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CFD Analysis of Solar Absorber Plate

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Abstract: Solar energy is becoming an alternative for the limited fossil fuel resources. One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat, which can be used in water heating systems. A commonly used solar collector is the flat-plate. Solar flat plate collectors are used for domestic and industrial purposes and have the largest commercial application amongst the various solar collectors. This is mainly due to simple design as well as low maintenance cost. A lot of research has been conducted in order to analyze the absorber plate operation and improve its efficiency.

An attempt is being made to analyze the solar absorber plate using the Computational Fluid Dynamics (CFD) so as to simulate the solar absorber plate for better understanding of the heat transfer capabilities of the absorber. In the present work, Fluid flow and heat transfer in the absorber panel are studied by means of Computational Fluid Dynamics (CFD). The conjugate heat transfer phenomenon between absorber and water is modeled using solid works CFD software. The analysis was carried out to investigate the effect of material, mass flow rate, riser position and riser shape. The solar radiation heat transfer is not modeled. The geometric model and fluid domain for CFD analysis is generated using Solid works flow simulation software, Grid generation is accomplished by solid works Meshing Software. The numerical results obtained using the CFD software for copper and aluminum for same boundary conditions has to be analyzed for different design constructions.

Keywords: CFD Analysis, Solar absorber plate, Efficiency, Radiation, Solid Works

I. INTRODUCTION

Solar collectors are key components of active solar-heating systems. They gather the sun's energy, transform its radiation into heat and then transfer that heat to a fluid (usually water or air). The solar thermal energy can be used in solar water-heating systems, solar pool heaters, and solar space-heating systems. The sides and bottom of the collector are insulated to minimize the heat loss. Sunlight passes through the cover and strikes the absorber plate, which then heats up, converting solar energy into heat energy. The heat is transferred to the water passing through the risers attached to the absorber plate. Absorber plates are most commonly painted with "selective coatings" which absorb and trap heat better than any other ordinary black paint. Absorber plates are usually made of metal—typically either copper or aluminum—because both of them are good heat conductors. Copper is the more expensive, but is better when it comes to resistance from corrosion. In locations with an average available solar energy, flat plate collectors are sized approximately at one-half-to one-square foot per gallon of one-day's hot water use.

In order to increase the heat transfer rate of the system, we can make use of different types of augmentation methods. Augmentation methods include active and passive methods with the latter being the most widely used

II. COMPUTATIONAL FLUID DYNAMICS APPROACH

Computational fluid dynamics or CFD is the analysis of systems involving fluid flow, heat transfer and associated phenomena such as chemical reactions by means of computer-based simulation. The technique is very powerful and spans a wide range of industrial and non-industrial application areas. Dynamics of fluids are governed by coupled non-linear partial differential equations, which are derived from the basic physical laws of conservation of mass, momentum, and energy. Analytical solutions of such equations are possible only for very simple flow domains with certain assumptions made about the properties of the fluids involved. For conventional design of equipment, devices, and structures used for controlling fluid flow patterns, designers have to rely upon empirical formulae, rules of thumb, and experimentation. However, there are many inherent problems with these conventional design processes. Empirical formulae and rules of thumb are extremely specific to the problem at hand and are not globally usable because of the non-linearity of the governing equations. For example, a rule of thumb for designing an aircraft wing may not be applicable for designing a wing mounted on a racing car, as the upstream flow conditions are completely different for the two configurations.

The above reasons make experimentation the leading conventional design technique. However, there are many limitations of experimentation techniques as well:

A. Measurement of flow variables may cause these variables themselves to change, might not be possible at all (in very small or unreachable spaces), and may be expensive.
B. Experimentation may take a long time to set up, sometimes lasts for a very short time, and may be very expensive, as in the case of supersonic wind-tunnel runs.
C. Experimental data has limited detail.

III. PROBLEM DEFINITION

A lot of research has been conducted in order to analyze the absorber plate operation and improve its efficiency. An attempt is being made to analyze the solar absorber plate using the Computational Fluid Dynamics (CFD) so as to simulate the solar absorber plate for better understanding of the heat transfer capabilities of the absorber. In the present work, Fluid flow and heat transfer in the absorber panel are studied by means of Computational Fluid Dynamics (CFD). The conjugate heat transfer phenomenon between absorber and water is modeled using SOLID WORKS CFD software. By using SOLIDWORKS CFD software solar heat absorber tube made of copper and aluminium are analyzed and compared to each other by passing different working fluids like water. The geometric model is generated in NX-CAD and fluid domain for CFD analysis is generated using, SOLIDWORKS Meshing Software. The numerical results obtained using the CFD software for copper and aluminium for same inlet temperature has to be analyzed.

IV. METHODOLOGY

The first objective is to determine the inlet water velocity and corresponding mass flow rate of the absorber plate. Materials, flow rate, pressure drop and all application based inputs must be addressed during this phase. Once operating parameters are complete the goal is to perform a CFD analysis of the solar heat absorber tube to compare results between the solar heat absorber tube made of copper and aluminium and obtain a better understanding of tube operation. Following the computer analysis, alternate forms of heat transfer capabilities will be looked into with emphasis on material and geometry of tubes. The objective is to design a solar heat absorber tube which has a comparable ability to do heat transfer.

A. 3D model of the solar heat absorber tube shall be developed from the 2D drawings using NX-CAD software.
B. The 3D model is imported into Solid Works flow environment to perform the CFD analysis.
C. Conjugate heat transfer analysis shall be done on the solar heat absorber tube made of copper and aluminium in the Solid Works flow simulation environment.
D. Temperature, velocity and Pressure distribution are observed, documented and compared.
E. Design optimization of the solar heat absorber tube shall be done by varying the material and geometry of the tubes.
F. Results discussions and comparison of the results by varying the material and geometry of the tubes will be made.

V. PART MODELING OF SOLAR ABSORBER PLATE

A solar absorber plate consists of a material or a selective coating over a material that absorbs the heat from the rays of sun falling on it. The heat from the absorber plate is transferred to the tubes or shells containing the usable water. As a result of convection phenomenon the water gets heated up. The temperature of the water depends on different factors like available day time temperature, efficiency of the absorber plate, arrangement of tubes w.r.t the absorber plate and contact area between the tubes and the absorber plate. The design of the solar absorber plate is made in CATIA v5 and the CFD analysis is made in solid works flow simulation package. The fluid model required for performing the CFD analysis is modeled in CATIA v5.

