ANALYSIS OF HEAT PIPE WITH DIFFERENT MATERIAL AND NANO FLUID USING CFD

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ABSTRACT

In the current work, the CAD model of heat pipe has been developed by using UNI-GRAPHICS NX-8.0. The model has been simulated using ANSYS software on fluent domain 15.0 workbench in order to observe various parameters affecting the thermal and phase transformation performance of heat pipe. Different types of glass materials of heat pipe have been used with different profile i.e. the simulations have been performed at a variable temperature w.r.t. time. The simulation of the soda lime silicate glass evacuated tube gives higher value of temperature. It has also been observed that at soda lime silicate glass evacuated tube 10mmwall thickness of copper pipe material engage with glass material configuration shows higher convergence compared to previous configurations. The results are validated with reported base paper results. The configuration of soda lime silicate glass material gives maximum convergence on all parameters amongst all the configurations used.

Inside the fluid flow (octadecane) Nano fluid on heat pipe. We found that they give better temperature distribution and mass transformation in capillary tube of heat pipe. Our analysis found that Erythritol Nano fluid are higher temperature in soda lime silicate glass evacuated tube in heat pipe.

Keywords— *Heat pipe, Temperature, Borosilicate, soda lime silicate, copper pipe, octadecane, Erythritol, Silicon oil.*

I INTRODUCTION

Evacuated tube solar collectors are extensively and widely used because it’s good thermal insulation characteristics and insensitivity to the direction of sun light. Sabiha et al. made a comprehensive review on the progress and latest developments of evacuated tube solar collectors and why evacuated tubes are mostly preferred. There are three common types of evacuated tube solar collectors, which are (a) Water-in glass evacuated tube solar collector, (b) U-type evacuated tube solar collector and (c) evacuated tube heat pipe solar collector.

The Evacuated tube collector consists of a number of rows of parallel transparent glass tubes connected to a header pipe and which are used in place of the blackened heat absorbing plate we saw in the previous flat plate collector. These glass tubes are cylindrical in shape. Therefore, the angle of the sunlight is always perpendicular to the heat absorbing tubes which enables these collectors to perform well even when sunlight is low such as when it is early in the morning or late in the afternoon, or when shaded by clouds. Evacuated tube collectors are particularly useful in areas with cold, cloudy wintry weathers. Evacuated tube collectors are made up of a single or multiple rows of parallel, transparent glass tubes supported on a frame. Each individual tube varies in diameter from between 1" (25mm) to 3" (75mm) and between 5′ (1500mm) to 8′ (2400mm) in length depending upon the manufacturer. Each tube consists of a thick glass outer tube and a thinner glass inner tube, (called a “twin-glass tube”) or a “thermos-flask tube” which is covered with a special coating that absorbs solar energy but inhibits heat loss.

II HEAT PIPE EVACUATED TUBE COLLECTORS

Heat pipe evacuated tube collectors, a sealed heat pipe, usually made of copper to increase the collectors efficiency in cold temperatures, is attached to a heat absorbing reflector plate within the vacuum sealed tube. The hollow copper heat pipe within the tube is evacuated of air but contains a small quantity of a low pressure alcohol/water liquid plus some additional additives to prevent corrosion or oxidation. This vacuum enables the liquid to vapourise at very lower temperatures than it would normally at atmospheric pressure. When sunlight in the form of solar radiation hits the surface of the absorber plate inside the tube, the liquid in the heat pipe quickly turns into a hot vapour type gas due to presence of the vacuum. As this gas vapor is now lighter, it rises up to the top portion of the pipe heating it up to a very high temperature. The top part of the heat pipe, and therefore the evacuated tube is connected to a copper heat exchanger called the “manifold”. When the hot vapors still inside the sealed heat tube enters the manifold, the heat energy of the vapor is transferred to the water or glycol fluid flowing through the connecting manifold. As the hot vapourlooses energy and cools, it condenses back from a gas to a liquid flowing back down the heat pipe to be reheated. The heat pipe and therefore the evacuated tube collectors must be mounted in such a way as to have a minimum tilt angle (around 30o) in order for the internal liquid of the heat pipe to return back down to the hot absorber plate at the bottom of the tube. This process of converting a liquid into a gas and back into a liquid again continues inside the sealed heat pipe as long as the sun shines. The main advantage of Heat Pipe Evacuated Tube Collectors is that there is a “dry” connection between the absorber plate and the manifold making installation much easier than with direct flow collectors. Also, in the event an evacuated tube cracking or breaking and the vacuum are becoming lost the individual tube can be exchanged without emptying or dismantling the entire system. This flexibility makes heat pipe evacuated tube solar hot water collectors ideal for closed loop solar designs as the modular assembly allows for easy installation and ability to easily expand by adding as many tubes as you want.

III MODELING AND ANALYSIS

3.1. CAD Modelling

CAD model is made by using CAD software to perform FEA, CAD model may be 2D or 3D.

- **Type of solver**: we have to choose the solver from pressure based or density based.
- **Physical model**: there are several types of physical models, we have choose one from them like multiphase, energy, viscous, etc.
- **Material property**: choose the material property of fluid and solid body.
- **Boundary condition**: Define the desired boundary condition for the problem i.e. radiation etc.

3.2 Solution

- Solution method: choose the solution method to solve the problem i.e. first order, second order.
- Solution initialization: Initialized the solution to get the initial solution for the problem.
- Run Solution: Run the solution by providing no. of iteration to perform.

3.3 Post Processing

For viewing and interpretation of result, this can be viewed in various formats like graph, value, animation etc.

