CFD Analysis of Plate Heat Exchanger Using CuO And SiO_2

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Abstract- *In this paper Heat transfer and fluid flow in a single pass counter flow chevron corrugated-plates plate heat exchanger considering nanofluids (SiO2 and CuO) as homogeneous mixtures has been presented using the CFD software, ANSYS FLUENT. The required thermo physical properties of the nanofluid have been taken from literature and used in CFD Model. Individual optimum concentration of Silicon dioxide/water and copper oxide/water nanofluids yields maximum heat transfer improvement with regards to the temperature, pressure and velocity fields. The results of CFD analysis of CuO and SiO2 were compared with Common fluid Water in order to verify the accuracy of the homogeneous model. Analysis can be performed to predict the plate heat exchanger performance with reasonable accuracy. SiO2/water gives better heat transfer performance compared to CuO/water. CFD Analysis shows that corrugation pattern of the plate develops turbulence and vortices of fluid which results in high heat transfer rates.*

I. INTRODUCTION

Plate heat exchangers (PHEs) were introduced meet the hygienic demands of the dairy industry and are still the most popular heat transfer devices widely used in many engineering applications because of their several advantages such as small size and weight, high thermal efficiency, suitability in hygienic applications, flexibility and ease of sanitation as well as their superior thermal performance compared to other types of compact heat exchangers. Innovative heat transfer fluids with suspended nanometer-sized solid particles are called ‘nanofluids’, Plate heat exchangers (PHEs) are not a new concept or technology. One of the first patents was issued in 1890 to Langem and Hundhanssen, a German company. In the past, this type of exchanger has been successfully used in industries such as dairy, process, paper/pulp, and heating, ventilating, and air conditioning (HVAC). The main purpose of this article is to direct potential re-searchers to the subject of PHE, because current industries lack fundamental information about them. These types of evaporators are being used in the heating, ventilating, air conditioning, and refrigeration (HVAC&R) industry on a regular basis, yet there is no guidance whatsoever. The objective here is to present the status of industrial practice and methods after considering years of fieldwork and “real world” data.

Early usage of the PHE was in the dairy industry, but innovative designs and improvements in its mechanical integrity and sealing aspects allowed application into new areas. These developments included several unique plate designs and complicated stamping techniques. Plates with high and low chevron angles began to be used in mixed configurations, which eventually resulted in a single mixed chevron plate. With the advent of fast computers, one could precisely distribute different chevron patterns in order to optimize the surface area at minimum pumping power.

Since plate exchangers use gaskets for sealing, the air conditioning and refrigeration industry did not readily adopt this technology due to concerns over leakage. However, the industry was aware of the extraordinary performance and compactness of PHEs. With the advent of the ozone-depletion issue in the mid-1980s, some companies started seriously considering the introduction of plate exchangers because their compact-ness would result in a low refrigerant charge. Obviously, a low charge meant lower environmental impact and lower inventory costs. The higher thermal efficiency of these exchangers allowed a system to operate at closer approach temperatures than did shell and tube exchangers, which would result in energy savings.of 1223K.

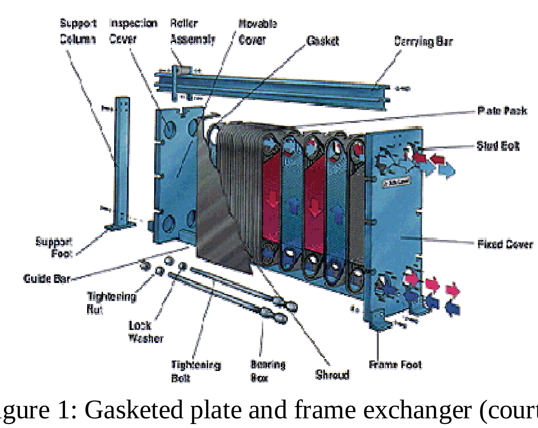

Figure 1: Gasketed plate and frame exchanger (courtesy Mueller).

Pantzali et al. [1] investigated experimentally the efficacy of nanofluids as coolants in a commercial herringbone-type PHE.

