Experimental and Numerical Analysis of Solar Water Heater

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ABSTRACT

Increasing energy demand around the world necessitates the use of carbon-neutral alternatives that are readily available and have low or no emissions of greenhouse gases. The sun's energy is limitless and cost-free. Using a solar water heater, we may be able to meet our commercial & domestic heating needs. An investigation into the viability of 3 different solar water heater design concepts is currently underway. The in-line tube plate, the tube above plate, and the tube below plate, arrangement are the three possible configurations. The Creo parametric design programme was used to create the CAD model of the solar water heater, and the ANSYS CFX software was used for the CFD study. The conventional k-epsilon turbulence model is utilised for analysis of turbulence. According to the solar intensity on the collection plate of the water heater, the thermal flux is measured at 12 PM and 3 PM, respectively, and is analysed. Studies comparing the efficiency & temperature rise of 3 design configurations are provided. According to CFD analysis, the experimental results are very similar.

Keyword: - *ANSYS CFX, CFD, Solar Water Heater*

1. Introduction-

The nuclear fusion taking place in near perfectly shaped spherical sun produces enormous amount of energy in form of heat, light, radiation. All life forms on earth are supported by this energy, and also affects earth's climatic conditions [1][2]. Sun comprises hydrogen (73%) with carbon, neon[3] and is located at 8mins light distance from earth[4]. The sun's distance is 149600000 Km from earth, and celestial axis is at 23°27', Plus or minus this amount, the declination angle varies[6][7].

1.1 Heat exchange phenomena

The transfer of thermal energy across a clearly defined border enclosing a thermodynamic system is what is known as "transfer of heat" in physics. The amount of work that a system can do is measured by its thermodynamic free energy. To calculate an enthalpy, use the thermodynamic potential symbol "H," which represents the product of the system's internal energy (U) and the pressure-volume product (PV). Energy, work, or heat can all be measured in joules. When energy is transferred between two objects, it is called thermal conduction. When energy is transferred between an object and its environment, it is called thermal convection. When energy is transferred between an object and its environment, it is called thermal radiation.

1.2 Solar Water Heating

It is referred to as solar water heating when sunlight is converted into heat by means of a solar thermal collector (SWH). The energy transfer mechanisms previously discussed are used to convert light into electricity in this way (Radiation, convection, conduction). - Components of a solar water heating system are numerous. To heat a liquid, solar thermal collectors gather and store solar-generated heat. Flowing water is the job of the pump, which keeps it moving. a tank: this holds the heated water from the solar collectors and is normally insulated to keep the heat in. When water leaves a solar collector, the controller keeps track of how much warmer or colder it is than water in a storage tank near the heat exchanger. A temperature differential of 3–5°C more or lower than that sets the controller to start and stop the pump, depending on how warm the collected water is compared to the tank water. This stops the pump from turning on and off excessively and guarantees that the stored water always receives heat while it functions

2. Objective

There are 3 alternative ways to design a solar heating system's tubing and plate. Tube above plate, tube in line, and tube under plate with plate are the three alternatives for design. ' ANSYS CFX software is used to conduct both experimental and numerical studies. The detailed objectives are as follows:

1> Fabrication of solar water heater has 3 design configurations:
   a. Tube over plate design
   b. Tube below plate design
   c. Tube in line with plate design
2> Experimental testing of 3 design configurations stated above.
3> The thermal efficiency calculation of all the 3 designs from outlet temperature and inlet temperatures.

2.1 Stages of Analysis using CFD

2.1 CAD Modeling:

A sketch-based parametric 3d modelling application called Creo 2.0 was used to create the CAD models for the solar water heaters. As depicted in the following diagram, the CAD model is made up of a box, glass, copper plate and copper tube.

