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CFD Analysis for Enhancing the Heating Performance on the Chimneys

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Abstract: *To provide naturally stacking venting, a simple vertical shaft built to collect solar heat causes hot air to ascend out from the top of a building and draw cold air into the bottom of the building. A solar thermal collector can help with natural ventilation, especially in places with low wind speeds and significant sun irradiation. The major goal of this study is to increase the heating performance of a chimney by applying computational fluid dynamics to change the quality. For the temperature differences within the Chimneys, a computational fluid dynamics assessment was conducted on three distinct designs of Chimney.*

Keywords: Solar Thermal Collector, Solar Chimney, CFD, Natural Ventilation, Passive Cooling

I. Introduction

By stimulating air convective upward, a solar chimney, also known as a solar thermo chimney, can help improve natural ventilation in buildings. To provide naturally stacking venting, a simple vertical shaft built to collect solar heat causes hot air to ascend out from the top of a building and draw cold air into the bottom of the building. A solar thermal collector can help with natural ventilation, especially in places with low wind speeds and significant sun irradiation.

The solar chimney has been one of the technologies which operates on the buoyancy concept. Where's the air is heated through green house gases which produced by solar radiation (heat energy) (heat energy). The costs aren't prohibitively expensive. Buildings can be cooled or heated using a variety of approaches. The solar chimney can be installed on the roof or on the inside of a wall. Solar chimneys are solar passive ventilating devices, which means they don't use any mechanical components. The heat is dissipated by the use of convective cooling. Because hot air rises, the solar chimney is meant to eliminate unnecessary heat during the day and exchange internal (warm) air for outdoor (cool) air [1].

The solar chimney is primarily composed of a black hollow thermal mass with an entrance at the top to allow hot air to escape. The air flowed through the room and out the chimney's top. The two objectives are achieved: greater venting and a reduction in the temperatures inside the space. It can also be used in reverse to heat the room.

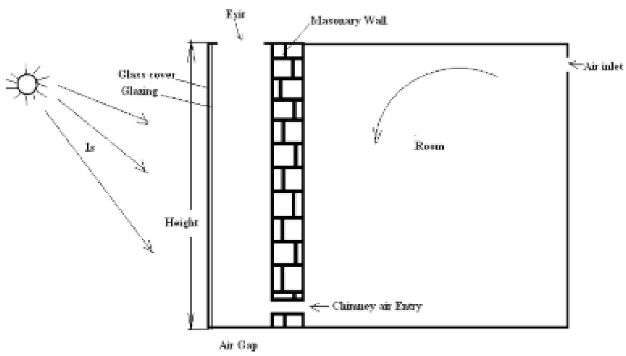

Figure 1 Solar Chimney

Solar chimneys can be used for a variety of purposes, including ventilation, electrical generation, and food dried.

When the outside temperature goes up, providing adequate interior conditions becomes difficult. Avoiding heating is the most efficient way to cool a building. Sunlight energy received through the roofs, walls, and windows, as well as heat produced by appliances and air leaking, are the primary sources of heat in a buildings. Although there are certain specific measures for preventing heat accumulating, implementing all of them may not be practicable or sufficient. Some relief is provided by air conditioners.

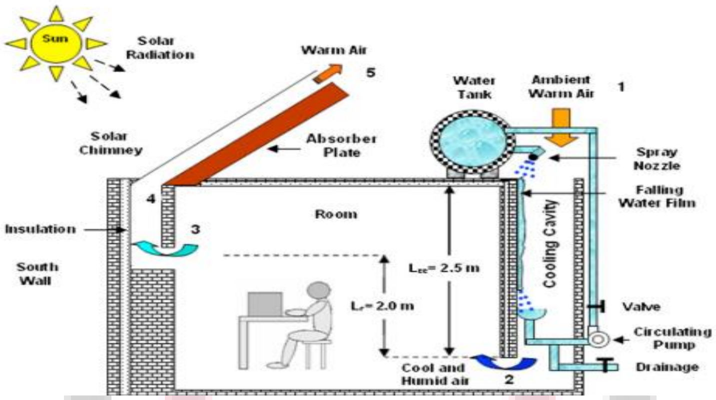

Figure 2 Passive Cooling and Natural Ventilation

The buoyancy-driven movement of air into and out of buildings is known as the chimneys effects. Buoyancy is caused by a difference in density between interior and exterior air due to temperature and moisture changes. The stack effect can be induced without raising the room temperature by using a solar-heated chimneys.

II. Literature review

(He et al., 2021) [1]The solar chimney's potential for buildings ventilating has long been known. Furthermore, very little information on its ventilating effectiveness in actual buildings has been published. The field performance of the solar chimneys connected to a testing housing was investigated in this study, which took place in Hangzhou. The airflow rate in the chimneys channel was used to calculate the ventilation rates. Despite being positioned on the south-east wall, the solar chimney supplied reasonably stable air change rates of roughly 2–5 h1 on average 24 hours a day.

(Dhahri et al., 2021)[2] The goal of this study is to analyze the thermal performance of four alternative absorber wall designs for solar chimney-shaped channels. For varied radiation from the sun intensity, a comprehensive energy and exergy analysis was done. The four configurations are investigated using Computational Fluid Dynamics in order to discover the best configuration. A flat corner, rounding corner, triangular corner, and trapezoid corner define the arrangements. The results of Computational Fluid Dynamics were compared to experimental data in the literature, and an excellent correlation was found between predictions and measurements.

(Mohamed et al., n.d.)[3] The impacts of contractions of the input and outflow regions of a vertical solar chimney were investigated using Computational Fluid Dynamics in this research. The flow rate fell in both the entrance and outflow locations, according to the findings. The outflow area had a greater influence than the entrance area. The flow rate fell linearly with the outlet area, but only when the inlet area was less than half of the air gap was it considerably influenced.

(Access, n.d.) [4] The computational domain, a factor impacting the accuracy of a CFD simulation of a solar chimney, a system for ventilation system of building, was explored in this study to see how it affected the expected performance of a solar chimney connected to a buildings. We looked at four different domains: both the chimneys and the housing, the chimney and the inlet lengths, the chimneys with the horizontally inlet, and solely the chimney's air channel. The RANS equations and RNG k-turbulence model were used to create the CFD model. The height, gaps, heat fluxes, and placement of the heat source in the air channel all varied in the chimneys.
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(Sakhri et al., 2020)[5] An experimentally investigated of the performances of a coupled network comprising of an earth-to-air heat exchanger and a solar chimneys is carried out. The major goal is to lower expenses while maximizing the direct benefit of the two techniques. The results revealed that the new technology was capable of generating two distinct heat regimes in the same day.

(Kong et al., 2020)[6]The ideal inclination angle of a small-scale roof-top solar chimney for maximal ventilating performance is determined using a CFD-based technique. The absorbers wall of the chimneys in question is 500 mm long, with a 40 mm air gap width. To begin, CFD simulations are run on a two-dimensional solar chimney models with inclination angles ranging from 30 to 90 degrees respect to the horizontal plane and various heat flows. Then, using the CFD data, a mathematical approach is provided for estimating the ventilating performance of a solar chimneys at various incidence angles under real-world climate circumstances.

(Cheng et al., 2018)[7] Solar chimneys have traditionally been used for natural ventilation, but their application against smoke exhaustion has received little attention. A 1:3 reduced-scale test platform with dimensions of 1.5 m 1.5 m 0.9 m (height) was used to optimize solar chimney under natural ventilation and smoke exhaustion, taking into account four influential factors: cavity inlet height (0.2-0.8 m), cavity depth (2.5-17.5 cm), solar radiation (400-1,200 W/m2), and fire size (6.8-15.8 kW). Both naturally ventilated and smoky exhaustion follow the same pattern along the air inlet heights and cavities depths, indicating that it can be used for smoking exhausting in a fire with sacrificing naturally ventilated effectiveness.

(Jubear, 2021)[8]For the summer climate patterns in Kut, Iraq, this research presents an experimental study of a coupled network comprising of a passively ventilation system and a hybrids cooling system for a two-story buildings. The building has two storeys, each of which has a room measuring 1 m3. A vertically solar chimney(SC) attached to the building, 3 m high, 1 m wide, and 0.3 m long, with an orientation to the geopolitical south, represents the passively ventilation system.

(Moosavi et al., 2020)[9]The thermal and ventilated performances of a newly built solar chimney in combination with a wind catcher and water spray systems for a two-story office building in a hot and arid area is highlighted. The building's north facade is a wind catcher, which, when combined with a solar chimney on the roof, provides ventilation for both levels through the shortest flooring void possible. To evaluate the chilling and ventilating capability of a solar chimney with and without the windcatcher, an experimentally investigated using a reduced scale replica and computational fluid dynamics (CFD) analysis was conducted.