Pantzali et al. [2] studied numerically and experimentally the effects of nanofluids on volumetric flow rate of nanofluid is lower than that of water causing lower pressure drop and resulting in less pumping power.

Roetzel et al. [3] experimentally evaluated thermal parameters of plate type heat exchangers using a temperature oscillation technique, and a mathematical model was used to calculate heat transfer coefficient characterized by Number of Transfer Units and Peclet Number.

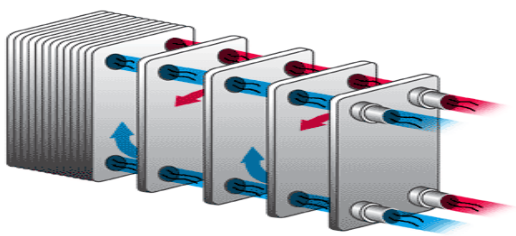

Figure 2: Plate Heat Exchanger

II. GEOMETRY OF THE MODEL

The computer aided design (CAD) geometry for all models was modeled in SOLID WORKS and simulations were carried out in ANSYS FLUENT.

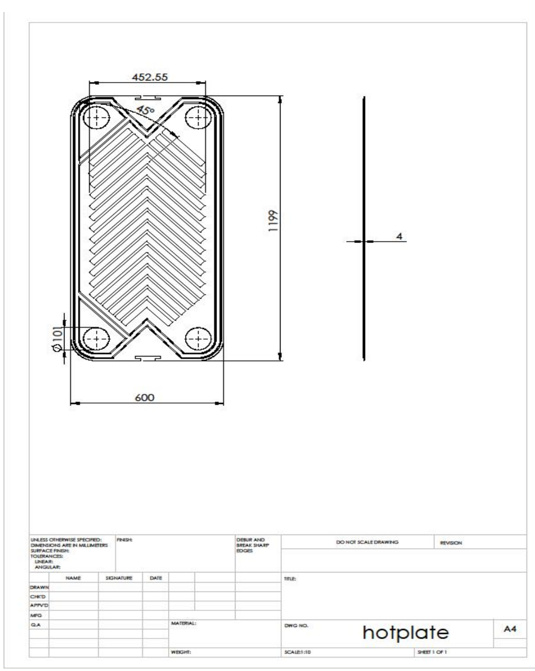

Figure 3: Geometry of Plate Heat Exchanger

Boundary conditions

Different boundary conditions were applied for different zones. Since it is a tube-in-tube heat exchanger, there are two inlets and two outlets. The inlets were defined as velocity inlets and outlets were defined as pressure outlets. The inlet velocity of the cold fluid was kept constant i.e. 2.5m/s, whereas velocity of hot fluid was varied from 1m/s to 2m/s for different experiments. The outlet pressures were kept default i.e. atmospheric pressure. The hot fluid temperature at inlet was 400K and cold fluid inlet temperature was kept 293K. The other wall conditions were defined accordingly. The surrounding air temperature was kept 270C and convective heat transfer coefficient between outer wall and surrounding was 2500W/m2K.

III. MESHING

In free meshing, a relatively coarser mesh is generated. It contains both tetrahedral and hexahedral cells having triangular and quadrilateral faces at the boundaries. Later, a fine mesh is generated using edge sizing. In this, the edges and regions of high pressure and temperature gradients are finely meshed.