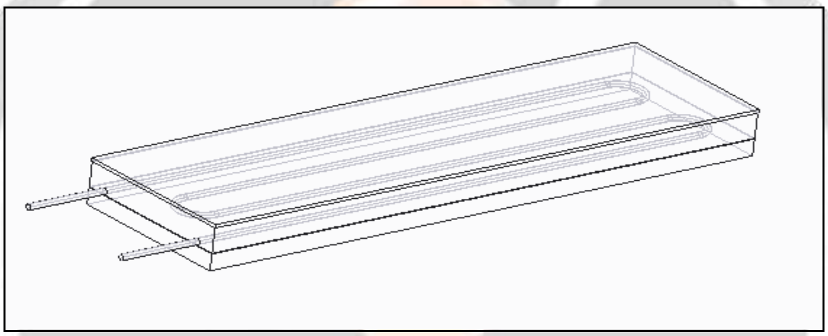

Figure 1: Solar water heater CAD model(copper plate below copper tube)

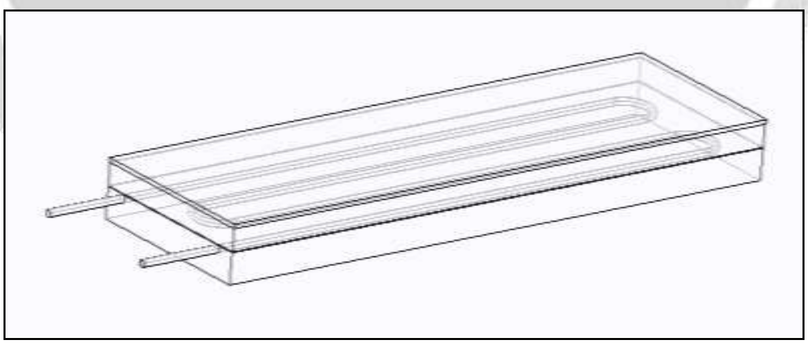

Figure 2: Solar water heater CAD model (copper plate above copper tube)

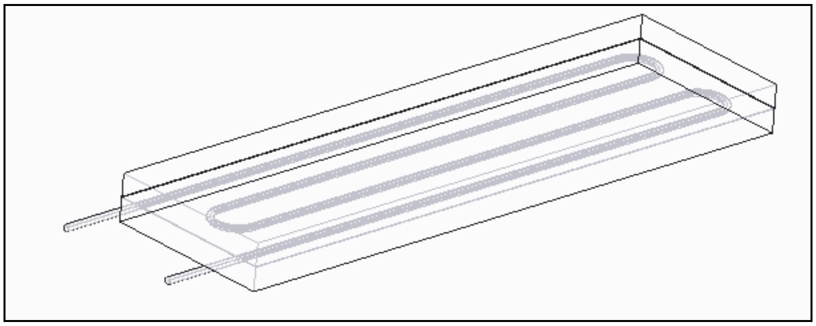

Figure 3: Solar water heater CAD model (copper plate in level with copper tube)

2.2 Sub Loads and Boundary Conditions

Model loads include creating radiation models, specifying 400W/m2 and 600W/m2 fluxes of heat. In order to delineate the top portion, a piece of glass was used. The air and water domains are used to determine the rest of geometry. At.002Kg/s, the water entry rate is established, and the outlet pressure level is set to zero.