Table 1: Geometric parameters which are used to design total assembly of solar absorber plate

Common outlet section diameter (mm)	56
Common inlet section diameter (mm)	52
Tubes diameter (mm)	22
Tubes length (mm)	1040
Absorber plate thickness (mm)	6
Absorber plate length (mm)	650
Absorber plate width (mm)	980

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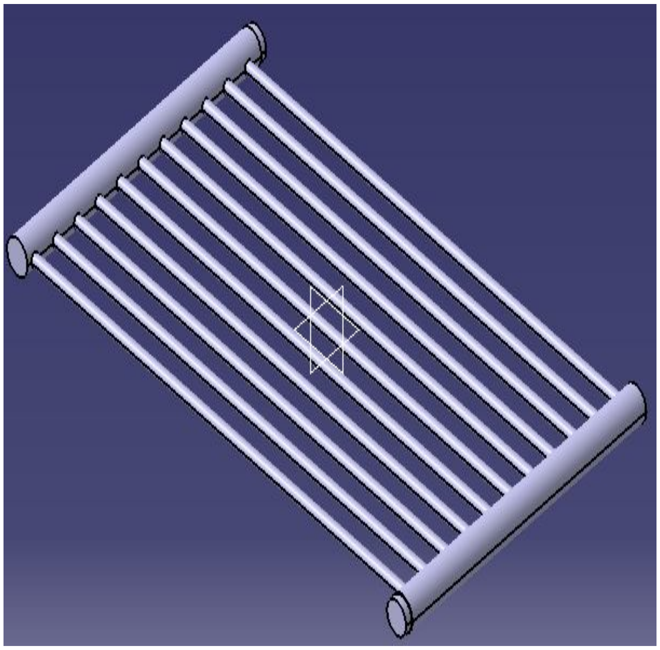

Fig 1 : Fluid model required for the CFD analysis

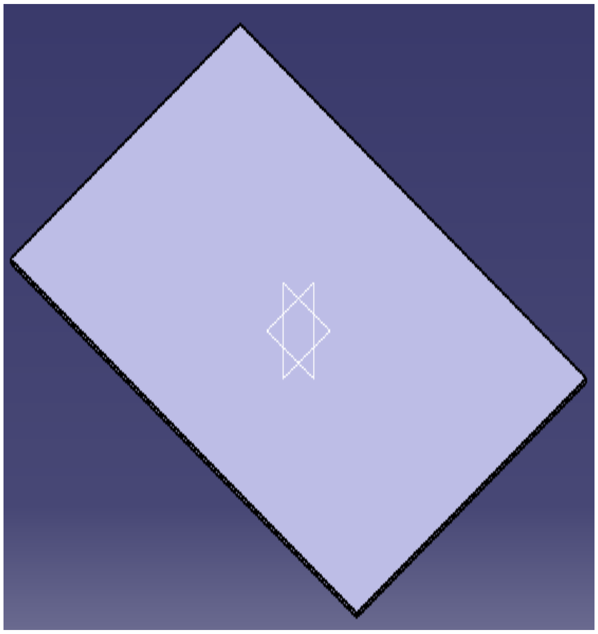

Fig 2 : Represents the absorber plate

VI. COMPUTATIONAL FLUID DYNAMIC (CFD) ANALYSIS

To perform Steady State conjugate heat transfer analysis of solar absorber plate to evaluate pressure drop and temperature distribution.Initially the analysis is carried out for two different materials (aluminium and copper).Later the analysis is extended by varying different parameters and comparing for thermal efficiency.