(Elghamry& Hassan, 2020) [10] The investigation is carried out for natural and forced airflow inside the geothermal tubes, as well as for the chimneys and PVs facing south at an angle of 30° and 45° with the horizontal. The naturally ventilator of the solar chimney and window is compared to the geothermal tube and chimneys ventilated methods. The results reveal that the proposed systems prove their ability to lower the room temp up to 3.5 °C and change daily its air 42 times. A naturally geothermal tube-chimney system with a 30° angle produces the least amount of ventilated air. At 30° and 45°, respectively, the ratio of total daily ventilated air by naturally geothermal tube-chimney to that by chimney-window is around 56.3 percent and 65 percent, while the ratio of heat released is 55.6 percent and 64 percent.

III. Methodology Used

The fundamental dimensions of a thermally chimneys with a rectangle cross-section of constant area were planned and manufactured. The chimneys is made up of four 5 mm thick translucent acrylic sheets held together by two aluminum frames. One row of holes in a pair of sheets allows for the installation of 12 cylindrical electricity heating with a diameter of 16 mm(d) and a length of 200 mm. These heaters act as the principal heat exchanger/hot fluid heater and are controlled by an OMEGATM PID (proportional integral derivative) control to maintain a consistent heated temperature increase. The secondary heat exchanger's bottom row of holes is disregarded and not simulated. The horizontally cartridges heating are placed evenly, with an optimum centre-to-centre spacing of 1.75d, which was calculated using 2D CFD heat transfer simulations in (Ma et al., 2019). The chimneys diameters below and above the heater, respectfully, are 32.5d and 12.5d.

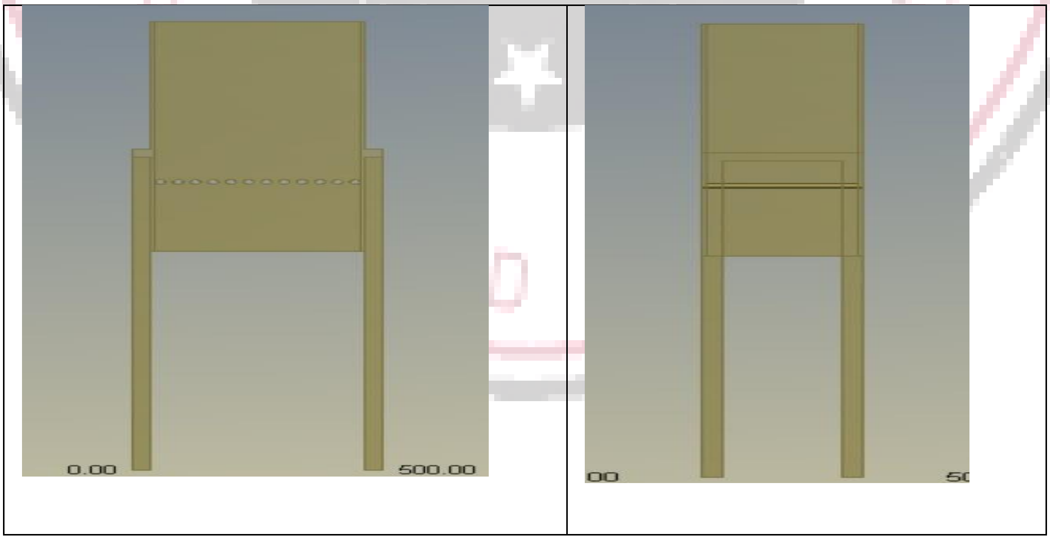

Figure 3 CAD Model Of Chimney

Table 1 : Meshing condition defined in various cases

	CASE-1	CASE-2	CASE-3
NODES	426180	563354	902046
ELEMENTS	1616353	2269505	3936056

Table 2 : Boundary condition selected for the analysis

Boundary conditions	Value
Inlet velocity	0.5m/s
Outlet pessue	101325pa
PIPE Temperature	443k

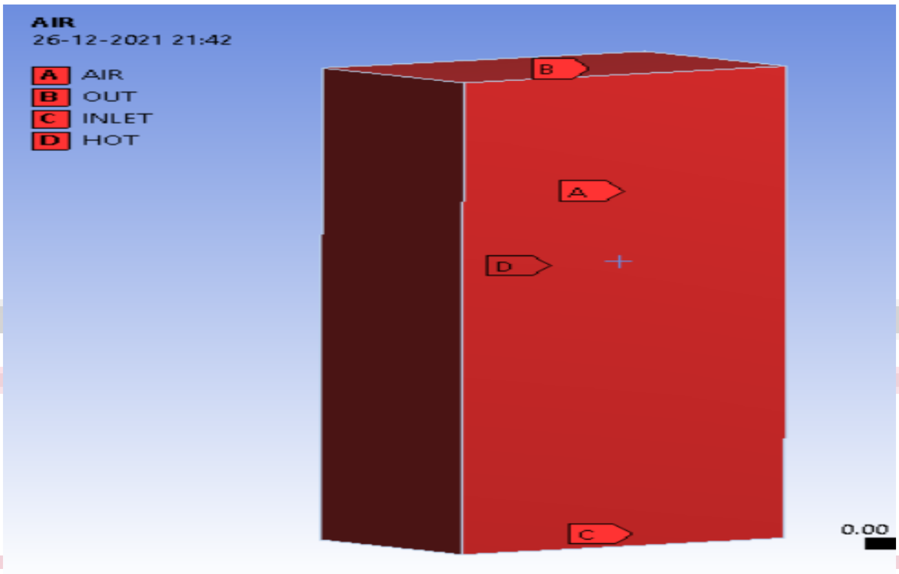

Figure 4 Boundary conditions for Analysis

IV. Result

1. The major goal of this study is to increase the heating performance of a chimney by applying computational fluid dynamics to change the quality.
2. For the temperature differences within the Chimneys, a computational fluid dynamics assessment was conducted on three distinct designs of Chimeny.
3. For a better knowledge of temperatures dispersion, three alternative planes were considered: vertically, middle, and bottom.
4. The Chimney's geometrical parameters are 930(width) 600(-depth) 1800(height)mm, while the inner air body's volume is 300(width) 190(depth) 730(height)mm to fully encapsulate the thermally boundary condition over the chimneys.
5..Various CFD study results are explained in this chapter utilizing contours diagrams, tabulated data, and graphical representation.

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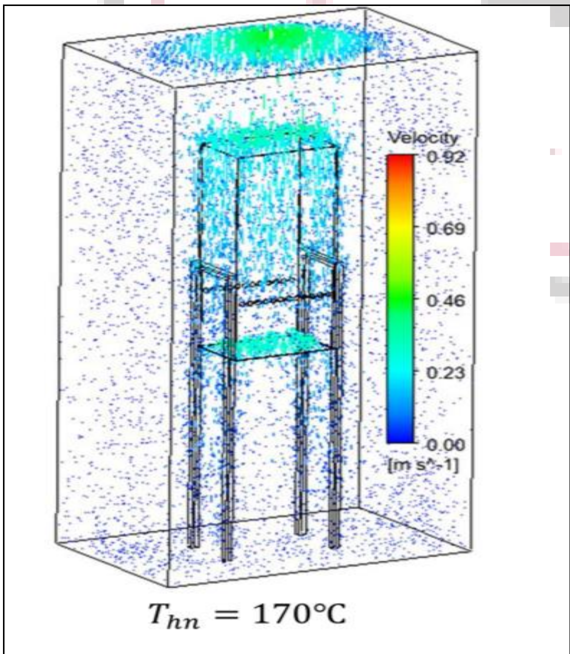
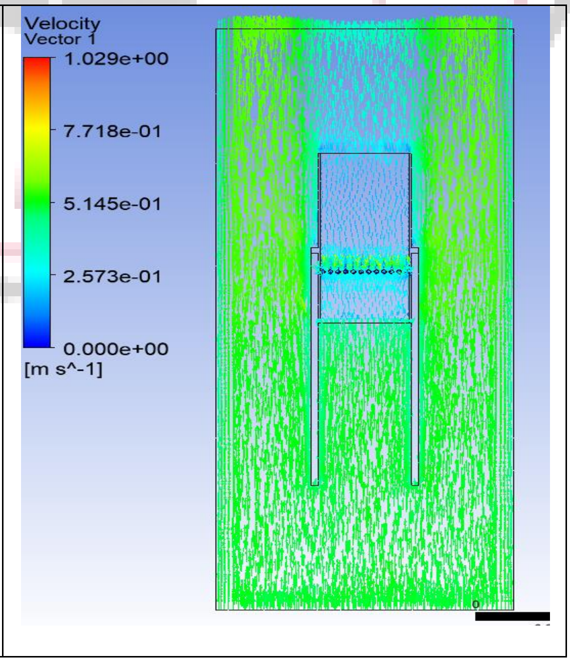
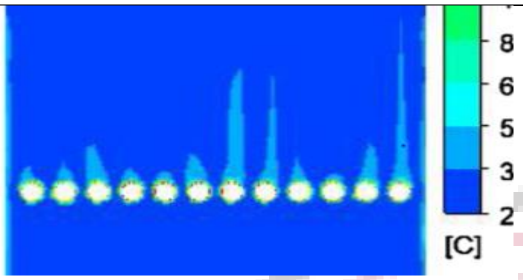
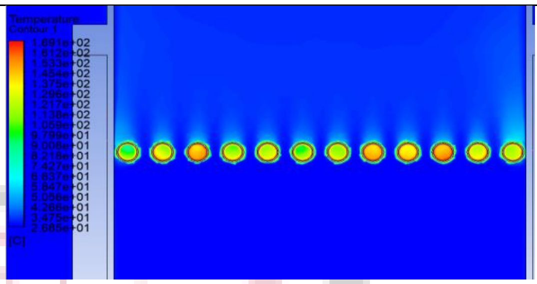




