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"DESIGN WITH THERMAL ANALYSIS OF SOLAR AIR HEATER USING CFD"

Chandra Bhooshan Saxena [1]***, Dr. Ankit Goyal*** [2]***, Gaurav Goswami*** [3]

[1] *M.Tech. Scholar, Department of Mechnical Engineering , Technocrats Institute of Technology and Science, Bhopal, MP, India*

[2] *Professor, Department of Mechanical Engineering , Technocrats Institute of Technology and Science, Bhopal, MP, India*

[3] *Assistant Professor, Department of Mechanical Engineering , Technocrats Institute of Technology and Science, Bhopal, MP, India*

ABSTRACT

Solar air heaters have several potential use including heating rooms drying out different materials preheating water as well as pre heating industrial process the purpose of the study to analyse solar heater while looking at the way the temperatures with in them change the working flood flows in a parallel fashion with in the heater resulting in improve heat transfer. Computational fliud dynamics is used to access the solar air heater. The computer model take turbulence, conduction, convection as well as surface to surface radiation into consideration. An evolution is conducted on the turbulence models.

Aluminium and Copper are two material which is used as absorber plate with 0.0031 kg per second and 0.00121 kg per second are 2 mass flow rate of fluid. For the investigation fluent analysis system where used CFD investigation so that the copper absorber plate give better temperature distribution over the aluminium plate at every point in the absorber.

Keyword*: Solar air heater, Fluid, Temperature, Mass flow rate, Absorber, Aluminium, Copper, CFD*

I. INTRODUCTION

Solar energy is the most considerable energy source in the world. Sun, which is 1.495x1011 (m) far from the earth and has a diameter of 1.39x109 (m), would emit approximately 1353 (W/m2) on to a surface perpendicular to rays, if there was no atmospheric layer. The world receives 170 trillion (KW) solar energy and 30% of this energy is reflected back to the space, 47% is transformed to low temperature heat energy, 23% is used for evaporation/rainfall cycle in the Biosphere and less than 0.5% is used in the kinetic energy of the wind, waves and photosynthesis of plants. Solar energy systems consist of many parts. The most important part of these systems is the solar air heaters where the heat transfer from sun to absorber and absorber to fluid occurs. In order to affect the performance of these systems, generally modifications on solar air heaters are performed. With the rapid development in civilization, man has increasingly become dependent on natural resources to satisfy his needs. Drying fruits and vegetables such as grapes, pepper, pawpaw, etc. is one of those indispensable processes that require natural resources in the form of fuels. Solar energy air heaters are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. The major component of any solar system is the solar air heater. Of all the solar thermal air heaters, the solar air heaters though produce lower temperatures, have the advantage of being simpler in design, having lower maintenance and lower cost. To obtain maximum amount of solar energy of minimum cost the solar air heaters with thermal storage have been developed. Solar air heater is type of solar air heater which is extensively used in many

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applications such as residential, industrial and agricultural fields. Solar air heaters, because of their simplicity are cheap and most widely used collection devices of solar energy, has great potential for low temperature applications, particularly for drying of agricultural products. The thermal efficiency of a solar air heater is significantly low because of the low value of the convective heat transfer coefficient between the absorber plate and the air, leading to high absorber plate temperature and high heat losses to the surroundings. It has been found that the main thermal resistance to the heat transfer is due to the formation of a laminar sub-layer on the absorber plate heattransferring surface. A solar air heater absorbs incident solar radiations and transforms them into useful heat for heating the collector fluid such as water and air. Solar air heaters, being inherently simple and cheap, are most widely used collection devices. Solar air heaters find several applications in space heating, seasoning of timber and crop drying.