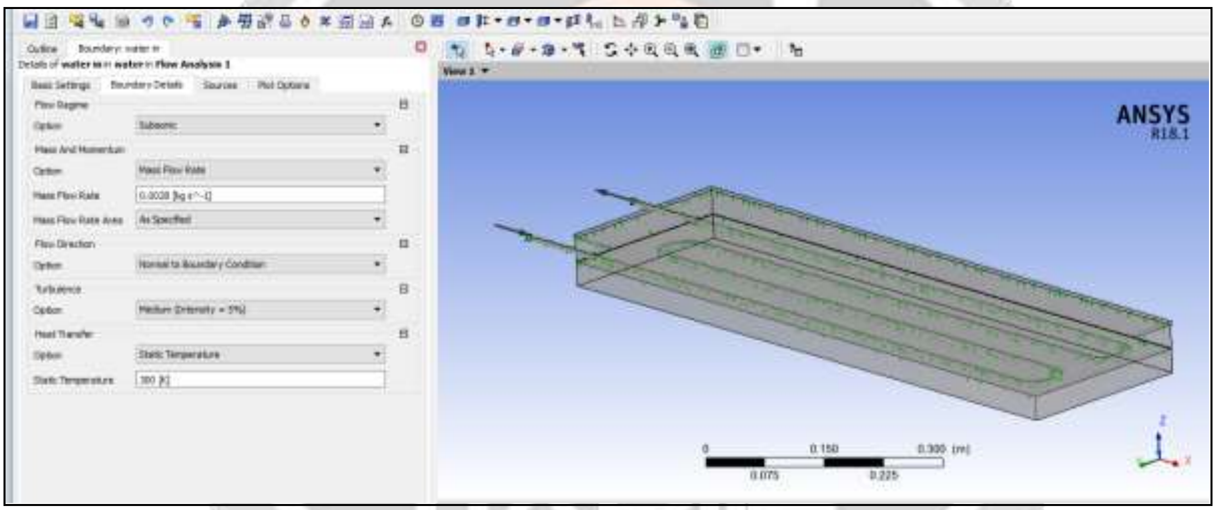

Figure4: Inlet/Outlet boundary conditions

1.3 Experimental setup

1> Collector inlet and outlet points are connected to hose coupling by 10mm inner diameter.
2> One side of both hose couplings is connected to a U-tube manometer. Minimum reading of manometer is 1mm Hg.
3> The third side of hose coupling of inlet is connected to fluid inlet control switch with the help of pipes.
4> And the third side of hose coupling of outlet side is connected to pipe, which is outlet of fluid point.

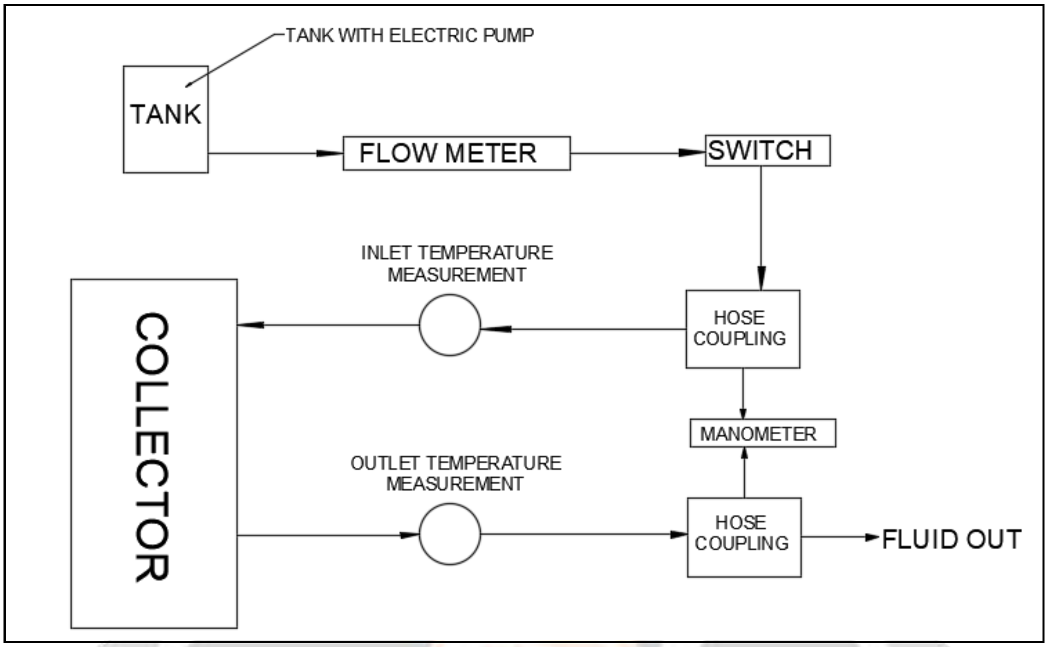

Figure5: Layout of experimental setup

- Inlet/Outlet fluid temperature is measured
- Ambient air temperature is measured
- Plate temperature at mid of plate is measured
- Pressure difference is measured
- Mass flow rate is measured and kept constant

5> The cold-water storage tank is maintained at 27^0C with the help of covering and mixing some ice cubes. Water is stirred thoroughly.

6> An electric water pump is connected to tank for maintaining mass flow rate with the help of digital thermometer with minimum reading of 0.1^0C with error of $\pm 0.5^0$C in reading. This thermometer gives correct reading in 1 minute of precision.

