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Computational Fluid Dynamics and Analysis of Heat Exchanger Using Different Cross-Sections of Pipe

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The paper presents a Computational Fluid Dynamics (CFD) mathematical investigation for another plan of a plate heat exchanger with five diverse flow designs. The effect of mathematical attributes of the two examined calculations of exchanger plates on the intensification cycle of warmth move was thought of. The speed, temperature and pressure dispersions along the warmth exchanger were inspected. The CFD results were approved against test information and a decent understanding was accomplished. The outcomes uncovered that mathematical course of action of the plates emphatically influence the fluid flow. An expansion in the Reynolds number prompted bringing down the erosion factor esteem and expanding the weight drop. The configuration II of the plate heat exchanger brought about lower outlet hot fluid temperature in examination with the configuration I, which implies improvement of warmth move.

Keywords: *CFD Simulation, Heat transfer, Heat transfer coefficient, Pressure and Temperature.*

1. Introduction

Because of their wide application in a wide scope of businesses counting cooling and warmthsiphon loops, steam power boilers, home warming convectors just as waste heat recovery. Advances influencing the presentation of plate heat exchangers were summed up by Abu-Khader. In the review, they chose issues, for example, warm and hydrodynamic attributes, two-stage flows just as fouling and erosion were talked about [1]. Primary examination endeavours were made to create progressed minimized plate heat exchangers that can successfully trade heat between two fluid streams having a low temperature distinction. So as to build the adequacy of plate heat exchangers, a multi-pass plan of a few complex microchannel portions was proposed. The short flow way through the micro-channels keep up the flow in the creating system and guarantee better warmth move than in that of completely created flow just as diminished pressure drop [2,3]. To appraise the ideal presentation of the warmth exchanger, a mixture computational technique was created dependent on arrangement of full 3D Navier-Stokes also, energy conditions in a microchannel portion of the heat exchanger in mix with 1D energy and mass parity conditions in manifolds. Another arrangement was introduced by [4]. They appeared that a two-fold pass course of action cools the channel dividers down more evenly, in contrast with the straightforward pass course of action, with better consistency in divider temperature conveyance. The consistency record increments by 16.7% contrasted with the first warmth exchanger. Be that as it may, power utilization for dealing with the coolant flow increments

in contrast with the first arrangement [5]. In expansion, they saw that sinusoidal isolating plate expanded warmth move execution contrasted with the flat one. Wavy plates rather than normal flat plate for channels' dividers were likewise perceived as better arrangement.
A 2D five-way fin with crease point 200 was utilized as the calculation for reproduction and the cross-cut was applied at the third wave [6]. The outcomes demonstrated that the warmth execution of improved cross-cut wavy fin was improved by a limit of 23.81% more than for an ordinary wavy fin. The weight drops additionally expanded up to 7.04% in streamlined case. Finned and wavy dividers produce optional flows along the flow course which increment the neighbourhood convective warmth move coefficient. Considering that the convective warmth move coefficient relies upon flow design through the channel, the main path for expanding its worth is to change the flow design inside the inward channel [7]. Subsequently, the impact of fluid flow nonuniformity on heat exchanger efficiency is of first request significance and has conclusive way on their efficiency because of mal-distribution of inside temperature. As indicated by Yaici et al. two primary sorts of the flow nonuniformity can be recognized: net mal-distribution and entry to-section mal-distribution [8]. The first type is related with ill-advised warmth exchanger entrance configuration, for example, helpless plan of header and merchant configuration.

The second kind of section to-entry flow mal-distribution happens in an exceptionally smaller warmth exchanger brought about by different fabricating resiliencies [9]. Their outcomes shown that either up to half improvement or decay in the Colburn factor and the rubbing factor was found contrasted with the pattern instance of a warmth exchanger with uniform channel speed profile. It was confirmed that the cylinder plan assumes a basic part in the warmth move and weight drop qualities. In staggered game plans, there was better flow blending due to staggered tube designs and higher warmth move. Also, it was indicated that the delta air flow circulation has a significant effect on the fluid flow and heat move qualities and the thermo-water driven execution. The weight drop diminished monotonically along the heat exchanger, notwithstanding, it’s worth expanded with the bay speed of the air flowing into the warmth exchanger [10]. The authors inferred that the channel airflow dispersion can be utilized as a system to upgrade the neighbourhood heat rate.

A comparable report was completed for flue gas-air Chevron type plate heat exchangers. A higher point of the Chevron type plates came about in 18% improvement in the yield air temperature and an increment of 63% in the gas pressure drop in examination with the plate heat exchanger. A large portion of the examination on heat exchangers has been done tentatively or scientifically due to their unpredictability. An assortment of methods of upgrading heat move in plate heat exchangers was introduced, dependent on the strategy for Logarithmic Mean Temperature Difference (LMTD) or the exchanger adequacy ε – Number of Transfer Units NTU (ε-NTU). Utilizing those strategies, Wakui and Yokoyama created a consistent state model of a shell and cylinder heat exchanger for execution checking dependent on an online model [11].

With improving capacities of business CFD codes furthermore, cost of processing power, mathematical examinations of flow mal-distribution impacts on heat exchanger execution turned out to be more normal. For instance, reproduced a multistage heat exchanger with plain fins and cut fins. The better warmth moves conditionsin the cut fin heat exchanger was ascribed to better cooperative energy between the speed and temperature inclinations [12]. An itemized investigation of the speed dissemination in a crease plate heat exchanger was given it was seen that the longitudinal crease in compound groove plate was initiating cross blending of the working fluid and subsequently improving choppiness and furthermore heat move between the fluid and the plate. Mathematical reproductions and tests indicated that the flow opposition of working fluid in the groove plate heat exchanger was diminished over half in contrast with the customary Chevron type one and subsequently the issue of flow way blockage can be viably maintained a strategic distance from. All the more as of late, performed flow investigation through scaled down diverts in plate heat exchangers [13]. The investigated scaled down channels had the tendency points from 300 to 600. Both the test and CFD results demonstrated that the best warmth move conditions were gotten for the plate heat exchanger with tendency point of 600. Moreover, it was seen that the math of the plates significantly influences the fluid flows through channels framed between the plates and features the execution of thermodynamic attributes of these gadgets.