Air heater Baffles

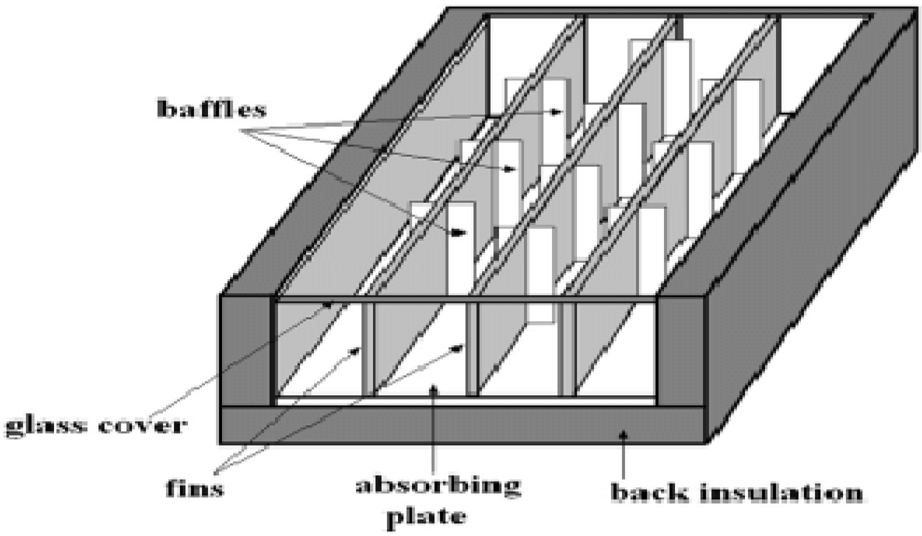

Fig. 1.1 Air heater Baffles

Advantage of Solar air heater :

Solar air heaters offer several advantages, making them an attractive option for certain applications. Here are some key advantages of using air heaters powered by solar energy:

Renewable Energy Source: Sunlight, a practically infinite and renewable energy source, is used by solar air heaters. Since solar energy doesn't eventually run out like fossil fuels do, it's a sustainable option for heating applications.

Lower Energy expenditures: Solar air heaters, particularly in situations where ventilation or space heating is necessary, can drastically lower energy expenditures. Users can reduce their reliance on conventional heating systems that run on gas, electricity, or other non-renewable energy sources by utilizing solar energy.

Environmentally Friendly: No greenhouse gases or other pollutants are released during the heating process by solar air heaters. By offering a clean and environmentally sustainable heating option, they aid in lowering carbon footprints and battling climate change.

Low Operating Costs: Solar air heaters typically have little running costs after installation. Because they run on sunshine, they don't need any fuel and require very little upkeep.

Versatility:

Solar air heaters are versatile and can be used for various applications, including residential heating, commercial buildings, industrial processes, and agricultural drying. They can also be integrated into existing heating systems to supplement conventional sources.

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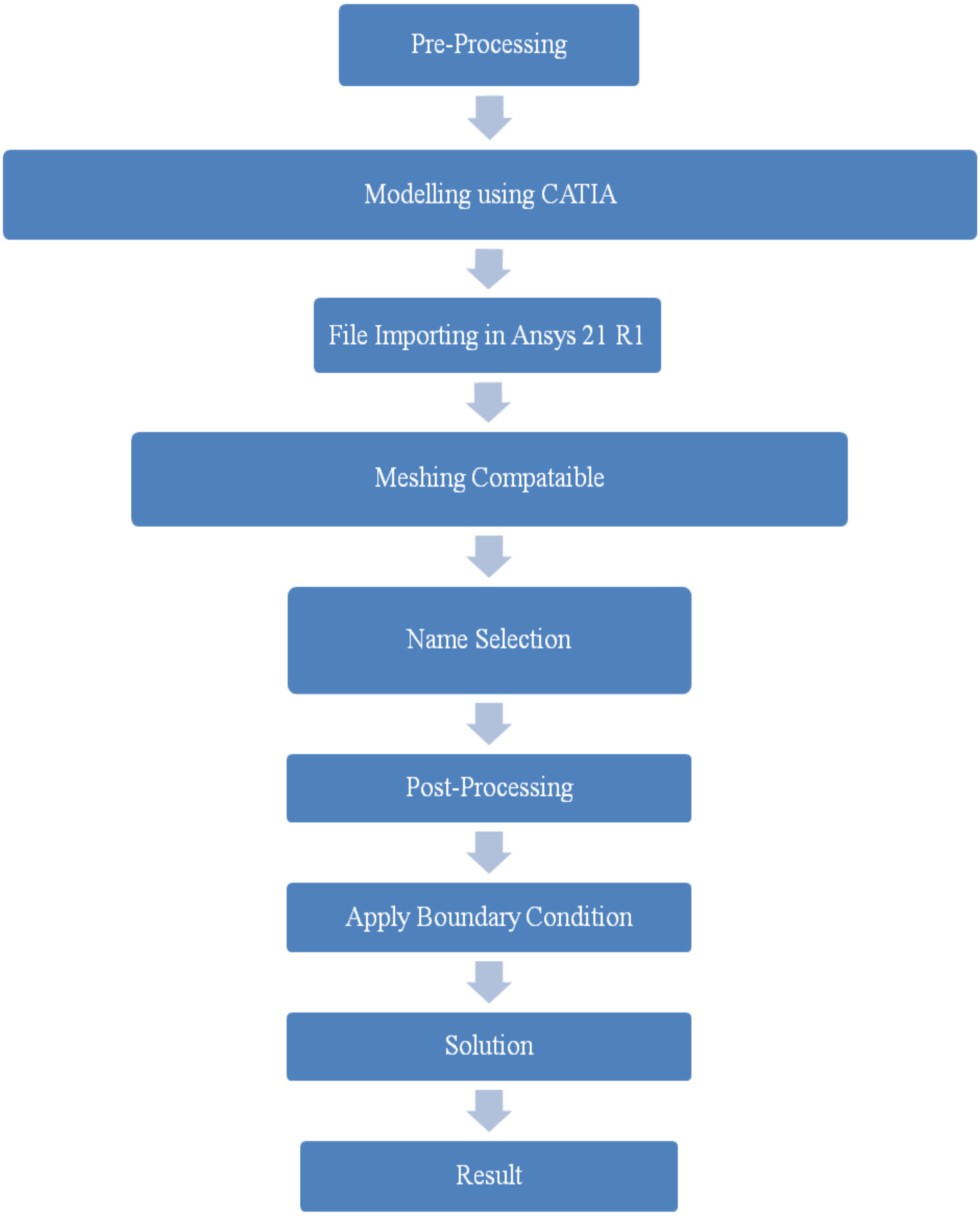
Independence from Utility Grids:

