CFD Analysis of differently arranged Solar Water Heater

Mukarram Haidari [1], Maneesh Dubey [2]

[1] *Student, ME, LNCT, Bhopal, MP, India*
[2] *Assistant Professo,. ME, LNCT, Bhopal, MP, India*

ABSTRACT

In the current energy scenario carbon-neutral alternatives that are readily available and have low or no emissions of greenhouse gases. The sun's energy is abundant. Using a solar water heater, we may be able to meet our commercial & domestic heating needs. An investigation into the viability of 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 program 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 utilized for analysis of turbulence. According to the solar intensity on the collection plate of the water heater, the thermal flux is measured at in afternoon, and is analyzed. Studies comparing the efficiency of 3 design configurations are provided. According to CFD analysis, the experimental results are very similar.

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

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].

There is much emphasis on solar energy to fulfill our energy requirements due to easy availability, free of charge and abundance. The simplest application of solar energy is heating of fluids for domestic or commercial purposes. For domestic applications, this form of energy can be used by incorporating solar water heaters.

The intensity of incident solar radiation on flat plate collectors are fixed due to latitude and longitudinal position of solar water heater placement. Therefore, nothing much can be done to improve the intensity of solar radiation. The design and positioning of the tube and plate, however, can be changed to increase the solar water heater's efficiency. 3 arrangements are feasible: a tube above the plate, a tube below the plate, and a tube parallel to the plate. ANSYS CFX software is used to conduct both numerical and experimental studies.

1.1 **Solar resources**

Solar power is the definitive source of natural energy, with a surface temp, of about 5500 °C. There would be no life on Earth if it weren't for the sun's vital part in the solar system's activities. Only in the 17th century did people begin to use the sun for scientific purposes. A pioneer of the convergent lens, Lavoisier used the sun's rays to liquefy iron rods located in the lens' central point. [9] Solar energy can supply enough power to power the entire planet for more than a year in a single hour, or 5000 times more than the predictable energy supply on Earth[10]..

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> All 3 designs were CFD analysed using ANSYS CFX software to find out the temperature and efficiency of the outlet.
2> Comparison of solar water heater efficiency using experimental method and numerical method.

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.

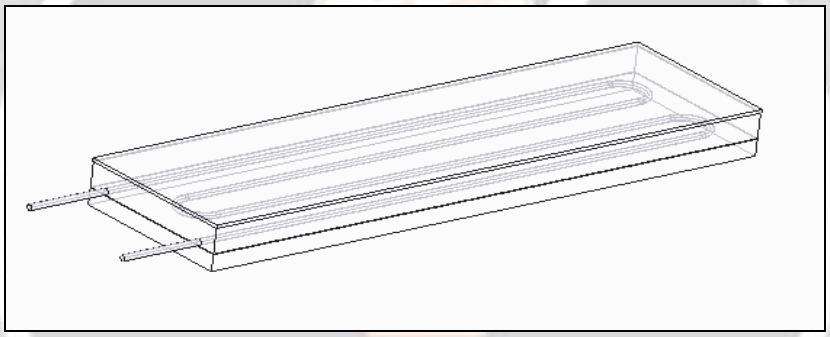

Figure 1: Solar water heater CAD model(copper plate below copper tube)

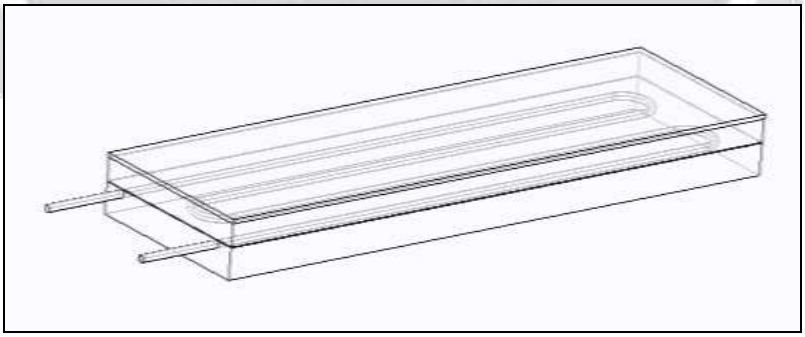

Figure 2: Solar water heater CAD model (copper plate above copper tube)