7> A flowmeter is added to read mass flow rate of this open cycle system. It has minimum reading of 0.1 LPH (liter per hour). It is installed between water pump and valve switch. Valve switch is used to increase or decrease flow rate of the system.

8> Temperature and pressure are measured in average time of 10 to 15min as prescribed by Indian standards.

9> The inclination of $\beta = 4.001^0$ is theirs in collector.

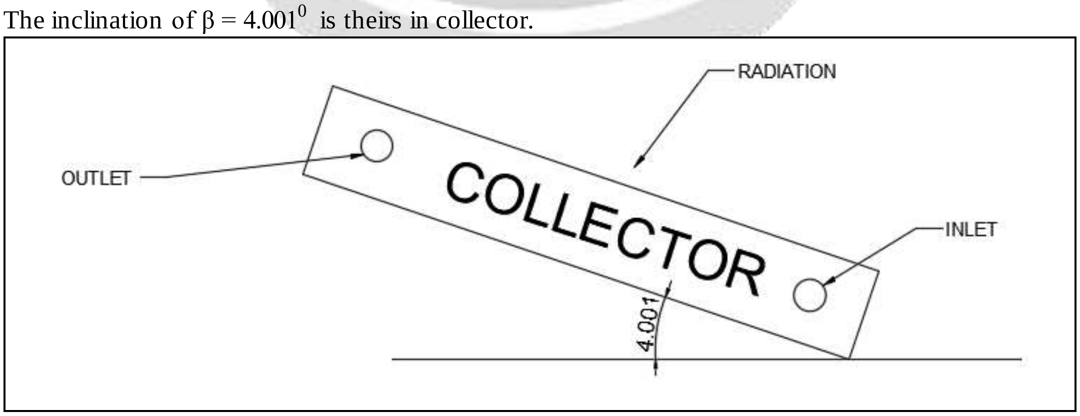

Figure 6: Collector Inclination

3. Result

Calculation of the temperature outlet and absorbed heat energy is carried out using CFD simulation on a solar water heater running on ANSYS CFX software. The CFD simulation is run between 12 p.m. and 3 p.m. 1037.80W/m^2 and 774.64W/m^2 are the heat fluxes, respectively.

3.1 Solar Water Heater at 774.64W (Bottom Plate Configuration)

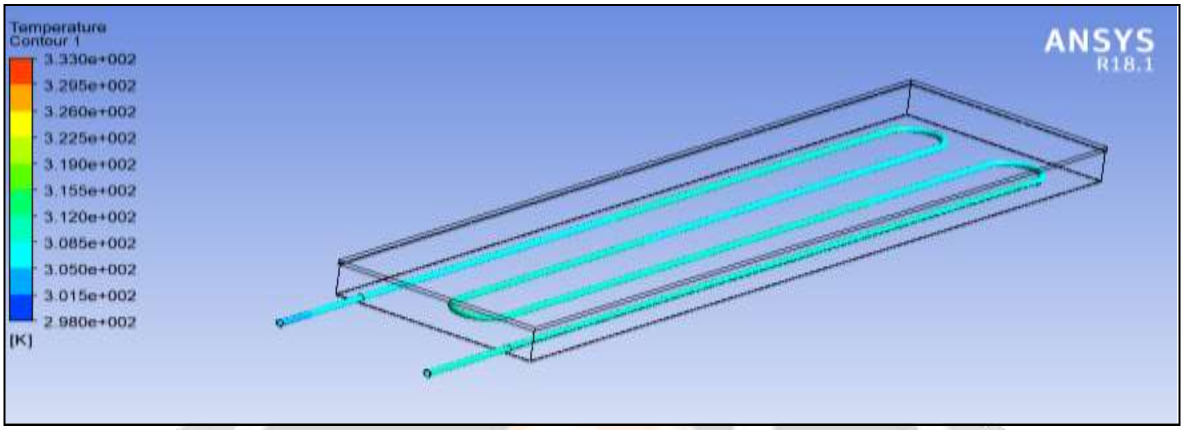

Figure 7: Solar water heater temperature plot at 774.64 watts (bottom plate configuration)

Above is a temperature map showing the tube's maximum temperature, which is 333K in magnitude. Near the inlet, temperatures are the lowest; as we travel toward the collector tube, they rise.

