Lab 4 – Take Home

CFD, MIXING OF SODA AND WATER

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I. Introduction

This report focuses on optimizing a mixing tea for a soda fountain, ensuring efficient mixing of syrup and cold water to achieve a beverage temperature between 2°C to 5°C. The emphasis is on accurate ratio mixing and temperature consistency, which are crucial for maintaining flavor and refreshment quality. Through detailed analysis, boundary condition modifications, and evaluations of mass flow rates and turbulent kinetic energy, this lab assignment aims to address the outlined concerns and enhance overall product quality and user satisfaction.

II. Problem Statement

The primary task is to simulate and optimize a mixing tee in a soda fountain device using Ansys, ensuring the efficient mixing of cold water and fountain drink syrup. The mixing tee features two inlets; inlet-y for cold water and inlet-z for fountain drink syrup. The objective is to achieve a 1:4 mass ratio mixing of syrup and cold water, with the resultant mixture having an average temperature ranging between 2°C to 5°C.

Obtaining Mass flow rates:

$$Volumetric\ Flow\ Rate\ of\ Water\ in\ \frac{m^3}{s}\ , 1.585\frac{gal}{min} * \frac{3.78541\ L}{1\ gal} * \frac{0.001\ m^3}{1\ L} * \frac{1\ min}{60\ s} = 0.0001\frac{m^3}{s}$$

$$Mass\ Flow\ Rate\ of\ Water\ in \frac{kg}{s} : 0.0001\frac{m^3}{s} * \ 998.2\frac{kg}{m^3} = 0.099948\frac{kg}{s}$$

$$Syrup\ to\ water\ ratio: \frac{m_s}{m_w} = \frac{1}{4}$$

$$m_s = \frac{1}{4}m_w = \frac{1}{4} * 0.10007469\frac{kg}{s} = 0.024987\frac{kg}{s}$$

The boundary conditions include the mass flow rate of the water, 0.10007469 kg/s, the mass flow rate of the syrup, 0.02501867 kg/s, and 22C temperature for the syrup. Material properties include water-liquid (density of 998.2 kg/m^3) to be used for the modeling of both the water and the syrup, and the solid is made of aluminum. Mesh statistics have 7993 nodes and 19549 elements. The metrics are kg/s for mass flow rate, Celsius for temperature, and m^2/s^2 for turbulent kinetic energy. Assumptions include k-epsilon for the Viscous model, steady state flow, inlet flows are normal, gravitational acceleration is not used, and all spatial discretization uses second order upwind for the solution methods.

III. Method

I began my analysis of the problem by calculating the mass flow rates of the water and syrup inlets, switching them to mass-flow-inlet in Ansys, setting the fountain drink syrup to 22C, and then I began iteratively changing the water inlet temperature with 26C, 10C, 1C, and 0.1C. The reason I decreased the temperature at the water inlet each iteration is because I noticed a pattern where the outlet temperature decreased. Once I reached 0.1C, I used the weighted average temperature tool at the outlet and verified a temperature of 4.79C. This temperature is within the 2C-5C requirement.