The utilization of Mani folding of micro-channels for execution improvement of plate heat exchangers in a counter flow configuration was concentrated additionally [14]. The warmth move coefficient got in the mathematical recreations was discovered to be around 16% higher than that in the exploratory findings. The deviation among mathematical and exploratory qualities was disclosed because of the changeability of the micro-channels. The heat exchanger was made of nickel, which is very deification to machine and it can prompt inconstancy in microchannel measurements. Another significant perception was that the presentation of the fluid into a creating flow locale improved the exhibition of the warmth exchanger. The shape plots of the speed acquired from the mathematical study indicated higher neighbourhood flow speeds close to the base of the microchannel [15]. This impact was clarified by turning of the flow from complex to microchannel and back to the complex in a short flow length. The need of examination of the impact of ridged flat plate heat exchanger with and without baffles on the warm pressure driven attributes, including efficiency of warmth move and flow opposition in heat exchanger, was perceived.

The effect of turns and separation between turns on the warmth move and the grating element were concentrated over a wide Reynolds number reach on account of non-Newtonian fluids flowing through the plate heat exchangers [16]. It was discovered that for all researched Reynolds numbers in the heat exchanger with two plates, the CFD results effectively fitted an experimental connection of the erosion factor. The variety of warmth move was introduced as a capacity of the siphoning power. It was discovered that at high flow rate, an expansion in the quantity of utilized plates brought down the proportion between the warmth move and the siphoning power [17]. Different perspectives were considered, who zeroed in on an impact of material thickness on pressure misfortune and viability of a counter flow plate heat exchanger.

The creators exhibited that the low material thickness, of just 5% of the plate pitch, was essential in making the best recuperative air to air heat exchanger with high viability and low pressure misfortune, while the properties of the material itself were irrelevant. The CFD results for adequacy compared well with the deliberate ones, while the results for pressure misfortune varied significantly and thought little of the deliberate weight drop by 19-75% in a wide Reynolds number reach [18]. The high contrast in pressure misfortune was clarified by not considering in recreations the plate boundaries, for example, plate harshness, plate miss happening or contrasts between the states of the mathematical and genuine plates of the warmth exchangers. A large portion of the assessed papers unmistakably demonstrated that non-uniform fluid flow at the inflow to the tight section shaped between the fins just as the warm contact opposition between the fin and cylinder/plate can emphatically influence the warmth move measure inside plate heat exchangers. Hence, on account of those exchangers, where fluid flow through equal flat plates is described by the arrangement of huge dead flow zones, supporting the unwavering quality of the calculation is by all accounts especially valuable. The CFD codes permit anticipating how these unwanted warm pressure driven attributes can be decreased what's more, thus lead to an expansion in the weight drop and the warmth move [19]. The introduced results8, 14 -17 appeared that 3D CFD re-enactments can give a compelling apparatus for designing investigation since different plan choices and a wide assortment of states of being can be analysed without developing costly test apparatuses or huge scope models. Hence an ideal plan of the plate heat exchanger can be resolved at a generally ease. In this manner, the point of the investigation was to analyze the influence of mathematical boundaries of the warmth exchanger plates on heat move conditions by methods for the CFD demonstrating. With this point, the plate heat exchangers of two distinctive flow designs were examined and the CFD results were contrasted and a current exploratory information for the first math of the plate heat exchanger.

2. Numerical Approach

The plan of a plate heat exchanger with five diverse configurations, for which calculations of velocity, pressure and temperature were directed, is appeared in below Figure. The plate heat exchanger is utilized for chilling the cathode gas leaving a created cross breed power age framework dependent on Solid Oxide Fuel Cells. To streamline the computational case, the cathode off gas was spoken to via air flow with a similar mass flow rate and temperature esteems as the cathode off gas in a genuine framework. The cathode off gas was checked as hot flow and it was cooled via air (cold flow). The complete plate heat exchanger was 95 mm wide, 210 mm long and 33 mm thick. The absolute number of plates was equivalent to 18 bringing about 9 and 8 channels for cold also, hot flows, individually. The plate fins and dividers were made of tempered steel with the thermal conductivity of k = 16.27 W/m-K. The fins of the hot and cold flows in the plate heat exchanger configuration, while for the configuration II the fins for the hot flow were straight and for the cool fluid flow they were S-formed. Significant 3D mathematical models of plate heat exchanger were underlying the CFD business programming ANSYS Workbench.

Figure 1: Different geomtrical models for analyse the heat transfer in multi-phase flow.

3. Mathematical Modelling and Numerical Simulation

The modelling and commercial code for computational fluid dynamics, Fluent, has been used for the simulations, and a user defined function (UDF) was performed to obtain a uniform external parameters parallel to the temperature gradient. The finite volume method was adopted to solve three dimensional governing equations.

3.1 Flow parameters

The basic flow variable measured and used in atmospheric flow analysis is the velocity. Few velocity fields have constant magnitudes and directions. Most often, the velocity changes in magnitude and/or direction from point to point.

In the present investigation, diesel after distillation is considered as hot fluid and water as cold fluid. Properties of diesel (hot fluid) and water (cold fluid) are tabulated below:

Table 1: Properties of hot fluid and cold fluid

Characteristic	value	unit	value	unit
	Diesel (Hot fluid)		Water (Cold fluid)	
Density	0.820	g/cm^3	0.997	g/cm^3
Viscosity	2.84	cSt	1.0038	cSt
Boiling point	370	°C	100	°C
Thermal conductivity	0.13	W/m-K	0.6	W/m-K

3.1.1. Temperature – The temperature variation along with the cross-section. Here the selection of all the layers of the model of uniform flow of the particles in it.

