HEAT TRANSFER AND FLUID FLOW ANALYSIS OF CIRCULAR RECEIVER TUBE OF SOLAR COLLECTOR

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Abstract: Solar Energy is radiant light and heat from the Sun, It is an important source of renewable energy that is available in abundant and can be converted to other form of energy by latest technology. Effective utilization of solar energy is one of the challenges faced globally. One of such problem is address in this thesis. Effective Utilization of solar energy for heating water using solar heat is addressed. Efficiency of Solar heater can be addressed if we research on Operating conditions (isolation, tracking mode, operating temperature, flow rate, etc.), Properties of material. , Receiver design parameter, Concentrator geometry. In this thesis we have taken Receiver design parameters as a parameter to improve the efficiency of solar heater. Bother experimental and CDF analysis is carried and compare for Circular Shape receiver.

Key Words- Solar Heater, Solar Heater Receiver, Circular Section Receiver, CFD Analysis, Fluid Flow**.**

1. INTRODUCTION

Globally organizations are working towards generation of clean, safe, low cost, pollution free Energy. Solar energy is one among that is available is freely and in abundant quantity. It is inexhaustible source of energy. Solar energy has been identified as one of promising alternative energy source from the future. Solar energy can be harnessed using a range of ever –evolving technologies such as solar water heater, photovoltaic conversion, biomass, Solar Cell etc. Now it is also important how efficiently we can convert solar energy in usable form of energy. In this thesis we will be exploring the ways to optimize the efficiency of solar heater by optimizing the design of Receiver Tube. Many designs have been considered for concentrating collectors. Parabolic trough Collector (PTC) is receiving attention wide range of applications in domestic as well as industrial process of heat generation. A parabolic collector includes the receiver tube, concentrator and power transmission collector structure. The Receiver is the element of system where solar radiation is absorbed and converted to thermal energy. The performance of any solar energy system improves if the receiver efficiency is increased, all other variable being constant. The performance of the receiver should be maximized independent of the rest of the system if such steps does not significantly increase the receiver cost.

2. Scope of Work

CFD analysis of receiver tube for different geometries with and without insert to analyze heat transfer and flow characteristic

Comparing experimental and CFD result of the receiver tubes.

3. Experimental Setup

- Metal frame of length 1200mm and height 750mm with M6 nut-bolt.
- Inlet pipe is assembled with the help of elbow on frame.
- Rotameter fixed with inlet pipe.
- Outlet pipe is assembled with the help of elbow and T-junction pipe on frame.
- Flanges are fixed with the washer to connect the receiver pipe.
- Inlet and outlet valve for thermocouple are assembled at inlet and outlet respectively.
- Flow control valves are fixed with pipe at inlet and outlet respectively
- Heaters are assembled on the receiver pipe; heater-1 to heater-9 respectively.
- Jack connector on receiver pipe to connect heater to demonstrator.
- Water storage tank of 750 litres.

Figure 1: Experimental Setup

Receiver Dimension

Length: 1m

Diameter: 0.025 m

Steps

- Start the pump and fluid is allowed to flow for few minutes.
- Switch on the demonstrator and set resistance as per requirement with the help of dimmer stat. Heater will start automatically.
- The flow rate of fluid through the test section is set at desired value and changed through flow control valve.
- Outlet is sent to the drainage directly.
- The variations in wall temperature at all 9 locations are observed until constant then outlet bulk temperature of fluid is monitored.
- At steady state condition, all thermocouple readings are recorded.
- The electrical power is kept constant for change of fluid flow rate.
- Repeat the same process with and without insert for different pipe shapes.
- Calculate Reynolds no, heat discharge, Nusselt no, Efficiency and friction factor from the data.
- The different data is recorded in similar way for each experimental run at the steady state conditions.

Calculation

	Flow Rate (LPM)	**Q (J/sec)**	**Efficiency%**	**h(w/m^2C)**	**Nu**	**V(m/s)**	**Re**	**Friction Factor**
Circular Pipe without Insert	2	200.73	77.5	313.59	13.06	0.068	2122.35	9.94*10^-3
	4	193.37	74.92	325.83	13.57	0.1346	4203.92	8.67*10^-3
	6	191.95	74.48	356	14.83	0.204	6367.04	7.97*10^-3
	8	187.6	74.45	361.2	15.05	0.2714	8470.66	7.53*10^-3

	10	184.84	72.12	403.88	16.282	0.338	10549.3	7.2*10^-3
Circular Pipe with Insert	2	204.75	78.48	325	13.54	0.0484	1510.79	0.01059
	4	201.9	77.74	353	14.708	0.09565	2985.39	9.28*10^-3
	6	191.95	74.13	389.6	16.23	0.144	4494.38	8.55*10^-3
	8	185	71.7	403.57	16.8	0.1927	6014.35	8.07*10^-3
	10	175	69.73	437.93	18.2	0.24	7490.64	7.72*10^-3

Table 1: Experimental Value and Calculation

4. CFD Analysis

Numerical analysis using CFD is carried out with plain absorber tube as well as tube with inserts for all circular geometric shapes using same flow parameter derived from experimentation.

The fluid flow simulation is accomplished using commercial CFD software Fluent R.17.0

Meshing of the model of absorber tube is done using pre-processor ICEM CFD meshing tool.