IV. Results

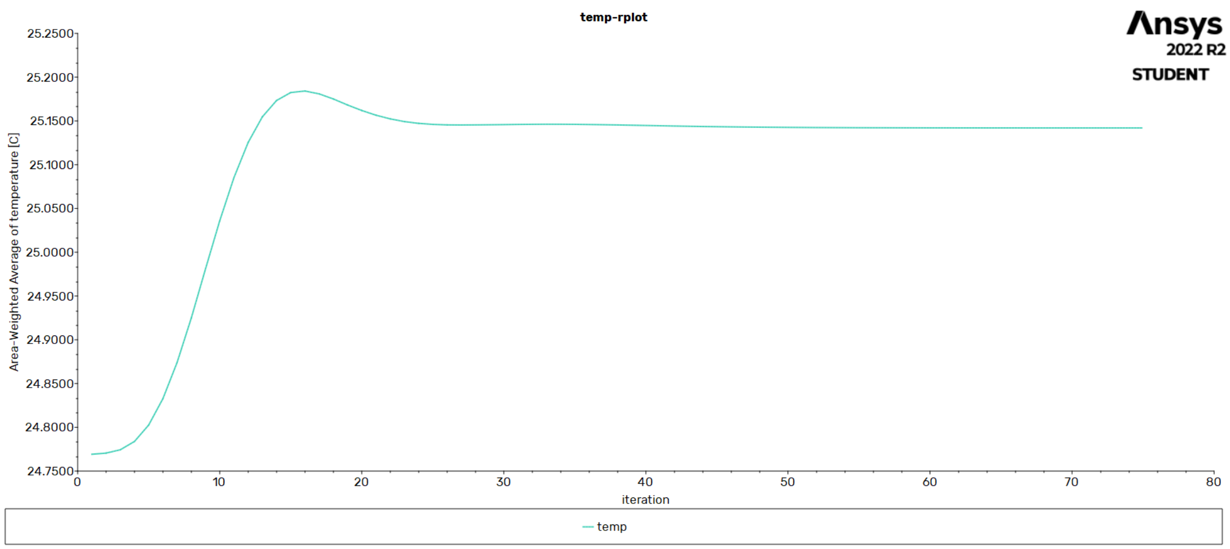

Figure 1: Converging solution of the outlet's temperature profile with water in-let set to 26 C.

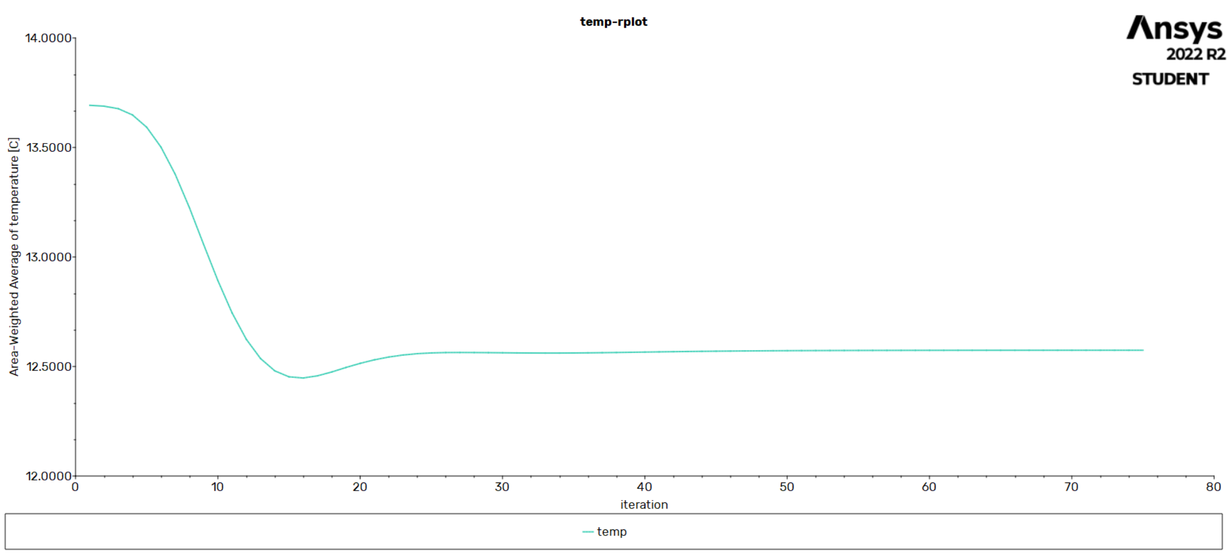

Figure 2: Converging solution of the outlet's temperature profile with water in-let set to 10 C.