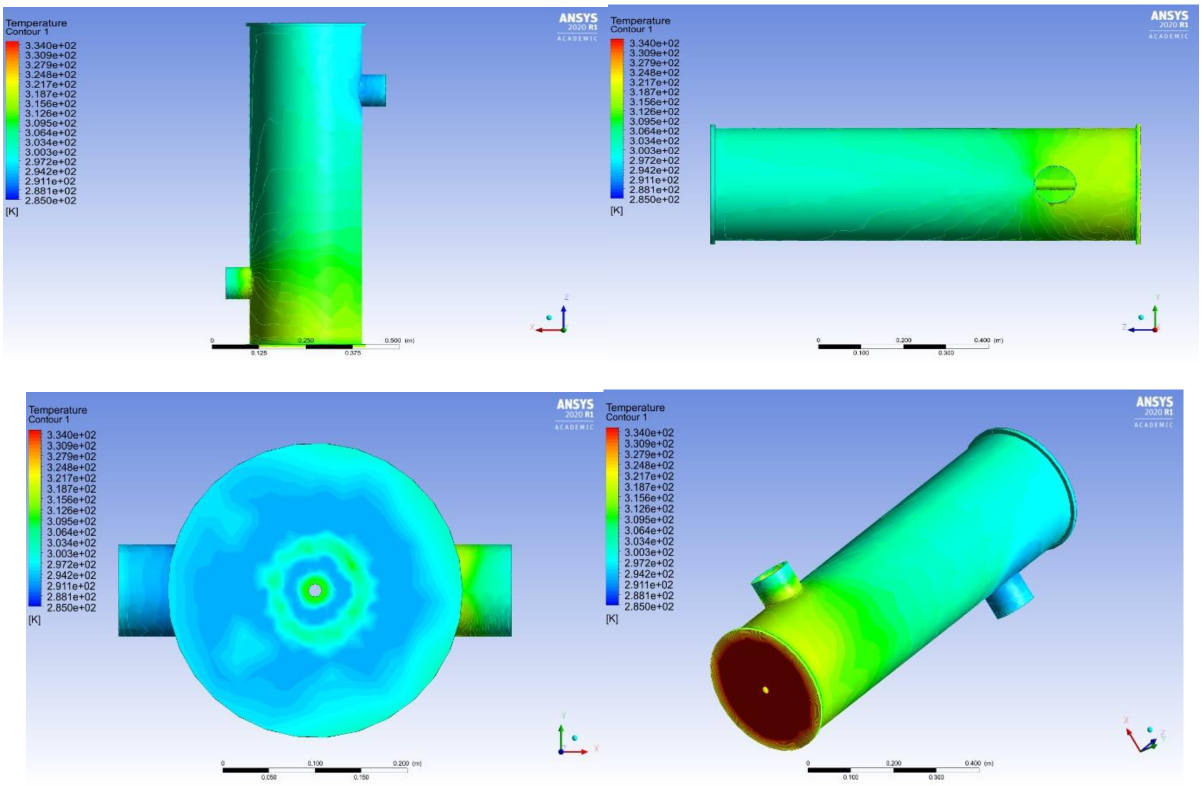


Figure 2: selection of layers for the Temperature variation

3.1.2. Surface Heat Transfer Coefficient – The surface heat transfer coeffiecent as found out the surface heat transfer coefficioent values in a similar way as the above pressure variation. The surface heat transfer coefficient analysis also we have done the same way as like temperature analysis.

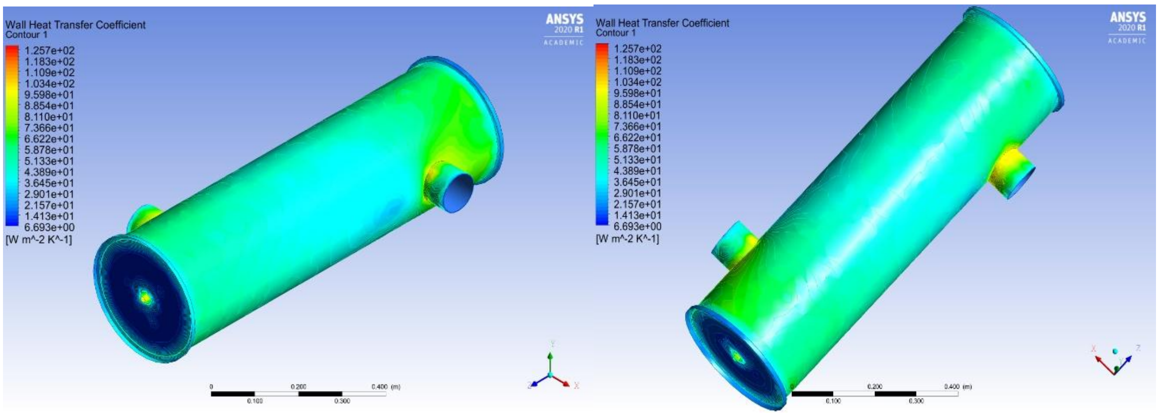


Figure 3: Surface heat transfer coefficient Analysis

3.1.3. Inner wall temperature – Here we have found out the inner wall temperature values in a similar way as the above pressure variation. The inner wall temperature analysis also we have done the same way as temperature analysis.

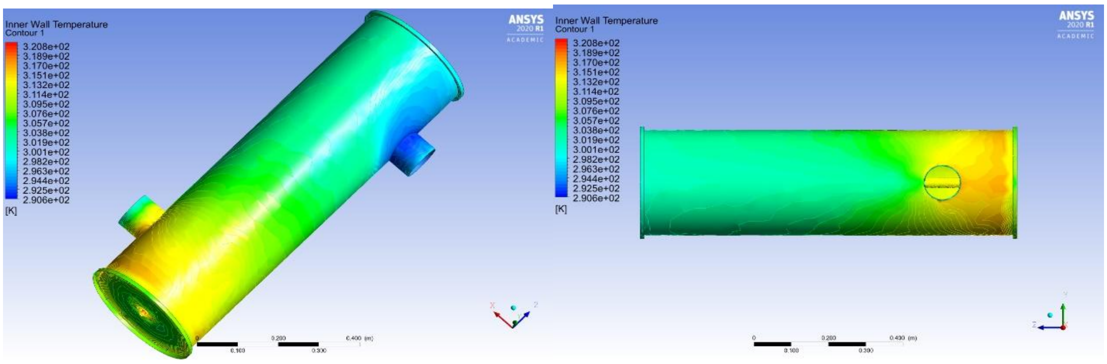


Figure 4: Inner wall temperature Analysis

3.1.4. Pressure – Here we have found out the pressure values in a similar way as the above pressure variation. The mass transfer analysis also we have done the same way as temperature analysis.