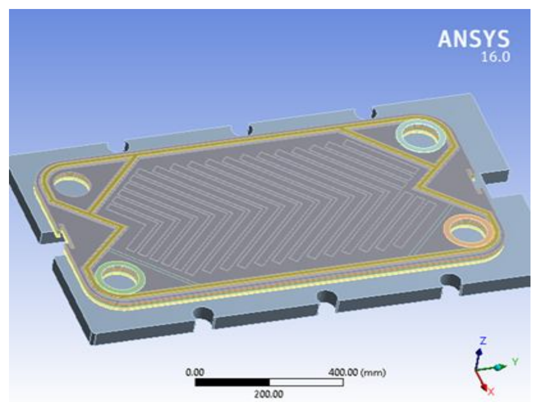

Figure 4: Mesh

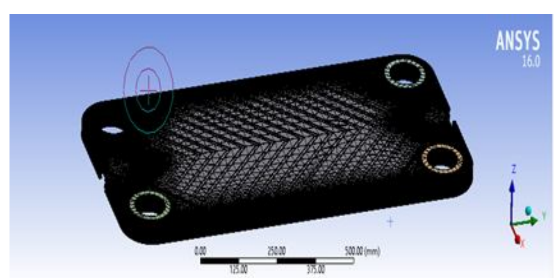

Figure 5: Final Mesh with tetrahedron elements

IV. RESULTS

Temperature Distribution of Plate Heat Exchanger with Water

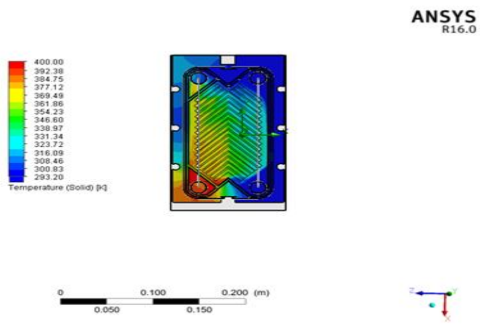

Figure 6: Temperature Contour with Water

Pressure & Velocity Distribution of Plate Heat Exchanger with Cold Fluid

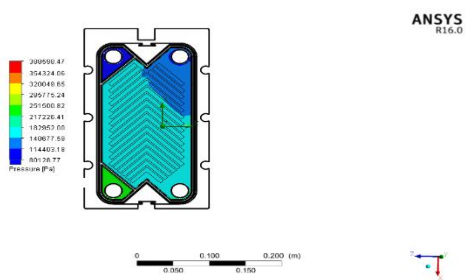

Figure 7: Pressure Distribution of the Fluids along the plate heat exchanger using Cold Fluids

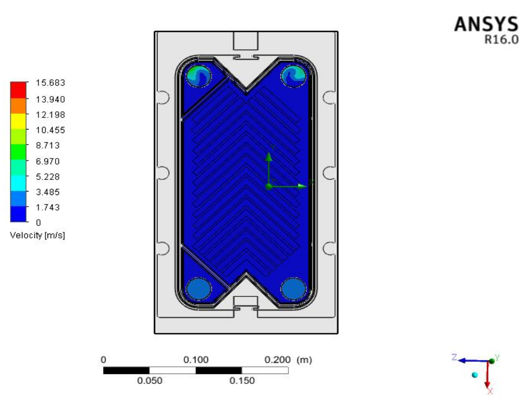

Figure 8: Velocity Distribution of the Fluids along the plate heat exchanger using Cold Fluids

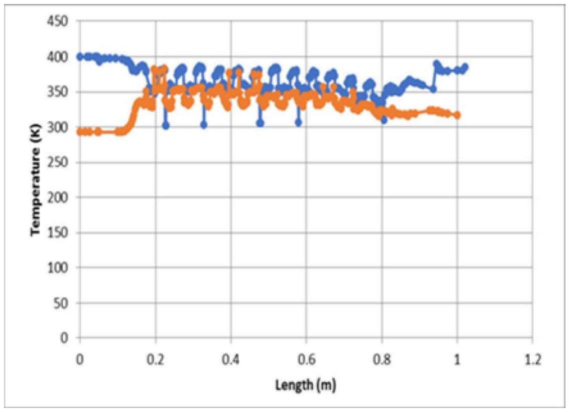

Figure 9: Temperature along the length of the plate heat exchanger using water as cold fluid

The above figure represents The temperature Distribution on the Fluid in the plate heat exchanger from the plot we can say that x-axis represents the length in meters of the plate heat exchanger vertically and the y-axis represents Temperature in Kelvin The Curves in the plots blue color curve indicates temperature distribution of hot fluid (water) and yellow color curve indicates temperature distribution of Cold Fluid (water) and we can observe from the graph the hot fluid temperature is decreasing and cold fluid temperature is increasing Due to hybrid nature of cold fluid

