INVESTIGATION OF HEAT TRANSFER PERFORMANCE OF DOUBLE PIPE COUNTER-FLOW HEAT PIPE USING THREE FLUIDS WATER, DOWTHERM, AND WATER-BASED NANOFLUID

by

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THESIS

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Abstract

INVESTIGATION OF HEAT TRANSFER PERFORMANCE OF DOUBLE PIPE COUNTER-FLOW HEAT PIPE USING THREE FLUIDS WATER, DOWTHREM, AND WATER-BASED NANOFLUID

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The University of Texas at Arlington, 2021

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Heat pipes are two-phase devices, capable of converting a significant amount of energy with low losses. They have been used in several applications such as systems thermal control and cooling. The purpose of the present work is to investigate the thermal performance of a double pipe counterflow against the fluid type. The pipe is divided into three zones including evaporator, adiabatic, and condenser zones. All thermal boundary conditions are defined in terms of heating or cooling temperatures in which the operating temperatures are defined between 303 K to 470 K. using Ansys Fluent, the pipe is analyzed in two-and three-dimensional spaces. For simplification in the present preliminary analysis, the two phases of the fluid are separated by a coupled wall and the flow is assumed to be in a steady state. Three thermal fluids are selected with different thermophysical properties including Water, Dowtherm, and Water-based nanofluid. when comparing between the three fluids in terms of the vertical temperature change, the temperature changed by 0.0455 % in the case of Dowtherm fluid, however, this change is found to be 0.227 % and 0.1948 % in the case of water and Nano-based Water respectively. No significant change is detected either between the water and Nano based Water fluids or between 2D and 3D analyses.

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Chapter 1

Introduction

1.1 Heat Pipe

Heat is transferred by devices such as sinks, heat exchangers, condensers, evaporators, and heat pipes. The enhancement of heat transfer rate continues to make these devices more compact in design, minimize the cost of energy and material, and more be efficient [1], The Heat pipes are two-phase devices, capable of converting a significant amount of energy with low losses. The heat pipes consider a passive device for heat transfer because the heat pipe does not include work output or input [2]. The heat pipes a container charged with a working fluid. The heat pipe consists of three sections: First, where heat is added is called the evaporator section. Second, where no heat transfer exists it's called the adiabatic section, Third, where heat is rejected, it's called the condenser section. The vapor flow from the evaporator section to the condenser section because the pressure difference is caused by the temperature difference between the evaporator and condenser, in this way the heat is transported from the evaporator section to the condenser section. The heat pipes are called small steam engines because the heat pipe does not have any work output or input externally so it's called a passive heat transfer. The heat pipe is a sealed container and a working fluid. The first part of the heat pipe (sealed container) may be constructed of material ranging from plastic to metallic materials but because the heat transfer principle prefers a material with low thermal conductivity, the most common materials are copper, stainless steel, and aluminum, the other part (working fluid) Selected based on vaporization and condensation [2]. The convection heat transfer is enhanced with the height of the heat pipe increasing [3]. The chosen heat pipe used in the present investigation study, which manufactured from copper, So the copper-water heat pipes to transfer the heat selected for the following reasons:(1) availability, (2) working fluid has suitable steam pressure, (3) The temperature range for working fluid [4]. The source of convection affected directly on flow behavior and heat transfer characteristics [5]. The figure below shows the principle, and the heat pipe parts.

