that an attack angle of 165^0 (θop) provides the best heat transfer performance with moderate pressure drop (ΔP). **R.P.P.D. da Silva et. al. [20],** The paper discusses the development of theoretical models for the thermal and hydrodynamic performance of a compact heat exchanger manufactured using the SLM process, with good agreement between the models and experimental data. The study also highlights the negligible impact of surface roughness on pressure drop and the significant influence of replacing the core material on thermal performance in the turbulent regime. One of the most popular and efficient techniques for improving heat exchangers is the use of helical inserts. This article focuses on investigating the performance of an ANSYS CFX tool for double tube heat exchangers equipped with helical inserts. **Talal M. Abou Elmaaty et. al. [21],** The paper focuses on the research and development efforts for corrugated plate heat exchangers, which are widely used in various engineering fields and applications. It discusses the structure, thermal performance, heat transfer enhancement mechanisms, advantages, and limitations of corrugated plate heat exchangers, as well as their efficiency in both single phase and two-phase flow. It aims to conduct a comparative analysis by comparing heat exchangers with helical inserts to those without, specifically examining heat flux and temperature distribution along the pipe. This research will shed light on the effectiveness of helical inserts in enhancing heat exchanger performance. **Alireza Jafari et. al. [22],** The paper presents experimental and numerical investigations of a brazed plate heat exchanger, highlighting the importance of considering brazing joints in the modelling process. The study also emphasizes the need for developing new correlations for Nusselt number and friction factor of brazed plate heat exchangers, based on the comparison with existing correlations. **Saeed Mohebbi et. al. [23],** The paper presents a numerical investigation of water flow in a small-sized plate heat exchanger with a chevron type corrugation pattern, and validates the numerical modeling with experimental tests. The study examines the influence of flow regime, heat transfer, and friction on the performance of the heat exchanger, and concludes that a chevron angle of 60° and increased corrugation depth or decreased corrugation pitch result in improved performance. **Ji Zhang et. al. [24],** The paper provides a comprehensive review of previous works on the effects of chevron corrugation geometrical parameters and heat transfer enhancement techniques in plate heat exchangers, focusing on passive surface techniques and the use of nanofluids. It aims to describe relevant studies, provide an understanding of the heat transfer mechanisms, evaluate and compare different enhancement techniques, and suggest prospective directions for future research. **Salman Al zahrani et. al. [25],** The paper aims to improve the thermal performance of the existing conventional flat plate heat exchanger (FPHE) by introducing two modified versions (FPHEm1 and FPHEm2) and comparing their performance with the conventional corrugated plate heat exchanger (CPHEC). Computational fluid dynamics (CFD) technique is used to numerically test the performance of the heat exchangers, and experiments are conducted to validate the numerical results. **WagdAjeeb et. al. [26],** Nanofluids, due to their improved thermophysical properties, offer promising cooling solutions in various applications, such as energy systems and electronics. This study investigates the convective heat transfer (CHT) and entropy generation of ethylene glycol (EG)/water-based nanofluids containing Al and Al_2O_3 nanoparticles. The research covers nanoparticle concentrations ranging from 1.0 to 3.0 vol.% and Reynolds numbers from 400 to 2000 (laminar flow) under constant heat flux conditions in a mini-channel. **M. D. Masaoudi et. al. [27],** The paper aims to numerically assess the effectiveness of using square fins supported by wavy wings on the performance of an inclined heat sink box filled with magnetized-radiative nano liquid. The study compares the influence of wavy and flat wings on the heat sink box performance and discusses the effects of wings length and waves number for various heat sink box inclinations. The results show that backing the square fins with flat wings improves the heat sink box performance by 10.52%, while extending the length of wings enhances it by 15.98%. The use of wavy wings and increasing the number of waves further improves the heat exchange performance.

3. INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS

CFD stands for "Computational Fluid Dynamics." It is a branch of fluid mechanics that uses numerical methods and algorithms to simulate and analyse the behaviour of fluid flows, such as the flow of air or liquids over and around objects. CFD is a powerful tool used in various engineering and scientific fields to study and predict fluid flow phenomena.

