



Abstract

The Double Pipe Heat Exchanger in counter flow configuration consists of one fluids flow from the inner pipe while the other flows in the opposite direction from the outer pipe. This project analyzed and designed this heat exchanger utilizing numerical simulation in ANSYS and facilitated optimization by performing a change in the inner tube material. Based on the second simulation analysis the minimum percentage difference was reduced from 2.70% to 0.70% When changing the inner tube material to copper and maintaining the same initials conditions a 12.07 K decrease in temperature difference was achieved for the hot water. It is found that the visualization of the distribution of the temperature and pressure that numerical simulation provides, gives a better understanding of the heat exchanger and having the system model in ANSYS useful for optimization.

Introduction

Heat transfer can occur in three ways: conduction, convection and radiation. In double pipe heat exchangers, heat is transferred only by conduction and convection where one fluid flows through a smaller pipe while the other fluids flow through the annular space between the two pipes without their direct contact. There are two methods to analyze this type of heat exchangers one of them is called the Logarithmic Mean Temperature Difference (LMTD) and the other one is the Number of Transfer Units (NTU) for this project LMTD was used.

Background

Heat transfer is the study of thermal energy transport that occurs between states of matter when a difference in temperature exists and only in the direction from the hot object to a cold one. A commonly used device to transfer heat in the industry, widely used in refrigeration, power plants, and chemical plant are heat exchangers [1]. A heat exchanger is any apparatus in which heat is transferred between a warmer and colder fluids. There is various type of heat exchangers like shell and tube, plate, and double pipe. On this system counter flow configuration is always more favorable than the parallel current [2]. Prior studies mention that double pipe heat exchangers performance is influenced by some parameters, including Nusselt Number (Nu), friction factor (f), and effectiveness (ϵ) [3]. In this project design ANSYS will be used to perform this numerical simulation. ANSYS utilizes the fundamental laws of fluid flow that are conservation of mass, conservation of momentum and conservation of energy and solves them utilizing the Finite-Volume Method (FVM). In **Figure 1** the summary of how ANSYS resolves the conservations laws of the system.