Step – 1

Analysis of heat pipe with different material and nano fluid using CFD

3.4 Pre Processing:

CAD Model: Generation of 3D model by using UNIGRAPHICS – NX 8.0 and exporting to the PARASOLID format and then import in ANSYS fluent 15.0

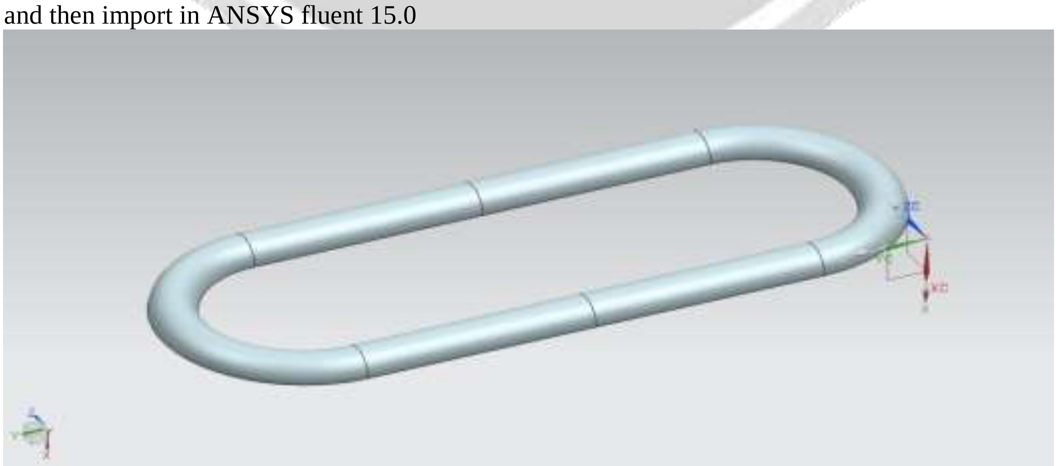

Fig. 3.1 CAD model of heat pipe.

Step - 2
Meshing of the Domain
Go to meshing - generate mesh

Nodes	27271
Elements	5805

Total number of nodes is 27271 and an element is 5805 which have been employed for the analysis of heat pipe.

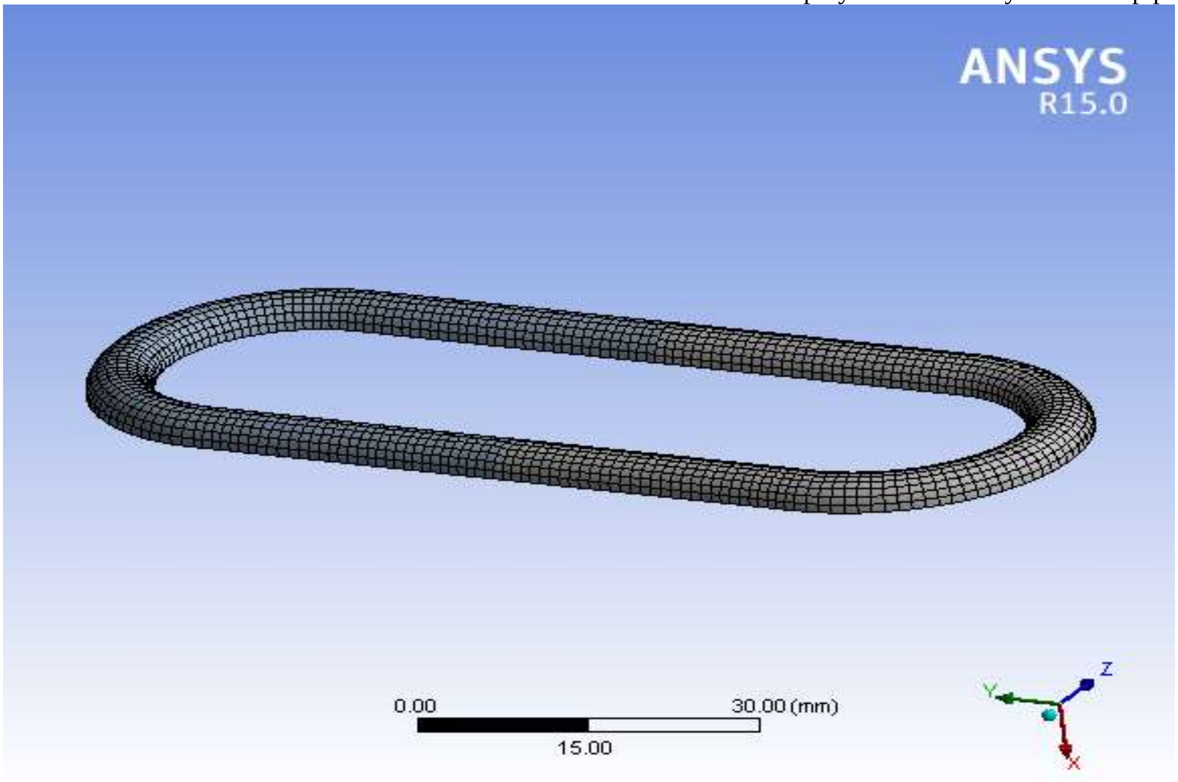

Figure 3.2 Meshed domain of heat pipe.

Step – 3
Fluent setup:
After mesh setup generation define the following steps in the ANSYS fluent 15.0

- Problem type – 3D solid
- Type of solver – pressure
- Physical model – viscous K-epsilon two equation turbulence model
- Mixture - volume of fraction

3.5 SOLUTION
Solution Method
Pressure – Velocity – Coupling – Scheme – Simple

- Pressure – standard pressure
- Momentum – 2^{nd} order
- Turbulence – kinetic energy 2^{nd} order
- Turbulence dissipation rate 2^{nd} order

Step - 4

Solution Initialization

- **Run Solution**

Run the solution by giving 500 no. of iteration for solving the convergence.

- **Post processing**

For viewing the interpret of result, the result can be viewed in various formats like graph, value, animations etc.