Base paper maximum velocity 0.92m/s.at 170 C	Current study maximum velocity 1.0m/s at 170C
The percentage of error during validation study was 8%.	
	
Base paper temperature contours	Current study temperature contours

CASE-1

It is observed from the Velocity contour diagram at mid plane at 170oC. The maximum Velocity at the mid surface is 1.024m/s as shown in figure no. 5.1.

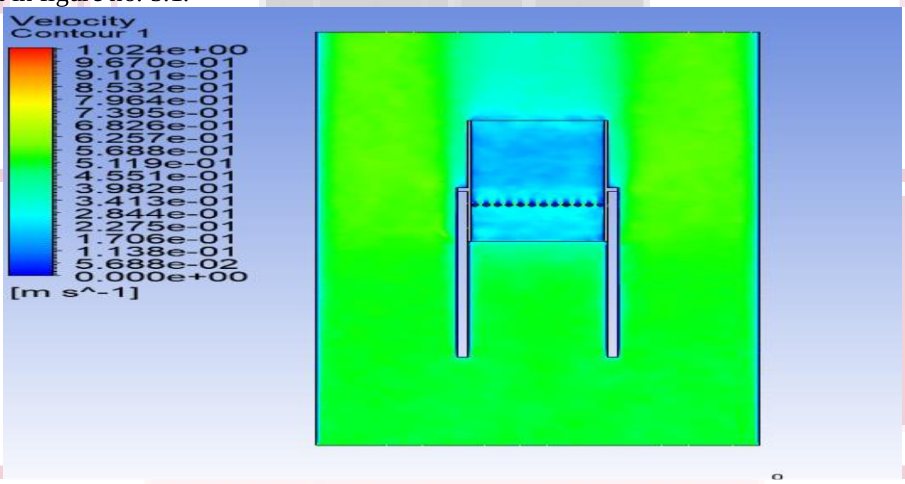


Figure 5 Velocity contours

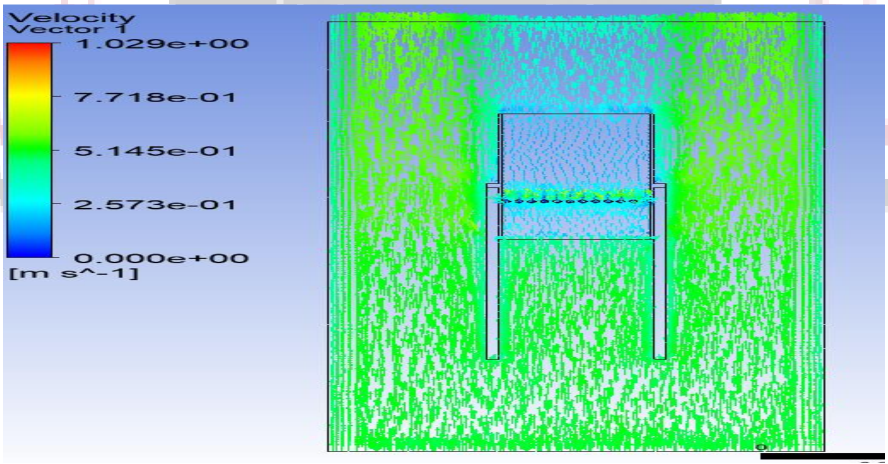


Figure 6 Velocity Vector

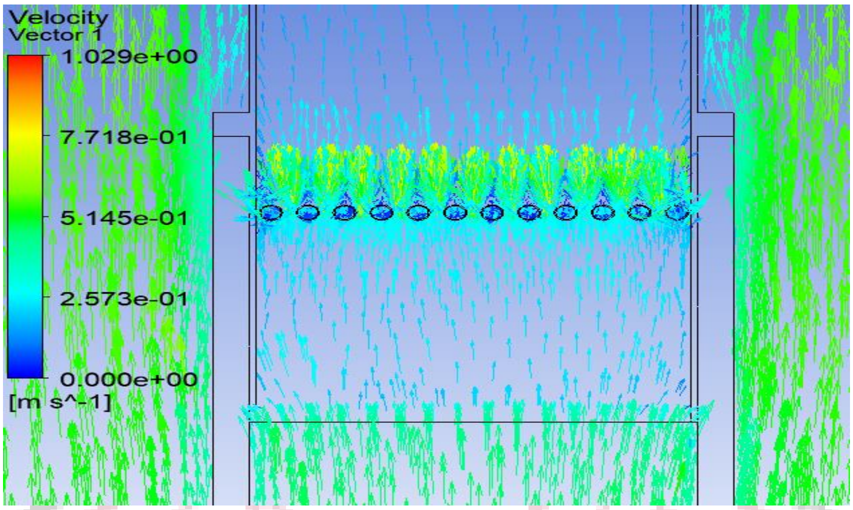


Figure 7 Velocity Vector

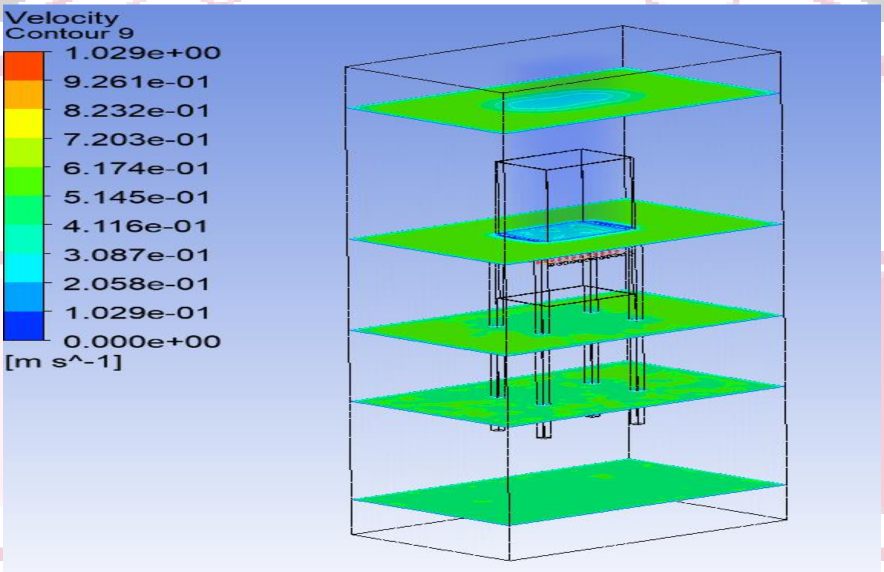


Figure 8 Velocity contours at different plane

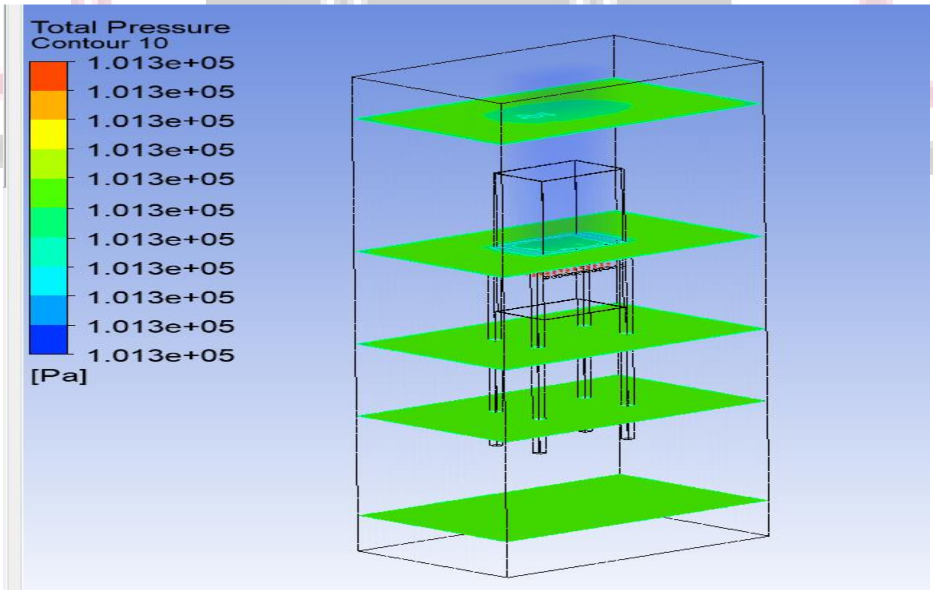


Figure 9 Pressure contours at different plane

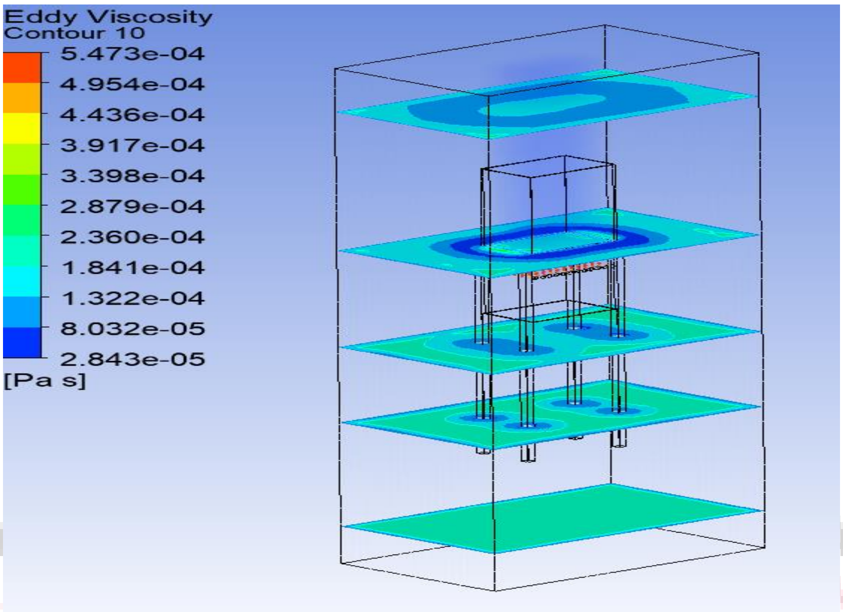