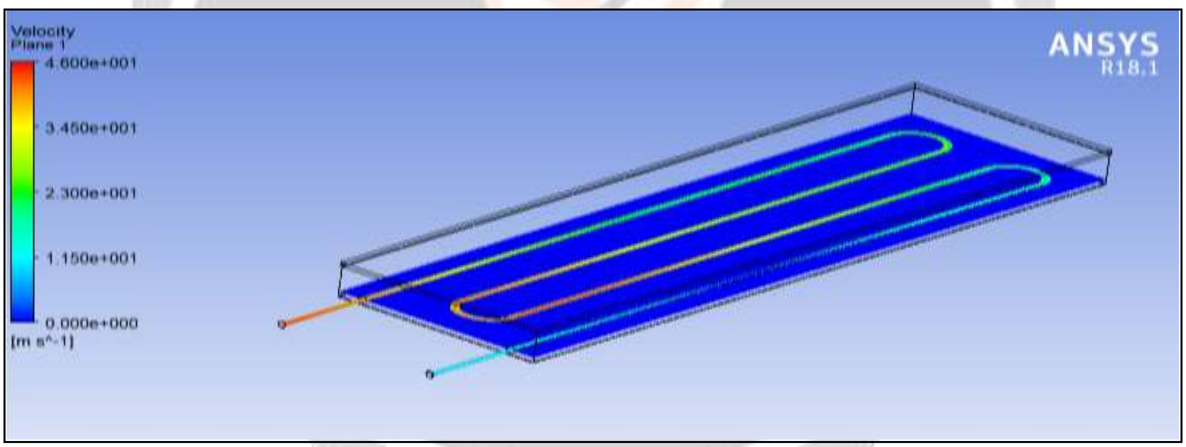

Figure 8: Solar water heater velocity map at 774.64W (bottom plate configuration)

Figure 6.2 shows a velocity curve that indicates a higher magnitude of velocity near the pipe's entrance and at its U-shape bend of magnitude 46m/s. The green color pattern shows that the other regions have a lower velocity magnitude of 23m/s.

3.2 Solar Water Heater at 1037.80W (Bottom Plate Configuration)

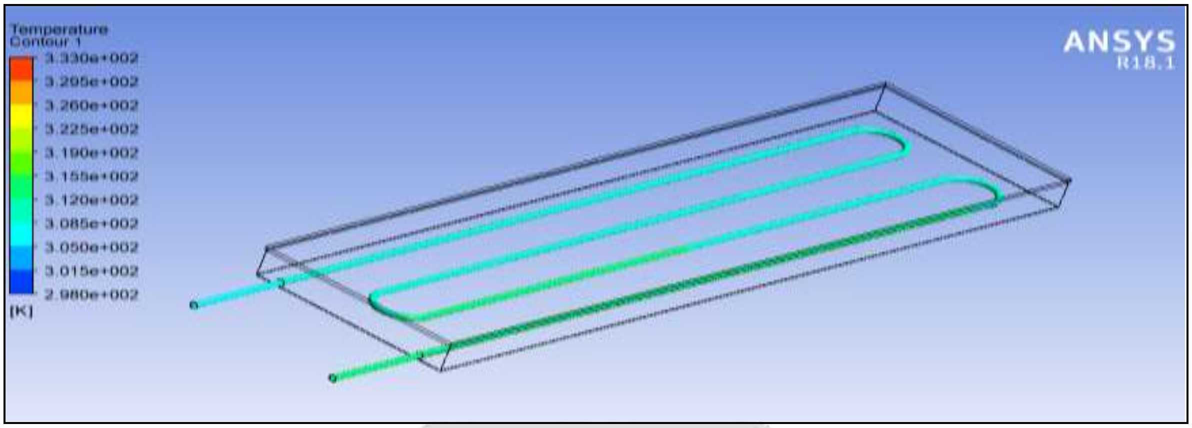

Figure 9: Solar water heater temperature plot at 1037.80 watts (bottom plate configuration)

As indicated in the graph above, the tube's maximum temperature at the outlet portion was measured to be 333K. Near the inlet, temperatures are the lowest; as we travel toward the collector tube, they rise.