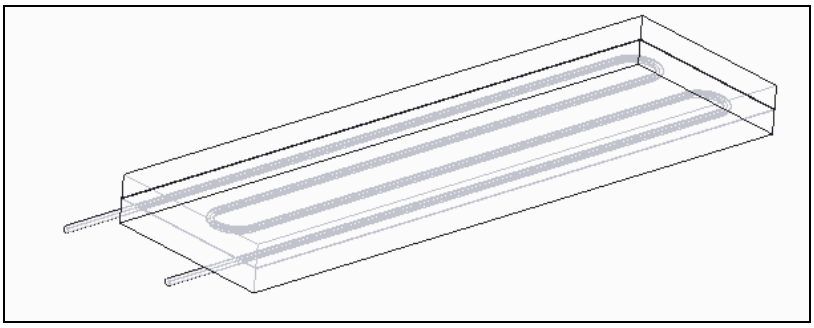

Figure 3: Solar water heater CAD model (copper plate in level with copper tube)

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.

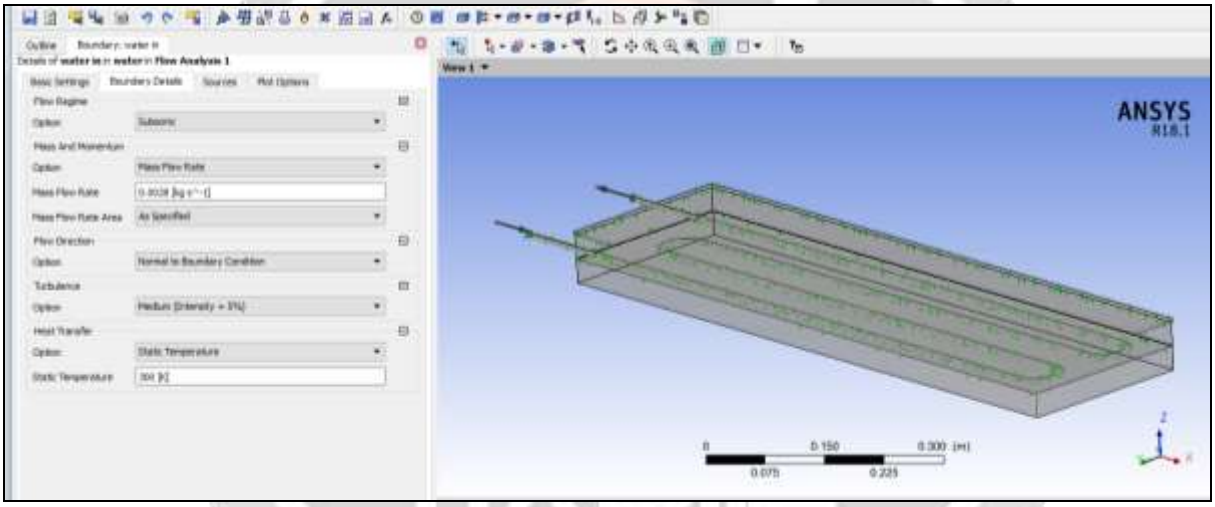

Figure4: Inlet/Outlet boundary conditions

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.