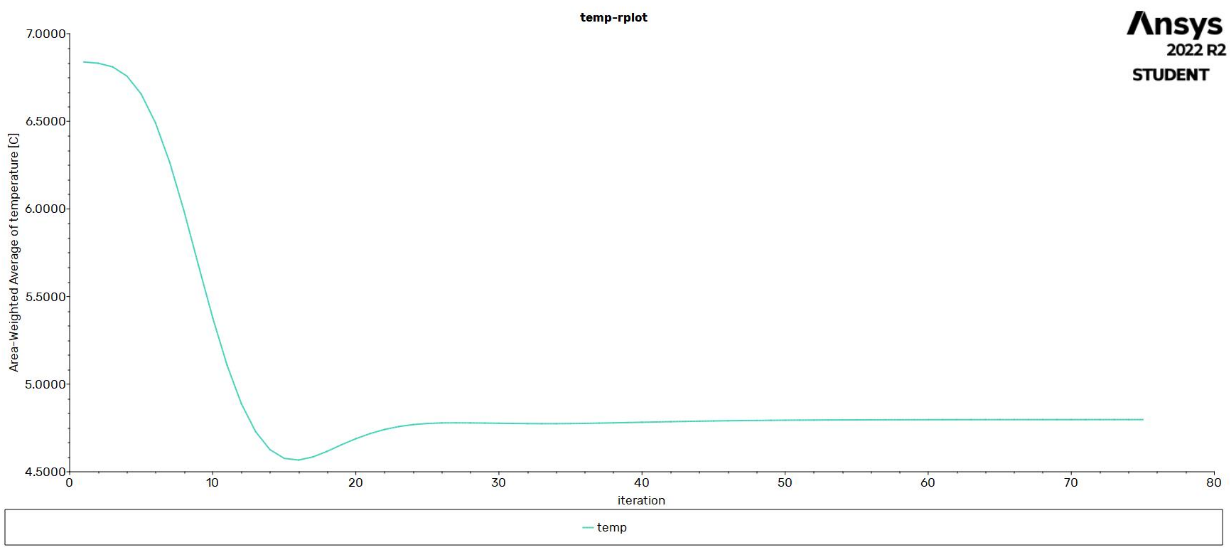

Figure 3: Converging solution of the outlet's temperature profile with water in-let set to 1 C.

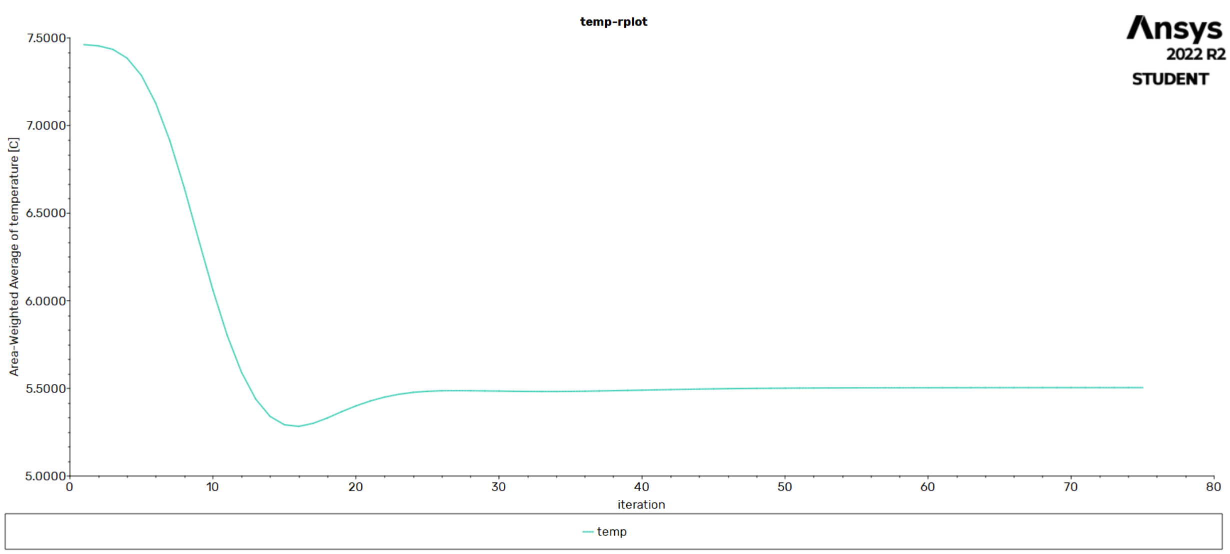

Figure 4: Converging solution of the outlet's temperature profile with water in-let set to 0.1 C.