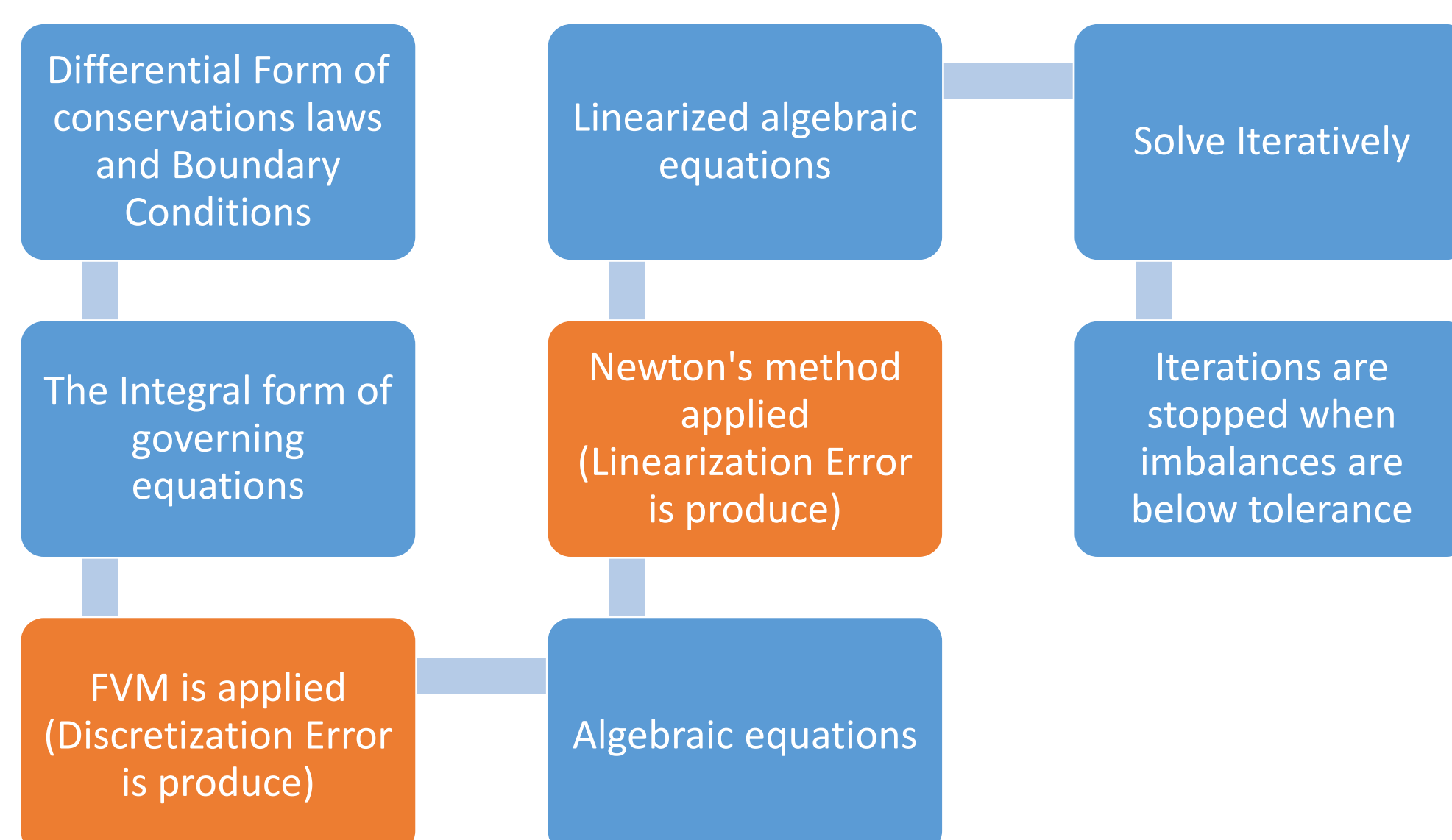


Figure 1: Summary of the process of resolving the conservations laws.

Problem

Nowadays, manufacturer companies utilize codes such as ASME Boiler Pressure Vessel and Tubular Exchanger Manufacturers Association (TEMA) to design their heat exchangers although this is a standard method, while utilizing numerical simulation analysis provides insurance that the system will perform as specified and modelling the system will make it easier for optimization such as a change of material or the working fluid, this type of practice is not commonly used. This projects design intends to design a double pipe heat exchanger in counter flow configuration, integrating numerical simulation to further increase design insurance, decrease errors by verifying and validation of results and facilitate optimization.

Methodology

First, design the geometry of the double pipe heat exchanger establishing parameters including but not limited to the materials of the pipes, selection of fluid, and size of the pipes and applying assumptions such as steady flow, kinetic and potential energy change negligible, Specific heat of the fluid is constant and no fouling. Second, the LMTD method will be used to resolve the fundamental equations for the heat exchanger. Then, a numerical simulation will be performed in ANSYS following these steps:

- Geometry Preparation
- Constructing the Mesh
- Configuring the Mathematical Model
- Setting up and running the Numerical Solution
- Verification and Validation of Results

with these results a change in design may happen. Finally, the inner material will be change to cooper for optimization purpose.

Results and Discussion

In **Figure 2** the Initial Model of the Double Pipe is shown the material chosen for the pipes was PVC.