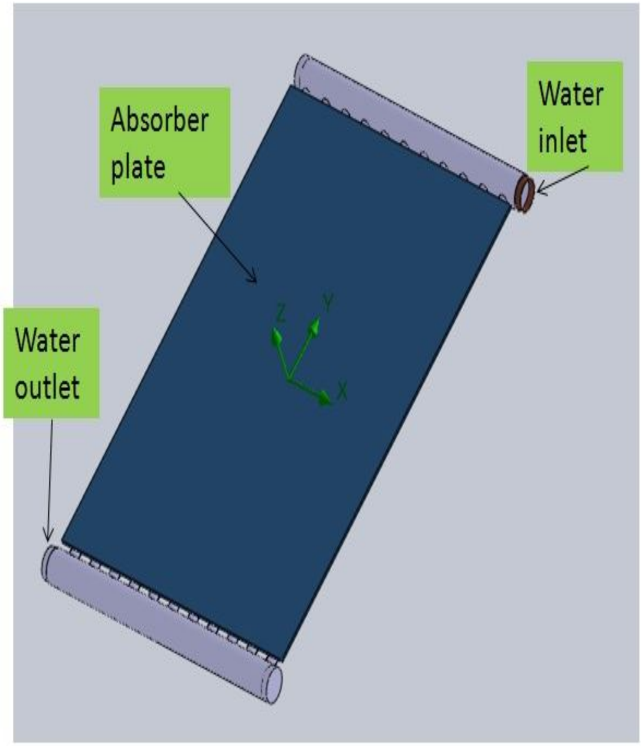

Fig 3: Shows the solar absorber plate with inlet and outlet

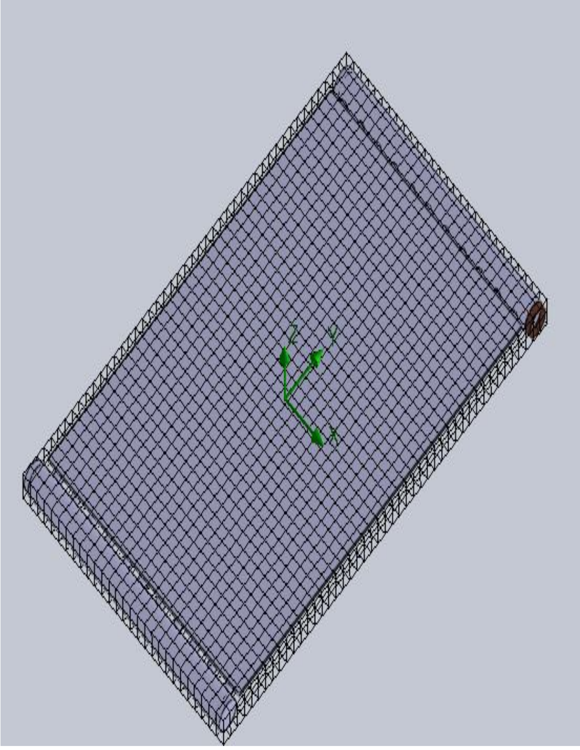

Figure 4 : Shows the mesh of the solar absorber plate

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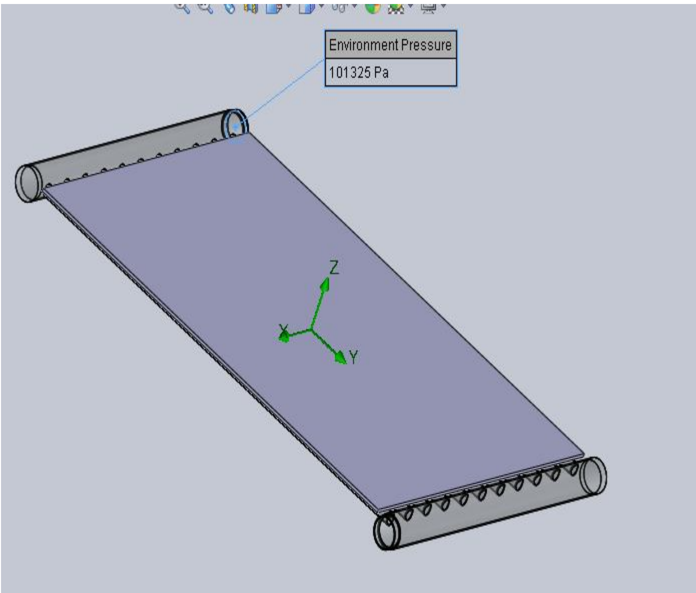

Figure 5 : Mass flow rate Boundary conditions applied

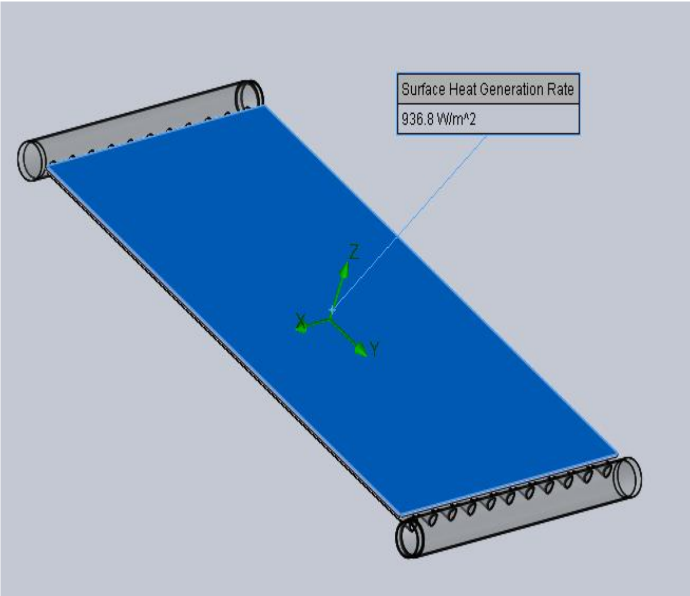

Figure 6 : Heat generation rate applied on the surface source of absorber plate

VII. CFD ANALYSIS WITH COPPER MATERIAL:

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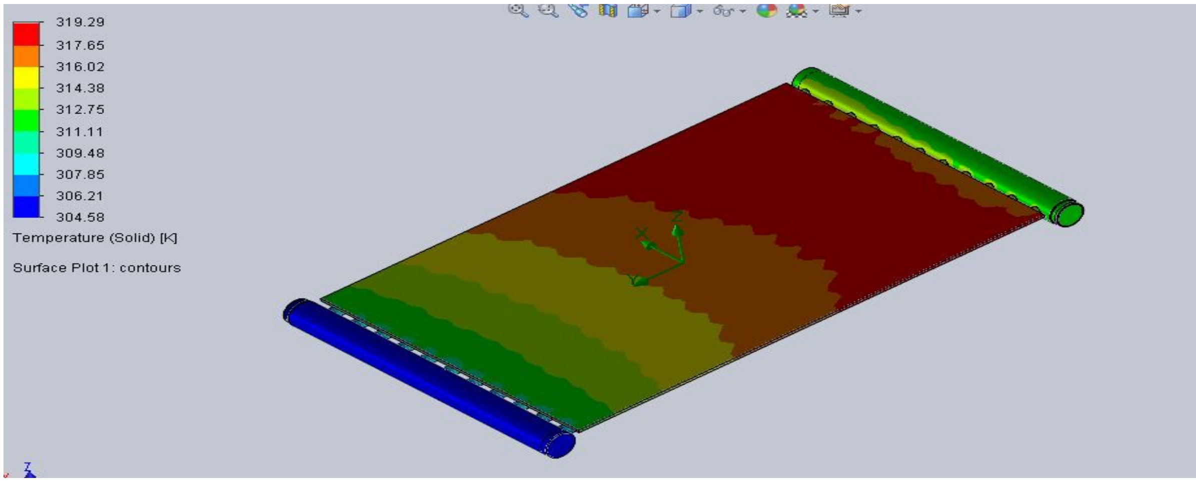