Some assumptions were made for CFD analysis which are:

a. Steady state heat transfer is considered so that the heat flux at the wall does not change.

b. The contact thermal resistance between the wall and the fluid is not considered.

c. Thermal conductivity of the absorber tube material is uniform and constant.

d. The radiation heat transfer from the absorber tube is neglected.

5. Result and Discussion

CFD Analysis for Circular (Pipe) Receiver without Insert

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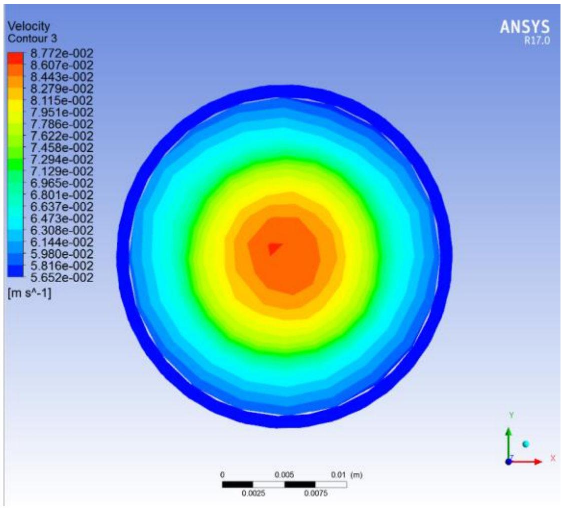