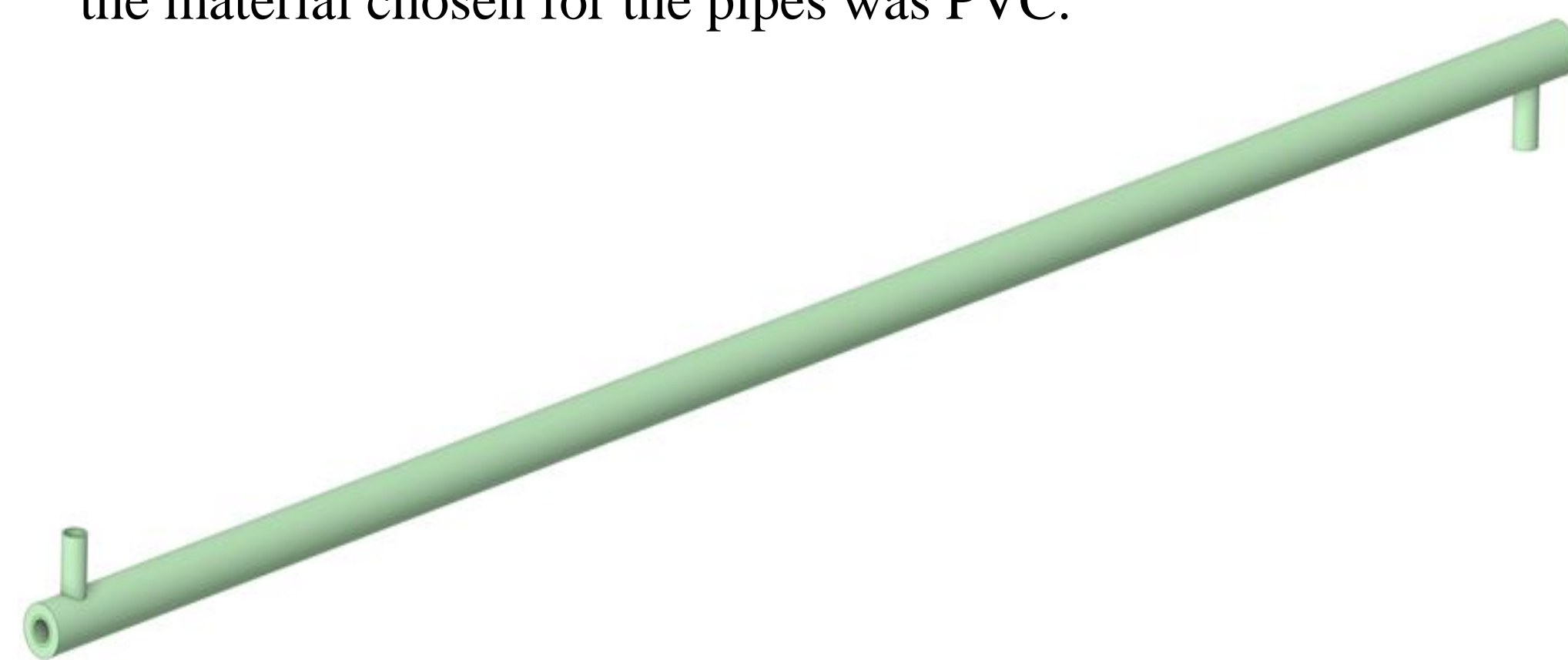


Figure 2: Initial Model Development of Double Pipe Heat Exchanger

After configuring the mathematical model and running the first simulation. of the heat exchanger with the design parameters established with length at **2.748 meters**, the biggest difference comparing with the theoretical values found in the results was the Heat Transfer of **2.70%** . In this case even though the difference is minor the results were verified and validated, and adjustments were done in the calculation of the convective heat transfer of the cold water with this change a new and final design was developed. In **Figure 3** is shown the final volume mesh generated in ANSYS utilizing the spectrum shown in **Figure 4** the mesh has a minimal orthogonal quality of 0.15 which is acceptable.