Fig 7: Temperature distribution on the top side of the absorber plate

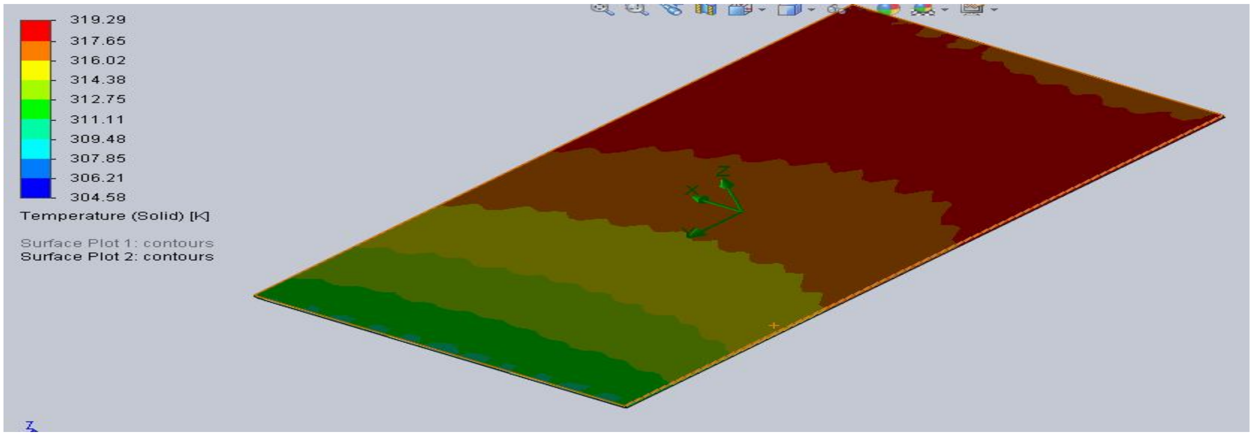

Figure 8 : Temperature distribution on the rear side of the absorber plate

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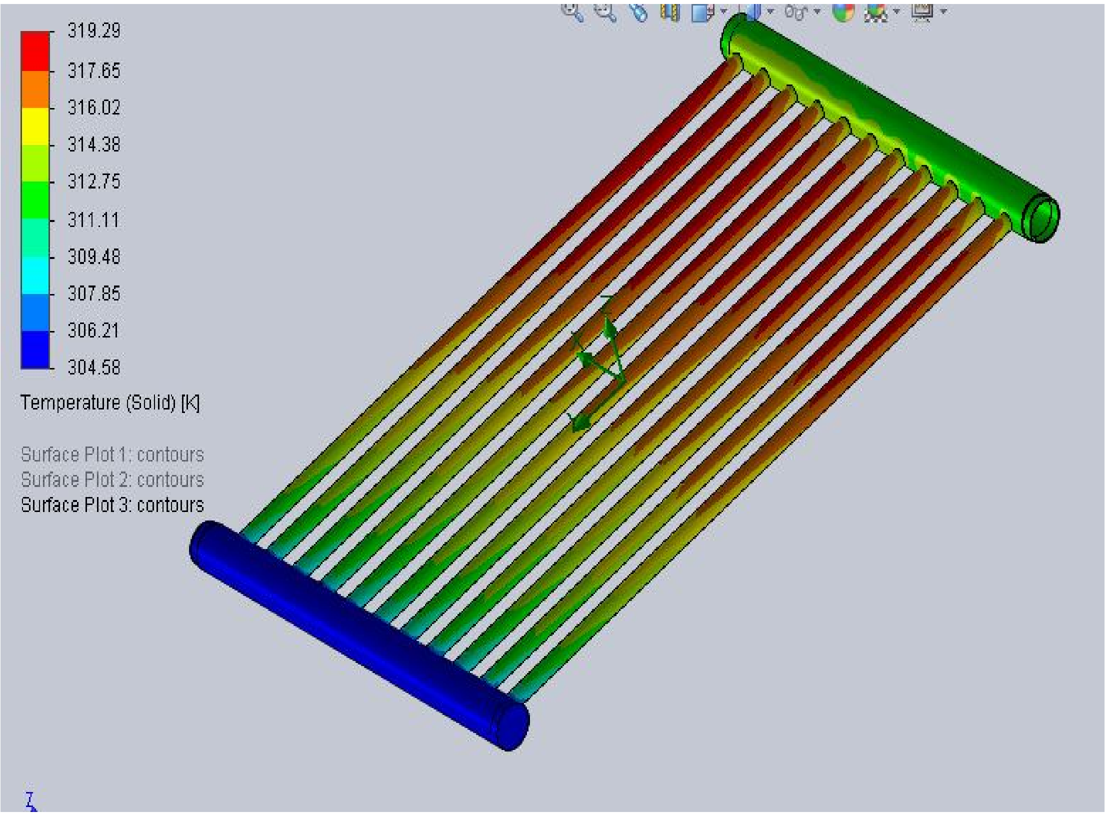