Figure 2: Velocity Contour for 2 LPM

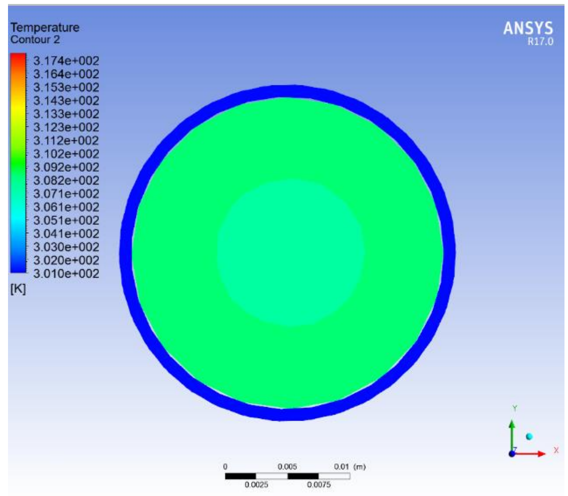

Figure 3: Fluid Temperature at 2 LPM

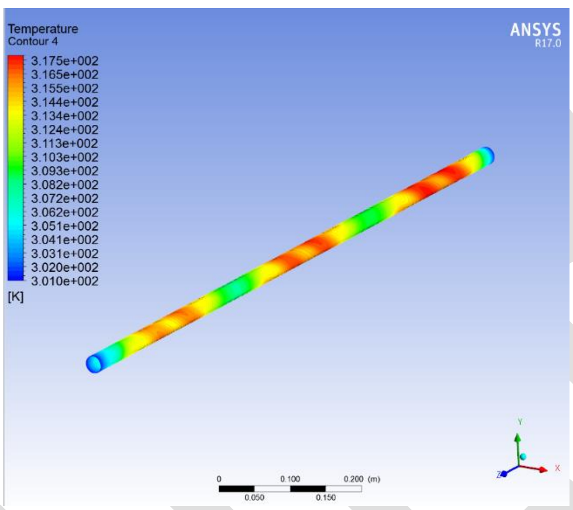

Figure 4: Surface Temperature at 2 LPM

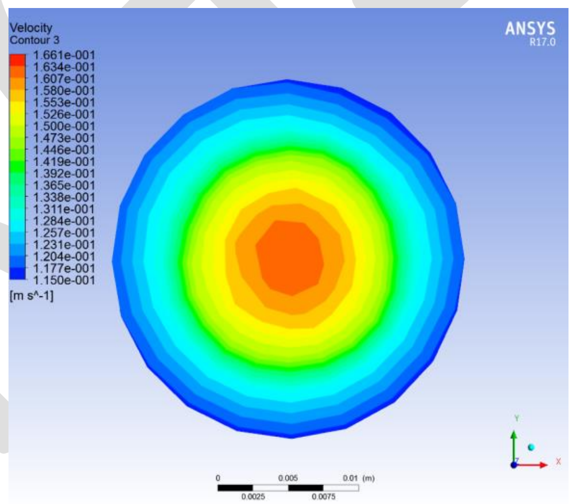

Figure 5: Velocity Contour for 4 LPM

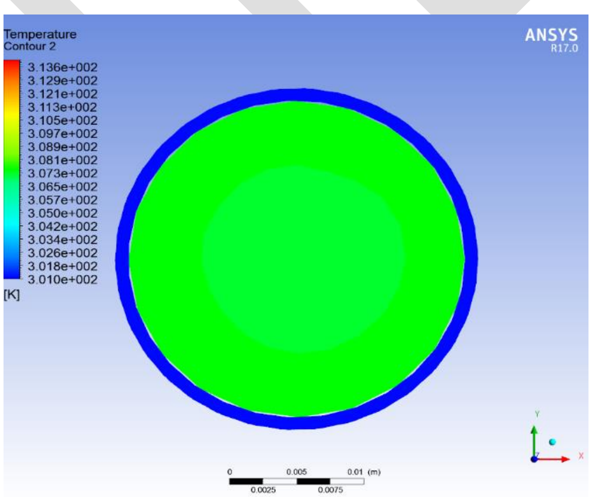

Figure 6: Fluid Temperature at 4 LPM

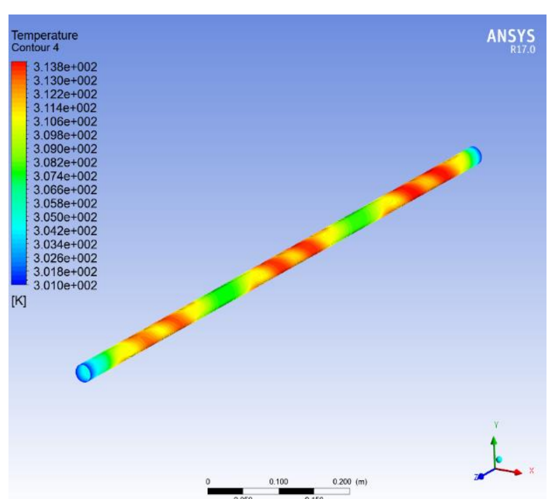

Figure 7: Surface Temperature at 4 LPM

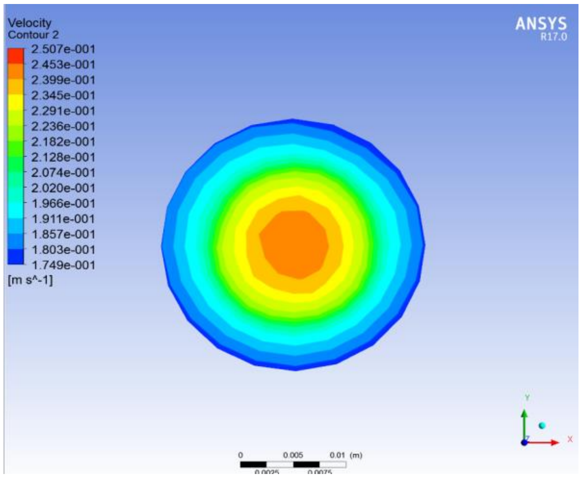

Figure 8: Velocity Contour for 6 LPM

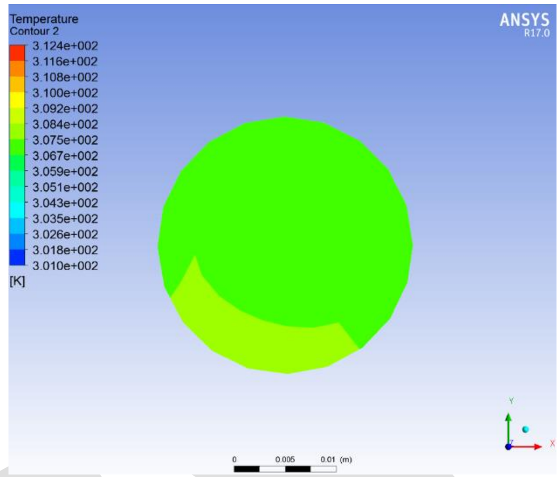

Figure 9: Fluid Temperature at 6 LPM

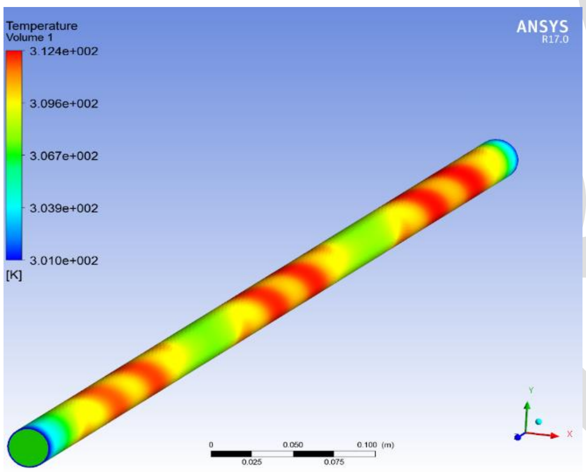

Figure 10: Surface Temperature at 6 LPM

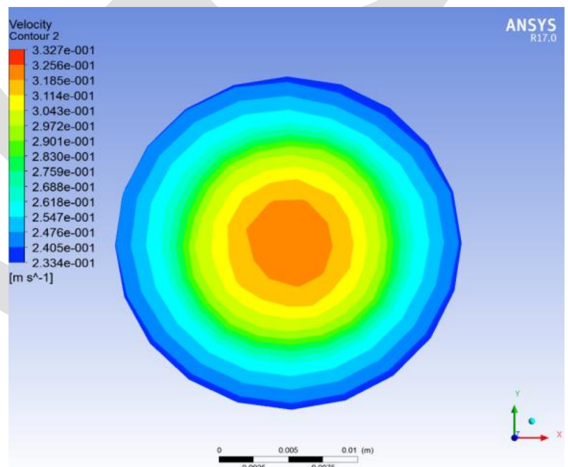