Table 3.1: Materials Properties

Properties	Borosilicate glass	Soda lime silicate glass	Phosphate silicate
Density, ρ	2230 Kg/m^3	2530Kg/m^3	2585 Kg/m^3
Thermal Conductivity, K	1.14 W/m-K	0.937 W/m-K	0.57 W/m-K
Specific Heat, C_p	830J/Kg-K	720 J/Kg-K	632J/Kg-K

Table 3.2 Properties of Nano-Fluids

Nano-Fluids	Density	viscosity	Thermal Conductivity	Boiling Point
Octadecane	0.777	-	0.153 W m^{-1} K^{-1}	317 °C (603 °F; 590 K)
Silicon Oil	0.971 g/mL at 25 °C	10,000 cSt(25 °C)	0.6 W/m/K	>140 °C/0.002 mmHg (lit.)
Hexacosane	0.8±0.1 g/cm^3		0.23 W/ mK	412.2±8.0 °C at 760 mm Hg
Erythritol	1.45 g/cm^3		0.733W m^{-1} K^{-1}	329 to 331 °C (624 to 628 °F; 602 to 604 K)

IV **RESULT AND DISCUSSION**

4.1 Temperature distribution on heat pipe with Soda lime Silicate Glass evacuated tube:

Table 4.1 Temperature variation w.r.t. Time of heat pipe

Time	Soda Lime Silicate (Temperature)	Base Paper Result	Percentage Error
12:00	25	22	12.0
12:20	54.2	51	5.9
12:40	57.9	55	5.0
13:00	57.5	54.3	5.6
13:20	54	52.5	2.8

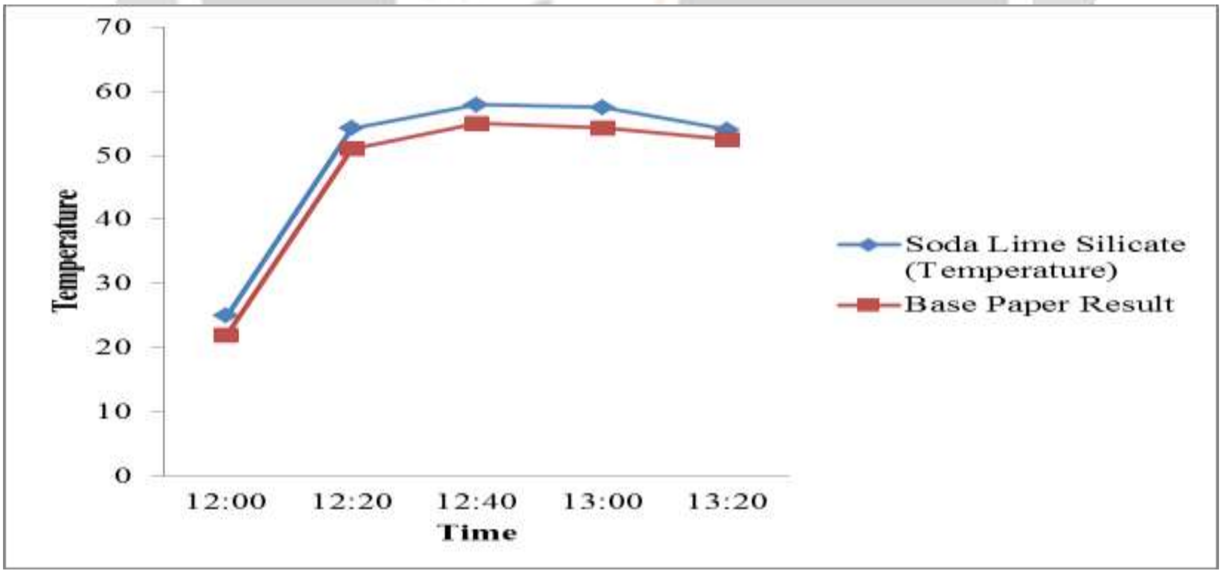

Figure 4.1 Temperature variation of Soda lime silicate glass evacuated tube on time.