Figure 9 : Temperature distribution on the cooling tubes for Copper material

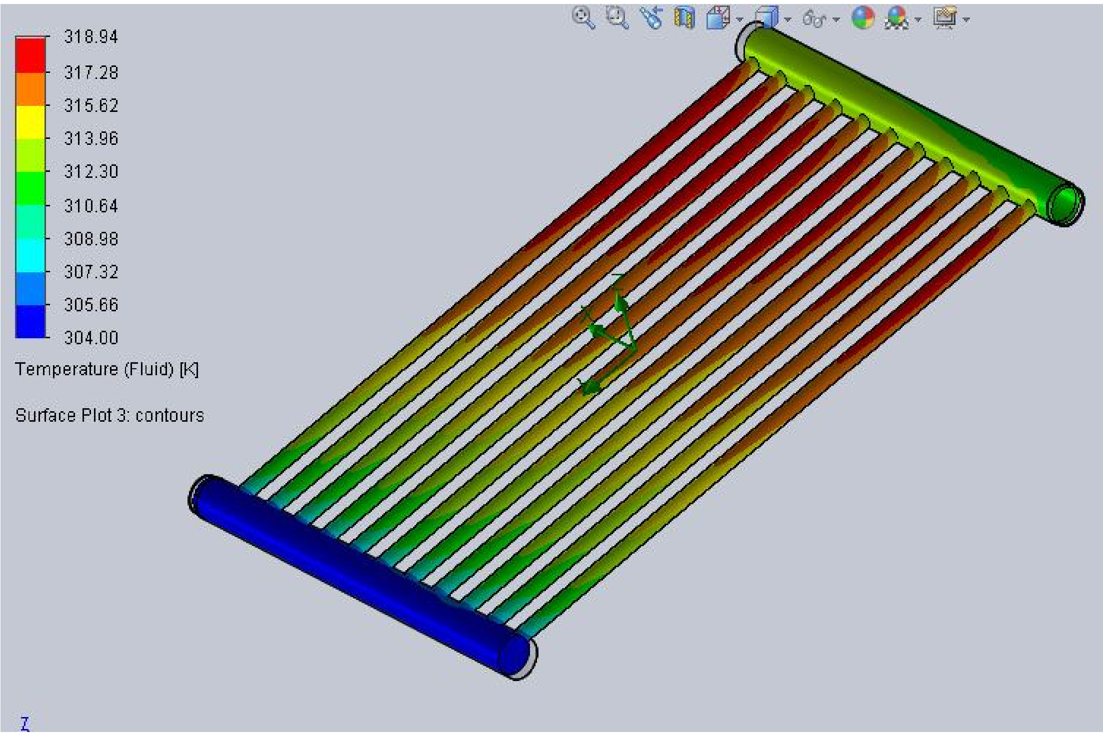

Figure 10 : Shows the fluid temperature on the cooling tubes

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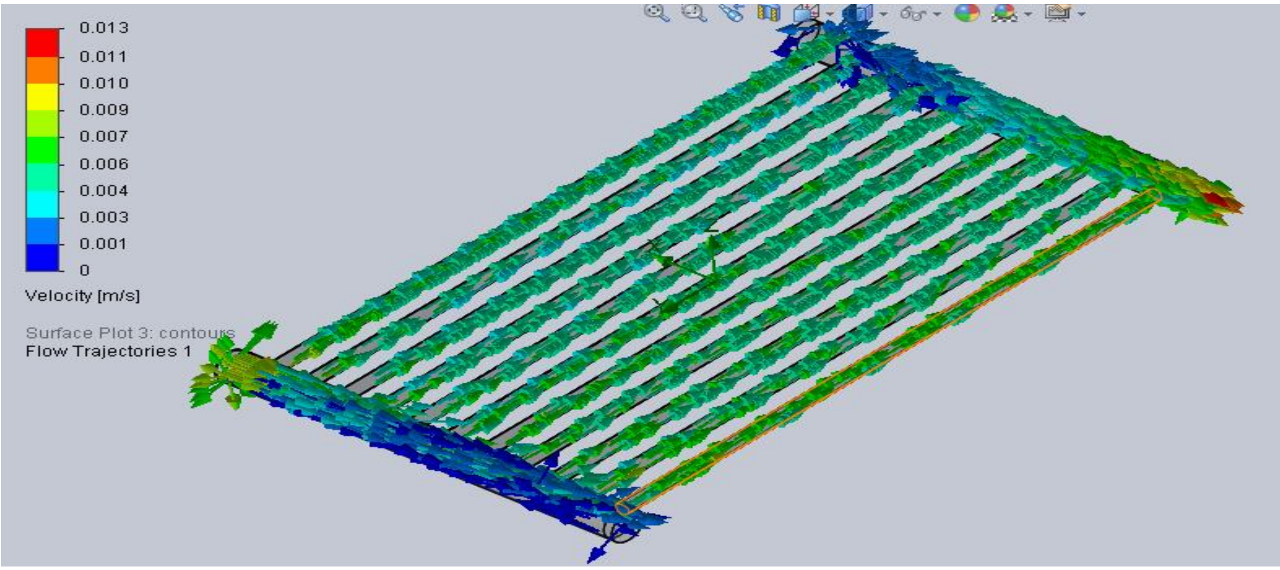

Figure 11 : Velocity of fluid in the cooling tubes

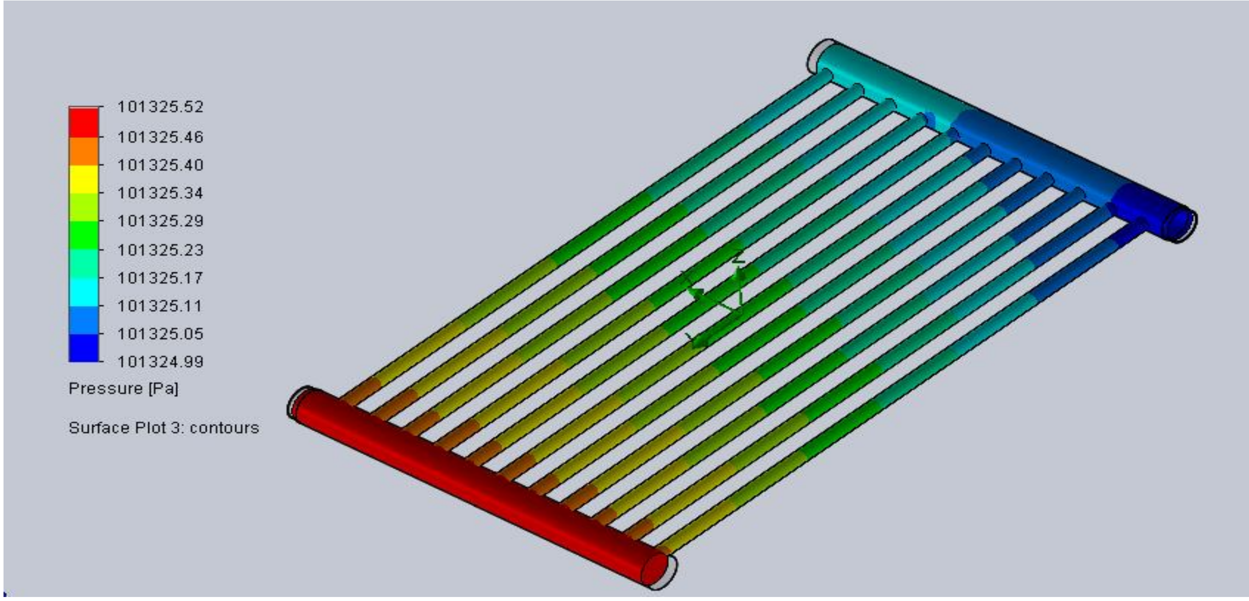

Figure 12 : Pressure of fluid in the cooling tubes

From the analysis the maximum pressure observed is 0.1 Mpa at the inlet. The maximum pressure observed at the outlet is 0.1 Mpa. It is concluded that there is no pressure drop from inlet to outlet.

From the above analysis the maximum temperature of solid, temperature of fluid, pressure drop and velocities of the fluid are recorded and tabulated. The summary of the results obtained is shown in the below table.

Table 2: Summary of the results of the absorber plate with Copper material

Item	Value
Solid Temperature (Aluminium)	319.2 K
Fluid temperature (water)	318.9 K
Velocity	0.013 m/s
Thermal efficiency	0.80

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VIII. CFD ANALYSIS WITH ALUMINUM MATERIAL