Figure 11: Velocity Contour for 8 LPM

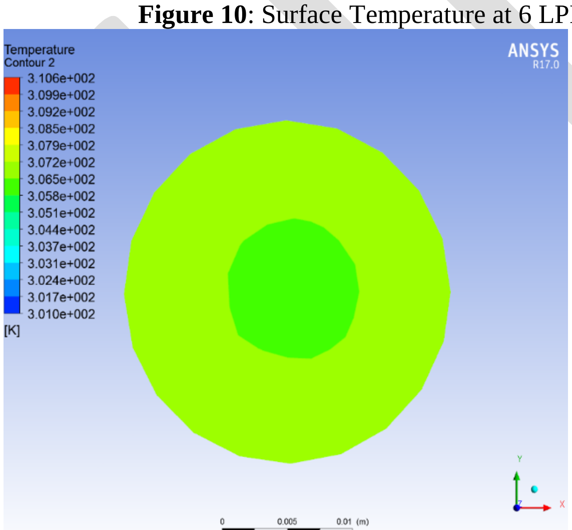

Figure 12: Fluid Temperature at 8 LPM

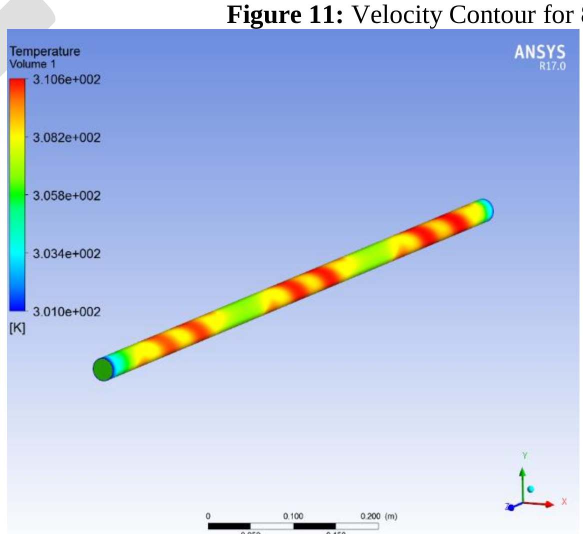

Figure 13: Surface Temperature at 8 LPM

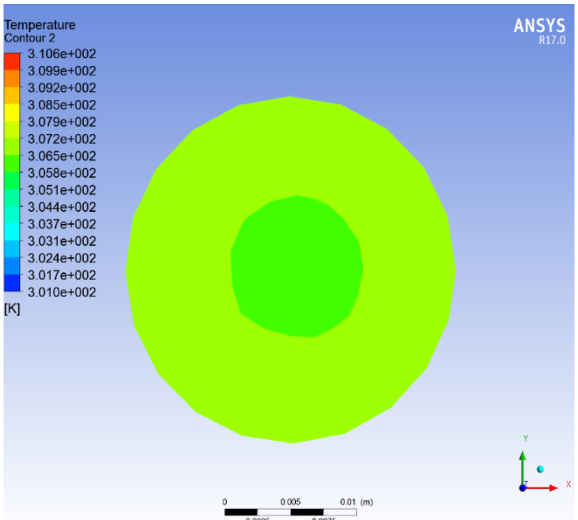

Figure 14: Fluid Temperature at 8 LPM

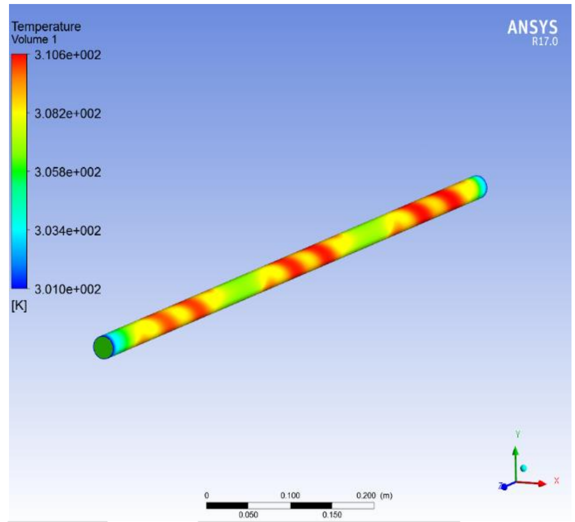

Figure 15: Surface Temperature at 8 LPM

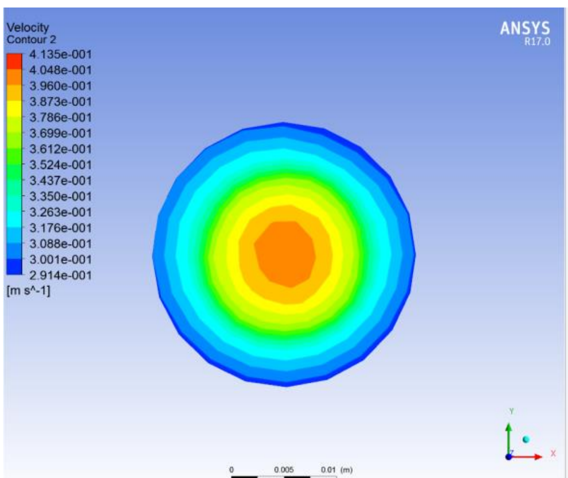

Figure 16: Velocity Contour for 10 LPM

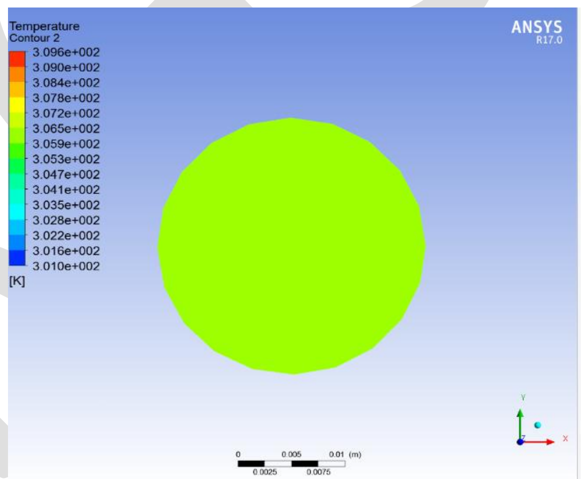

Figure 17: Fluid Temperature at 10 LPM

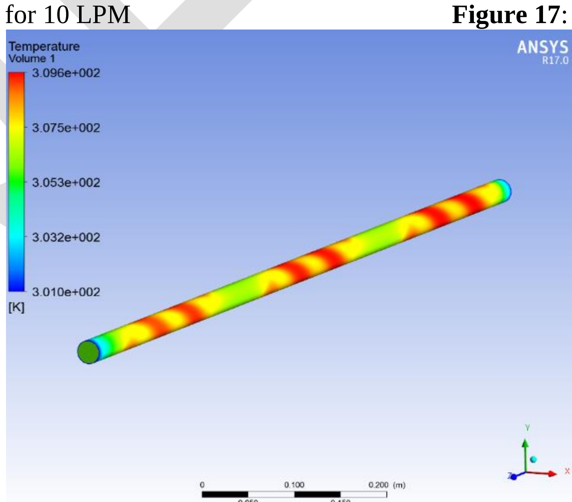

Figure 18 Surface Temperatures at 10 LPM

CFD Analysis for Circular (Pipe) Receiver with Insert

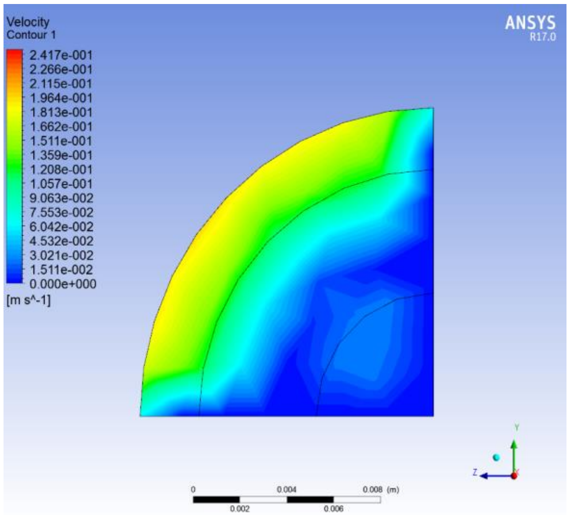

Figure 19: Velocity Contour for 2LPM