Figure 10 Eddy Viscosity contours at different plane

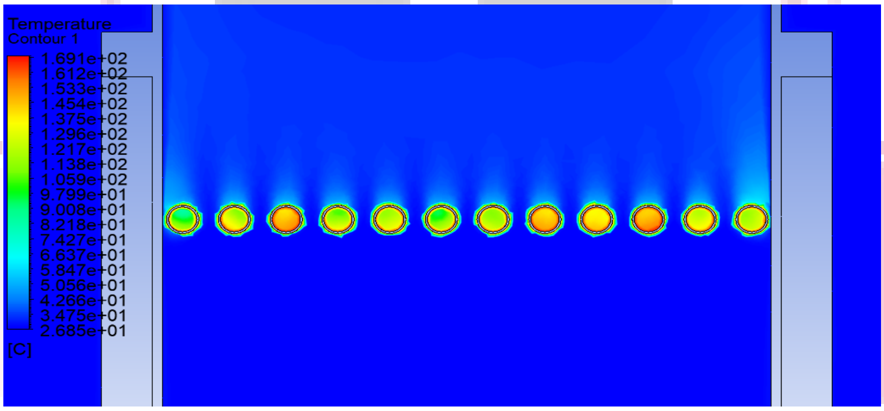


Figure 11 Temperature Contour

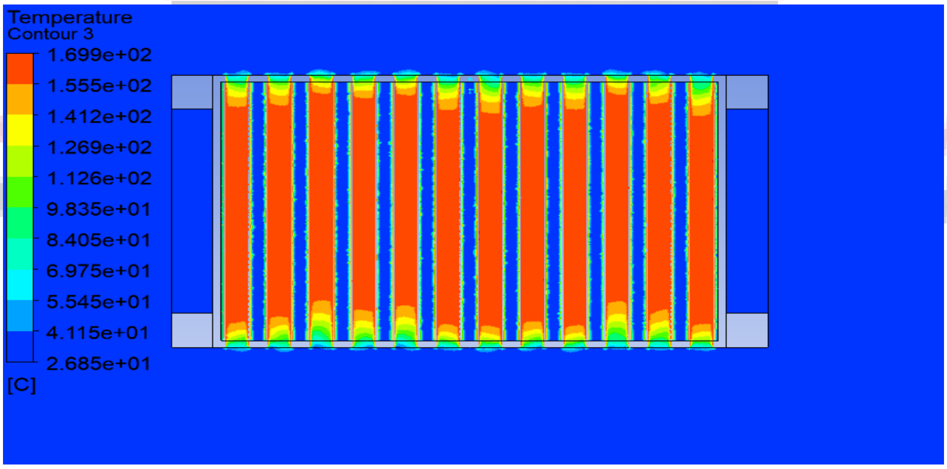


Figure 12 Temperature Contour

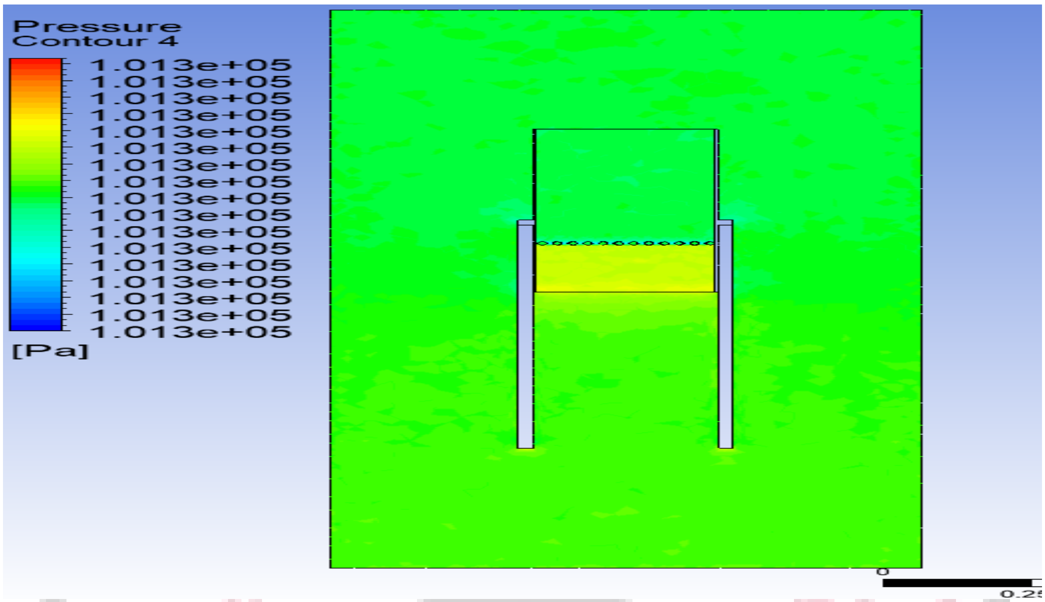


Figure 13 Pressure contours

CASE-2

1. It may be seen in the mid-plane of the Velocity contour diagram at 170°C. As illustrated in Figure 5.11, the highest velocity at the mid surface is 1.174m/s.
2. It may be seen in the temperatures contours diagram at 170oC in the vertical plane.
As indicated in figure 5.18, the highest temperature at the vertical surface is 169 oC.
3. It can be seen in the Eddy viscousity contours graphic at 170oC in the horizontal plane.
Figure 5.16 indicated that the maximum Eddy viscosity at the vertical plane is 4.17E-4Pa S.