In Fig. 1-4 the converging solutions of the out-let's temperature profile are plotted with iterations on the x-axis and area-weighted average temperature C on the y-axis. Each time the water inlet temperature was decreased, the resulting outlet temperature's converging solution also decreased. Finally, at 0.1 C for the water in-let temperature, Fig. 4 shows an acceptable temperature profile for the out-let of the mixture.

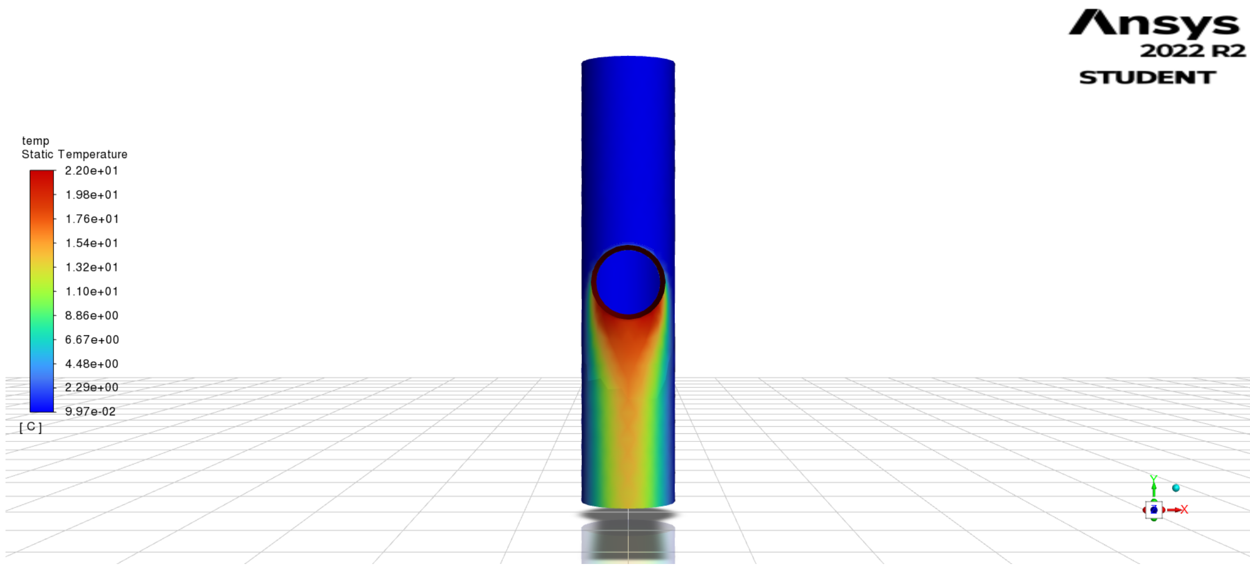

Figure 5: Side view showing the temperature profile in the middle of the pipe.

The inside of the temperature profile measures roughly 9.97e^-02 C according to Fig. 5. Additionally, the inlet of the syrup is the hottest region in the pipe as designed by the boundary conditions.

Table 1: Converging solution of out-let mixture temperature at varying water-inlet temperatures.

Water in-let Temperature (Celsius)	Out-let mixture temperature (Area-Weighted average, Celsius)
26	25.141977
10	12.574068
1	5.5046186
0.1	4.7976737

Table 1 shows the corresponding mixture out-let temperatures with the water in-let temperatures. The out-let mixture temperature measurements were taken using the area-weighted average. At 0.1 C of the water in-let temperature, the out-let mixture temperature clearly meets the criteria of the 2C-5C range.