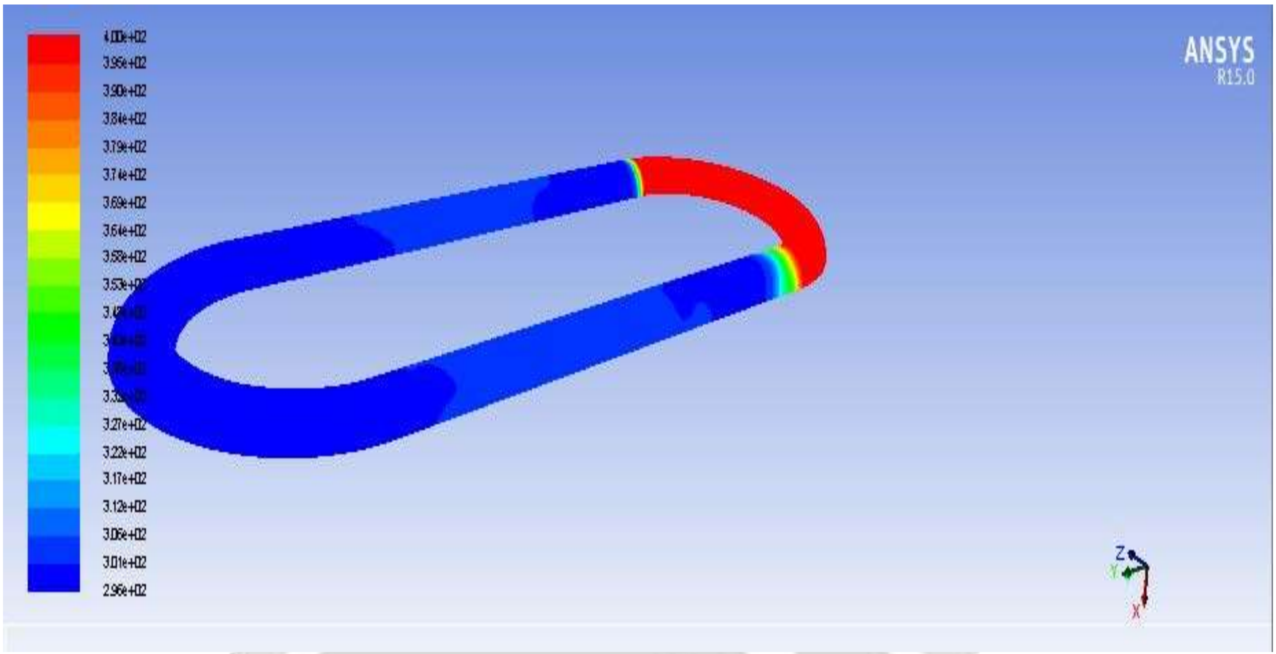

Figure 4.2: Temperature variation of heat pipe on 12:00.

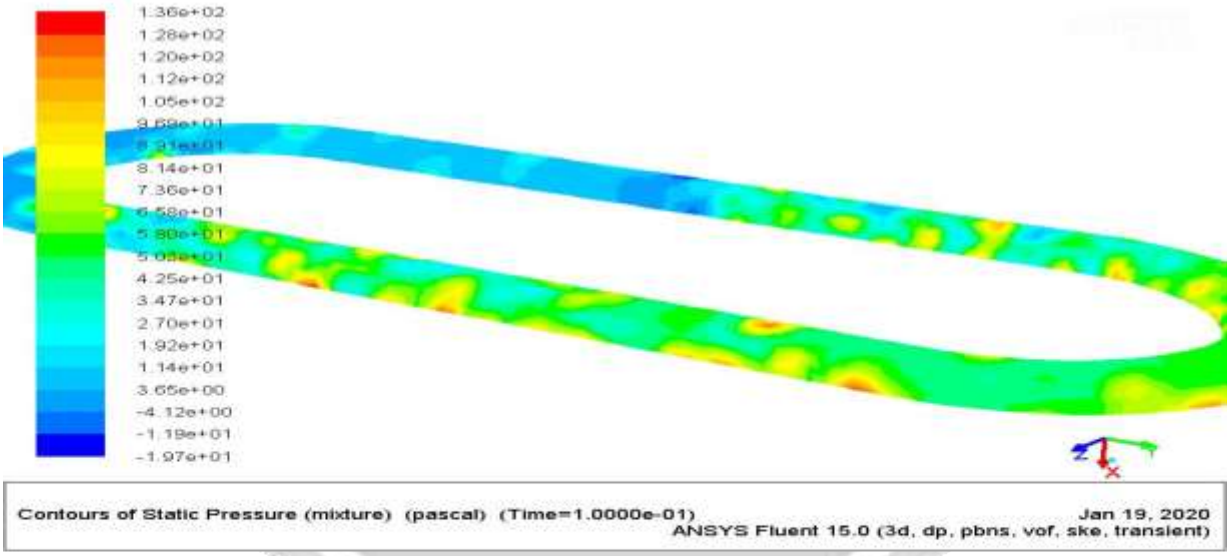

Figure 4.3: pressure variation of heat pipe on 12:00..

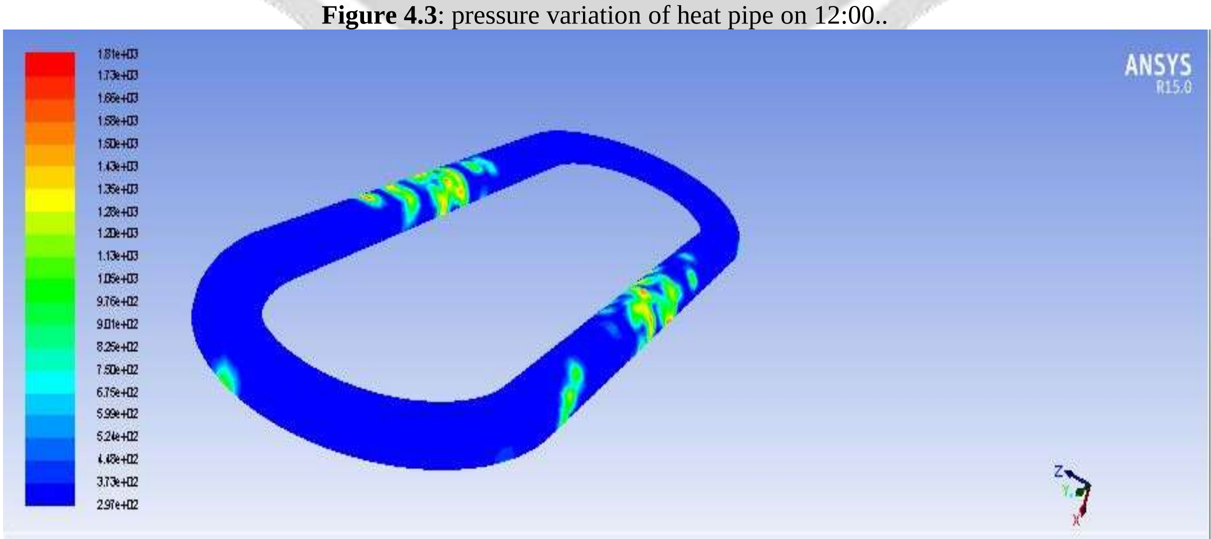

Figure 4.4 Temperature variations of heat pipe on 12:20.