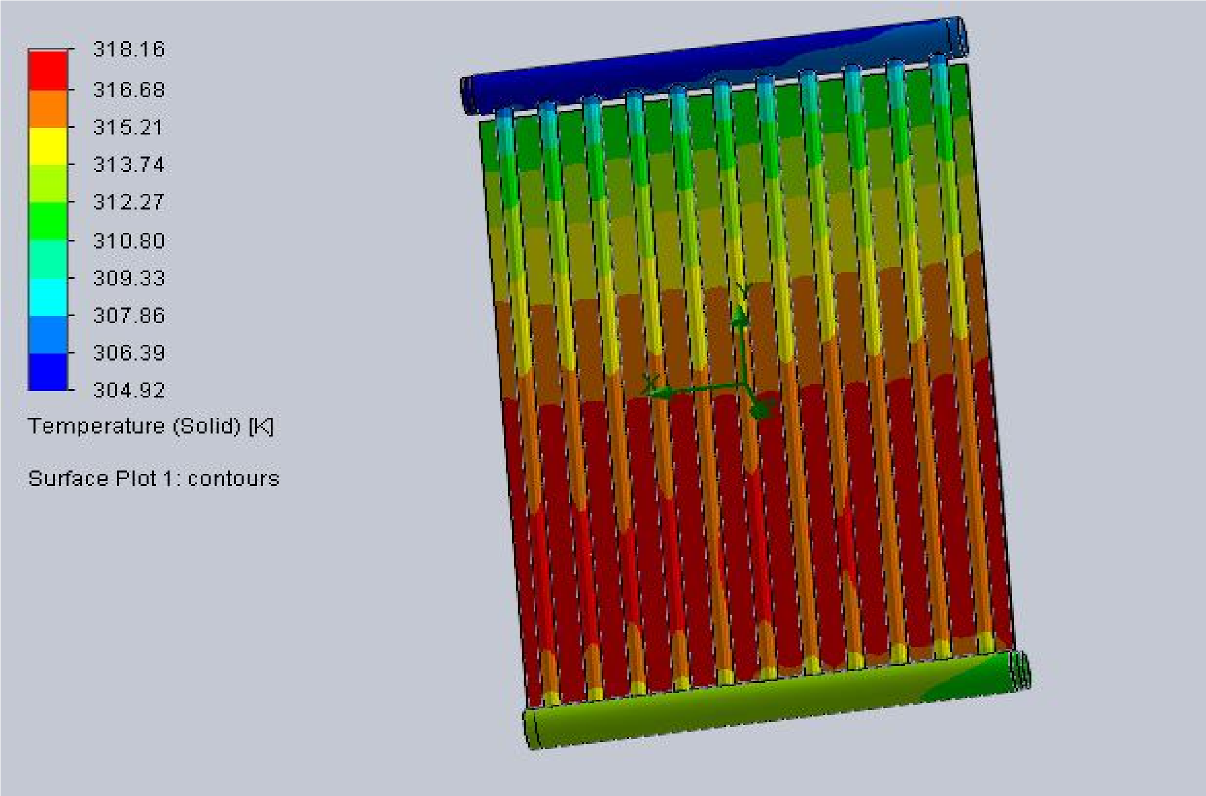

Figure 13 : Temperature distribution on the top side of the absorber plate

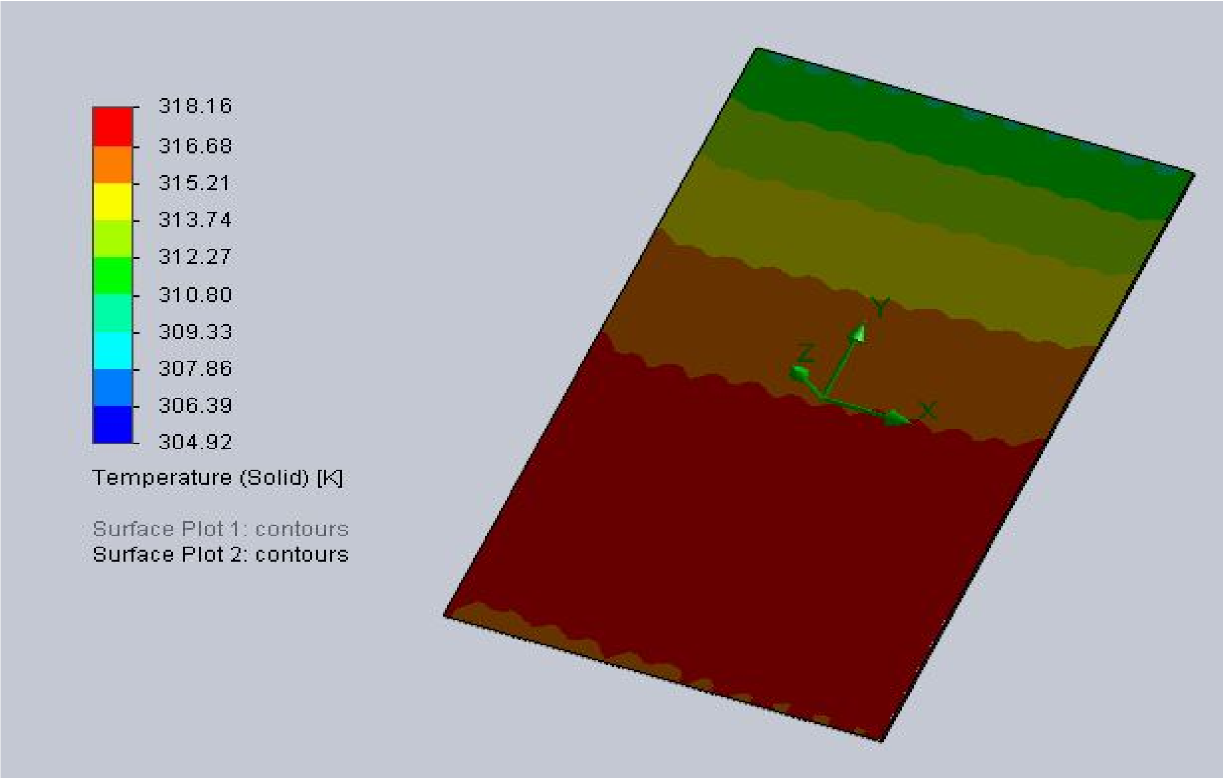

Figure 14 : Temperature distribution of the absorber plate for Aluminum material

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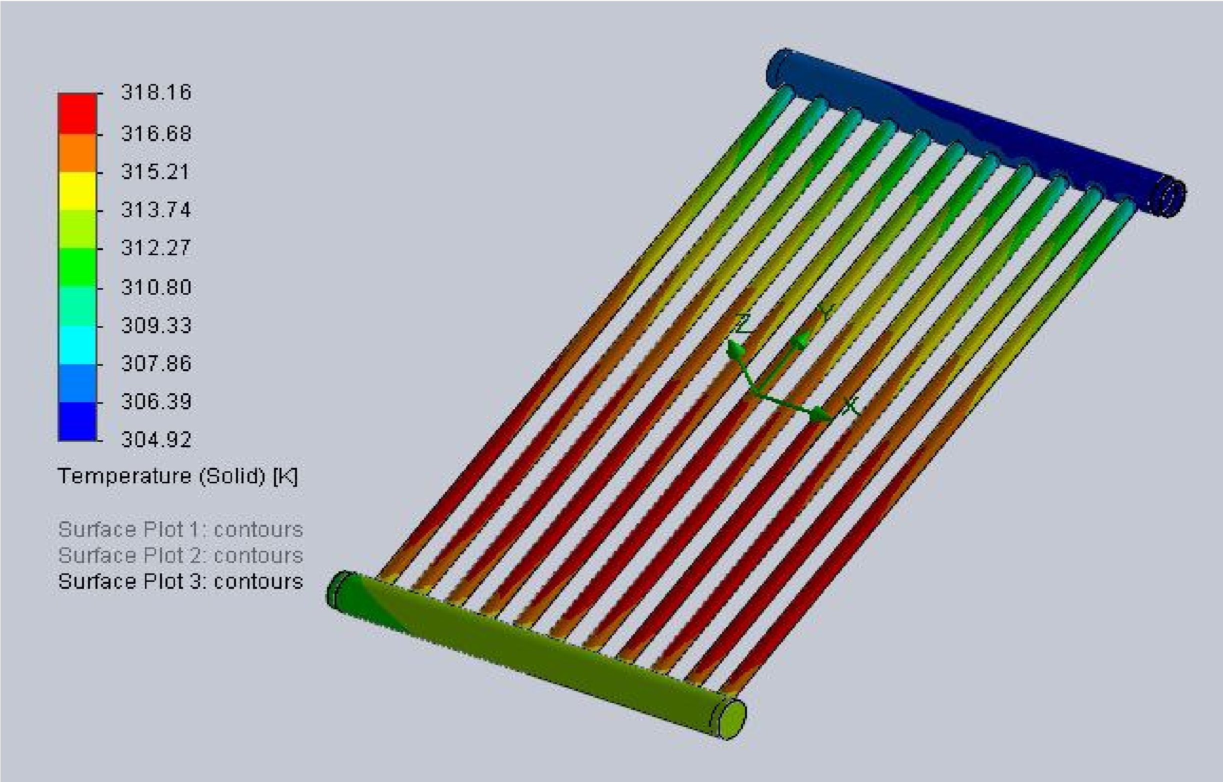