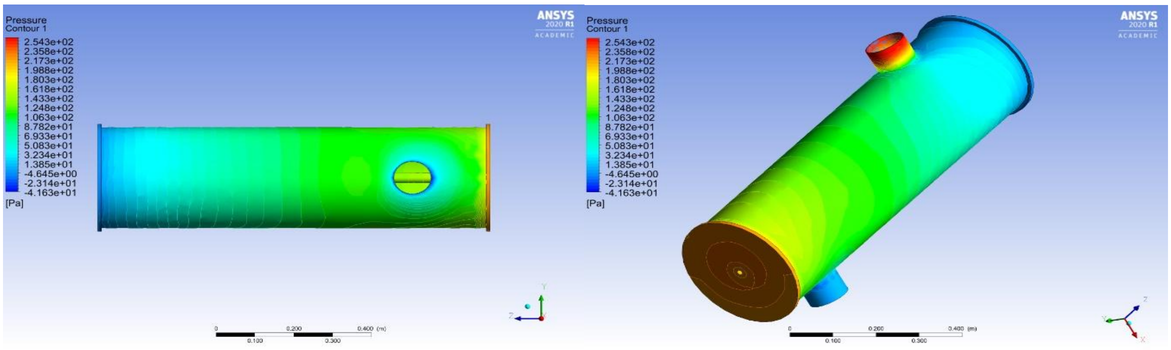


Figure 5: Pressure Analysis

3.1.5. Velocity – Here we have found out the velocity of flow values in a similar way as the above pressure variation. The thermal conductivity analysis also we have done the same way as temperature analysis.

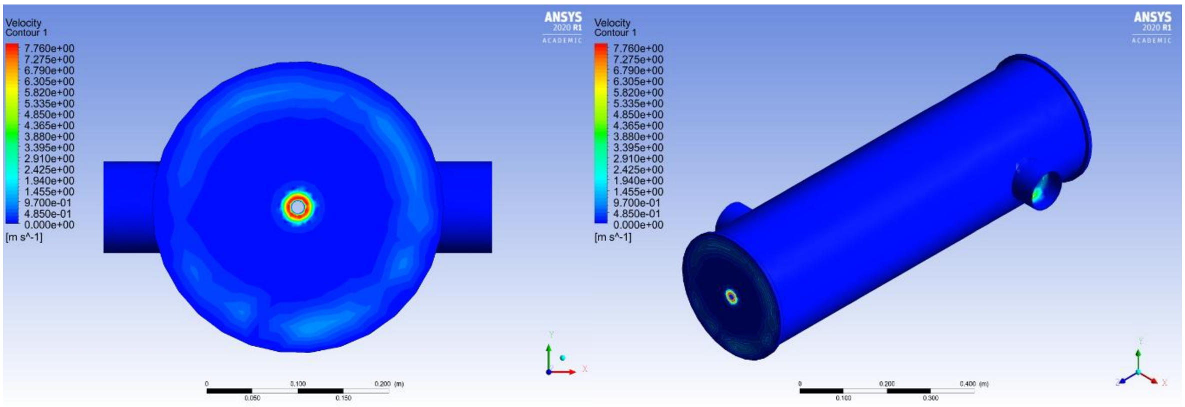


Figure 6: velocity Analysis

4. Results and Discussions: -

4.1. Temperature variation w. r. t. Velocity

The temperature variation along the cross-section of the heat pipe w. r. t. the velocity of flow is shown in the below table. From the table and graphical results, we can see the temperature gradually decreasing along the length of the pipe.

Table 2: Temperature variation w.r.t. Velocity

Temperature	Velocity For Uniform Pipe	Velocity For L-Pipe	Velocity For U-Pipe	Velocity For Wave Pipe	Velocity For Spring Pipe
3.34e+02	7.76	7.81	8.04	8.72	9.56
3.30e+02	7.275	7.42	7.42	7.96	8.72
3.28e+02	6.79	6.91	7.92	6.84	7.94
3.25e+02	6.305	7.012	6.24	6.98	7.01
3.22e+02	5.82	6.45	6.98	6.35	6.65