Solar air heaters provide a degree of energy independence, especially in remote or off-grid locations. This can be particularly beneficial in areas where access to traditional energy sources is challenging or expensive.

Long Lifespan:

Solar air heaters are designed to be durable and have a long lifespan. With proper maintenance, these systems can provide reliable and consistent performance for many years

II. Methodology



III. Governing rquation

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The foundation of computational fluid dynamics lies in the continuity, momentum, as well as energy equations, which are the basic governing equations of fluid dynamics. The language of these equations is mathematical physics. These are the mathematical expressions of the three underlying physical concepts that form the basis of modern fluid dynamics:

1. Mass is conserved;
2. F=ma (Newton's second law)
3. Energy is conserved

The governing equations may be derived in an extensive variety of forms. The specific formulation of the equations is irrelevant to the majority of aerodynamic theories. One version of the equations may work for computational fluid dynamics (CFD), while another form may cause instability or wiggles within the numerical results. Thus, the different formulations of the equations have great significance in the field of computational fluid dynamics (CFD). The following are descriptions of these equations:

Navier-Stokes Equation

The Navier-Stokes equations regulate fluid motion and may be considered Newton's second law of motion for fluids.

$$\rho \frac{D\vec{V}}{Dt} = \rho\vec{g} - \nabla P + \mu \nabla^2 \vec{V}$$

Where,

$$\frac{D}{Dt}(\vec{V}) = \frac{\partial}{\partial t}(\vec{V}) + u\frac{\partial}{\partial x}(\vec{V}) + v\frac{\partial}{\partial y}(\vec{V})$$

$$\nabla^2(\vec{V}) = \frac{\partial^2}{\partial^2 x}(\vec{V}) + \frac{\partial^2}{\partial^2 y}(\vec{V})$$

Continuity Equation

The continuity equation states that in the absence of any fluid addition or removal along the length of the conduit, the mass that traverses various sections shall remain constant. This is consistent with the conservation of mass principle, which holds that matter cannot be generated or destroyed.

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

Momentum Equation

The development of the linear momentum equations for fluids may be accomplished by using Newton's 2nd Law, which specifies that the total force must be equivalent to the time rate of change of momentum, denoted as ΣF = d(m**V**)/dt. The control volume complicates the application of this principle from particle mechanics to fluid mechanics.