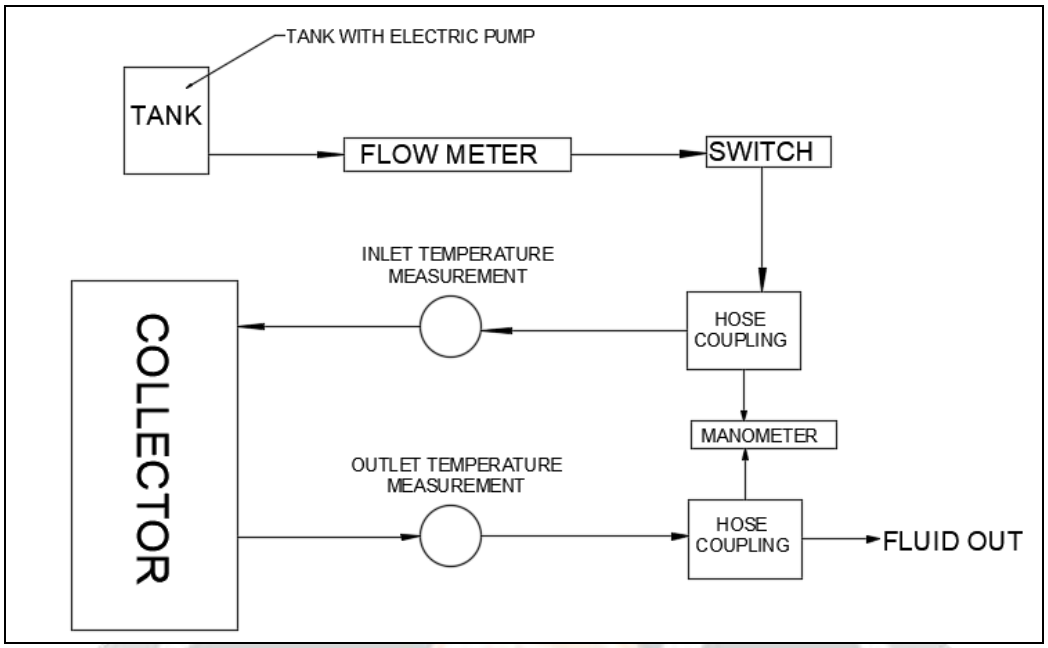

Figure5: Layout of experimental setup

- 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.

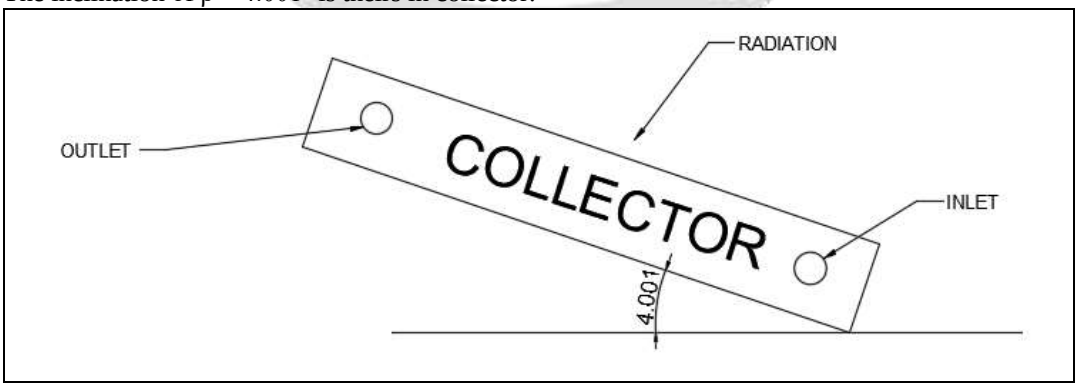

Figure 6: Collector Inclination

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.

Instantaneous Efficiency

Case	Time	ṁ	Avg C_{pw}	Avg F_R	Mean T_i	Mean T_o	Avg I_t
	12PM	0.0028	4178	0.444	300.0	303.9	1041.325
Case 1	3PM	0.0028	4178	0.368	300.0	302.5	774.430
	12PM	0.0028	4178	0.686	300.0	305.0	1041.325
Case 2	3PM	0.0028	4178	0.701	300.0	303.4	774.430
	12PM	0.0028	4178	0.412	300.0	302.8	1034.289
Case 3	3PM	0.0028	4178	0.374	300.0	301.9	774.747

Case	Time	η_i (Theoretical)	η_i (Practical)
	12PM	20.45%	15.49%
Case 1	3PM	17.63%	13.41%
	12PM	26.22%	19.75%
Case 2	3PM	23.98%	17.82%
	12PM	14.79%	11.30%
Case 3	3PM	13.39%	10.32%

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:

At 1037.80W heat flux, or around 3 PM, the 3 design combinations' maximum thermal efficiency is seen.

For all 3 solar water heater arrangements, the practical efficiency is lower than the theoretical efficiency.

When compared to practical efficiency, the numerical findings of CFD study show a nearly 20% difference of outcomes. Due to the way the meshing properties.

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