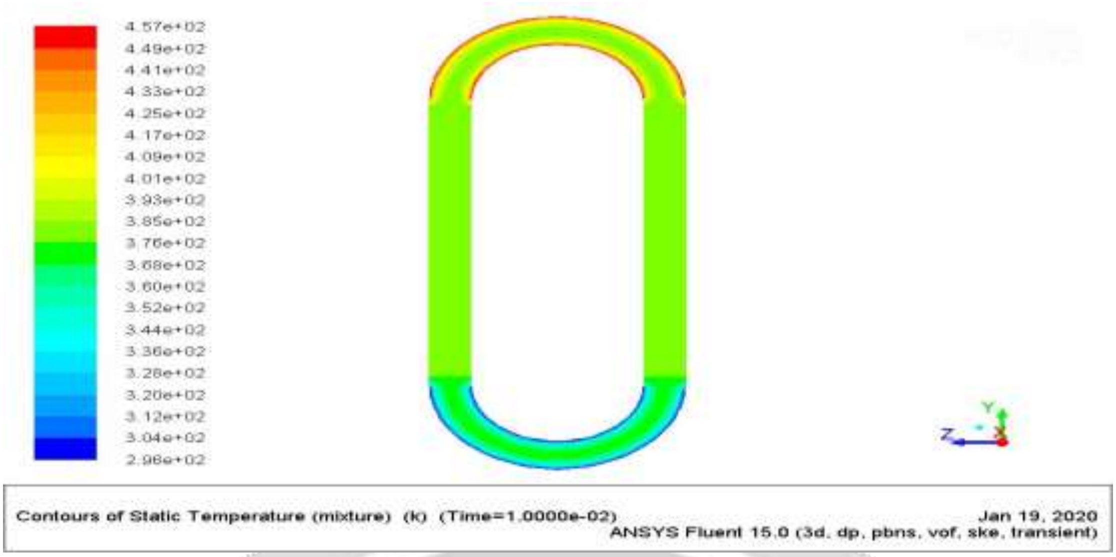

Figure 4.5: Temperature variations of heat pipe on 12:40.

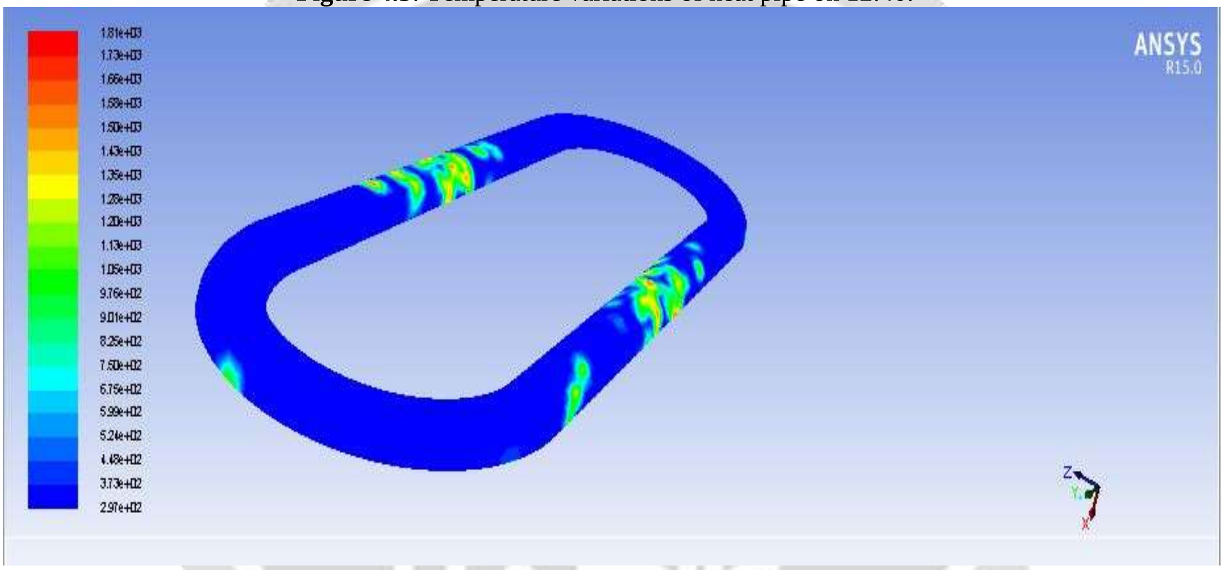

Figure 4.6 Temperature variations of heat pipe on 13:00.

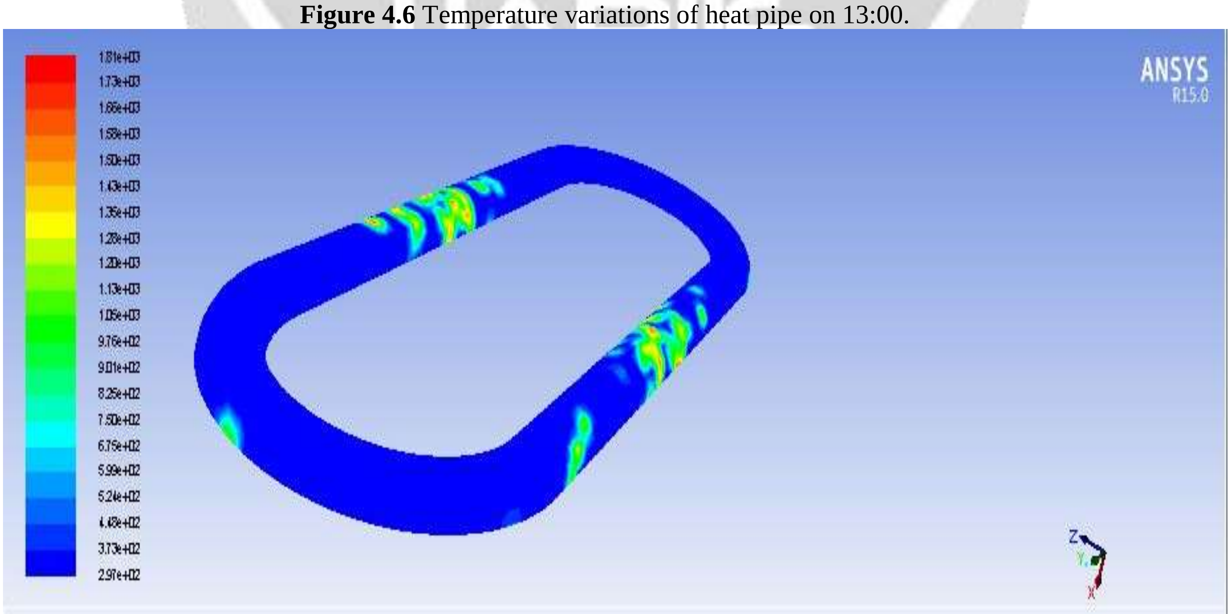

Figure 4.7: Temperature variations of heat pipe on 13:20.