- x – momentum: $$\rho \frac{D}{Dt}(u) = \rho g_x - \frac{\partial P}{\partial x} + \mu \nabla^2 (u)$$
- y – momentum: $$\rho \frac{D}{Dt}(v) = \rho g_y - \frac{\partial P}{\partial y} + \mu \nabla^2 (v)$$
- z – momentum: $$\rho \frac{D}{Dt}(w) = \rho g_y - \frac{\partial P}{\partial y} + \mu \nabla^2 (w)$$

The mass flow rates of the hot fluid stream (m_h) must be calculated using the known inlet as well as outlet temperatures through Eq.

$$m_h = \rho_h \times v_{tube} \times A_{tube}$$

In this equation, ρ_h represents the density of the hot fluids, v_{tube} represents the fluid's velocity within the tubes, as well as A_{tube} represents the cross-sectional area of the tubes. From Eq., one can then derive the heat load (q) that is absorbed by the frigid fluid or removed via the hot fluid.

$$q = mc_{ph}(T_{h,i} - T_{h,o}) = mc_{pc}(T_{c,i} - T_{c,o})$$

The temperature is denoted by T, whereas the inlet as well as outlet conditions are indicated by the subscripts i and o.

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Subsequently, the shell design as well as the tube bank configuration was examined.