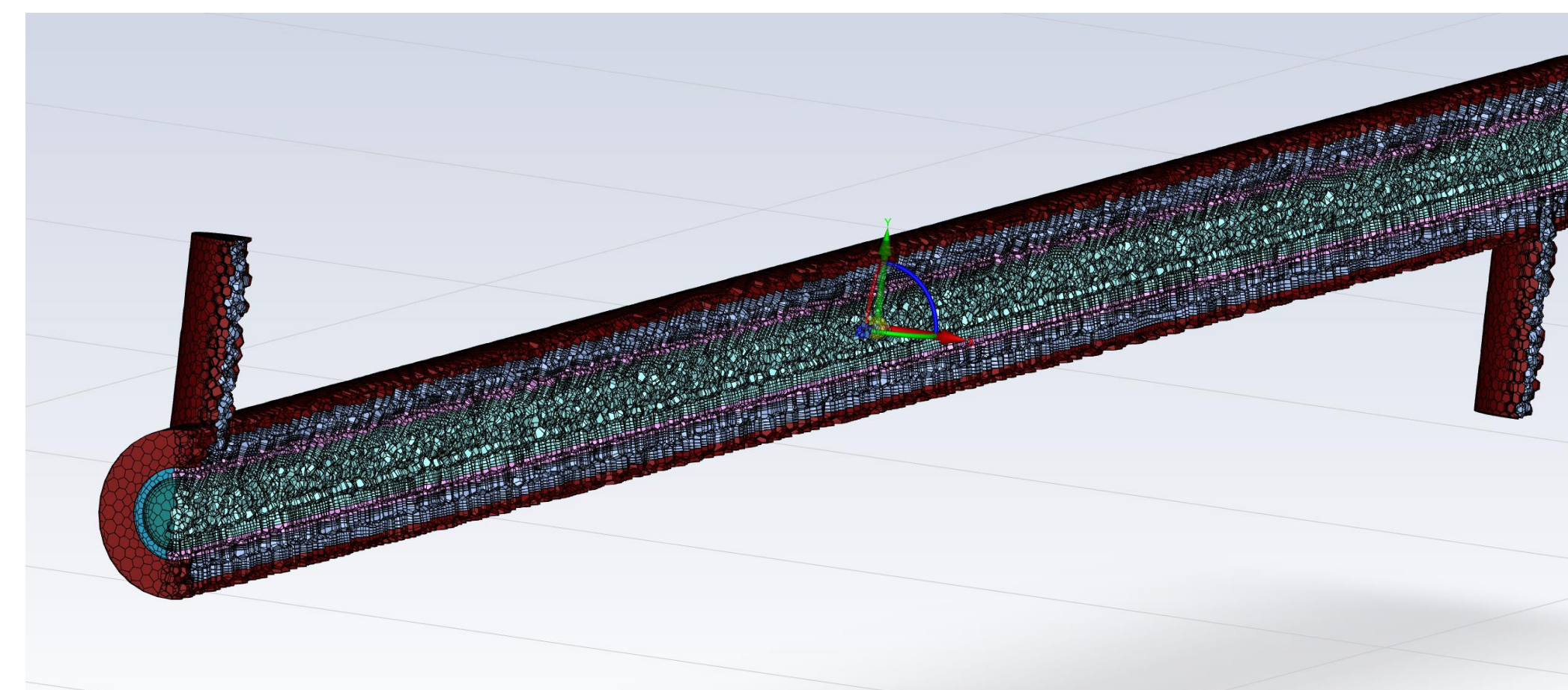


Figure 3: Volume Mesh Generated with a total of 257,434 cells

Unacceptable	Bad	Acceptable	Good	Very good	Excellent
0-0.001	0.001-0.14	0.15-0.20	0.20-0.69	0.70-0.95	0.95-1.00

Figure 4: Mesh Orthogonal Quality Metrics Spectrum [4]

As mentioned above the second simulation was performed with the new length of the heat exchanger at **2.864 meters** with the biggest difference in the outlet temperature of cold water of **0.23%** the results are shown in **Table 1**.

Table 1: Second Simulation Performed-Difference in Theoretical and Simulation values length of heat exchanger 2.864m

Theoretical	Values	Simulation	Values	Difference %
Heat Transfer	618.46 W	Heat Transfer	617.09 W	0.22%
Outlet Temperature Cold Water	285.95 K	Outlet Temperature Cold Water	285.30 K	0.23%
Outlet Temperature Hot Water	331.65 K	Outlet Temperature Hot Water	331.59 K	0.02%

A third simulation was performed changing the inner material of the tube to copper and the result comparison are shown in **Table 2**.

Table 2: Comparing simulation results changing the inner tube material length of heat exchanger 2.864m

Inner tube material PVC	Values	Inner tube material Copper	Values	Increase
Heat Transfer	617.09 W	Heat Transfer	4761.15 W	4,144.06 W
Outlet Temperature Cold Water	285.30 K	Outlet Temperature Cold Water	304.90K	19.6 K
Outlet Temperature Hot Water	331.59 K	Outlet Temperature Hot Water	321.08 K	10.51 K