Table-4.2: Overall comparison of variation in Temperature for different nanofluid with the heat pipe with respect to Time.

Temperature variation for Soda Lime Silicate Glass					
Time	**Silicon oil**	**Octadecane**	**Tritriacotane**	**Erythrital**	**Hexacosane**
12:00	24.5	22	26.2	28.4	27.1
12:20	52.8	51	56.5	59.3	57.4
12:40	55.9	55	58.3	59.7	58.9
13:00	54.8	54.3	57.3	58.8	58.2
13:20	53	52.5	55	57	56

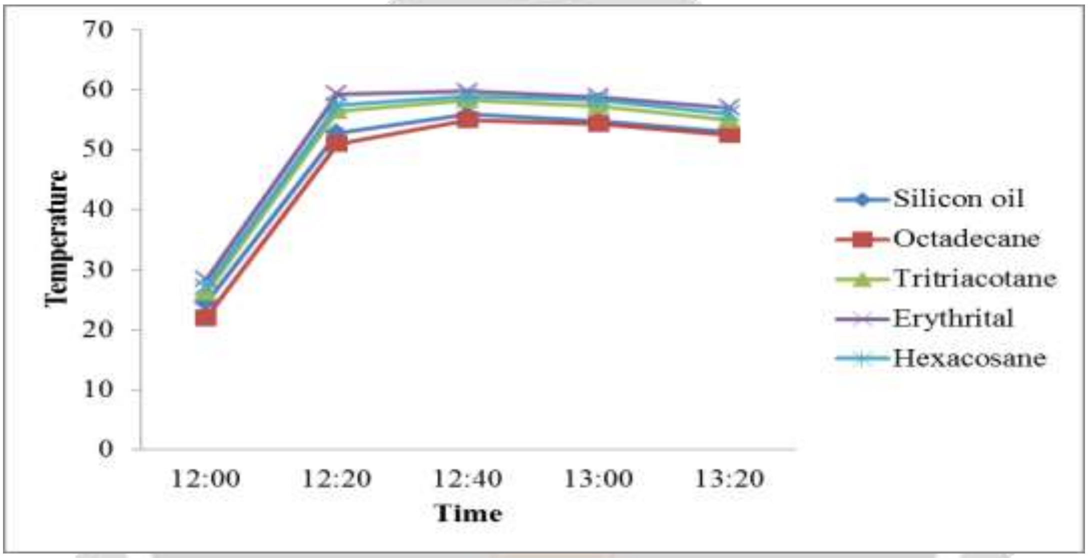

Figure 4.8 Overall comparison of variation in Temperature for different nanofluid with the heat pipe with respect to Time.

4.2Temperature distribution on heat pipe with phosphate silicate Glass evacuated tube:

Table 4.3 Temperature variation w.r.t. Time of heat pipe

Time	**phosphate Silicate (Temperature)**	**Base Paper Result**	**Percentage Error**
12:00	23.5	22	6.4
12:20	52.7	51	3.2
12:40	56.8	55	3.2
13:00	55.6	54.3	2.3
13:20	53.1	52.5	1.1

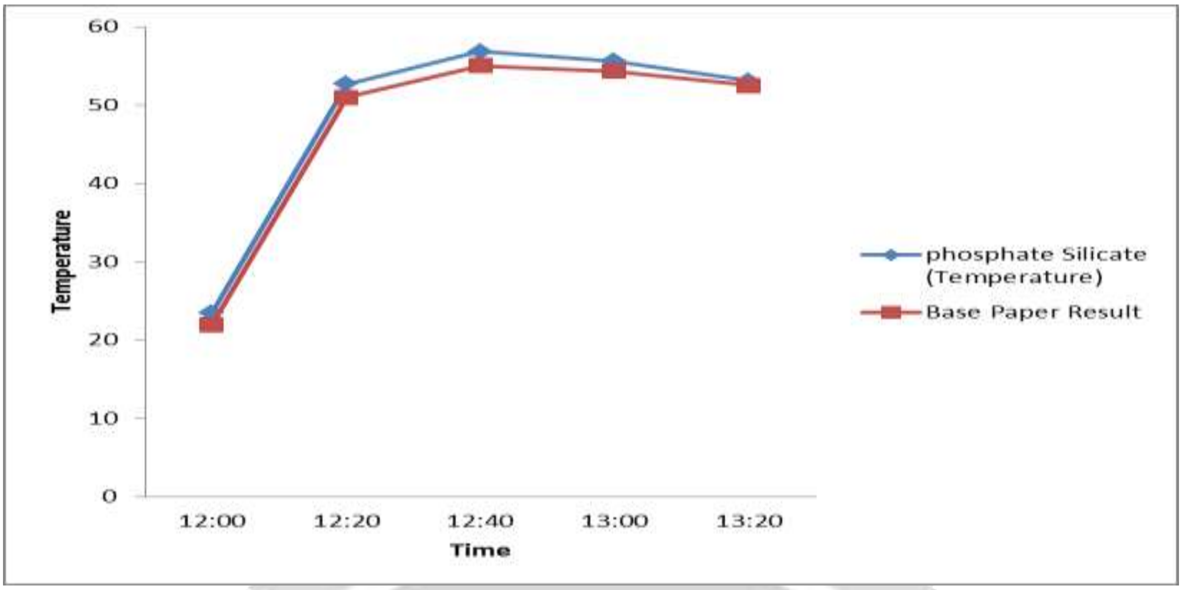

Figure 4.9 Temperature variation of phosphate silicate glass evacuated tube on time.