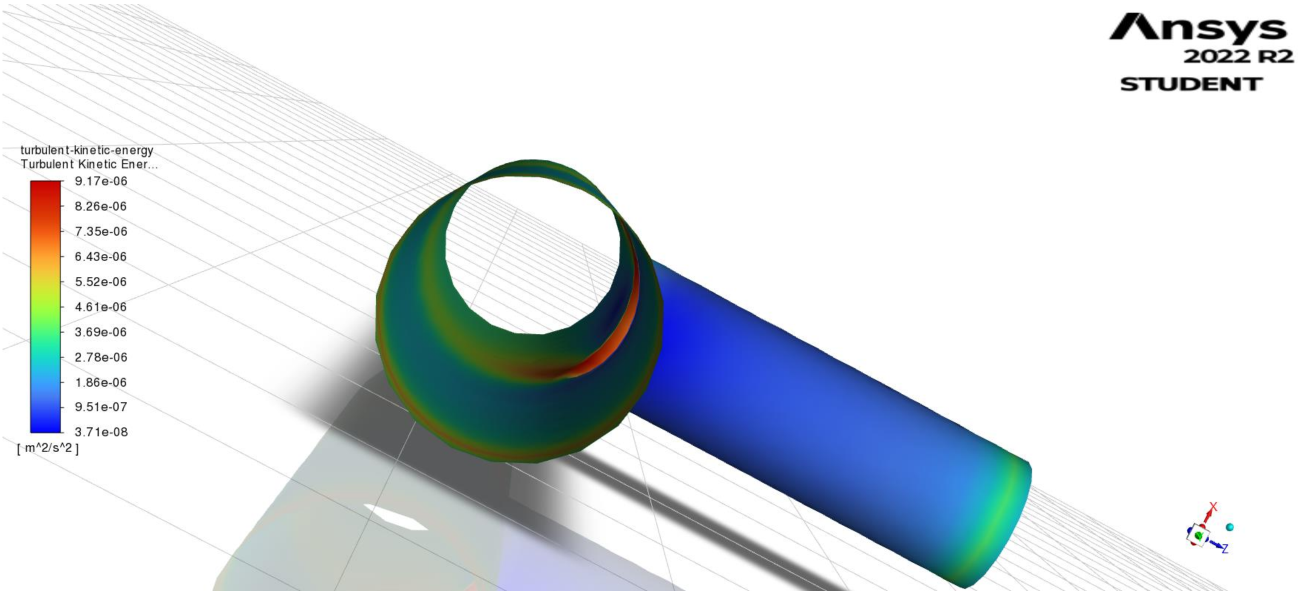

Figure 6: Turbulent Kinetic Energy of water in-let.