Case I: Results of plate heat Exchanger with SiO_2 nanofluid

A vortex crosses the pressure opening Boundary Condition: Environment Pressure 1; Inlet flow/outlet flow=0.144563 Boundary Condition: Environment Pressure 2; Inlet flow/outlet flow=0.0405056

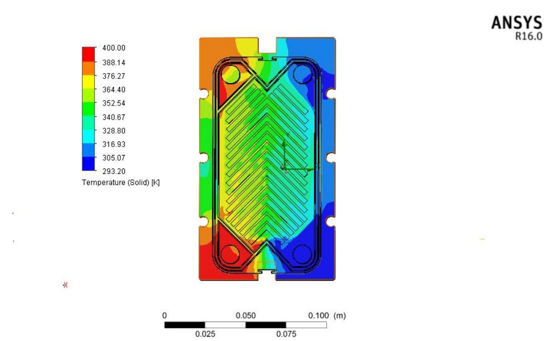

Figure 10: Temperature Distribution on the plate heat exchanger using SiO_2 nanofluid

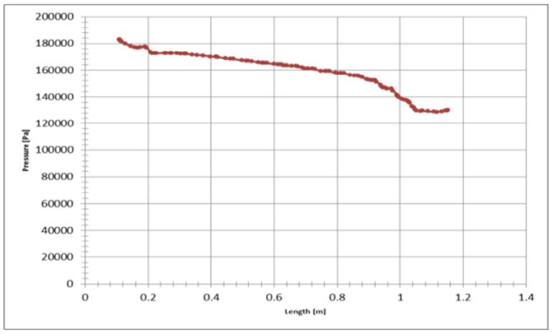

Figure 11: Pressure along the length of plate with SiO_2 nanofluid

The figure 11 represents The static Pressure Distribution on the Fluid in the plate heat exchanger from the plot we can say that x-axis represents the length in meters of the plate heat exchanger vertically and the y-axis represents pressure in Pascal the decrease in the plot is because the velocity in the plate area is higher because of constantly converting area and volume

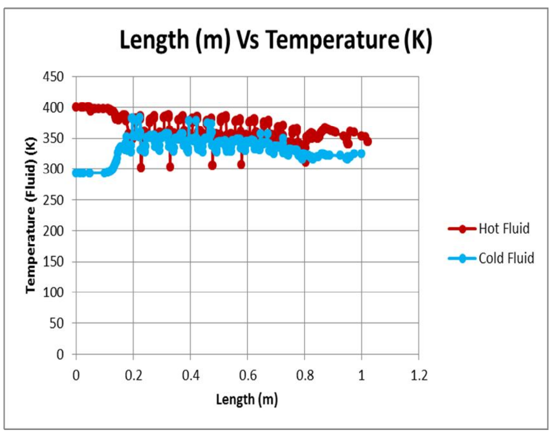

Figure 12: Temperature along the length of the plate heat exchanger using SiO_2 nanofluid

The figure 12 represents The temperature Distribution on the Fluid in the plate heat exchanger from the plot we can say that x-axis represents the length in meters of the plate heat exchanger vertically and the y-axis represents Temperature in Kelvin The Curves in the plots indicate Hot Fluid and Cold fluid i.e. in this case cold fluid is SiO2 we can observe from the graph the hot fluid temperature is decreasing and cold fluid temperature is increasing Due to hybrid nature of cold fluid i.e., nano fluid the higher thermal conductivity and due to the conduction heat transfer and non-linearity in the plates result in the above plot