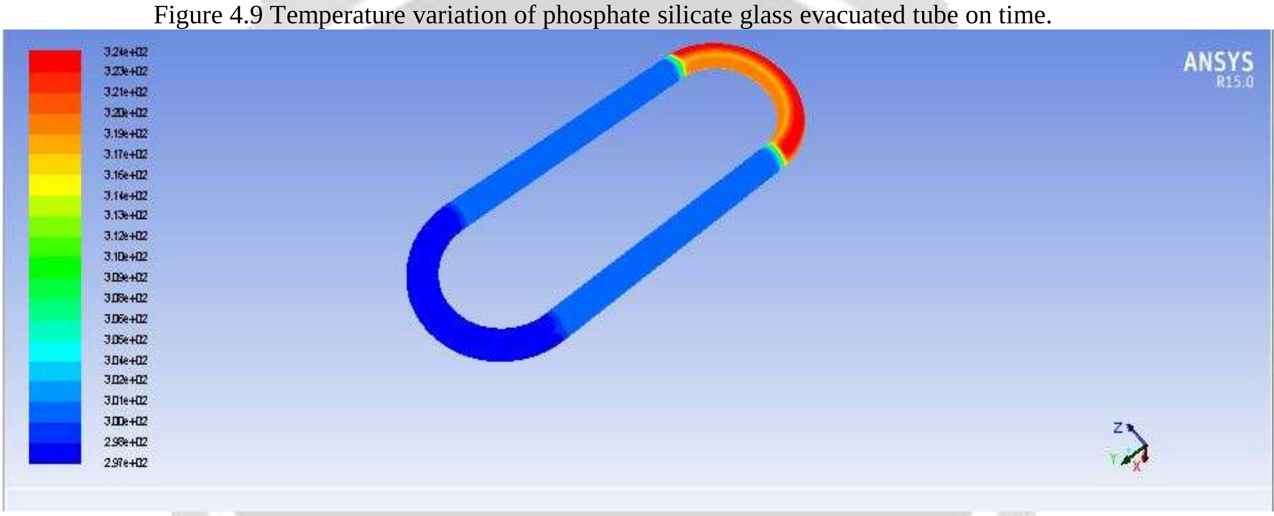

Figure 4.10 Temperature variation of heat pipe on 12:00.

Figure 4.12 Show the temperature variation on heat pipe. From the above contour plot, it is observed that nearly 296.5K of temperature was observed on heat pipe. Temperature distribution is seems to be average in phosphate silicate glass evacuated tube.

Figure.4.11 Temperature variation of heat pipe on 12:20.

Figure 4.13shows the temperature at variation on heat pipe on 12.20. From the above contour plot, it is observed that nearly 325K of temperature was observed on heat pipe.

Table 4.4 Variation in temperature on heat pipe w.r.t. time

	Temperature			
Time	Base Paper Result	(Borosilicate glass)	Soda Lime Silicate (Temperature)	phosphate Silicate (Temperature)
12:00	22	23.8	23.5	25
12:20	51	52.3	52.7	54.2
12:40	55	55.9	56.8	57.9
13:00	54.3	54.8	55.6	57.5
13:20	52.5	53.6	53.1	54

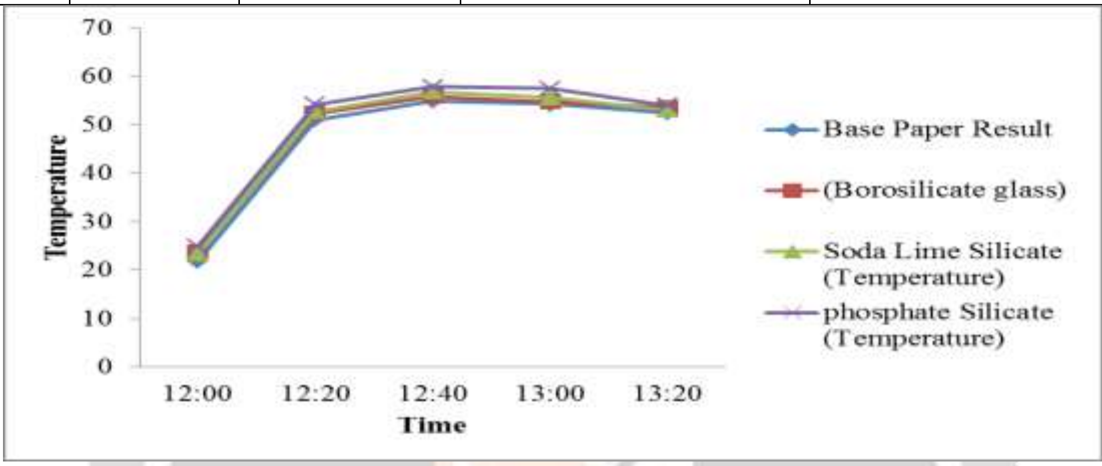

Figure 4.12Variation in temperature on heat pipe wr.t. time

Table-4.5: Overall comparison of variation in Temperature for different nanofluid with the heat pipe with respect to Time.