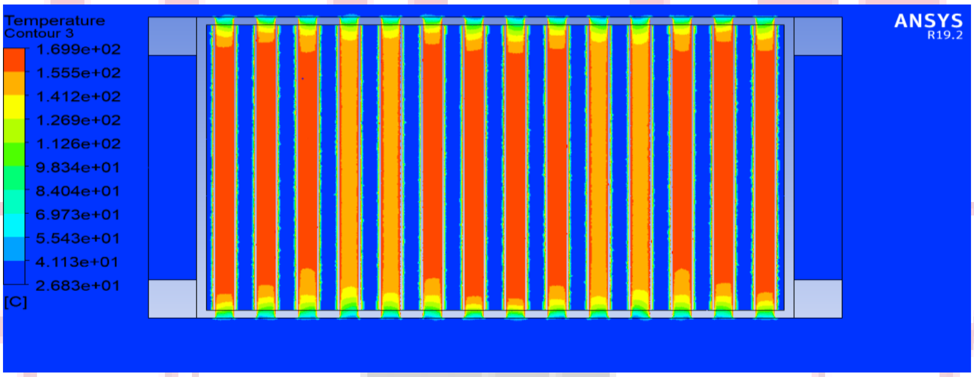


Figure 14 Temperature Contour

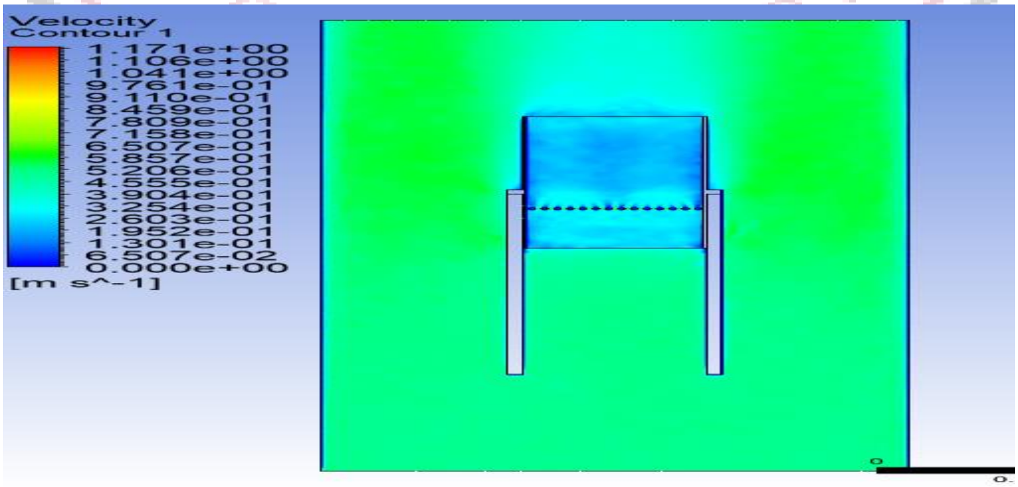


Figure 15 Velocity Contour

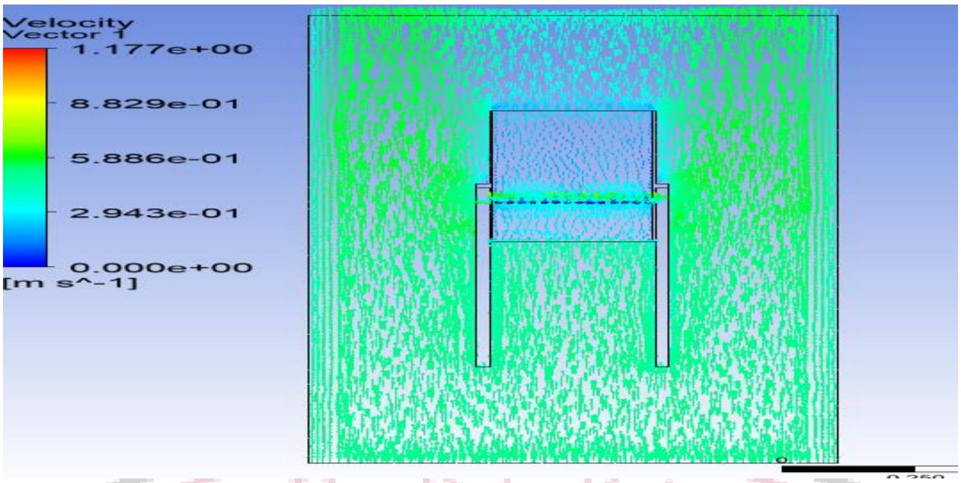


Figure 16:Velocity Vector

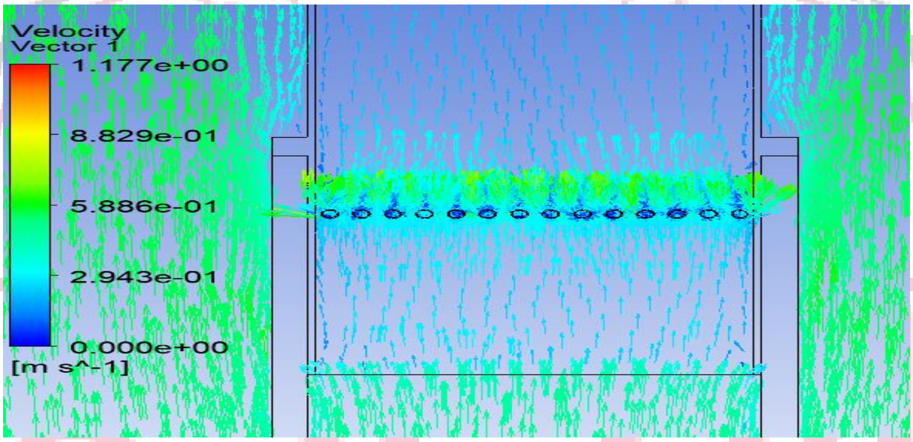


Figure 17 Velocity Vector Near Pipe ares

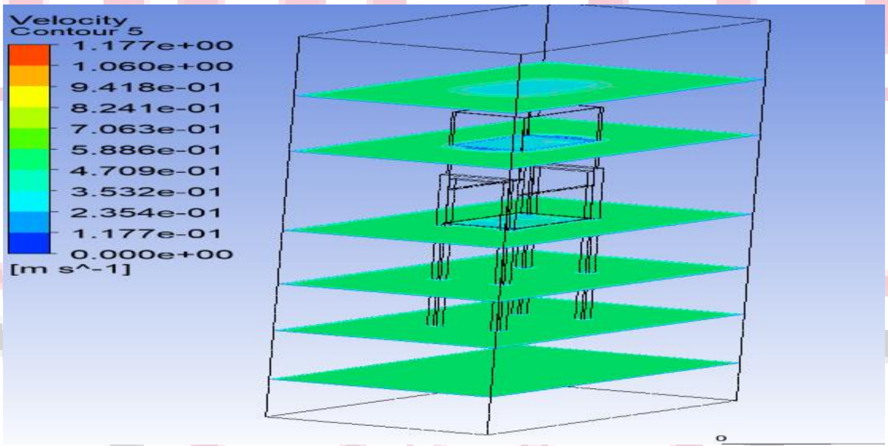


Figure 18 Velocity contours at different plane

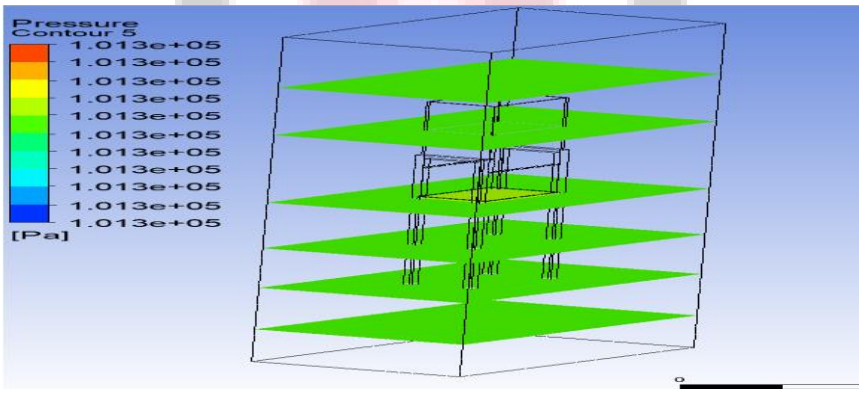


Figure 19 Pressure contours at different plane

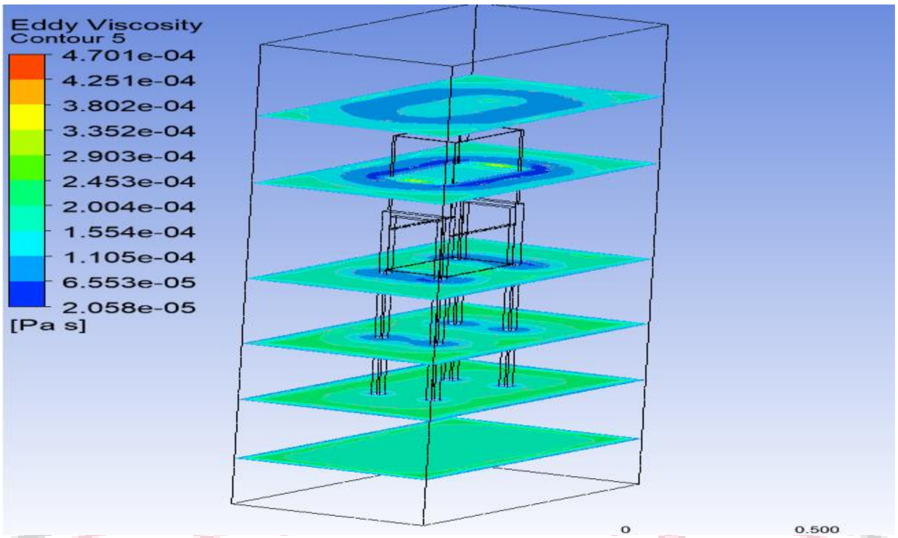


Figure 20 Eddy Viscosity contours at different plane

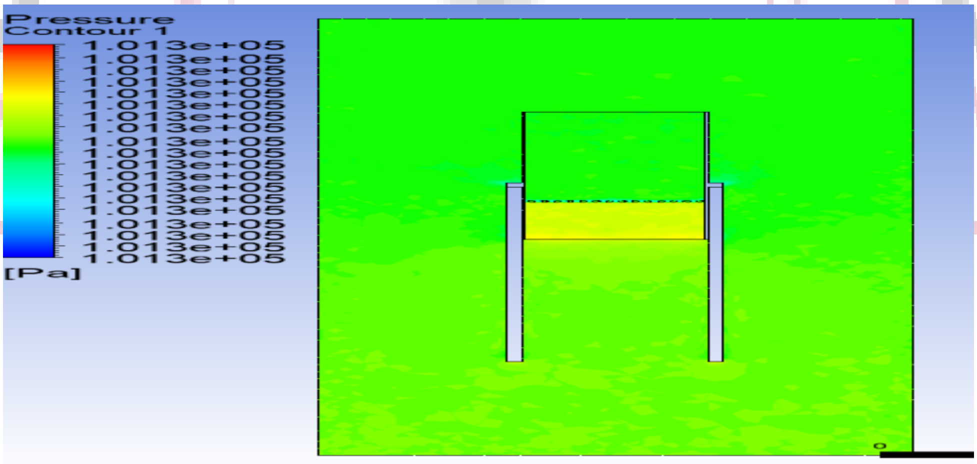