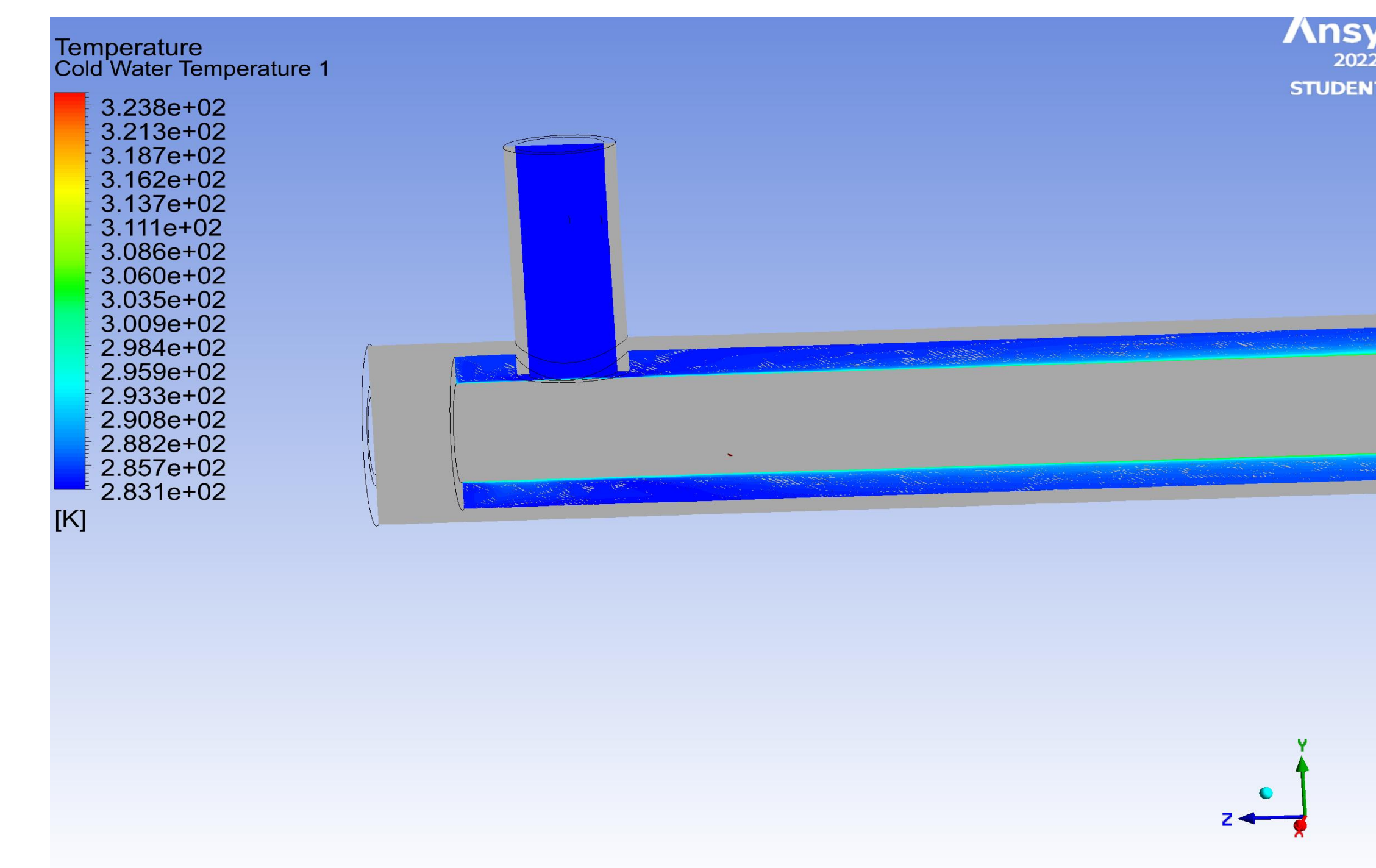


Figure 4: Inlet Temperature Variations of the Cold Water with inner tube material copper