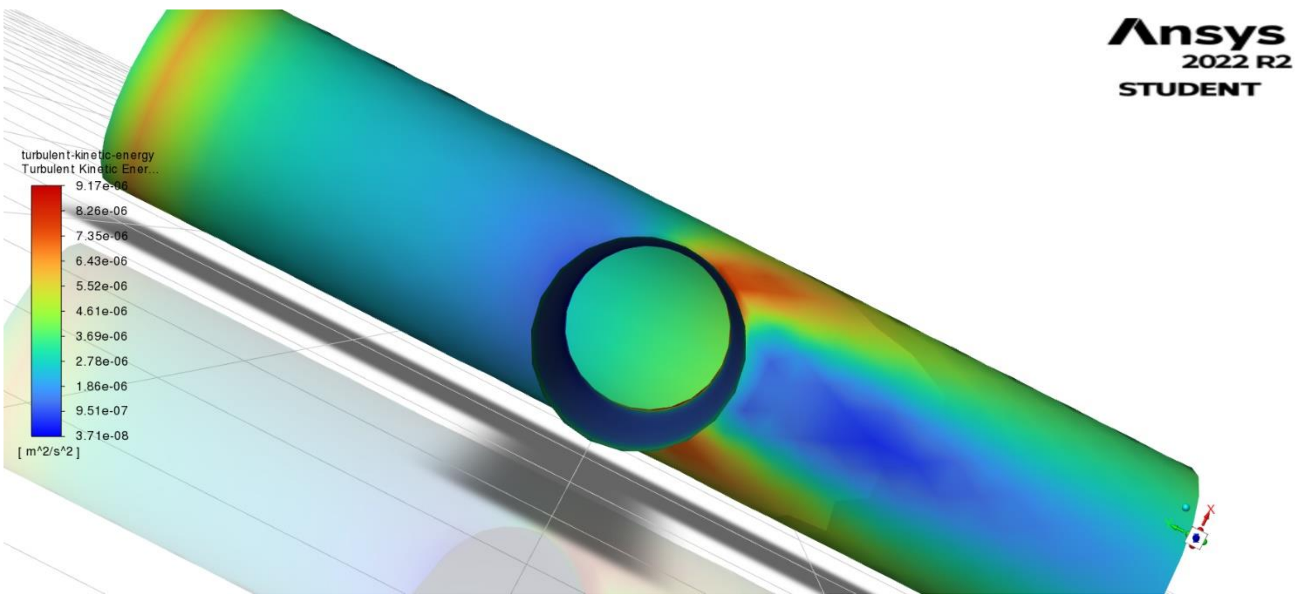

Figure 7: Turbulent Kinetic Energy of syrup in-let.

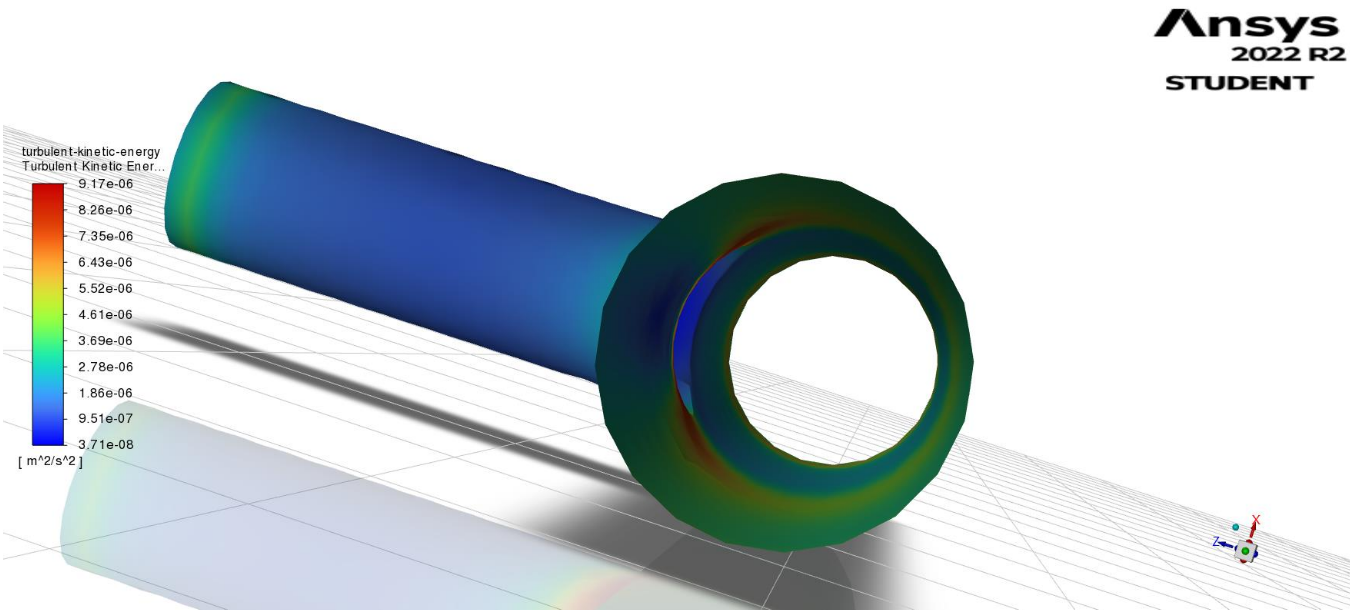

Figure 8: Turbulent Kinetic Energy of mixture out-let.

Fig. 6 shows regions up to 2.78e-06 TKE, Fig. 7 shows regions of 3.71e-08 TKE, and Fig. 8 shows 3.69e-06 TKE m^2/s^2. However, Fig. 8 also shows the middle portion of the pipe where TKE measures up to 9.17e-06. This is due to the mixing of the water and syrup fluids causing turbulence.