Figure 21 Pressure contours

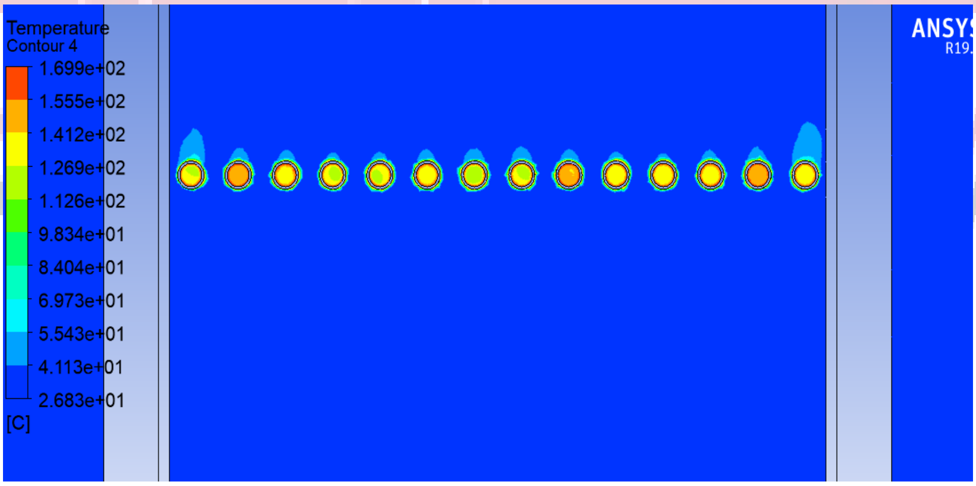


Figure 22 Temperature contours

CASE-3

1. It may be seen in the mid-plane of the Velocity contours diagram at 170°C. As illustrated in figure 5.19, the highest velocity at the mid surface is 1.496m/s.
2. It may be seen in the temperatures contours diagram at 170oC in the vertical plane.
As indicated in figure 5.26, the maximum temperature at the vertical surface is 169 oC.
3. It can be seen in the Eddy viscosity contours graphic at 170oC in the horizontal plane.
Figure 5.24 indicated that the maximum Eddy viscosity at the vertical wall is 5.2E-4Pa S.