3.1 Steps for Solving CFD

Behind the scenes of Computational Fluid Dynamics (CFD), there are several key components and processes that make it work effectively. Here's an overview of what happens in the background when performing CFD simulations:

1. **Geometry Modelling:** The process typically begins with the creation or import of a three-dimensional (3D) model of the physical system or object under consideration. This model defines the geometry of the system and is crucial for setting up the CFD simulation. The geometry may be created using specialized CAD (Computer-Aided Design) software or obtained from real-world measurements.
2. **Mesh Generation:** The next step involves dividing the computational domain (the space around the object) into a grid or mesh of smaller elements or cells. This mesh can be structured (organized in a regular manner) or unstructured (cells of varying shapes and sizes). Mesh generation is a critical step as it significantly impacts the accuracy and efficiency of the simulation. Finer meshes capture more detail but require more computational resources.
3. **Discretization:** Once the mesh is generated, the equations governing fluid flow (usually the Navier-Stokes equations) are discretized. This means breaking down these partial differential equations into a set of algebraic equations that can be solved numerically for each cell in the mesh. Various numerical methods, such as finite difference, finite volume, or finite element methods, can be used for this purpose.
4. **Boundary Conditions**: Boundary conditions are applied to the surfaces of the geometry to specify how the fluid interacts with those surfaces. These conditions include information about inlet and outlet velocities, temperatures, pressures, and any other relevant physical quantities. Boundary conditions are essential for defining the problem and obtaining meaningful results.
5. **Solver:** The heart of CFD is the solver, which performs the actual numerical calculations to solve the discretized equations. It iteratively computes the flow properties (velocity, pressure, temperature, etc.) within each cell of the mesh based on the specified boundary conditions. Solvers use numerical algorithms to update the flow properties until a convergence criterion is met.
6. **Turbulence Modelling:** In many cases, turbulence modelling is required because real-world flows are often turbulent. CFD offers various turbulence models (e.g., k-epsilon, Reynolds-averaged Navier-Stokes, Large Eddy Simulation) to simulate turbulent behaviour within the flow.
7. **Post-Processing:** After the solver converges to a solution, post-processing is performed. This involves analysing and visualizing the simulation results. Engineers and scientists use post-processing tools to create velocity contours, pressure distributions, temperature profiles, streamlines, and other visual representations of the fluid flow to gain insights into the system's behaviour.

4. METHODOLOGY

1. A concentric shell and Tube heat exchanger is virtually designed in ANSYS and Creo Parametric version. The dimensions of the heat exchanger are as per the experimental base paper.
2. The inner tube has an inner diameter of 12mm and outer diameter of 14mm, whereas the shell is made of inner diameter of 17mm and outer diameter of 18mm respectively.
3. 2 models are being created. One with plane fins and 2nd with wavy fins.
4. The material used for both the tubes are copper with its standard properties at given temperature. The inlet temperature of cold fluid is kept at 303K and inlet temperature of hot fluid is kept at 343K. The mass flow rate of hot fluid flowing through the annuus of both the tubes is kept constant at a value of 0.05kg/s, whereas the mass flow rate of cold fluid flowing through the

annulus is varied from 0.05kg/s, 0.1kg/s, 0.15kg/s, and 0.2kg/s respectively.

5. The initial readings of this virtual model is validated with experimental results of our base paper. The water-water heat exchanger results are calculated, and data is presented for heat transfer rate, effectiveness, and LMTD values.
6. A Nano-Fluid is defined in virtual software whose properties are calculated based on standard formulas as mentioned ahead. The cold water flowing through annulus is replaced by this nano fluid while keeping the inlet temperature and its mass flow rate same. The calculations are found for this arrangement as well. Also, the nano fluid is checked for various values of volume fraction, and the best suitable volume fraction is used for the calculations.