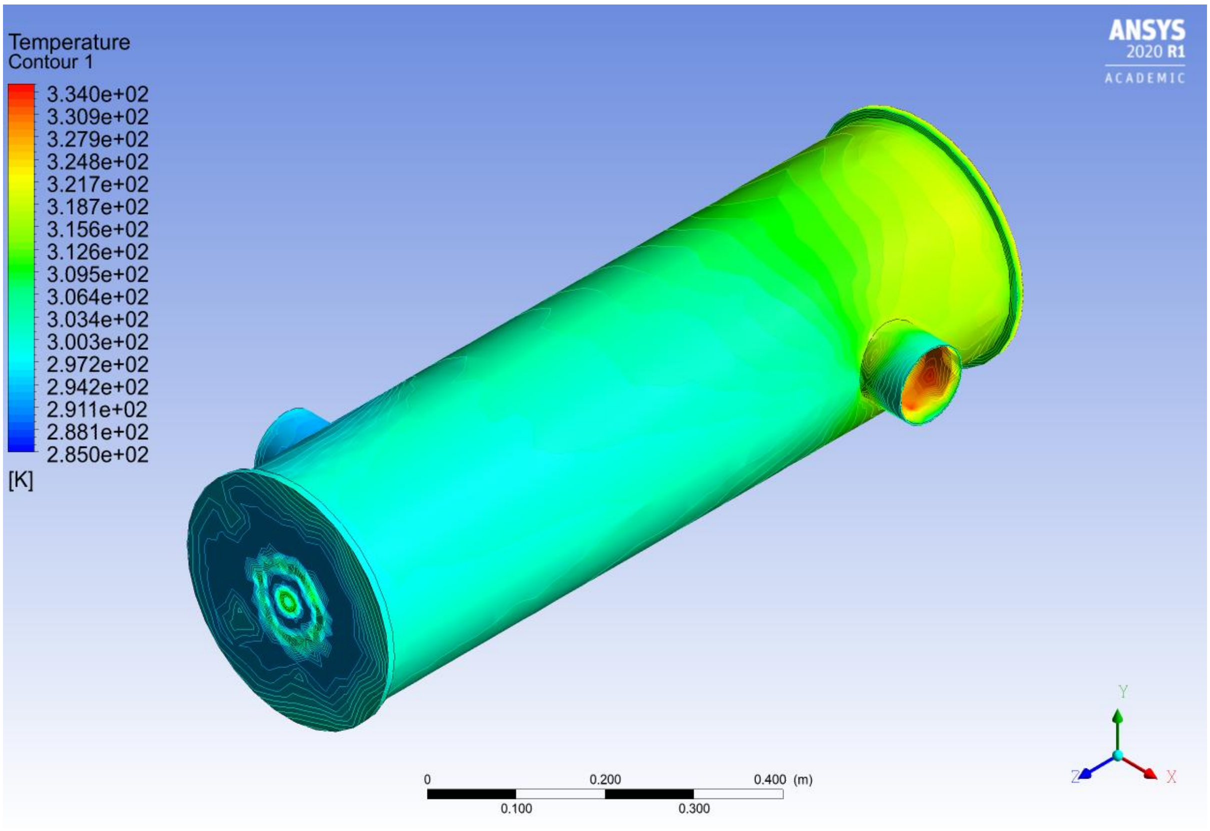
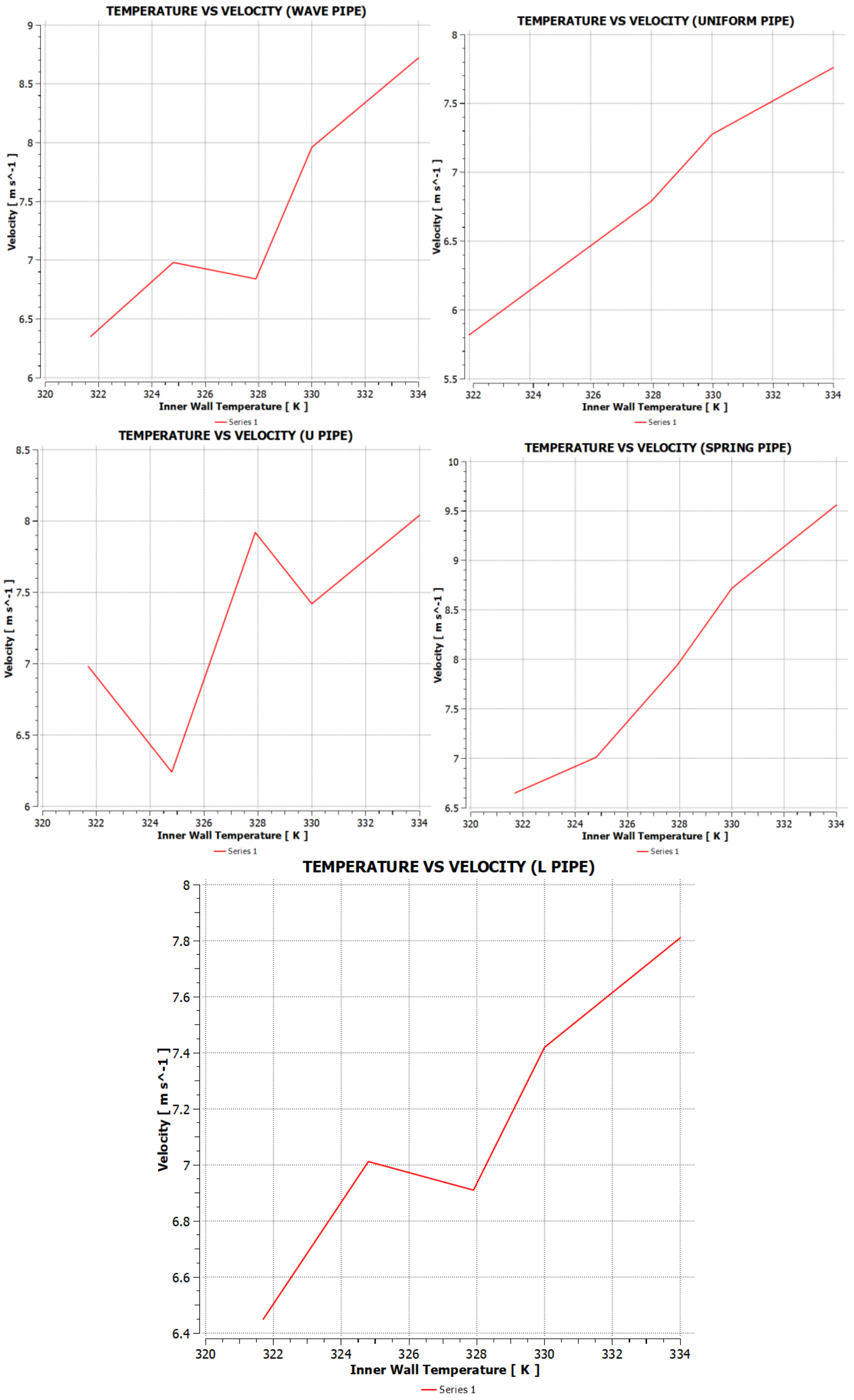


Figure 7: Velocity Analysis



Graph 1: Temperature variation w.r.t. Velocity for different cross-sections

From the above graphs we can see that the velocity of flow is uniform and laminar for uniform pipe and spring pipe apart from that the remaining cross-sections are having turbulent flow. This work numerically examined effects of fluid flow on heat transfer in a different shaped geometry with the aim to evaluate potential advantages of using fluids in a flow. Numerical computations revealed that the flow of fluids through different cross-sections can be an effective way to improve thermal performance of laminar flows.

4.2. Temperature w. r. t. Heat transfer coefficient

The heat transfer coefficient along the cross-section of the heat pipe w. r. t. the temperature of flow is shown in the below table. From the table and graphical results, we can see the heat transfer coefficient is decreasing along the length of the pipe.