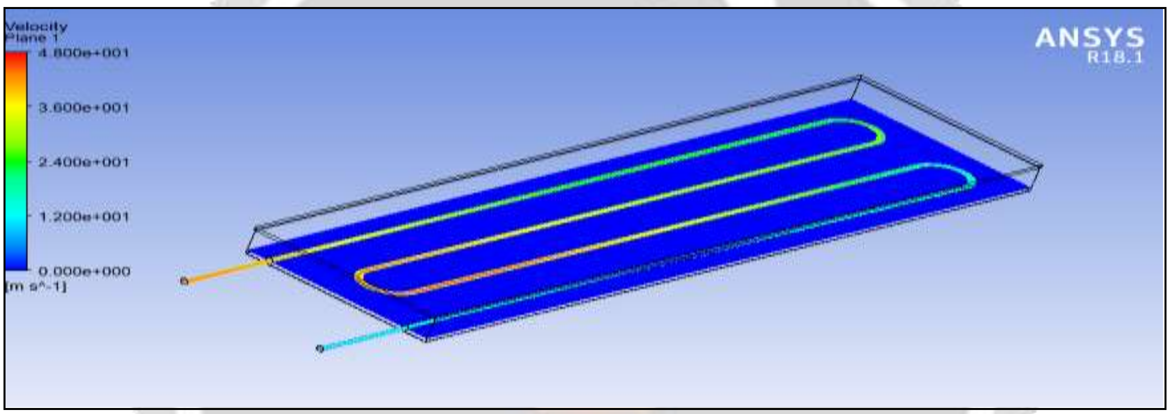

Figure 10: Solar water heater velocity map at 1037.80W (bottom plate configuration)

There will be a 46m/s velocity near the intake and at the U-shaped bend of a pipe, as seen by the red color zone in figure 6.4 above, according to the velocity map above. Using the green color plot, we can see that the other regions have a lower velocity magnitude of 24m/s.

3.3 Solar Water Heater at 774.64W (Top Plate Configuration)

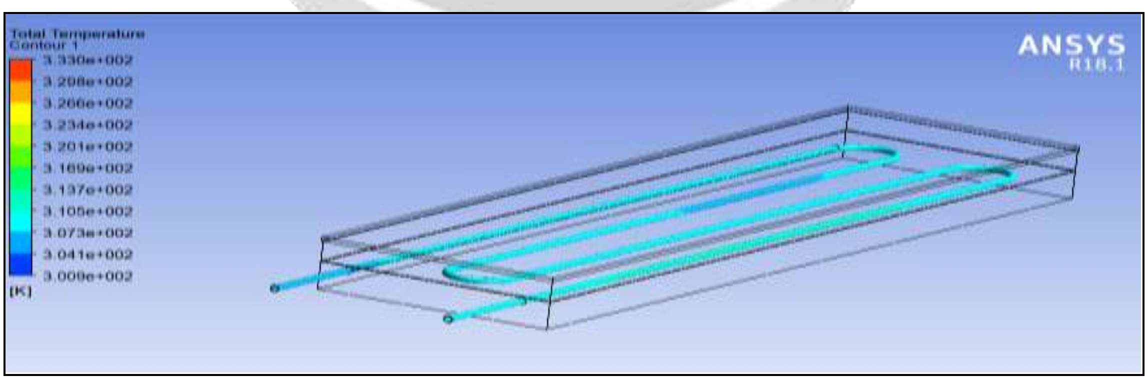

Figure 11: Solar water heater temperature plot at 774.64 watts (Top plate configuration)

As indicated in the graph above, the tube's maximum temperature at the outlet portion was measured to be 333K. Near the inlet, temperatures are the lowest; as we travel toward the collector tube, they rise.