IV. MODELING

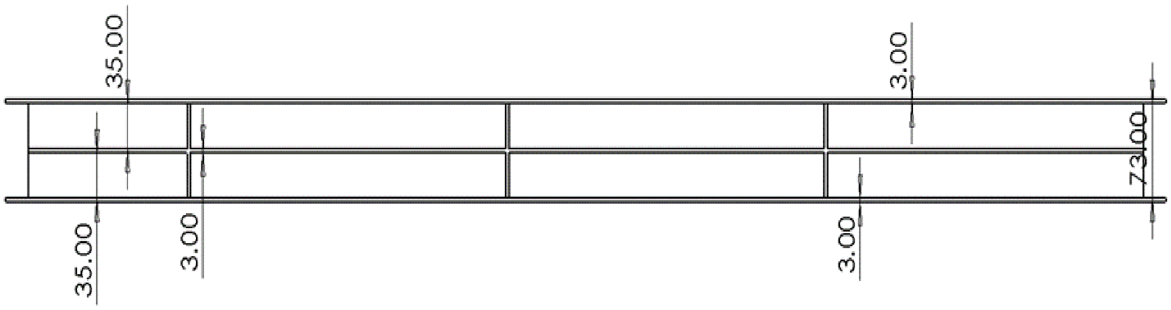

Figure 4.1 Side view of solar air heater with dimensions

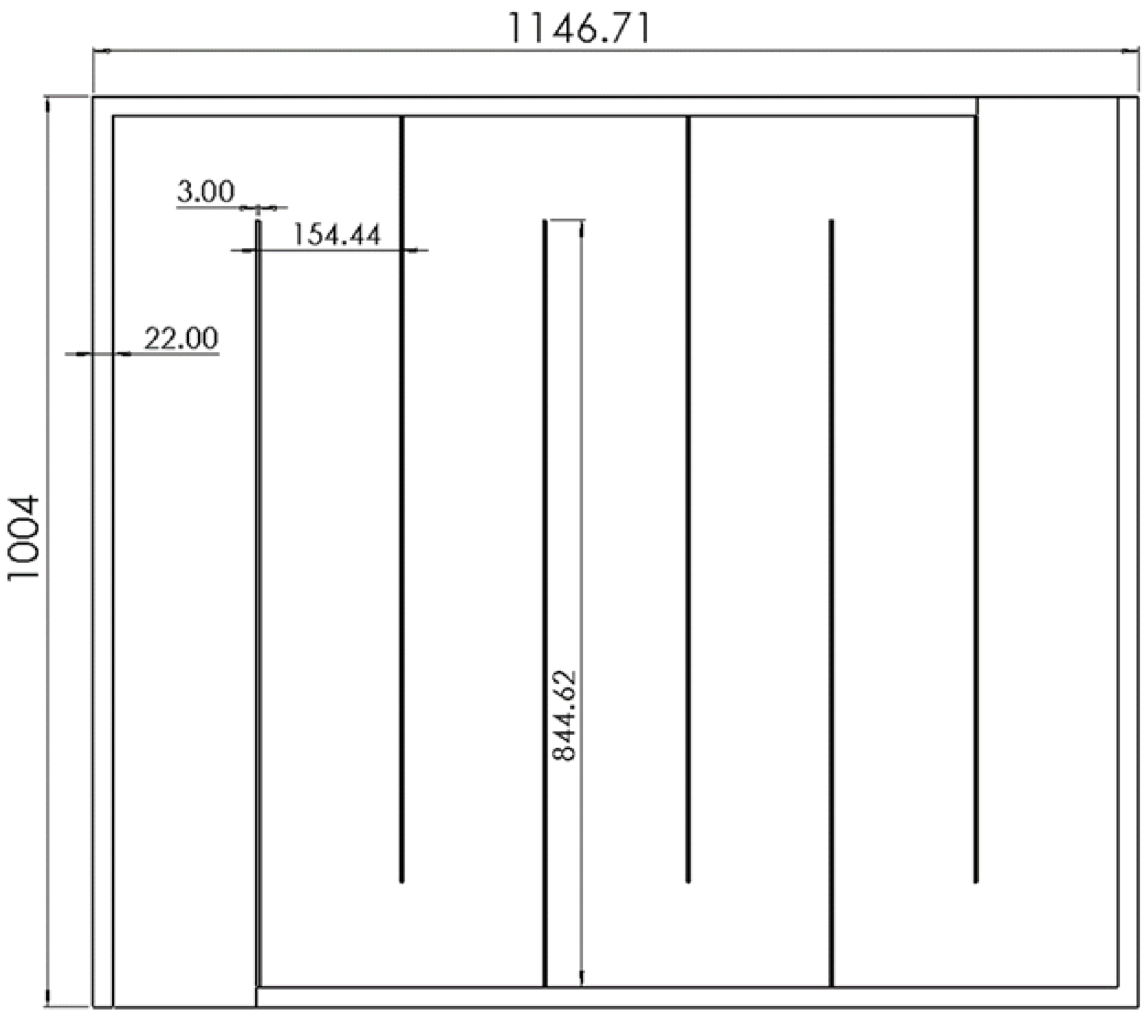

Figure 4.2 Top view of solar air heater with dimensions

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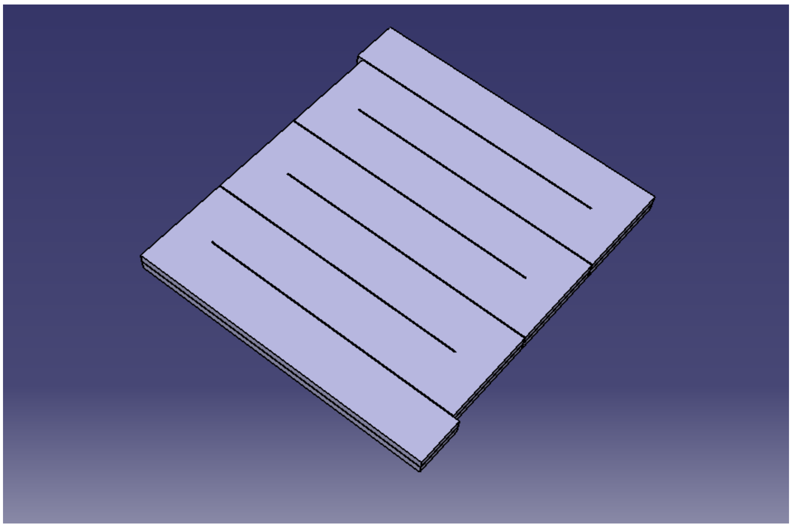