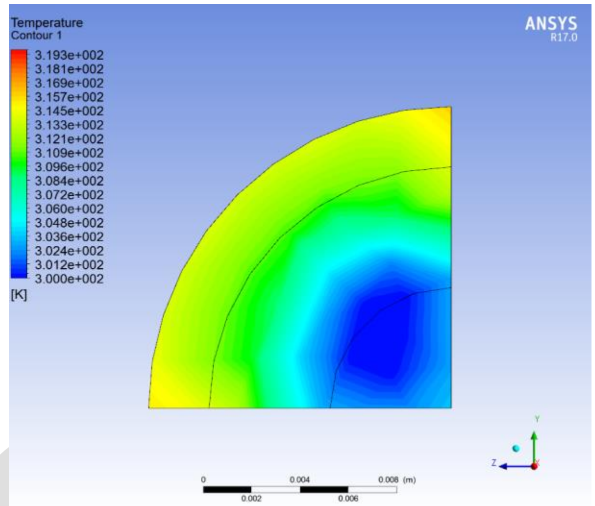

Figure 20: Fluid Temperature at 2 LPM

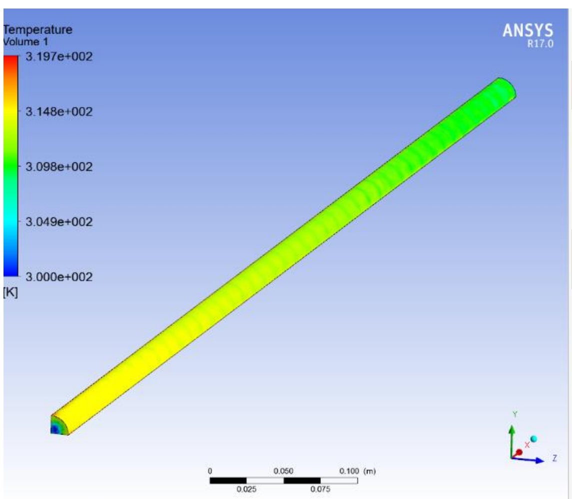

Figure 21: Surface Temperature at 2 LPM

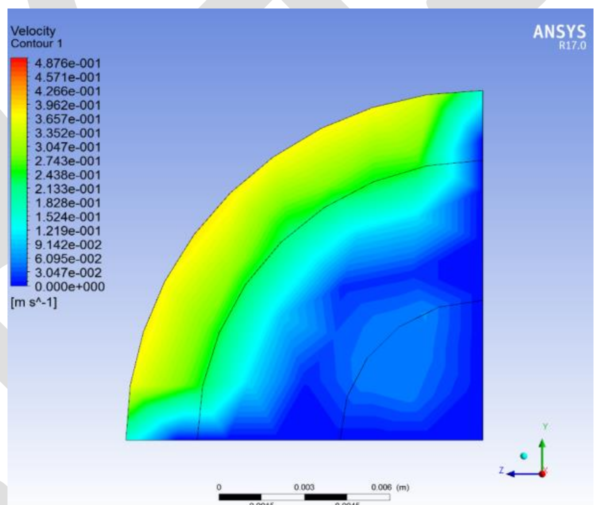

Figure 22: Velocity Contour for 4 LPM

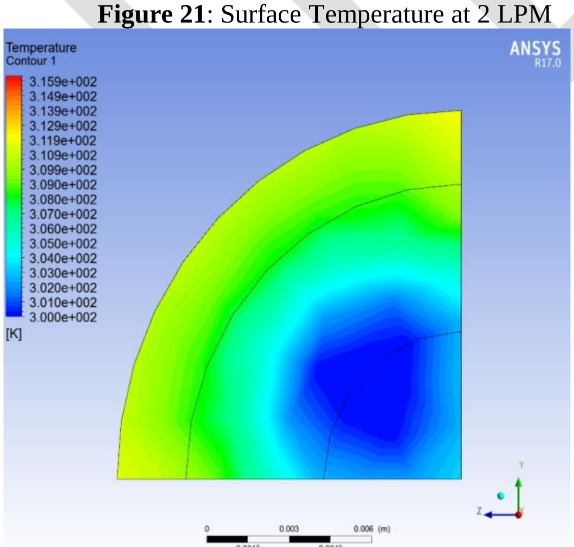

Figure 23: Fluid Temperature at 4 LPM

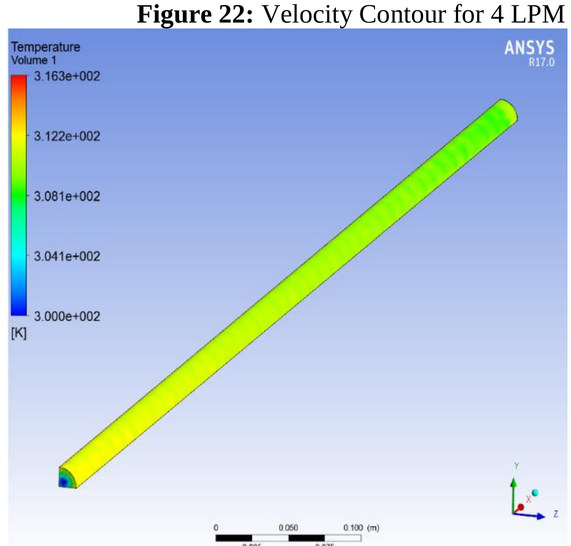

Figure 24: Surface Temperature at 4 LPM

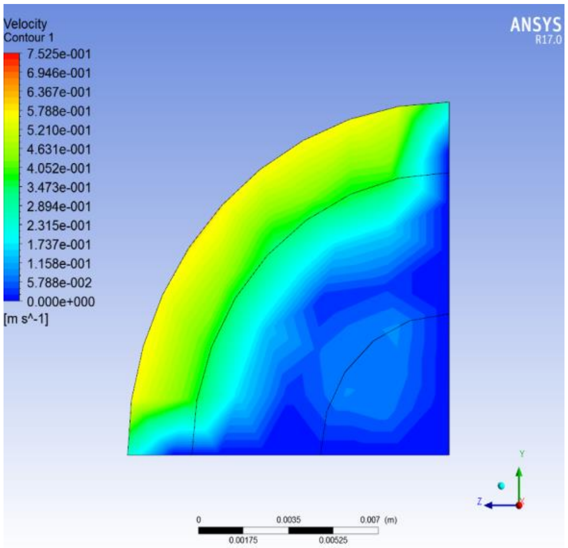

Figure 25: Velocity Contour for 6 LPM

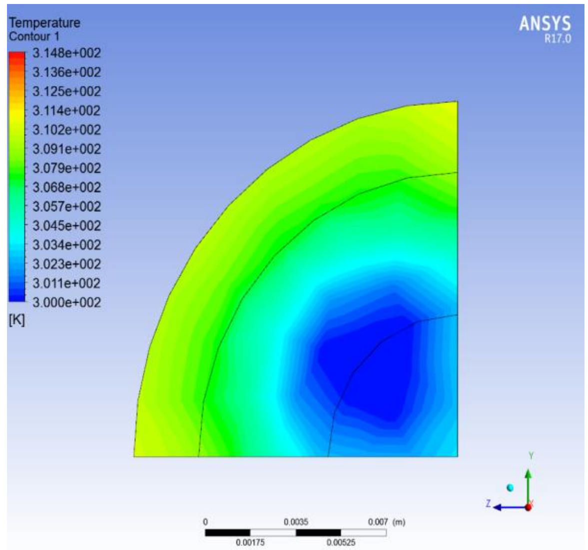

Figure 26: Fluid Temperature at 6 LPM

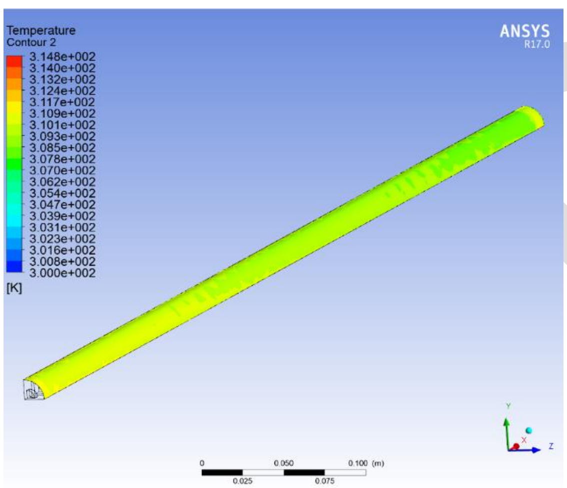

Figure 27: Surface Temperature at 6 LPM

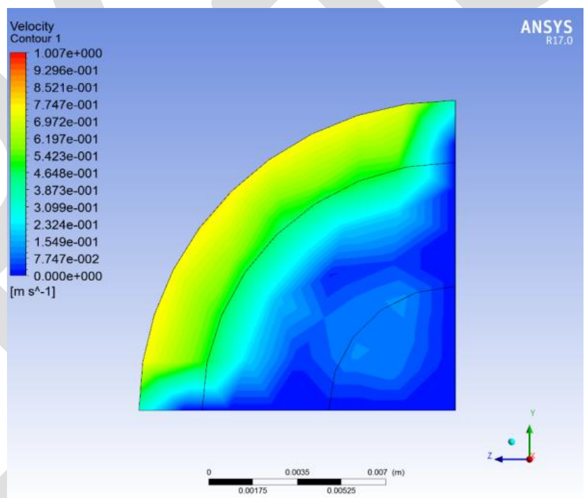

Figure 28: Velocity Contour for 8 LPM