Case II: Results of plate heat Exchanger with CuO nanofluid

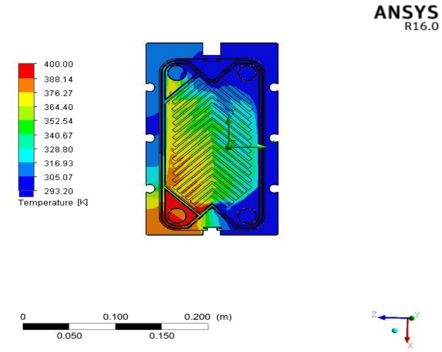

Fig 13: Temperature Distribution on the plate heat exchanger using CuO nanofluid

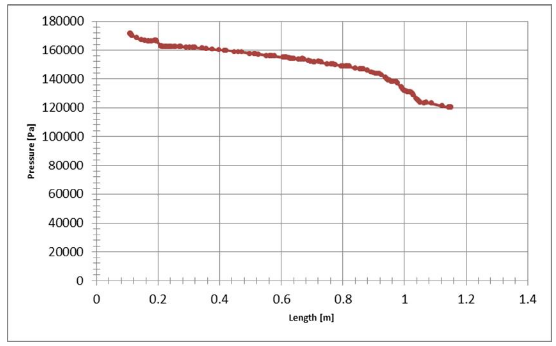

Figure 14: Pressure along the length of plate with nanofluids CuO nanofluid

The figure 14 represents The static Pressure Distribution on the Fluid in the plate heat exchanger from the plot we can say that x-axis represents the length in meters of the plate heat exchanger vertically and the y-axis represents pressure in Pascal the decrease in the plot is because the velocity in the plate area is higher because of constantly converting area and volume.

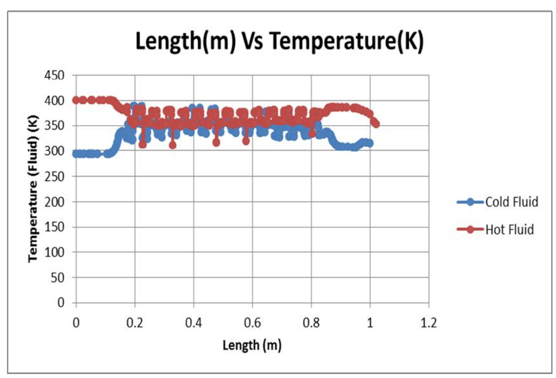

Figure 15: Temperature along the length of the plate heat exchanger using CuO nanofluid

The figure 15 represents The temperature Distribution on the Fluid in the plate heat exchanger from the plot we can say that x-axis represents the length in meters of the plate heat exchanger vertically and the y-axis represents Temperature in Kelvin The Curves in the plots indicate Hot

Fluid and Cold fluid i.e. in this case cold fluid is CuO we can observe from the graph the hot fluid temperature is decreasing and cold fluid temperature is increasing Due to hybrid nature of cold fluid i.e., nanofluid the Ribbed nature of the current volume and the thermal conductivity result in the above plot.

PLOTS COMPARISON

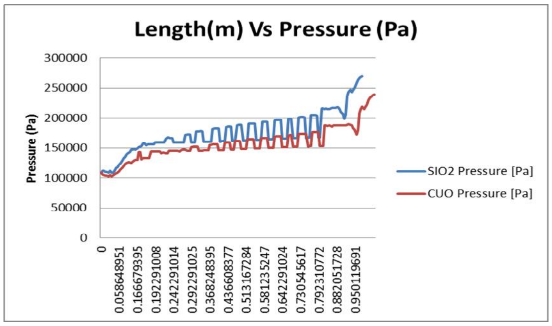

Figure 16: Pressure comparison along length of plate with nanofluids

The figure 16 represents the Comparison of Pressure Distribution Vs. length of the cold fluid i.e., SiO_2 and the CuO the above pressure plot indicates that the slight variation in pressure i.e. increase in pressure when SiO_2 is used than CuO although the same volumetric concentrations of the nanofluid is used the variable density levels in both fluids results in above plot.