Table 3: Temperature w.r.t. Heat transfer coefficient

Temperature	Heat transfer coefficient FOR UNIFORM PIPE	Heat transfer coefficient FOR L-PIPE	Heat transfer coefficient FOR U-PIPE	Heat transfer coefficient FOR WAVE PIPE	Heat transfer coefficient FOR SPRING PIPE
3.34E+02	1.26E+02	1.25E+02	1.89E+02	1.90E+02	1.89E+02
3.30E+02	1.18E+02	1.17E+02	1.73E+02	1.81E+02	1.79E+02
3.28E+02	1.11E+02	1.12E+02	1.75E+02	1.86E+02	1.64E+02
3.25E+02	1.03E+02	1.04E+02	1.65E+02	1.76E+02	1.12E+02
3.22E+02	9.60E+01	9.80E+01	9.70E+01	9.90E+01	9.70E+01

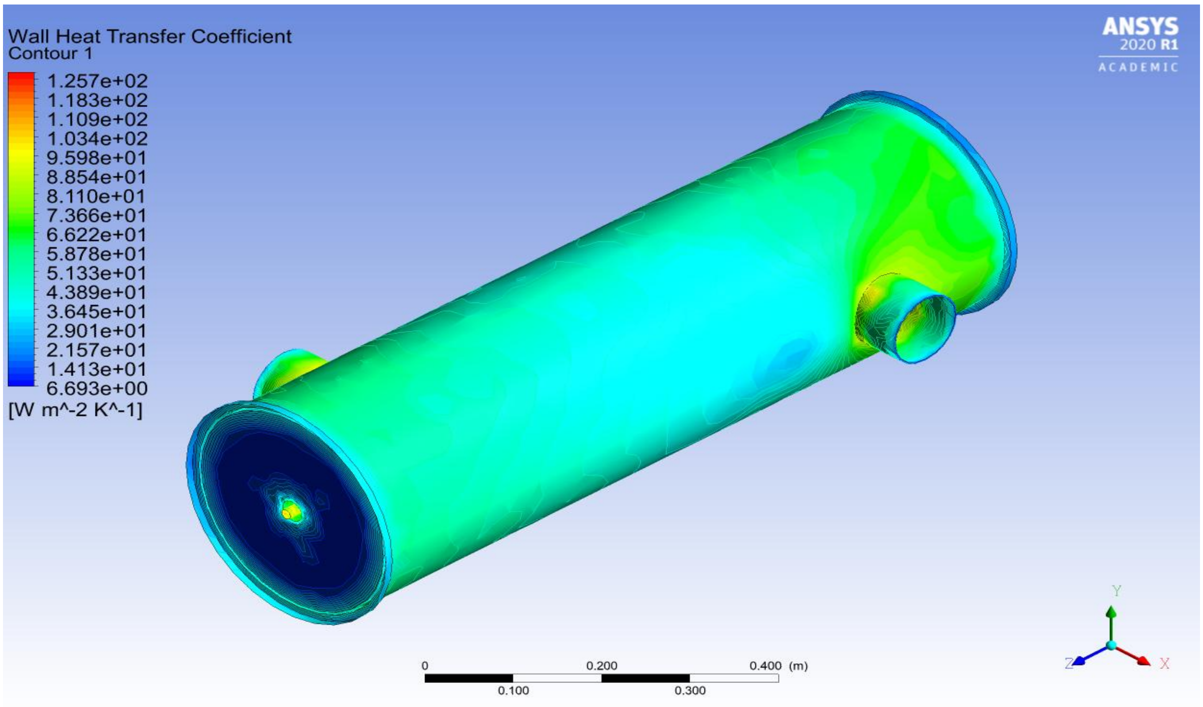


Figure 8: Heat transfer coefficient Analysis

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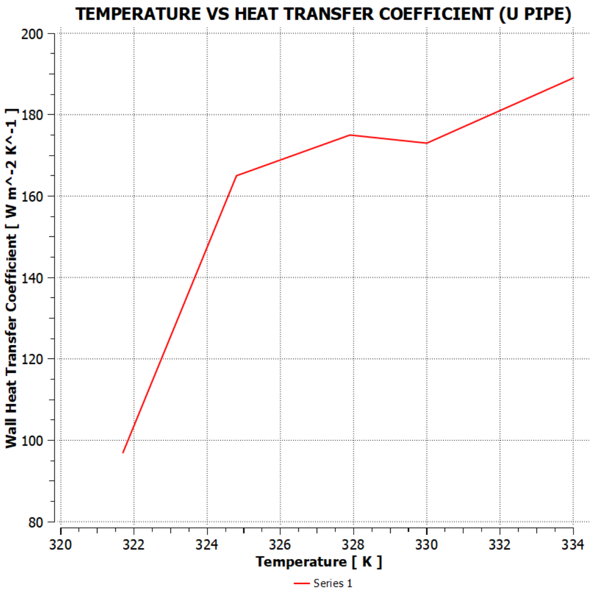
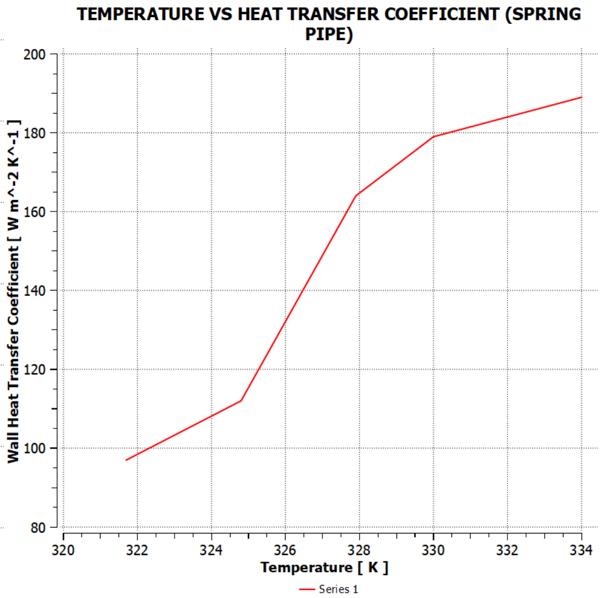
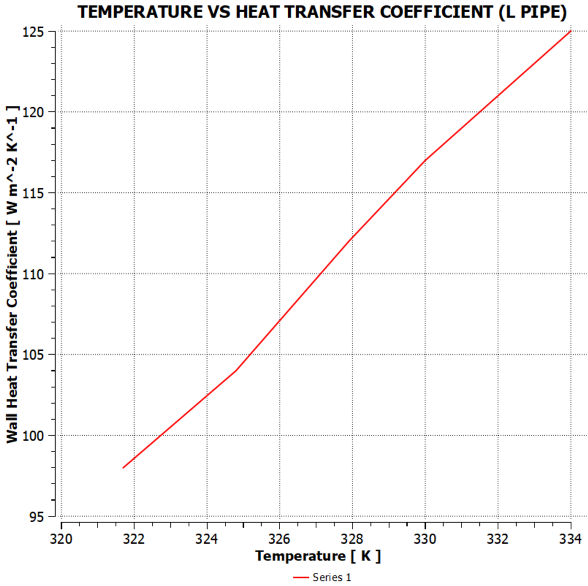
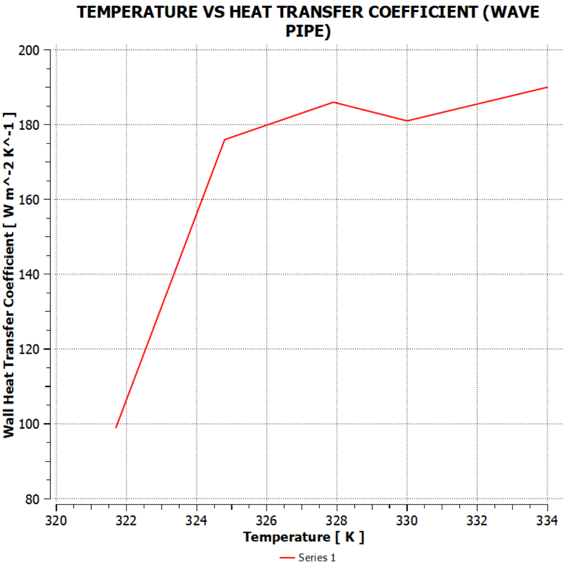
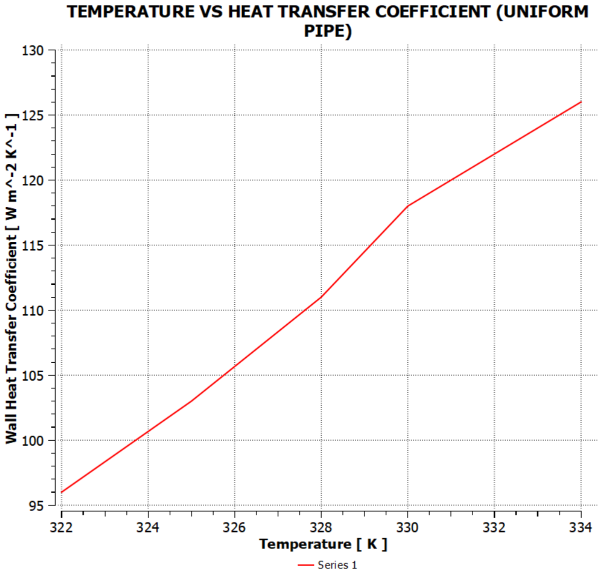