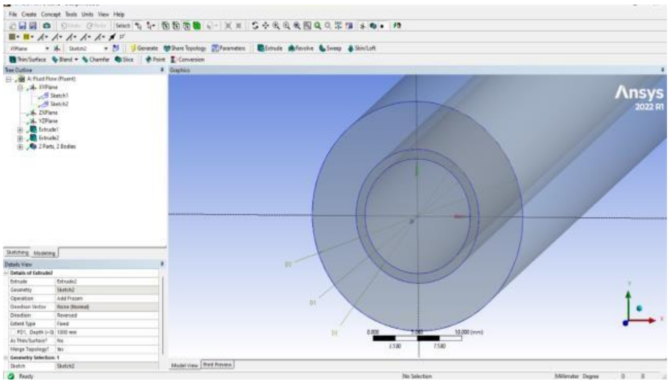

Fig. 1: Showing dimension of the heat exchanger

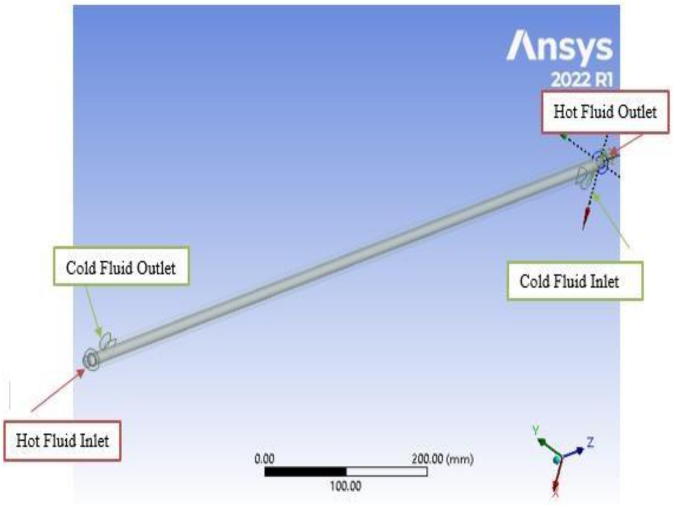

Fig. 2: Geometry showing inlet and outlet of hot and cold fluid according to counter flow arrangement

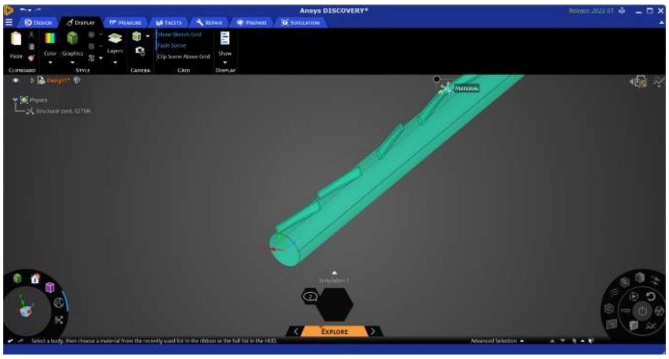

Fig. 3: Geometry of plain rectangular fins all around the tube side.

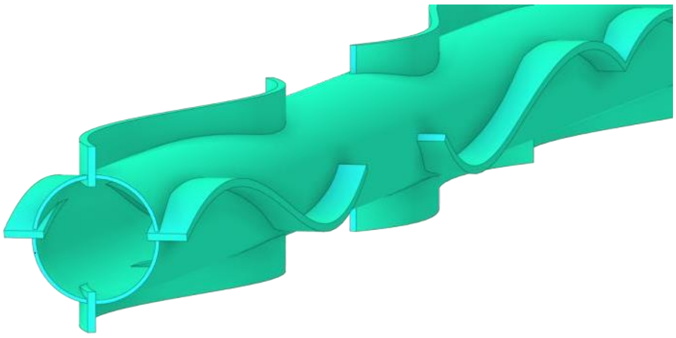

Fig. 4: Wavy Fins

Table 1: Dimension of Heat Exchanger

S.No	Dimension (mm)
Tube Inner Dia	14
Tube Outer Dia	16
Shell Side Dia	24
Number of Flat Fins	36
Nuber of Wavy Fins	24