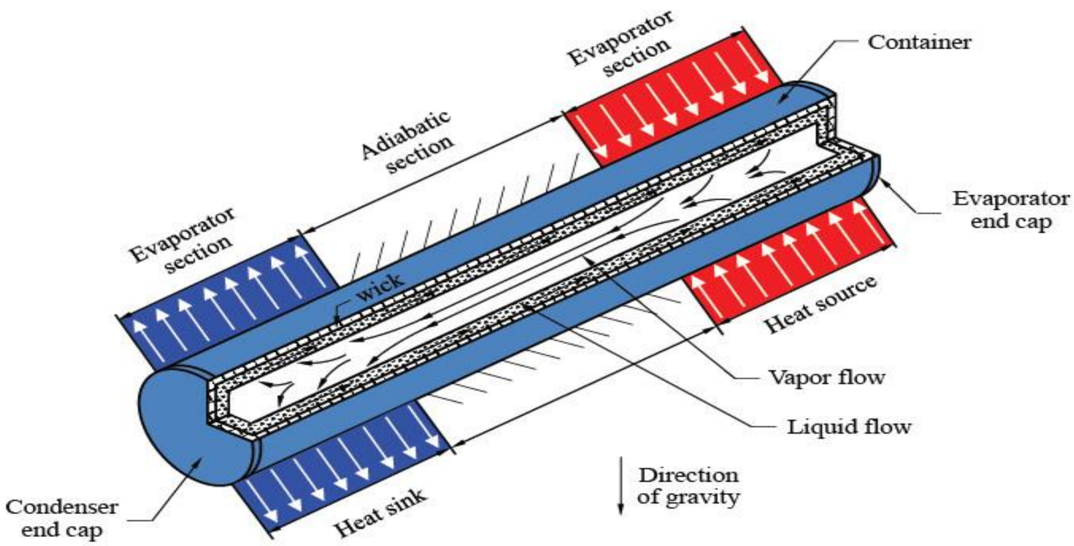

Fig. 1.1: Schematic of a conventional heat pipe showing the principle of operation and circulation of the working fluid [4].

Recently, the number of companies that used heat pipes filled with nanofluids for technology is increasing [6]. Nanofluids could increase the energy efficiency in heat pipe because the viscosity changed [7]. In addition, DOTHERM is used as a working fluid for heat pipe because it stable does not decompose readily at high temperature and has low viscosity and change slightly between the melting point [8]. The thermophysical properties of DOWTHERM for both the liquid and vapor phases are recommended using at Intermediate Temperature Range [9]. Determine the type of flow (laminar, turbulent, or transitional) for these fluids is necessary by finding Reynold’s number [10].

1.2 Types of Heat Pipes

According to the design and working fluid, there are different types of heat pipes:

1. Two-Phase Closed Thermosyphon
2. Capillary-Driven Heat Pipe
3. Vapor Chamber
4. Annular Heat Pipe
5. Rotating Heat Pipe
6. Gas-Loaded Heat Pipe
7. Loop Heat Pipe
8. Capillary Pumped Loop Heat Pipe
9. Pulsating Heat Pipe
10. Monogroove Heat Pipe
11. Inverted Meniscus Heat Pipe
12. Nonconventional Heat Pipe
13. Oscillating heat pipes (OHPs)

The operate on the principle of pressure and temperature in Oscillating heat pipes changes occurring during the phase change of the working fluid [11]. the main conditions to for OHPs has the internal diameter should small enough and partially filled with working fluid.

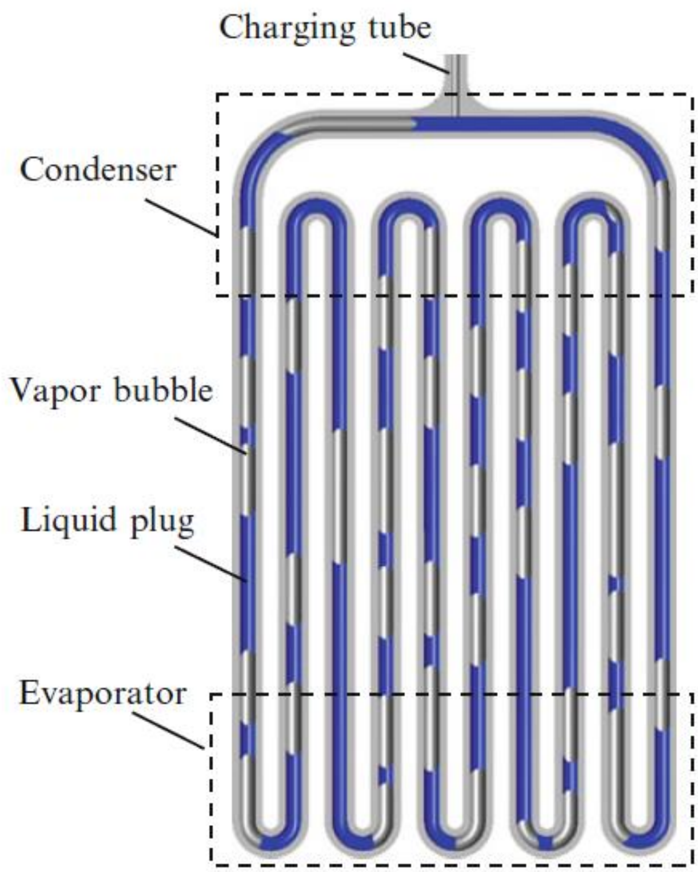

Fig. 1.2: Schematic of an oscillating heat pipe [2].