Graph 2: Temperature w.r.t. Heat transfer coefficient

The heat transfer coefficient is higher for the wave pipe at 322K. The overall heat transfer coefficient is used to calculate total heat transfer through a wall or heat exchanger construction. The overall heat transfer coefficient depends on the fluids and their properties on both sides of the wall, the properties of the wall and the transmission surface.

4.3. Temperature w. r. t. Heat flux

The Heat flux variation along the cross-section of the heat pipe w. r. t. the temperature of flow is shown in the below table. From the table and graphical results, we can see the heat flux gradually decreasing along the length of the pipe.

Table 4: Temperature w. r.t. Heat flux

TEMPERATURE	Heat flux FOR UNIFORM PIPE	Heat flux FOR L-PIPE	Heat flux FOR U-PIPE	Heat flux FOR WAVE PIPE	Heat flux FOR SPRING PIPE
3.34E+02	5.41E+02	5.32E+02	6.24E+02	6.50E+02	6.87E+02
3.30E+02	4.24E+02	4.31E+02	5.89E+02	5.90E+02	5.75E+02
3.28E+02	3.07E+02	2.98E+02	5.92E+02	6.10E+02	4.35E+02
3.25E+02	1.90E+02	1.84E+02	3.51E+02	4.01E+02	3.98E+02
3.22E+02	7.34E+01	7.10E+01	9.70E+01	8.90E+01	8.60E+02