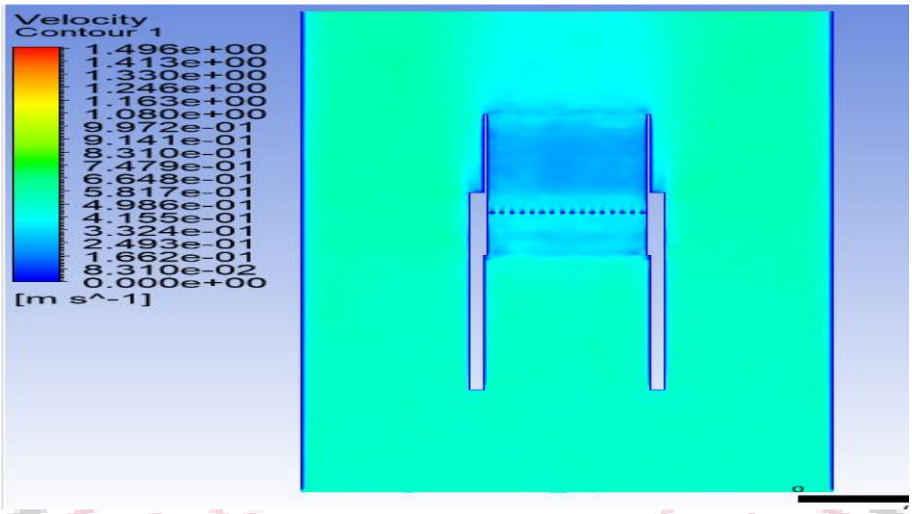


Figure 23 Velocity contours

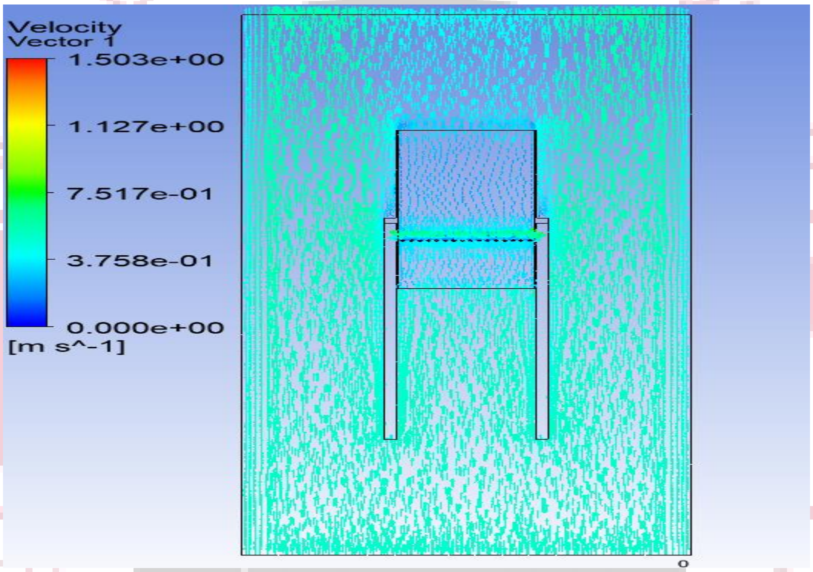


Figure 24 Velocity vector

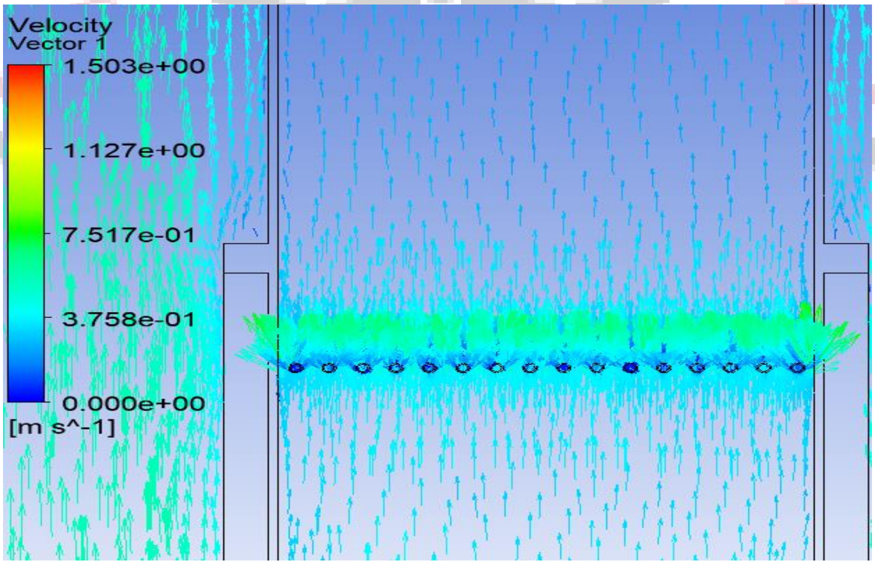


Figure 25 Velocity vector near heater tube

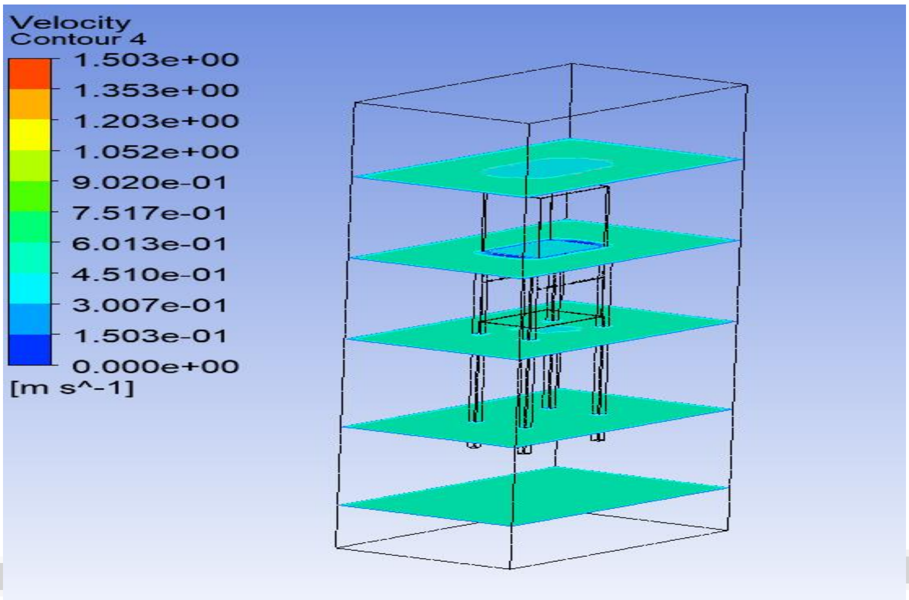


Figure 26 Velocity contours at different plane

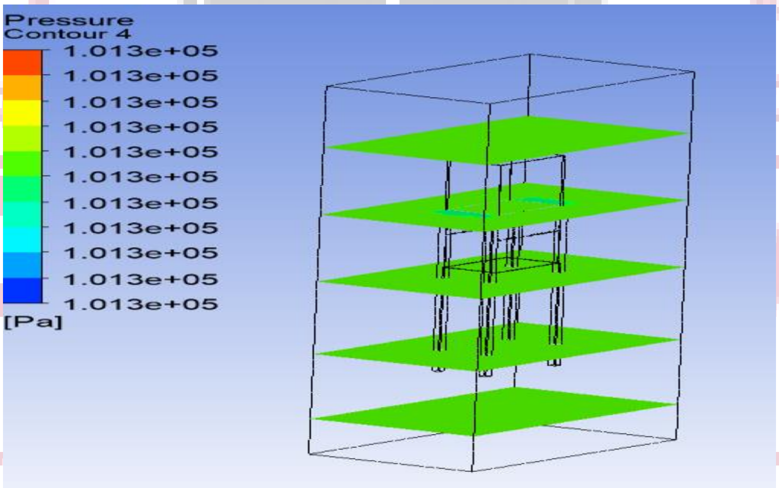


Figure 27 Pressure contours at different plane

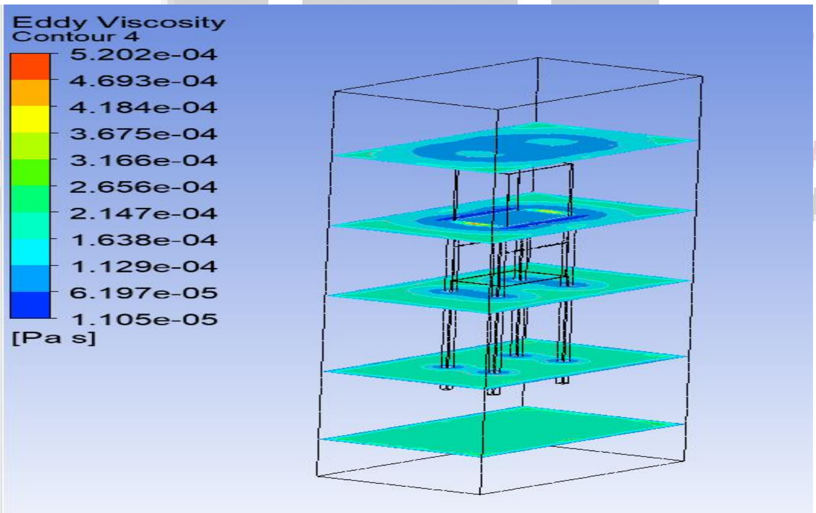


Figure 28 Velocity contours at different plane

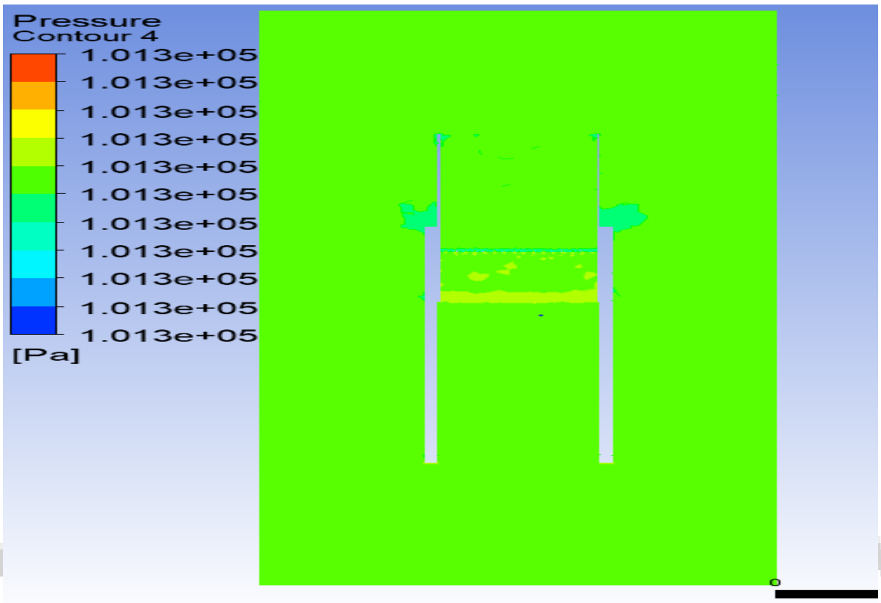


Figure 29 Pressure contours at XY plane

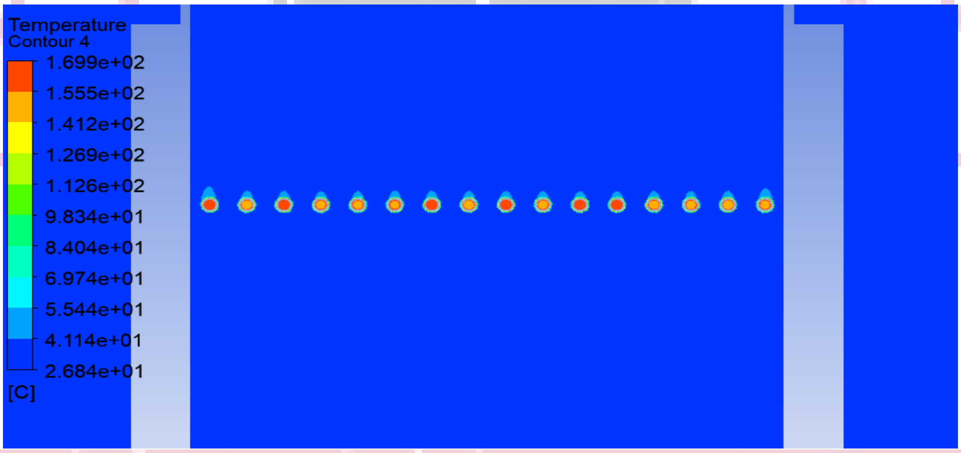


Figure 30 Temperaturecontours at XY plane

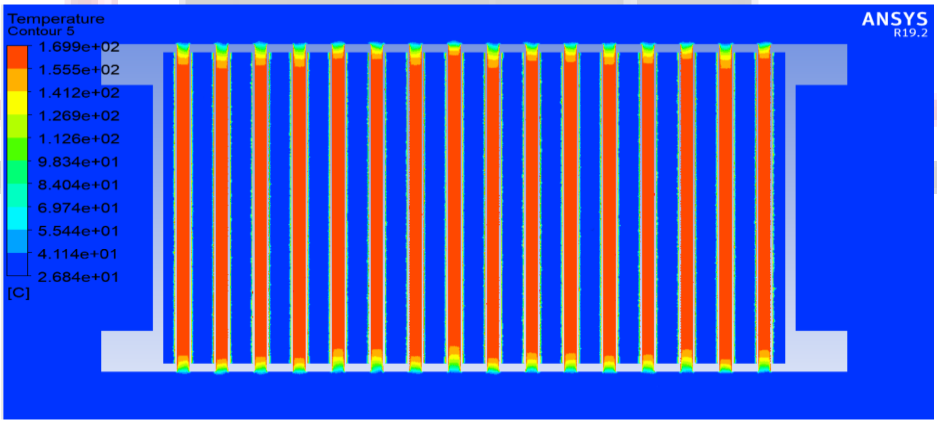


Figure 31 Temperature contours at XY plane

Table 3: Parameters in various cases

CASES	Velocity(m/s)	Temperature(C)	Pressure(Pa)	Eddy viscosity
1	10.24	161	101325	5.47
2	11.71	155	101325	4.7
3	14.96	141	101325	5.2

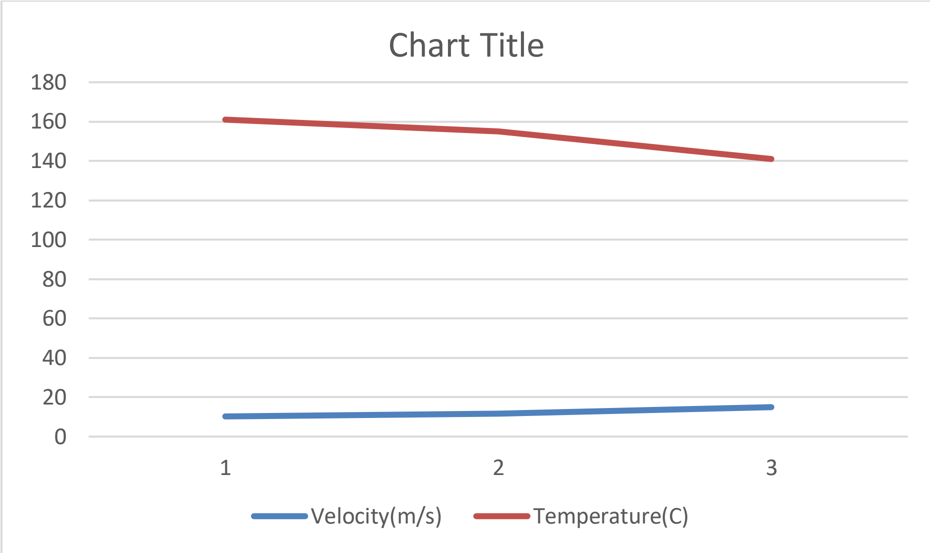


Figure 32 Temperature and velocity variation in three cases