Figure 4.3 Solar air heater design in CATIA

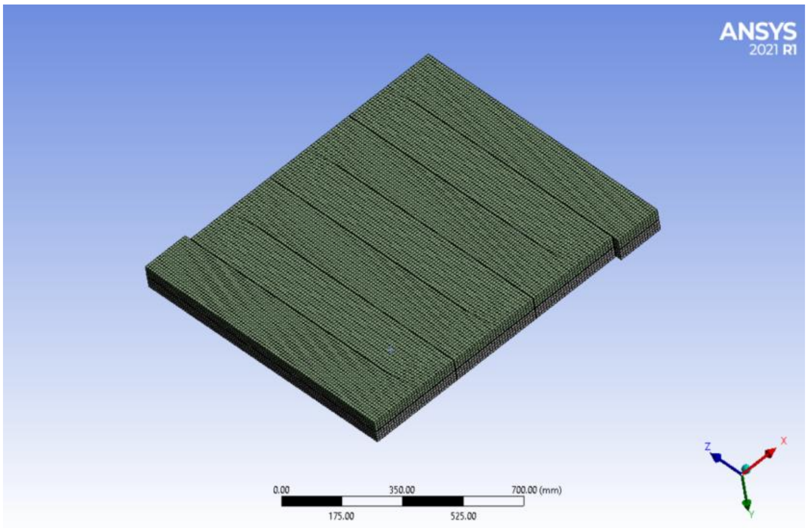

Figure 4.4 Meshing of overall solar air heater

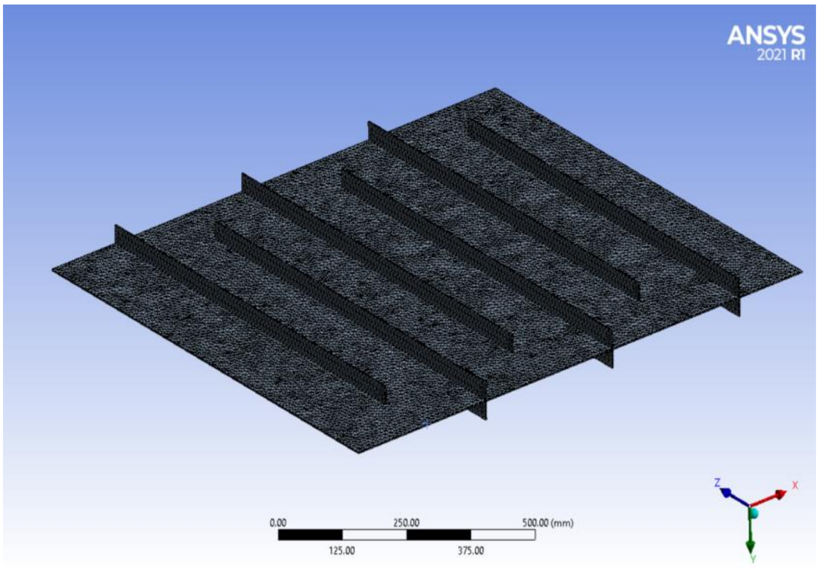

Figure 4.5 Mesh generation in absorber plate

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V. Result

Case-1

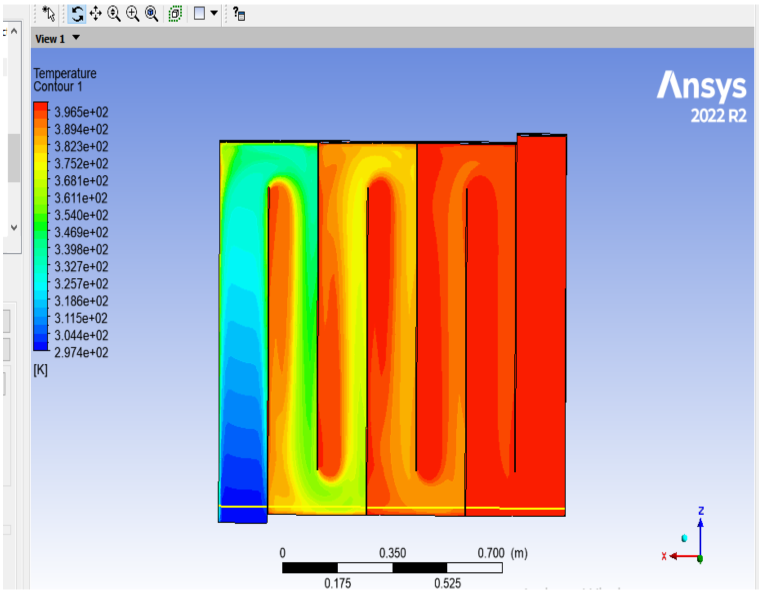

Figure 5.1 Temperature at plane above absorber plate (Al) in case 1 (0.0032 kg/sec)