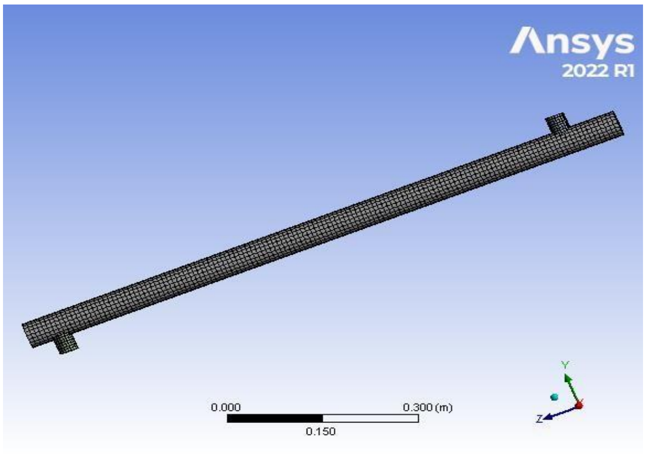

Fig. 5: Meshed Geometry with Elemental Size of 10 mm

Table 2: Boundary Conditions

Inlet	
hot_fluid_inlet	
Reference Frame	Absolute
Mass Flow Specification Method	Mass Flow Rate
Mass Flow Rate [kg/s]	0.05
Total Temperature [K]	343
Supersonic/Initial Gauge Pressure [Pa]	0
Direction Specification Method	Normal to Boundary
Turbulent Specification Method	Intensity and Hydraulic Diameter
Turbulent Intensity [%]	5
Hydraulic Diameter [m]	0.02
cold_fluid_inlet	
Reference Frame	Absolute
Mass Flow Specification Method	Mass Flow Rate
Mass Flow Rate [kg/s]	0.05
Total Temperature [K]	303
Supersonic/Initial Gauge Pressure [Pa]	0
Direction Specification Method	Normal to Boundary
Turbulent Specification Method	Intensity and Hydraulic Diameter
Turbulent Intensity [%]	5
Hydraulic Diameter [m]	0.02
Outlet	
hot_fluid_outlet	
Backflow Reference Frame	Absolute
Average Pressure Specification?	no
Specify targeted mass flow rate	no
cold_fluid_outlet	
Backflow Reference Frame	Absolute
Gauge Pressure [Pa]	0
Pressure Profile Multiplier	1
Backflow Total Temperature [K]	300
Backflow Direction Specification Method	Normal to Boundary
Turbulent Specification Method	Intensity and Viscosity Ratio
Backflow Turbulent Intensity [%]	5
Backflow Turbulent Viscosity Ratio	0.02
Backflow Pressure Specification	Total Pressure
Build artificial walls to prevent reverse flow?	no
Radial Equilibrium Pressure Distribution	no
Average Pressure Specification?	no
Specify targeted mass flow rate	no
Wall	
wall-part-solid	
Wall Thickness [m]	0
Heat Generation Rate [W/m^3]	0
Material Name	aluminum
Thermal BC Type	Heat Flux
Heat Flux [W/m^2]	0
Enable shell conduction?	no
Convective Augmentation Factor	1
wall-part-hot_fluid	
Wall Thickness [m]	0
Heat Generation Rate [W/m^3]	0
Material Name	aluminum
Thermal BC Type	Heat Flux
Heat Flux [W/m^2]	0
Enable shell conduction?	no
Wall Motion	Stationary Wall
Shear Boundary Condition	No Slip

Wall Surface Roughness	0
Wall Roughness Height [m]	0
Wall Roughness Constant	0.5
Convective Augmentation Factor	1
wall-part-cold_fluid	
Wall Thickness [m]	0
Heat Generation Rate [W/m^3]	0
Material Name	aluminum
Thermal BC Type	Heat Flux
Heat Flux [W/m^2]	0
Enable shell conduction?	no
Wall Motion	Stationary Wall
Shear Boundary Condition	No Slip
Wall Surface Roughness	0
Wall Roughness Height [m]	0
Wall Roughness Constant	0.5
Convective Augmentation Factor	1
wall-part-cold_fluid-part-solid	
Wall Thickness [m]	0
Heat Generation Rate [W/m^3]	0
Material Name	**aluminum**
Thermal BC Type	Coupled
Enable shell conduction?	no
Convective Augmentation Factor	1
wall-part-hot_fluid-part-solid	
Wall Thickness [m]	0
Heat Generation Rate [W/m^3]	0
Material Name	**aluminum**
Thermal BC Type	Coupled
Enable shell conduction?	no
Convective Augmentation Factor	1
wall-part-hot_fluid-part-solid-shadow	
Wall Thickness [m]	0
Heat Generation Rate [W/m^3]	0
Material Name	**aluminum**
Thermal BC Type	Coupled
Enable shell conduction?	no
Wall Motion	Stationary Wall
Shear Boundary Condition	No Slip
Wall Surface Roughness	0
Wall Roughness Height [m]	0
Wall Roughness Constant	0.5
Convective Augmentation Factor	1
wall-part-cold_fluid-part-solid-shadow	
Wall Thickness [m]	0
Heat Generation Rate [W/m^3]	0
Material Name	**aluminum**
Thermal BC Type	Coupled
Enable shell conduction?	no
Wall Motion	Stationary Wall
Shear Boundary Condition	No Slip
Wall Surface Roughness	0
Wall Roughness Height [m]	0
Wall Roughness Constant	0.5
Convective Augmentation Factor	1