Table 2: Liquid flow and Area-Weighted Average of Turbulent Kinetic Energy values.

Liquid flow	Area-Weighted Average TKE (m^2/s^2)
In-let water	1.1713218e-07
In-let syrup	3.7061318e-08
Out-let mixture	1.8333625e-06

Similarly, table 2 shows the out-let mixture having an increased value in turbulence kinetic energy in comparison to the in-let water and in-let syrup flows. Therefore, it can be concluded that both visually and graphically the results show there is sufficient mixing at the outlet region.

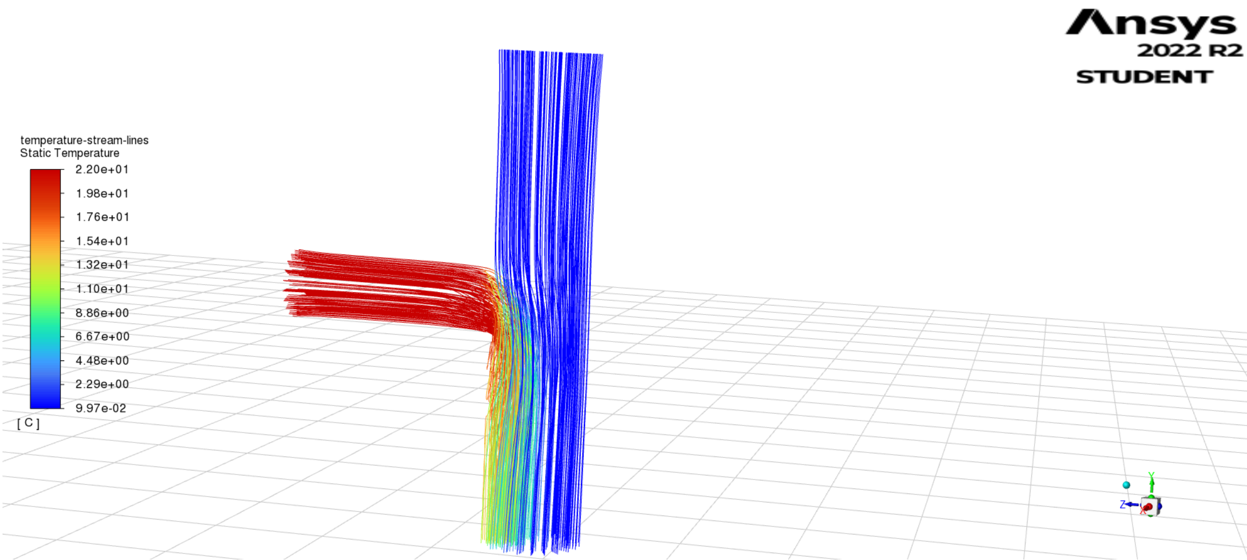

Figure 9: Streamlines colored by temperature for both the water and syrup in-lets.

In fig. 9, the red streamlines indicate the syrup, and the blue streamlines indicate water. The middle of the pipe shows the beginning of a temperature gradient till the end of the outlet mixture. This is because the two fluids are at different temperatures and have mixed. Interestingly, the right side of the pipe remains blue at the outlet while the varying temperature is on the left side. This could mean water is still the predominant fluid on the right side of the pipe.

V. Conclusion

In this take-home lab, the primary objective was to achieve an optimized mixing of syrup and cold water in a soda fountain using Ansys, aiming for a beverage temperature between 2°C to 5°C. The resulting outlet temperature was 4.79°C, and the turbulent kinetic energy graphs and tables indicated sufficient mixing of the two fluids. To enhance this mixing further, modifications such as varying the mass flow rates of the fluids and optimizing the pipe's internal surface roughness in the middle section can be made to induce increased turbulent flow. The application of Ansys Fluent provided valuable insights into the interplay between fluid mechanics and computational fluid dynamics, essential for achieving the designated objectives. This interaction not only met the established goals but also suggested possible improvements to the pipe design for increased efficiency, illustrating the practical utility of theoretical fluid dynamics in optimizing real-world fluid interactions and design solutions.