Figure 15 : Temperature distribution on the cooling tubes for Aluminum material

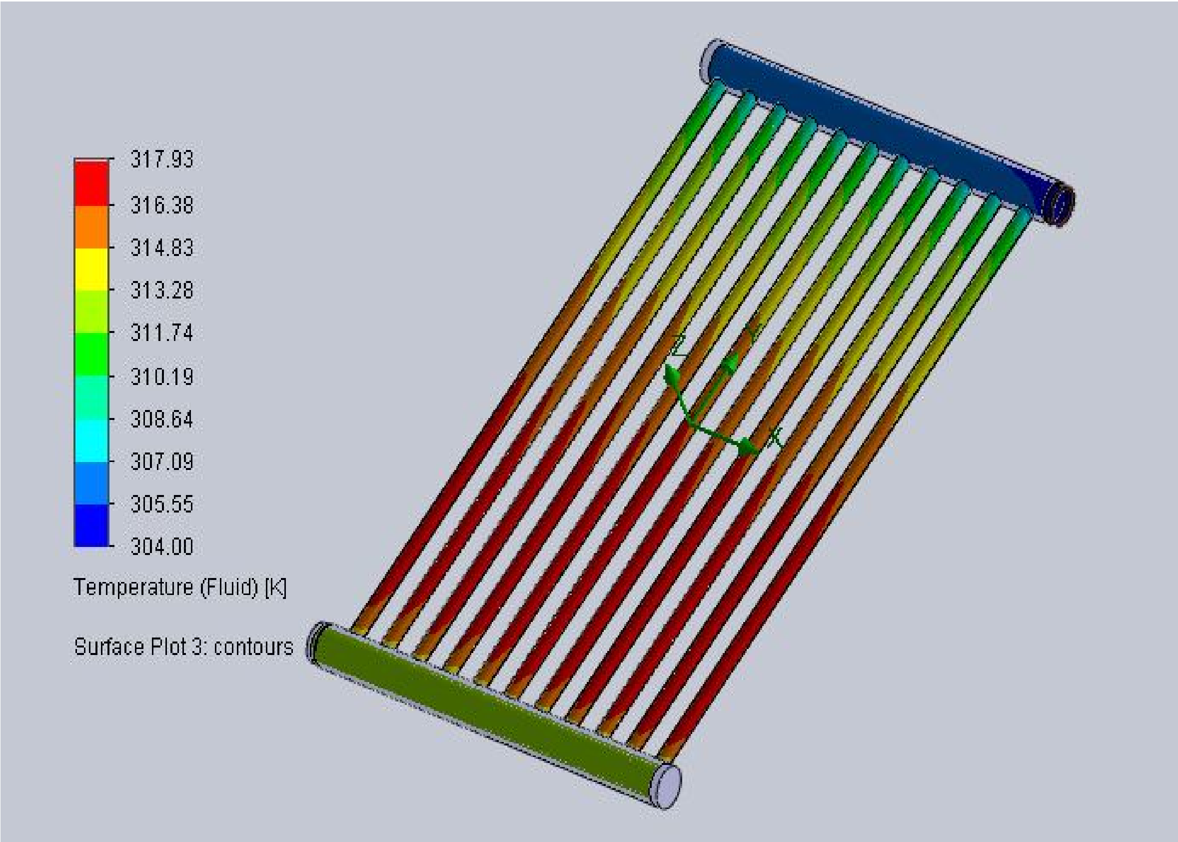

Figure 16 : Temperature on the cooling tubes for Aluminum tubes

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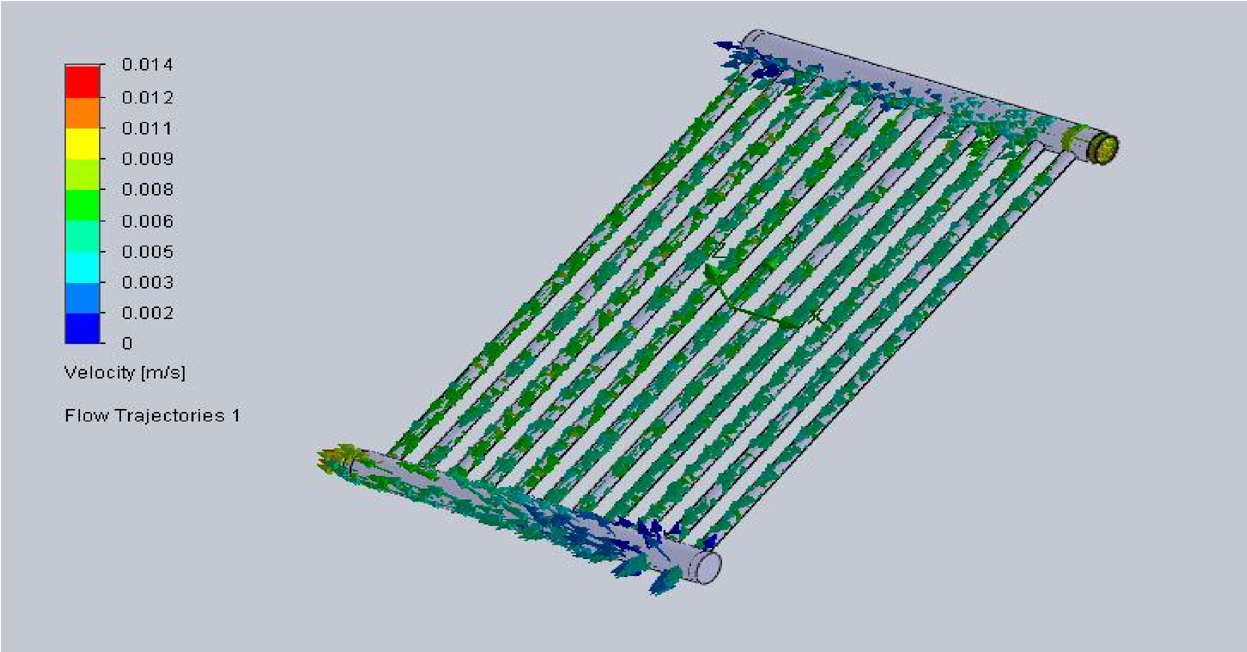