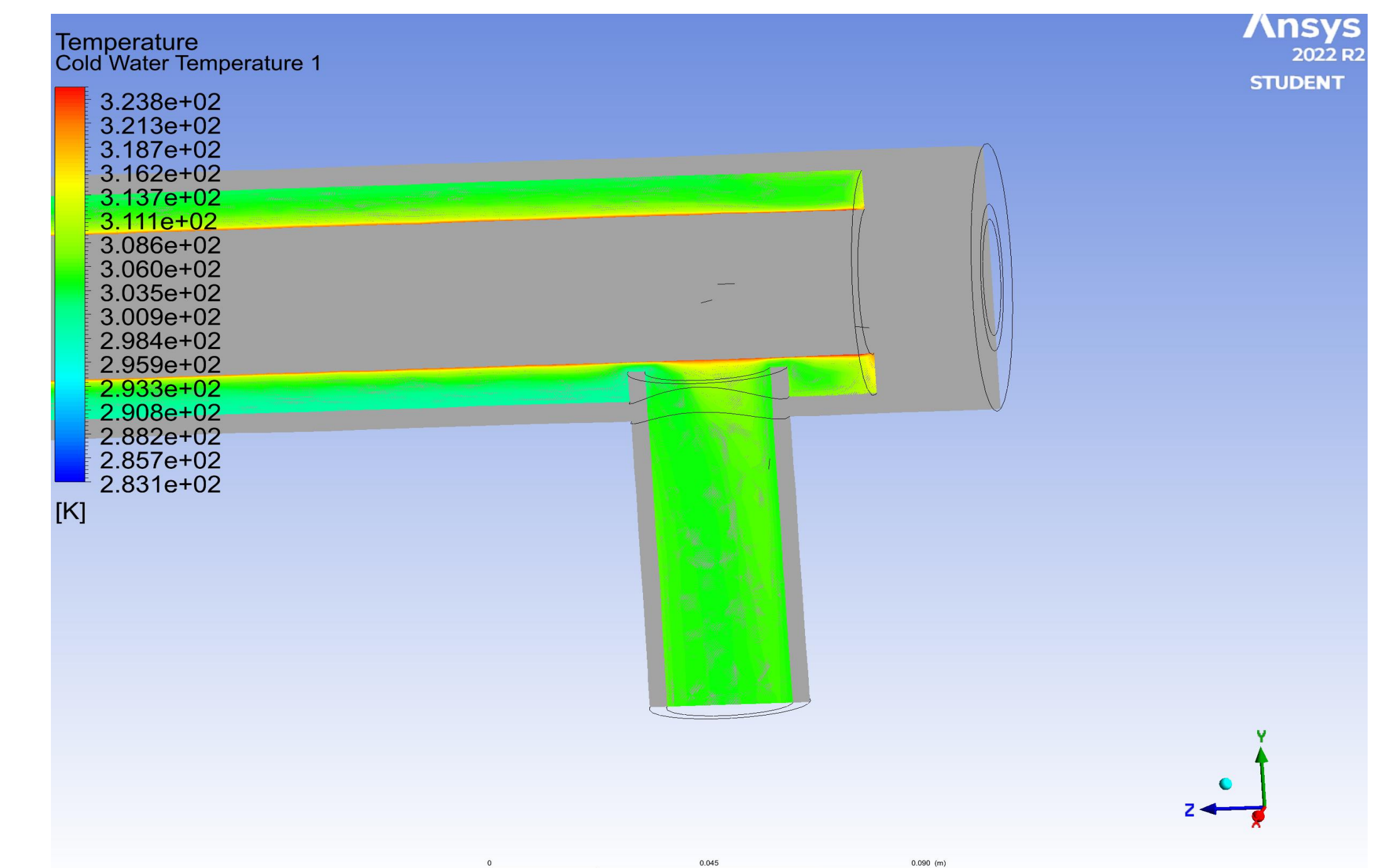


Figure 5: Outlet Temperature Variations of the Cold Water with inner tube material copper

Closely inspecting **Figure 4** it can be observed how the fluid get closer to the outlet the temperature is increasing. However, an important thing to notice is that the closer this fluid is to the inner tube the biggest temperature difference has this is due to the heat transfer occurring in the tube and slowly spreading to the outer area of the fluid.

Conclusions

In this case based on the simulation analysis, can be concluded that:

- Numerical Simulation analysis can be a useful tool to found errors in the theoretical calculation.
- After having the model verified and validated optimizing is easier in the change of the inner tube material to copper there is an increase in heat transfer of 4,144,06 W because copper is a material with a high thermal conductivity which makes perfect sense compared to PVC.
- The linearization and discretization errors are big factors that can induced an unwanted difference in the results.

Future Work

Two thing are to be considered for additional work for this project design those are:

- Construction of the prototype
- Optimization it further with different materials/geometry configurations.

Acknowledgements

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