5. RESULT AND DISCUSSION

5.1 Comparison of Heat Transfer Rate

Table 3: Comparison of Heat Transfer Rate

Mass flow rate of cold fluid (kg/s)	Heat Transfer Rate (Watts)			
	Water-water	Water-nanofluid	Plain Rectangular Fins	Wavy Rectangular Fins
0.05	327	777	1785	2899
0.1	754	1340	2548	4748
0.15	1319	2826	4530	6829
0.2	2219	5016	6422	8974

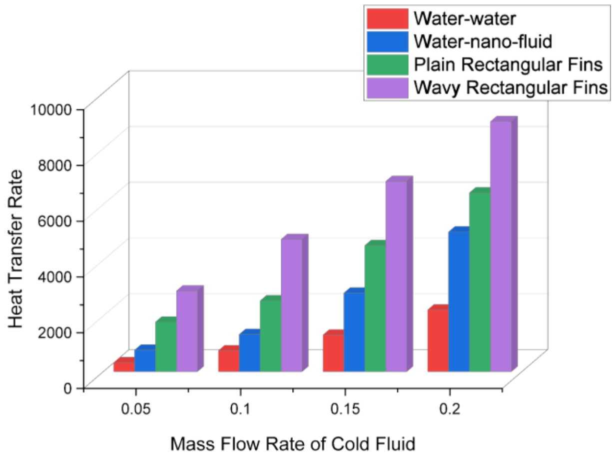

Fig. 6: Comparison Graph of Heat Transfer Rate

5.2 Comparison of Overall Heat Transfer Coefficient

Table 4: Comparison of Overall Heat Transfer Coefficient

Mass flow rate of cold fluid (kg/s)	Overall Heat Transfer Coefficient (Watts/metre SquareKelvin)			
	Water-water	Water-nano-fluid	Plain Rectangular Fins	Wavy Rectangular Fins
0.1	1178	1337	1572.5	1781
0.1	1357	1673	1812.8	1923
0.2	1506	1875	1975.1	2016
0.2	1725	1928	2123.7	2398

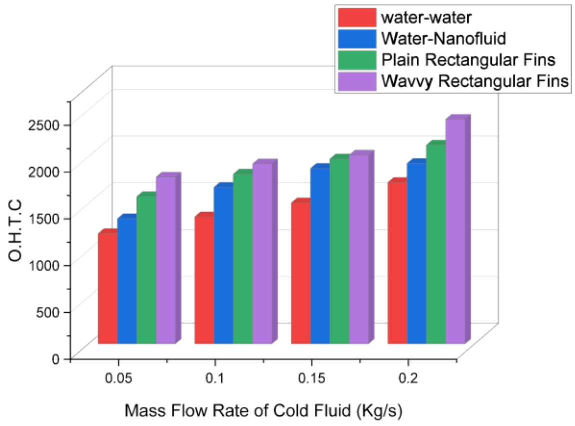

Fig. 7: Comparison Graph of Overall Heat Transfer Coefficient

5.3 Comparison of LMTD

Table 5: Comparison of LMTD

Mass flow rate of cold fluid (kg/s)	LMTD			
	Water-water	Water-nano-fluid	Plain Rectangular Fins	Wavy Rectangular Fins
0.1	4.66	4.66	5.7	6.64
0.1	5.377	6.28	7.5	8.72
0.2	6.185	7.72	9.1	10.2
0.2	6.969	9.21	10	10.7