Figure 17 : Velocity of fluid in the cooling tubes

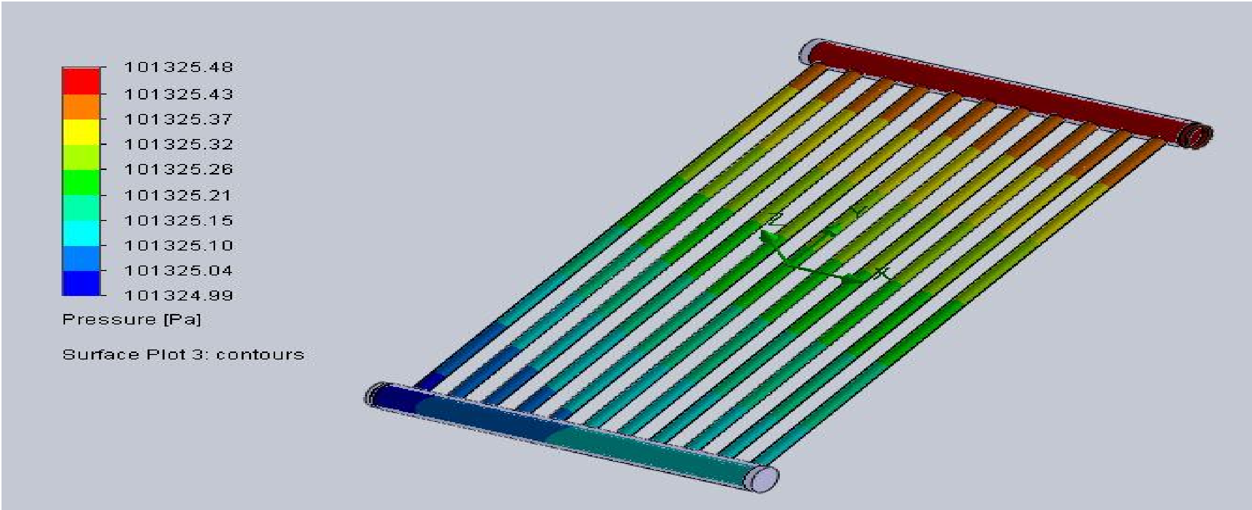

Figure 18 : Pressure of fluid in the cooling tubes

From the analysis the maximum pressure observed is 0.1 Mpa at the inlet. The maximum pressure observed at the outlet is 0.1 Mpa. It is concluded that there is no pressure drop from inlet to outlet.

From the above analysis the maximum temperature of solid, temperature of fluid, pressure drop and velocities of the fluid are recorded and tabulated. The summary of the results obtained is shown in the below table.

Table 3 : Summary of the results of the absorber plate with Aluminum material

Item	Value
Solid Temperature (Aluminum)	318.1 K
Fluid temperature (water)	317.9 K
Velocity	0.014 m/s
Thermal efficiency	0.74

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IX. CONCLUSION

In the present work, heat transfer analysis on the absorber plate are studied by means of Computational Fluid Dynamics (CFD). The analysis was carried out to investigate the effect of material, mass flow rate, riser position and riser shape. From the analysis the following observations were madeIt is observed that the solar absorber plate with aluminum is having 6% less thermal efficiency than Copper plate.

REFERENCES

[1] E.Ekramian, Gh.Etemad, M.Haghenasfard "Numerical Analysis of Heat transfer performance of flat plate solar collectors ", International Journal of Chemical Engineering, Volume- 1, ISSN: 2368-6111.

[2] Amraoui. M. A., Aliane. K, "Numerical analysis of a three dimensional fluid flow in a flat plate solar collector", International Journal Renewable and sustainable Energy, Volume- 3.

[3] Anjali A. Vyas & Dr. Dinesh shringi "CFD Based Thermal Efficiency Analysis of Solar Air Heater with Smooth Plate & Perforated Plate ", Imperial Journal of Interdisciplinary Research (IJIR) Vol-3, Issue-2, 2017 ISSN: 2454-1362.

[4] Zain shariff, David jose, Linto kurien philip, Abinsha Joseph, thejaraju R. "CFD Analysis of solar flat plate collector with semicircular baffles" Proceedings of 48th IRF International Conference, ISBN: 978-93-86291-639.

[5] Basavanna S and K S Shashishekar "CFD ANALYSIS OF TRIANGULAR ABSORBER TUBE OF A SOLAR FLAT PLATE COLLECTOR" International journal of Mechanical Engineering and Robotic research Vol-2, ISSN 2278-0419

[6] Anil Singh Yadav, J.L.Bhagoria "A CFD Analysis Of A Solar Air Heater Having Triangular Rib Roughness On The Absorber Plate" International Journal of Chem Tech Research Vol.5, No.2 ISSN: 0974-4290.

[7] Sandeep Koundinya , Dr. A S Krishnan have published a paper on "COMPUTATIONAL STUDY OF COOLING OF PV SOLAR PANEL USING FINNED HEAT PIPE TECHNOLOGY" INTERNATIONAL JOURNAL OF MECHANICAL ENGINEERINGAND TECHNOLOGY (IJMET), ISSN 0976, Volume 5.

[8] Patel Neel kumar Kantilal have published a paper on "Effect of Pitch on Thermal Performance of Solar Water Heater" IJSRD - International Journal for Scientific Research & Development| Vol. 5, Issue 10, 2017 | ISSN : 2321-0613