Case-2

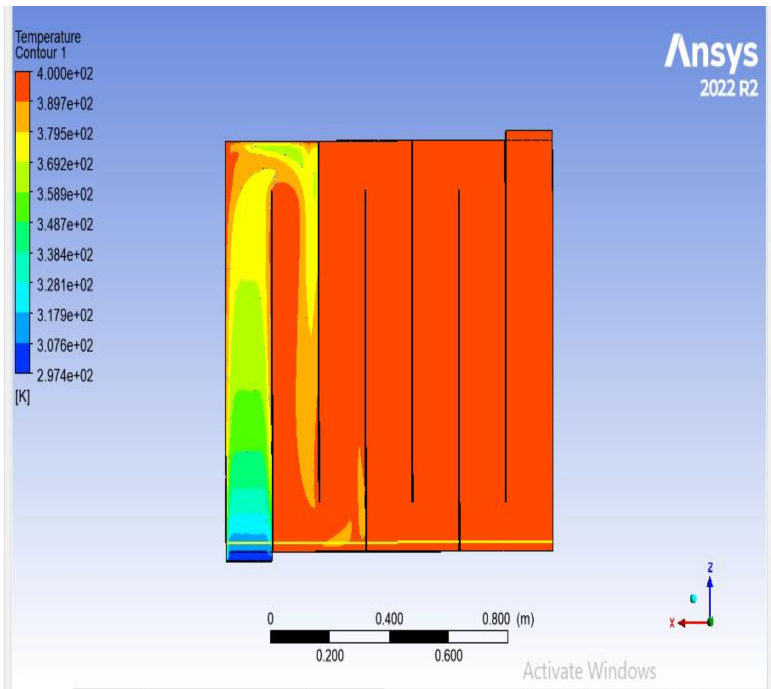

Figure 5.2 Temperature at plane above absorber plate (Al) in case 2 (0.00121 kg/sec)

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Case-3

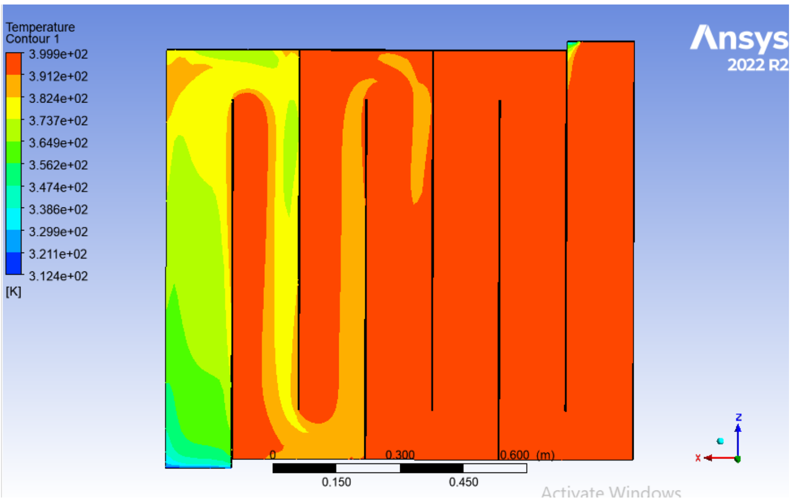

Figure 5.3 Temperature at plane above absorber plate (Cu) (0.0032 kg/sec) in case 3

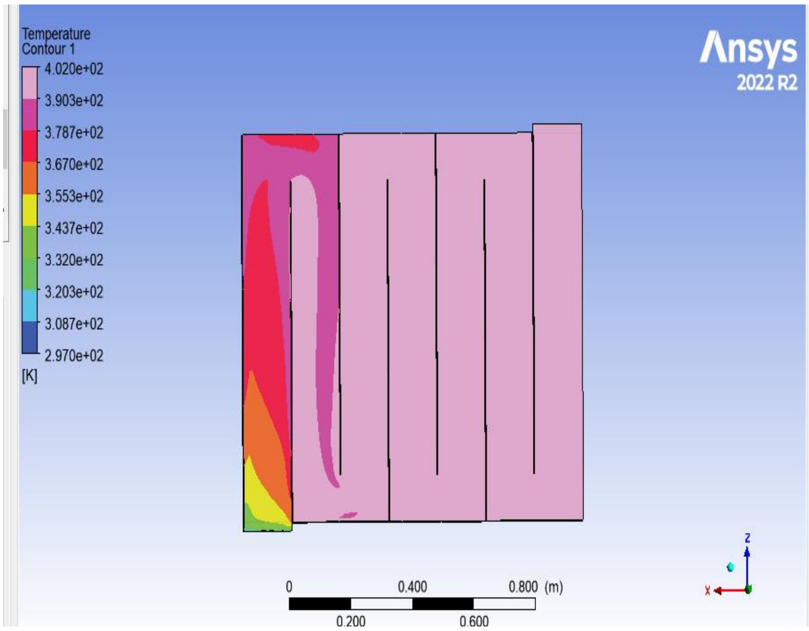

Figure 5.4 Temperature at plane above absorber plate (Cu) (0.00121 kg/sec) in case 4

V. CONCLUSION REMARK

The aim of this research was to evaluate the SAH by means of CFD. ANSYS Fluent was used to develop the CFD model. Two absorber plate were used to heat up the working fluid. There is 6 boundary used to make the path of fluid to flow from inlet to outlet. Absorber plate were placed at the middle of the SAH which means the working fluid contact with absorber plate in both side up and down. Predicted result of the CFD investigation of SAH are mention in below.