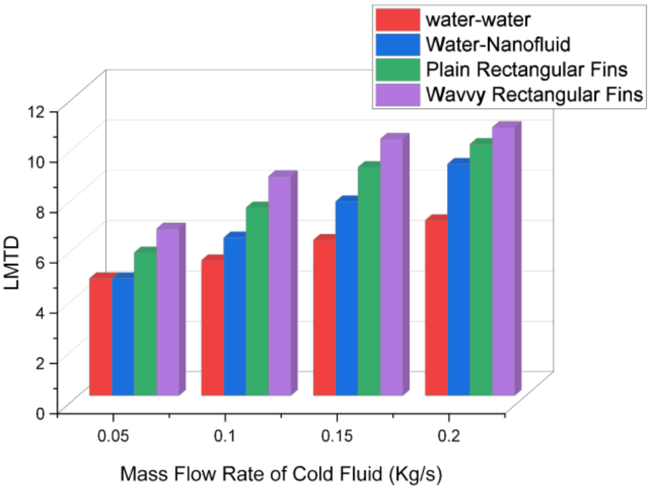

Fig. 8: Comparison Graph of LMTD

5.4 Comparison of Effectiveness

Table 5: Comparison of Effectiveness

Mass flow rate of cold fluid (kg/s)	Effectiveness			
	Water-water	Water-nano-fluid	Plain Rectangular Fins	Wavy Rectangular Fins
0.05	0.039	0.045	0.052	0.059
0.1	0.045	0.08	0.089	0.097
0.15	0.0525	0.113	0.121	0.127
0.2	0.0662	0.15	0.157	0.166

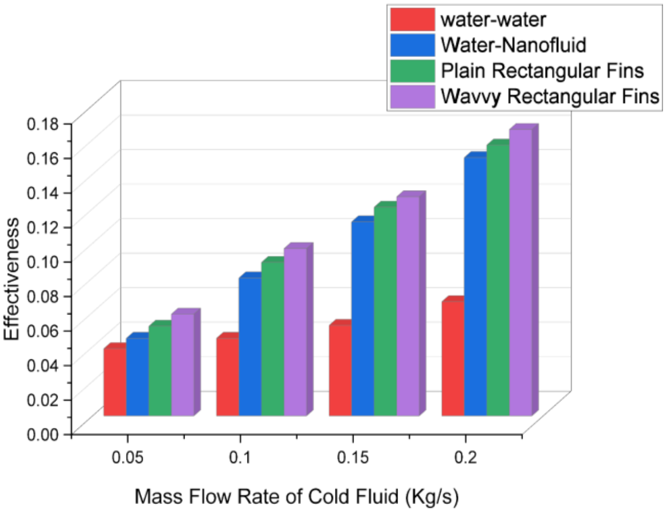

Fig. 9: Comparison Graph of Effectiveness

6. CONCLUSIONS

A computational study on straight copper tube inserted in a copper shell with counter flow arrangement, straight copper tube with nanofluid of TiO2 flowing as cold liquid in place of water. The analysis is performed on a virtually modeled heat exchanger in ANSYS and Creo 2022. Tubes used for the analysis having same diameter and same length. Simulations carried out for all the tubes for same mass flow rate and the fluid used for the experiment was water and with the fins.

In this research work the properties of TiO2 nanofluid were found out and defined in software for various values of concentration factor. The performance of nanofluid is observed to be optimum at concentration factor of 0.4, which was selected to calculate the performance of heat exchanger.

- In the present research work it is found out that the overall heat transfer coefficient is having a maximum value of 1724.5361 Watts/m^2 k for the counter flow arrangement of water-water type heat exchanger and 1927.9 W/m^2K for water- nanofluid heat exchanger, which is 11 % more. And for rectangular plane fin, 2123.7 W/m^2K which is 17 % more and 8974.1 W/m^2K for wavy fins.

- It is noted that LMTD for water-nanofluid arrangement was found to be 10.66 K which is greater than water-water arrangement by 32%.

- The effectiveness of water-nanofluid arrangement was also found to be maximum with a value of 0.166 which is more than that of water-water heat exchanger arrangement by 56% at a volume flow rate of 0.2kg/s of cold water.

- The maximum heat transfer rate was noted to be increased by an amazing amount of 55% for a massflow rate of 0.2kg/s water-nanofluid arrangement in comparison to the water-water arrangement which had a value of 8974.1 Watts for the same working conditions.

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