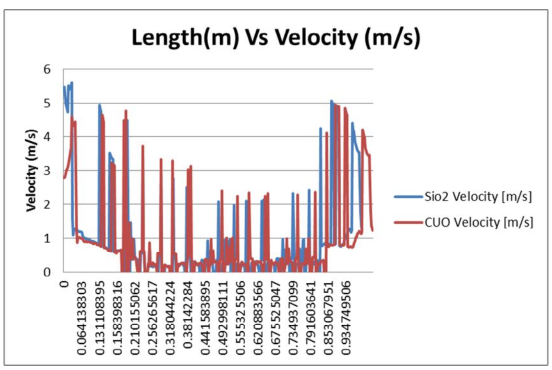

Figure 17: Velocity comparison along the length of the plate with nanofluids

The figure 17 represents the Comparison of Velocity Distribution Vs. length of the cold fluid i.e., SiO_2 and the CuO the above Velocity plot indicates that the slight variation in Velocity i.e. increase in Velocity when SiO_2 is used than CuO although the same volumetric concentrations of the nanofluid is used the nonlinear formation of volume and increase and decrease of the path where fluid flows results in such type of fluid behaviour.

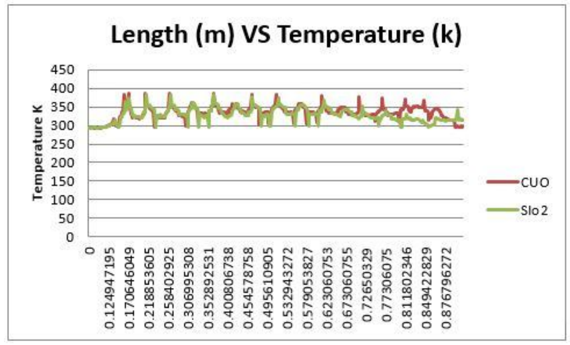

Figure 18: Temperature Distribution along the length of the plate with cold fluid

The figure 18 represents the cold fluid Temperature (k) in y axis and Length (m) of the plate in X-axis From the graph, we can say that the wavy nature of the graph is because the rib channel temperature varies with both fluid i.e., SiO_2 or CuO and solid plate the end temperature i.e. the outlet temperature of the hot fluid is decreasing with SiO_2 nanofluid when compared to the

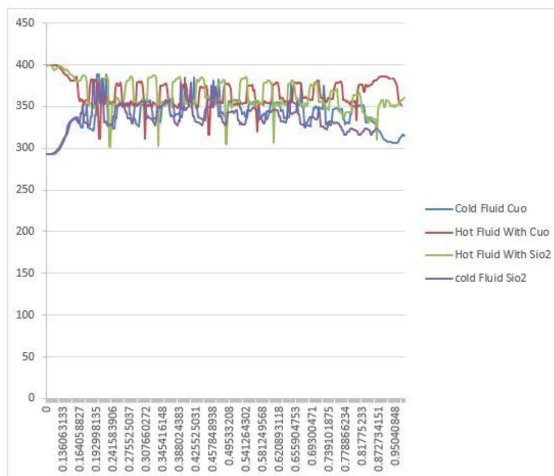

Figure 19: Temperature Distribution of Cold Fluid and Hot Fluid in CuO and SiO_2 along the length of the plate

The figure 19 comparison graph is between hot fluid in both the cases and Cold fluid i.e., Nano fluid SiO_2 and CuO the x-axis represents length of the plate from inlet to outlet and the y axis represents the temperature (k) of the both hot fluid and cold fluid in both cases from the plot we can say that the hot fluid temperature is decreasing more in SiO_2 case when compared with CuO and the cold fluid temperature is i.e., SiO_2 temperature is increasing more when compared with CuO

Comparison of Cold Fluid Properties between Sio_2 CuO and Water

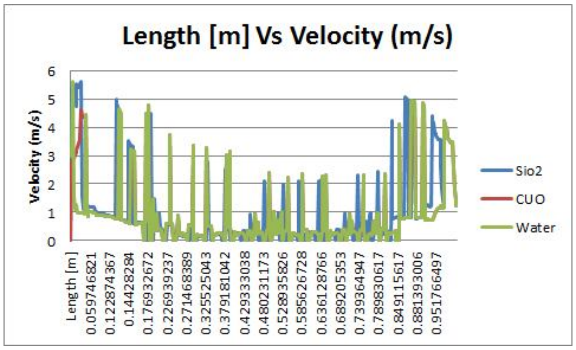

Figure 20: Velocity Distribution along the plate with Cold Fluid as Water, SiO_2 and CuO

The figure 20 comparison plot represents the velocity Distribution of the both nanofluids with water we can say from the plot the x-axis represents length of the plate i.e., inlet to outlet and y-axis represents Velocity (m/s) we can observe from the graph the distribution of the water and CuO is almost same but when it comes to the SiO_2 there is slight increase in velocity due to wavy nature of the volume we have designed.