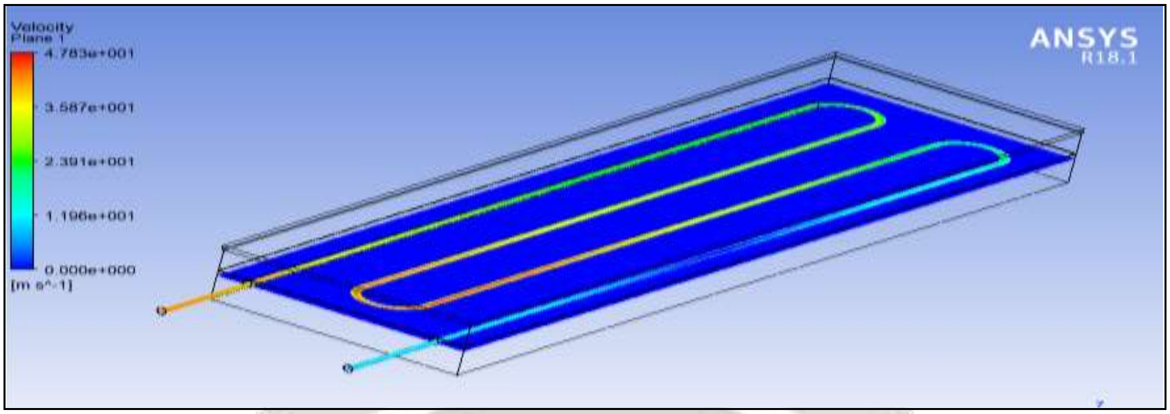

Figure 12: Solar water heater velocity map at 774.64W (Top plate configuration)

The red zone in figure 6.6 above indicates where the velocity map forecasts a greater magnitude of 47.8 m/s near the intake and at the U-shaped bend of the pipe. Using the green color plot, we can see that 24 m/s is the maximum velocity in other areas.

4. CONCLUSIONS

3 alternative design configurations, including, tube below plate,in-line tube plate, and tube above plate are used in the experimental & CFD analysis of the solar water heater. The instantaneous efficiency, temperature plot and velocity plots are generated. The CFD (Computational Fluid Dynamics) has offers a useful tool for analysing the solar water heater's heat transfer properties, saving time and money in the process.

The detailed findings are as follows:

1> For all 3 of the solar water heater's design configurations, the K-epsilon turbulence model provided reliable fluid flow predictions. Comparing the turbulence model to other models, it requires less calculation time.
2> Inline tube configurations have the lowest solar water heater efficiency, while tube below plate configurations has the highest efficiency.
3> Inline tube configuration results in the lowest temperature rise, while tube below plate configuration results in the highest temperature rise.

6. REFERENCES

[1] M. Woolfson, “The origin and evolution of the solar system,” *Astron. Geophys.*, 2000, doi: 10.1046/j.1468-4004.2000.00012.x.

[2] A. Simon, *The Real Science Behind the X-Files: Microbes, meteorites, and mutants*. New York: simon & schuster, 2001.

[3] S. Basu and H. M. Antia, “Helioseismology and solar abundances,” *Physics Reports*. 2008, doi: 10.1016/j.physrep.2007.12.002.

[4] D. R. Williams, “Sun Fact Sheet,” *BibSonomy Lesezeichen und Publ. teilen - blau!*, 2013, [Online]. Available: https://www.bibsonomy.org/bibtex/5fb2612cefd9f288a0b4554c5c4a2b3f?lang=de.

[5] “Relative Sun sizes.” .

[6] D. D. M. and P. K. Seidelmann, *TIME – From Earth Rotation to Atomic Physics*. 2002.

[7] J. Meeus, “Astronomical Algorithms (2nd Edition Errata),” *Astron. Algorithms*, 1991.

[8] "Earth's orbit." https://fr.wikipedia.org/wiki/Orbite_de_la_Terre.

[9] J. Priestley, "An account of further discoveries in air," *Philos. Trans. R. Soc. London*, 1775.

[10] L. R.Brown, "Earth Policy Institute." http://www.alternet.org/environment/sunlight-strikingearths-surface-just-one-hour-delivers-enough-energy-power-world.

[11] Cener, "Nacional de Energías Renovables," 2020. https://www.cener.com/.

[12] D. R. Myers, "Introduction to Solar Radiation Measurements," in *Solar Radiation*, 2013.

[13] K. Mertens, "textbook-pv.org." .