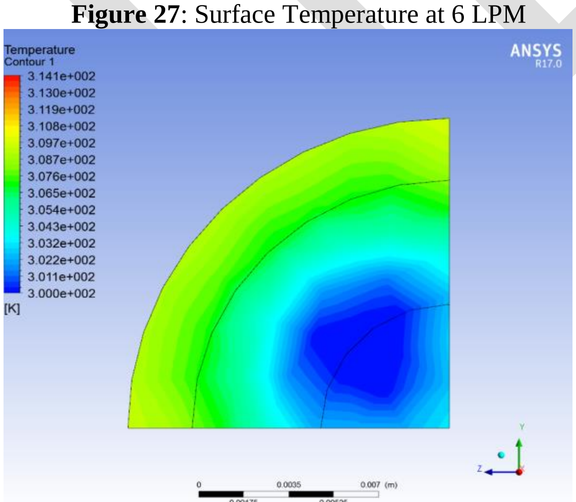

Figure 29: Fluid Temperature at 8 LPM

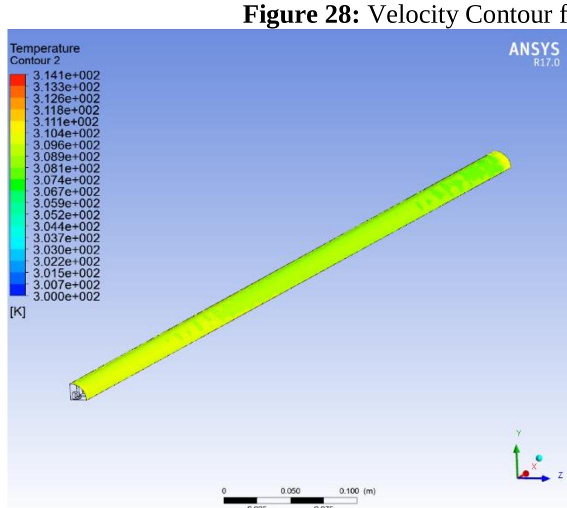

Figure 30: Surface Temperature at 8 LPM

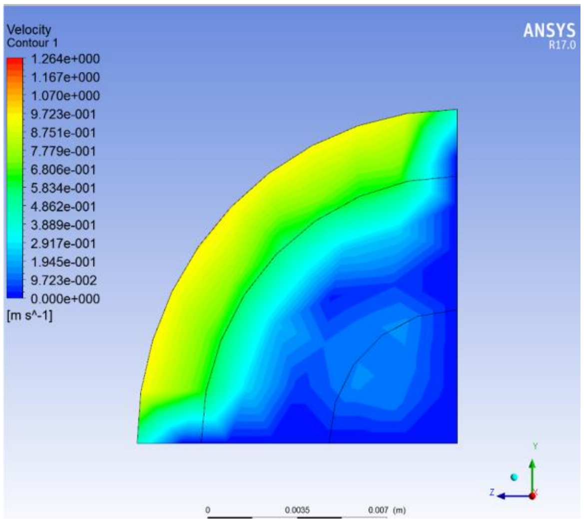

Figure 31: Velocity Contour for 10 LPM

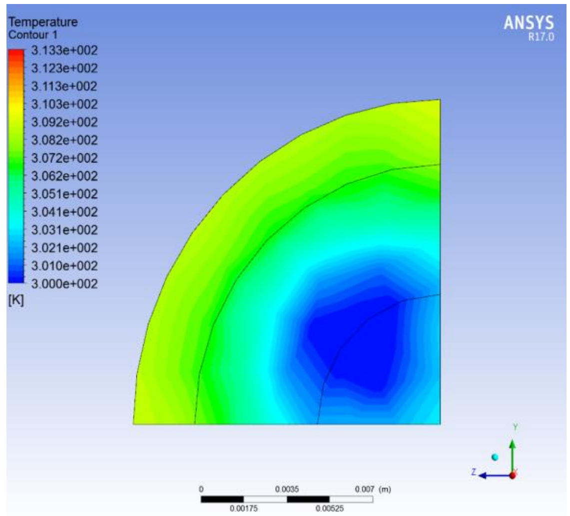

Figure 32: Fluid Temperature at 10 LPM

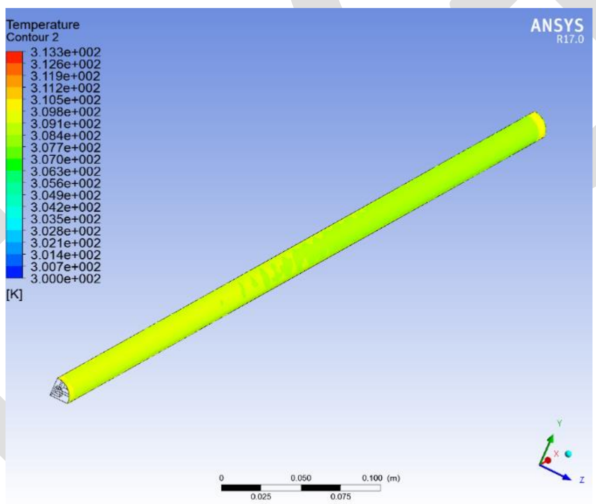

Figure 33: Surface Temperature at 10 LPM

From CFD Analysis of Circular Pipe (Receiver) without Insert

(Value are round off to 2 decimal places)

Flow Rate		Velocity (m/s)	Surface Temp	Fluid Temp
2 LPM	Min	$5.65xe^{-2}$	$3.01xe^{2}$	$3.01xe^{2}$
	Max	$8.77xe^{-2}$	$3.17xe^{2}$	$3.17xe^{2}$
4 LPM	Min	$1.15xe^{-1}$	$3.01xe^{2}$	$3.01xe^{2}$