1.3 Working Fluids and Temperature Ranges

The heat pipe application has a temperature range in which the heat pipe needs to operate. In addition, the design of the heat pipe must account for the temperature range by specifying the working fluid. See the table below:

Table 1.1: Working fluid temperature ranges of heat pipe [4].

Working Fluid	Melting Point, K at 1 atm	Boiling Point, K at 1 atm	Useful Range, K
Helium	1.0	4.21	2-4
Hydrogen	13.8	20.38	14-31
Neon	24.4	27.09	27-37
Nitrogen	63.1	77.35	70-103
Argon	83.9	87.29	84-116
Oxygen	54.7	90.18	73-119
Methane	90.6	111.4	91-150
Ethane	89.9	184.6	150-240
Freon 22	113.1	232.2	193-297
Ammonia	195.5	239.9	213-373
Freon 21	138.1	282.0	233-360
Freon 11	162.1	296.8	233-393
Freon 113	236.5	320.8	263-373
Acetone	180.0	329.4	273-393
Methanol	175.1	337.8	283-403
Ethanol	158.7	351.5	273-403
Heptane	182.5	371.5	273-423
Water	273.1	373.1	303-550
Toluene	178.1	383.7	323-473
Flute PP9	203.1	433.1	273-498
Naphthalene	353.4	490	408-623
Dowtherm	285.1	527.0	423-668
Mercury	234.2	630.1	523-923
Sulphur	385.9	717.8	530-947
Cesium	301.6	943.0	723-1173
Potassium	336.4	1032	773-1273
Sodium	371.0	1151	873-1473
Lithium	453.7	1615	1273-2073
Lead	600.6	2013	1670-2200
Indium	429.7	2353	2000-3000
Silver	1234	2485	2073-2573

1.4 Limitations and Temperature Ranges for Working Fluids

Low-Temperature Range

The low-temperature range is from 200 to 550 K. Most heat pipe applications fall within this range.

Intermediate Temperature Range

The working fluids in the medium temperature range, 450 to 750 K, are mercury and Sulphur. Compounds such as Thermex or Dowtherm-A (diphenyl/diphenyl oxide eutectics) are also employed in this range.

High-Temperature Range

The working fluid often used in the high-temperature range (750 K and above) such as Sodium, lithium, cesium, silver, and sodium-potassium compound.

Chapter 2

Literature Review

Investigation of heat transfer performance for heat pipe (Thermosyphon) for better thermal performance and substantial energy savings are being tested by using three types of fluids (Water, DOTHERM and Nanofluids), These fluids used in the current study with three different lengths for pipe that help us to determine the heat transfer performance. To get better temperature uniformity and high thermal conductivity of heat pipe this study will investigation at same boundary condition [7]. DOTHERM A heat transfer fluid is a eutectic mixture of two very stable organic compounds [8].

DOWTHERM was selected in this study for several reasons:

1. Thermal Stability

DOTHREM has thermal stability at temperatures of 400°C (750°F).

2. Freeze Point

DOWTHERM has a freezing point of 12°C (53.6°F).

3. Vapor Pressure

DOWTHERM used in vapor phase heat transfer from 257°C (495°F) to 400°C (750°F).

4. Viscosity

DOTHERM has low viscosity and changes only slightly between the melting point and top operation temperature [8]. Also, nanofluid fluid (Water-based Nanofluid) selected in present study because of Nanofluid enhance thermophysical properties like conductivity, viscosity, thermal diffusivity, and convective heat transfer [1]. Adding nanoparticles in appropriate concentrations increases the thermal conductivity of the fluid. Using nanoparticles with the size of the nanoparticles of 1 to 100 nanometers will help to have larger magnitudes of thermal conductivities compared to water [9].

Researchers investigated the compatibility of different materials to understand the behavior of the materials and the change of properties of the materials with the change of temperature [12], [13]. Measurement technique is an important factor which needs to be considered when determining properties of materials. Different technique can be used to determine the accuracy of measurement of the material properties [14]. To enhance the heat transfer, different cooling technique are used. Immersion cooling is becoming of the major area of interest for the researchers. Increasing reliability of immersion cooled components are very important to enhance the performance of the devices [15]–[17].

There are two ways for nanofluid preparation first one is called the on-step method it is directed by nanoparticle fabrication combined with nanofluid synthesis. The second way is the most common and economic method by producing dry powder for nanomaterial by using physical or chemical and then dispersed into the fluid as second process [1]. This present study will prepare nanofluid by dispersing nanoparticles ɣ-Fe_2O_3 in pure water [18]. There are different types of heat pipe used nanofluid to get high performance of heat transfer such as mesh wick heat pipe, oscillating heat pipe sintered metal wick heat pipe, and two-phase closed thermosyphons. in this case, the study will work specifically on thermosyphon with nanofluid and DOTHREM and water [18], [19].