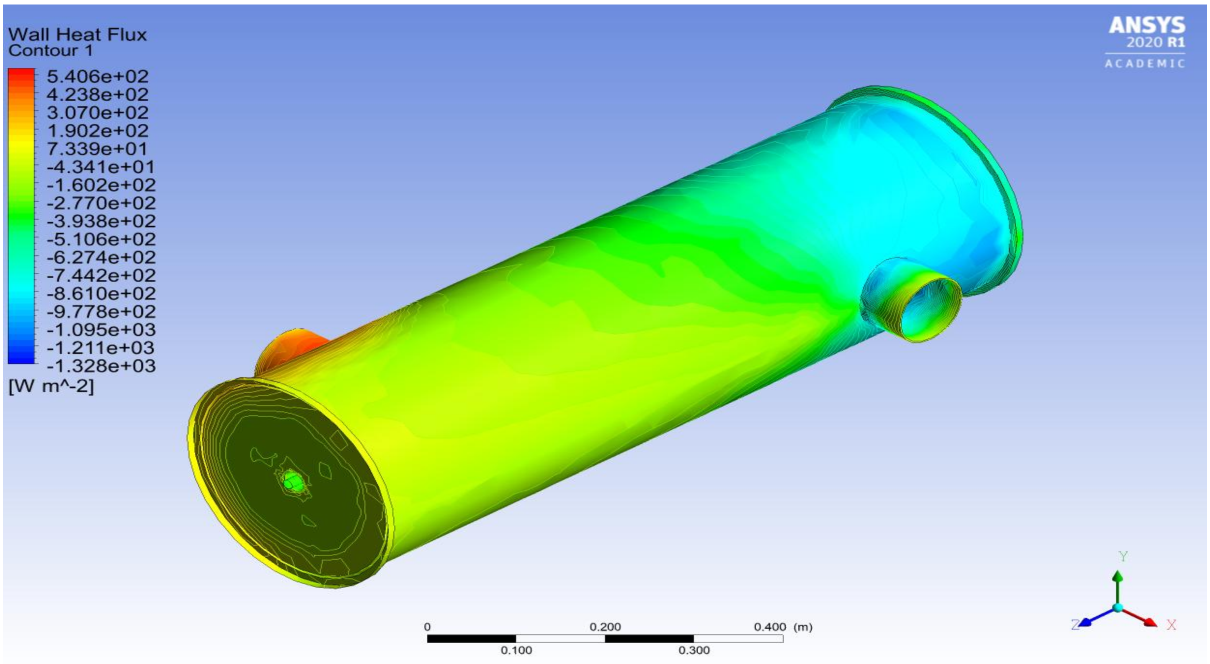
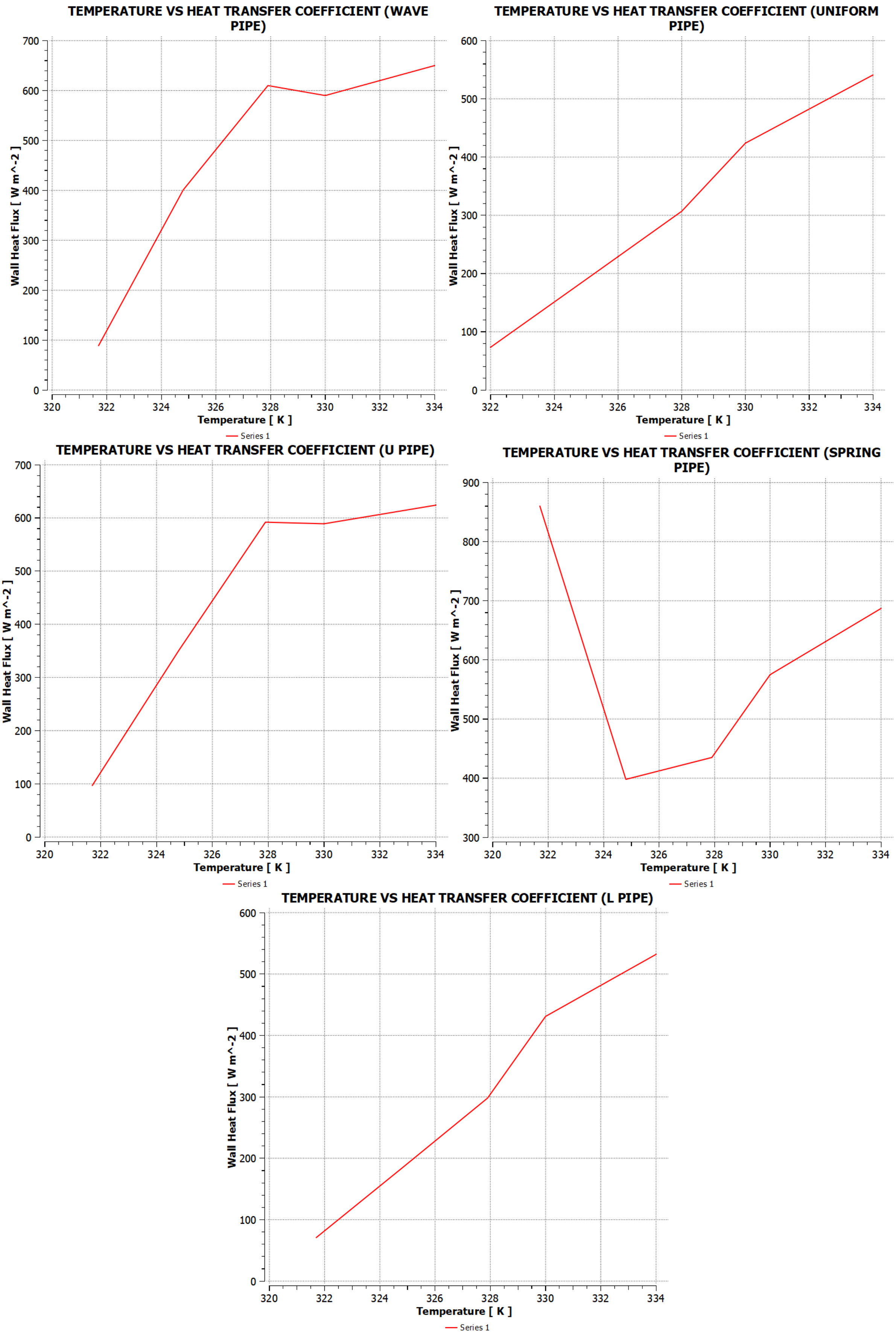


Figure 9: Heat flux Analysis



Graph 3: Temperature w .r .t. Heat flux

The heat flux is higher for the U- pipe at 322K. The heat flux is used to calculate total heat transfer through a wall or heat exchanger construction. The overall heat flux depends on the fluids and their properties on both sides of the wall, the properties of the wall and the transmission surface.

5. Conclusions:

- 3D turbulent flow structure and the heat transfer performance of the different cross-sections of heat exchanger have been investigated.
- Spatial flow characteristic predicted by computational fluid dynamic simulations agree very well with those observed by the Particle Image Velocimetry experiments conducted.
- Comparison between 3D and 2D flow simulations reveals that the spatial structure of vortices formed in the wake of cross-section is influenced by the presence of wall.
- That could have profound effects on the performance of the shell-tube heat exchanger.
- In this paper we have found out that the maximum heat flux, maximum heat transfer coefficient and pressure variations are found out using a spring pipe flow.
- And also we can observe that the maximum outputs are also observed using the graphical and mathematical representation.
- We can see that the velocity of flow is uniform and laminar for uniform pipe and spring pipe apart from that the remaining cross-sections are having turbulent flow.
- The heat transfer coefficient is higher for the wave pipe at 322K.
- The overall heat transfer coefficient is used to calculate total heat transfer through a wall or heat exchanger construction.
- The heat flux is higher for the U- pipe at 322K.
- The heat flux is used to calculate total heat transfer through a wall or heat exchanger construction.
- The overall heat flux depends on the fluids and their properties on both sides of the wall, the properties of the wall and the transmission surface.
- The overall heat transfer coefficient depends on the fluids and their properties on both sides of the wall, the properties of the wall and the transmission surface.
- This work numerically examined effects of fluid flow on heat transfer in a different shaped geometry with the aim to evaluate potential advantages of using fluids in a flow.
- Numerical computations revealed that the flow of fluids through different cross-sections can be an effective way to improve thermal performance of laminar flows.

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