	Max	$1.66xe^{-1}$	$3.14xe^{2}$	$3.14xe^{2}$
6 LPM	Min	$1.75xe^{-1}$	$3.01xe^{2}$	$3.01xe^{2}$
	Max	$2.51xe^{-1}$	$3.12xe^{2}$	$3.12xe^{2}$
8 LPM	Min	$2.33xe^{-1}$	$3.01xe^{2}$	$3.01xe^{2}$
	Max	$3.33xe^{-1}$	$3.11xe^{2}$	$3.11xe^{2}$
10 LPM	Min	$2.91xe^{-1}$	$3.01xe^{2}$	$3.01xe^{2}$
	Max	$4.14xe^{-1}$	$3.10xe^{2}$	$3.10xe^{2}$

From CFD Analysis of Circular Pipe (Receiver) with Insert

Flow Rate		Velocity (m/s)	Surface Temp	Fluid Temp
2 LPM	Min	$1.511xe^{-2}$	$3.00xe^{2}$	$3.00xe^{2}$
	Max	$2.42xe^{-1}$	$3.20xe^{2}$	$3.19xe^{2}$
4 LPM	Min	$3.05xe^{-2}$	$3.00xe^{2}$	$3.00xe^{2}$
	Max	$4.88xe^{-1}$	$3.16xe^{2}$	$3.16xe^{2}$
6 LPM	Min	$5..79xe^{-2}$	$3.00xe^{2}$	$3.00xe^{2}$
	Max	$7.53xe^{-1}$	$3.15xe^{2}$	$3.15xe^{2}$
8 LPM	Min	$7.75xe^{-2}$	$3.00xe^{2}$	$3.00xe^{2}$
	Max	$1.01xe^{0}$	$3.14xe^{2}$	$3.14xe^{2}$
10 LPM	Min	$9.72xe^{-1}$	$3.00xe^{2}$	$3.00xe^{2}$
	Max	$1.26xe^{0}$	$3.13xe^{2}$	$3.13xe^{2}$

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6. Conclusion

The 2-D numerical analysis is able to predict the fluid flow and heat transfer characteristics for plain absorber tube and with inserts for circular geometric shapes.

At 2 LPM for all the pipes plain as well as with inserts temperature difference between outlet and inlet fluid temperature is maximum

The results of CFD analysis are compared with experimental results and found deviation less than 7%, thus validating present CFD analysis.

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