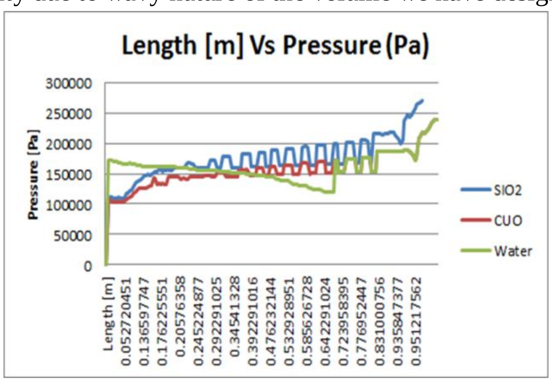

Figure 21: Pressure Distribution along The plate With SiO_2, CuO and Water as Cold Fluid

The figure 21 comparison plot represents the velocity Distribution of the both nanofluids with water i.e., SiO_2 and the CuO the above pressure plot indicates that the slight variation in pressure i.e. increase in pressure when SiO_2 is used than CuO although the same volumetric concentrations of the nanofluid is used the variable density levels in both fluids results in above plot

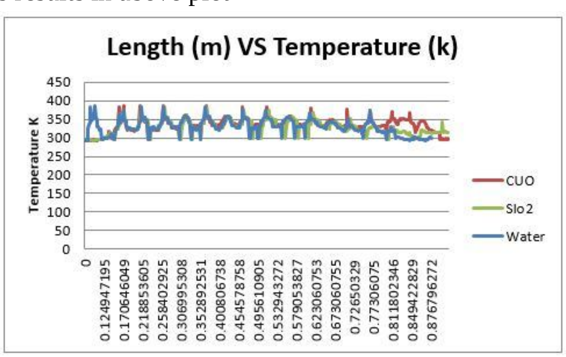

Figure 22: Temperature Distribution along The plate With SiO_2, CuO and Water as Cold Fluid.

The figure 22 comparison plot represents the velocity Distribution of the both Nano fluids with water Temperature (K) in y axis and Length (m) of the plate in X-axis From the graph, we can say that the wavy nature of the graph is because the rib channel temperature varies with both fluid i.e., water SiO_2 or CuO and solid plate the end temperature i.e., the outlet temperature of the hot fluid is decreasing with SiO_2 nanofluid when compared to the CuO and water.

V. CONCLUSION

In the present study, the heat transfer performance and fluid flow characteristics of various Nano fluids flowing in a counter flow PHE have been presented. The corrugated chevron PHE has been Analyzed, and the 3-D temperature and velocity fields have been obtained through CFD based analysis has been used by considering Nanofluids as homogeneous mixture. Analyzed results for various flow rates and particle volume concentrations. The significant conclusions derived from this work are highlighted below.

- Various Nano fluids have different optimum volume concentration in which the heat transfer characteristics show the maximum enhancement.
- A realistic but computationally less intensive geometrical model for plate heat exchanger was developed and testing of this model with water and Nano fluid as coolants was done.
- CFD results, which confirm that homogeneous mixture simulation can be effectively used to predict the Nano fluid, cooled plate heat exchanger.
- The Nano fluid is beneficial if and only if the increase in their thermal conductivity is increases despite undesirable effect of increase in viscosity.
- The rib pattern of the plate develops turbulence of fluid, which results in high heat transfer rates.
- The highest temperature appears around the upper port while the lowest temperature appears in the cold fluid inflow around the lower port, temperature gradient is larger, and effect of heat transfer is more satisfactory. In the present study SiO_2 and CuO is taken as the nanofluid concentration which SiO_2 processes the most heat transfer which has adequately shown in the graphs that are presented below

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