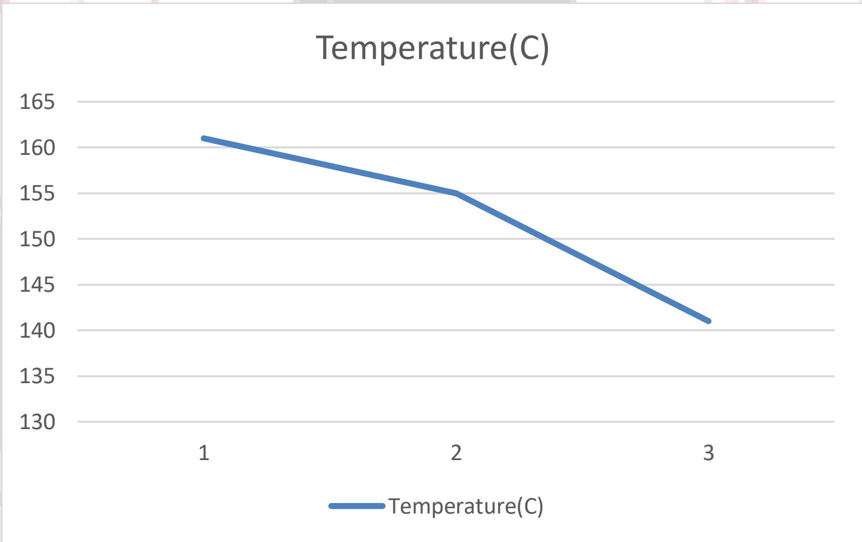


Figure 33 Temperature variation in three cases

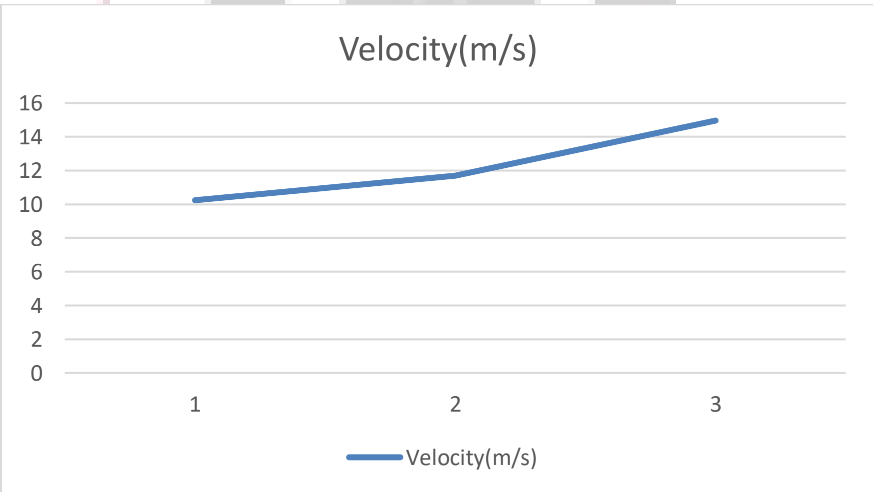


Figure 34 Velocity variation in three cases

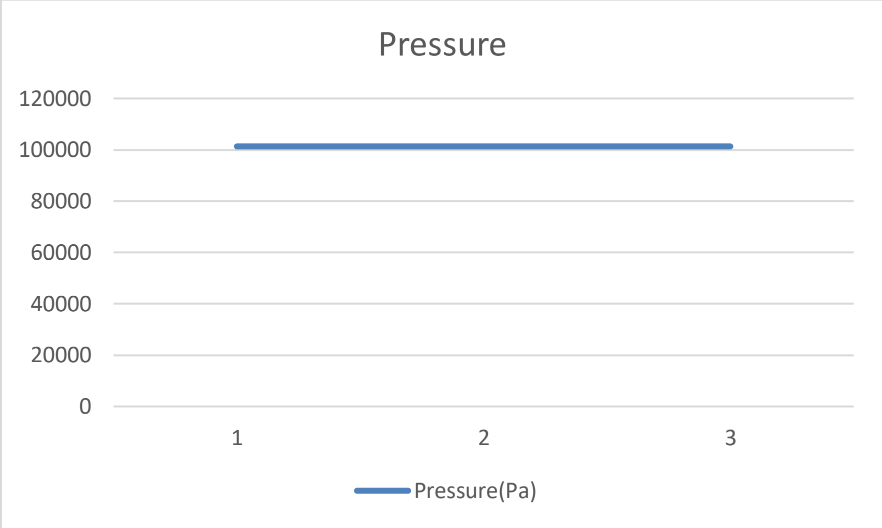


Figure 35 Pressure variation representation in different cases

V. Conclusion

The velocity of the system increase with increasing the number tube and total heat tranfer rate increae with tube.

- In first case number of tube is 12 and maxium velocity 10.24m/s.
- In case second maxium number of tube 14 and maxium velocity 11.71m/s
- In case third maxium number of 16 and maxium velocity 14.96m/s.
- The diameter of tube decrease with incease the number of tube.In case first maxiumdia of tube is 16mm and in case-2 and case-3 are 12mm,8mm.
- The heat tranfer rate increase in the system.the total temperature in case-3 deeacreseupto 141 degreee.
- The overall performance of the system increase with increase the heat tranfer rate.

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