Temperature variation for Phosphate Silicate Glass					
Time	Silicon oil	Octadecane	Tritriacotane	Erythrital	Hexacosane
12:00	23.1	22	24.2	26.2	25.1
12:20	52.2	51	53.4	55.7	54.2
12:40	56.4	55	57.2	58.9	58.5
13:00	55.9	54.3	56.7	58.1	57.8
13:20	52.8	52.5	53.9	54.9	54.3

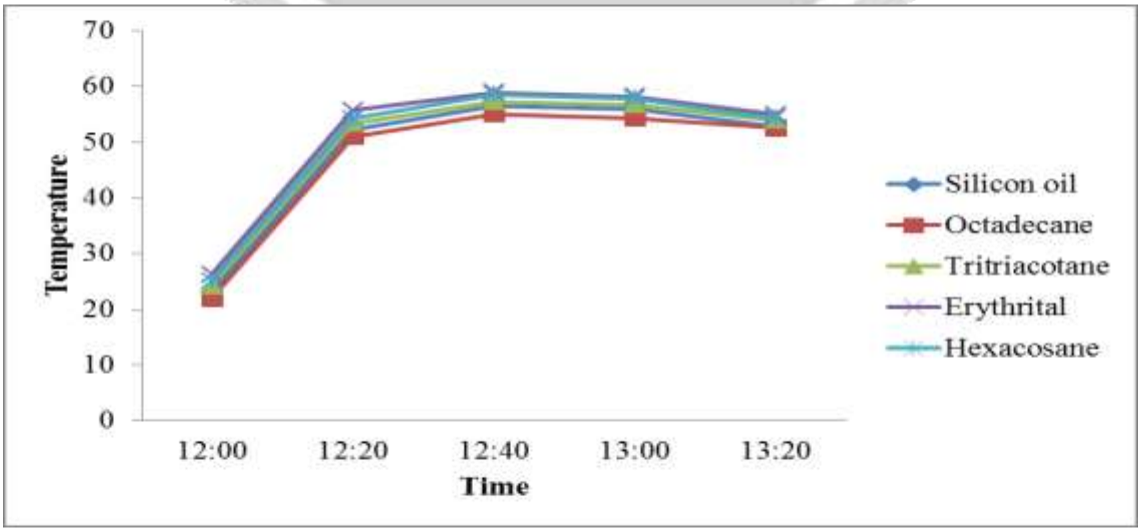

Figure 4.13 Overall comparison of variation in Temperature for different nanofluid with the heat pipe with respect to Time.

4.3 Temperature Drop of Nano fluid

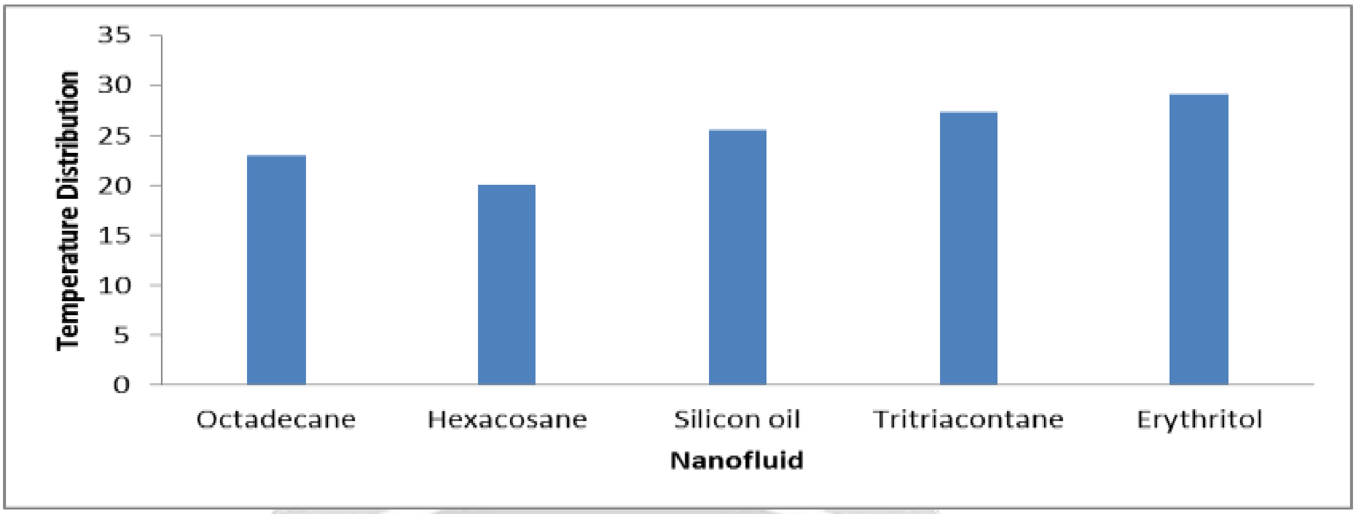

Figure 4.14 Temperature Distribution of Different Nano fluid

Table and graph shows the higher temperature drop is Erytrithol Nano fluid comparison to different Nano fluid of heat pipe.

VII CONCLUSION

1. Computational model has been developed in UGNX 8.0 and analysis has been done in Fluent 15.0.

2. Numerical results are in good agreement with base paper results.

3. The internal consistency of the results confirms the validity of the CFD model.

4. From results, higher value of temperature is found out for different glass materials of heat pipe.

5. Soda lime silicate with copper pipe material shows more convergence than other glass materials of heat pipe (heater zone) thus result shows improvement of 6.8% average deviation on temperature.

6. Temperature distribution shows 0.73% average on simulation results than base paper results thus convergence on temperature effect is achieved.

7. Thus numerical simulation of heat pipe with respect to different glass materials with copper pipe shows an optimum result on both temperature and mass transfer.

8. From results, higher temperature drop is found out for Erytrithol Nano fluid comparison to different Nano fluid of heat pipe.

9. Our analysis found Erytritholnanofluid are higher temperature in soda lime silicate glass evacuated tube in heat pipe.

10. The combination of sodalime silicate glass with Erythritol imposes optimum configuration in temperature distribution also this combination is economical.

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