- Minimum temperature in the aluminium and copper absorber is in point 1, and maximum temperature is in point 2.

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- In both aluminium and copper absorber temperature behaviour is increases, decreases, and increases from point 1-2, 2-3, and 3-4 respectively.
- Temperature of aluminium absorber are increases from point 1 is 24%, 19%, and 22.5% in point 2, point 3, and point 4 respectively.
- Temperature of copper absorber are increases from point 1 is 24.5%, 19.5%, and 22.5% in point 2, point 3, and point 4 respectively.
- Temperature in copper absorber is increases from aluminium is 0.08%, 0.02%, 0.35%, and 0.25% in point 1, point 2, point 3, and point 4 respectively.

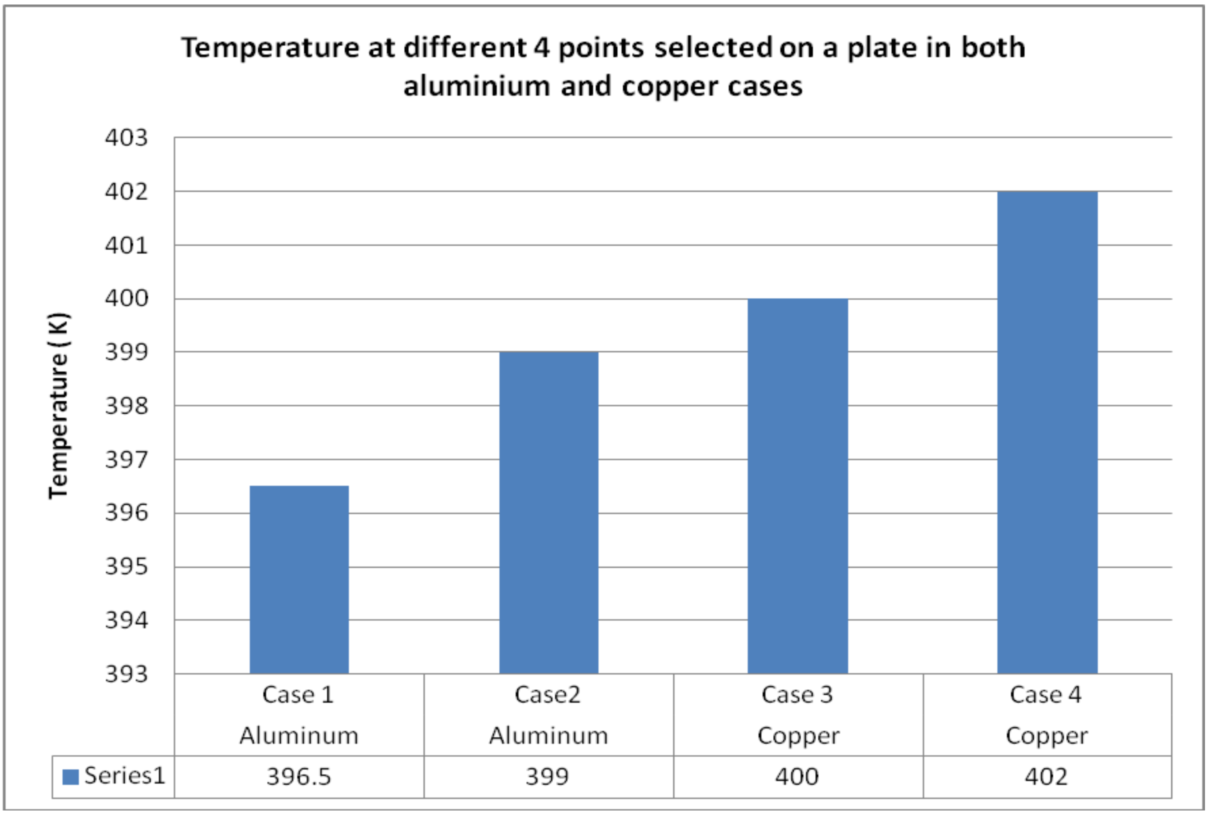

Figure 6.1 Temperature at different 4 points selected on a plate in both aluminium and copper cases

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