Chapter 3

Computational Methods

3.1 Two-dimensional Axisymmetric Heat Pipe

The problem will be solved as shown in the figure with two vapor and liquid regions.

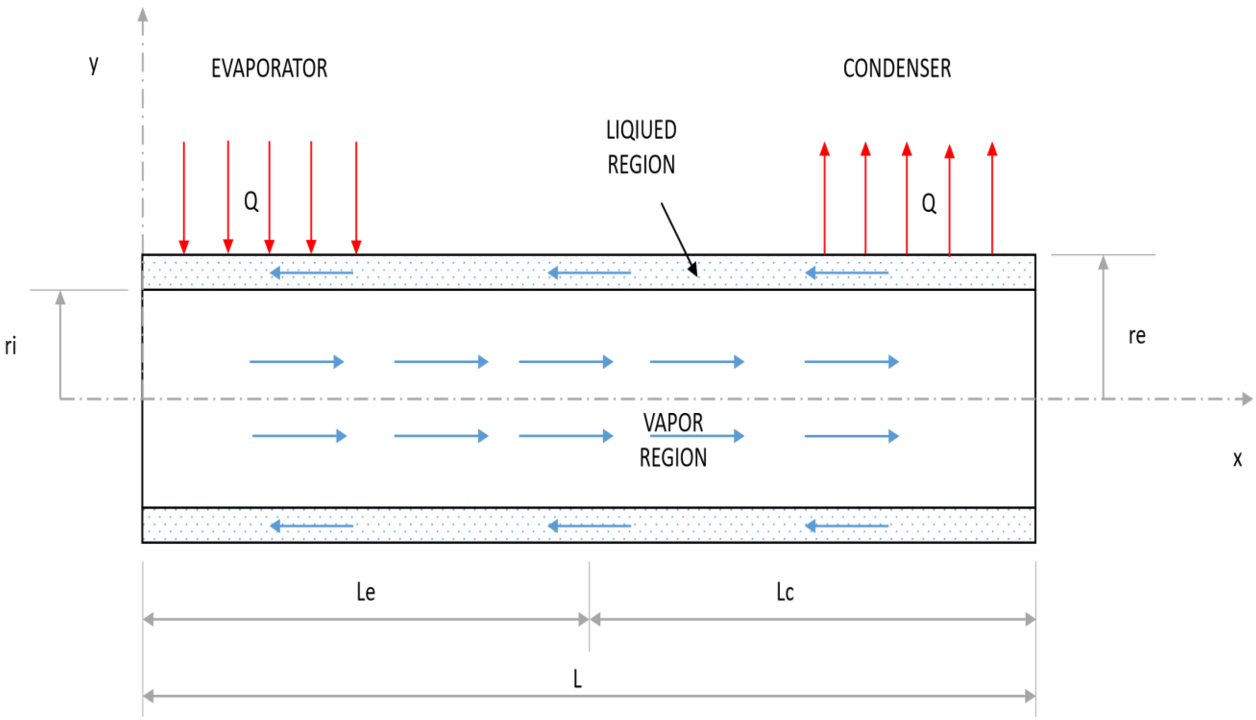

Fig. 3.1: Representation of a heat pipe [10].

There are three fluids used in the current study with three different lengths for pipe that help us to determine the heat transfer performance. In this work, by using two-dimensional analysis is used to investigate the heat transfer of thermosyphon heat pipe using water, DOTHERM and nanofluids as the working fluid, and three-dimensional analysis.

3.2 Boundary Conditions

The problem is assumed to be a laminar, 2D, Axisymmetric, and steady problem the geometry has an inlet and outlet vapor and liquid in the x-direction of the pipe, the flow velocity is specified as below, and the velocities in the y and z directions are assumed to be zero. The top and bottom walls in the y-direction at condenser and evaporator parts has a heat flux.

The boundary conditions are summarized as follows:

Inlet vapor

u_x = 0.2m/s

$u_y = u_z = 0$

Inlet fluid

u_x = 0.04 m/s

$u_y = u_z = 0$

Pressure Gage =0

Temperature at evaporator and condenser parts 303K

Wall type: nonslip wall

Pipe size:

$ri = 6.8\ mm$

$ro = 7.5mm$

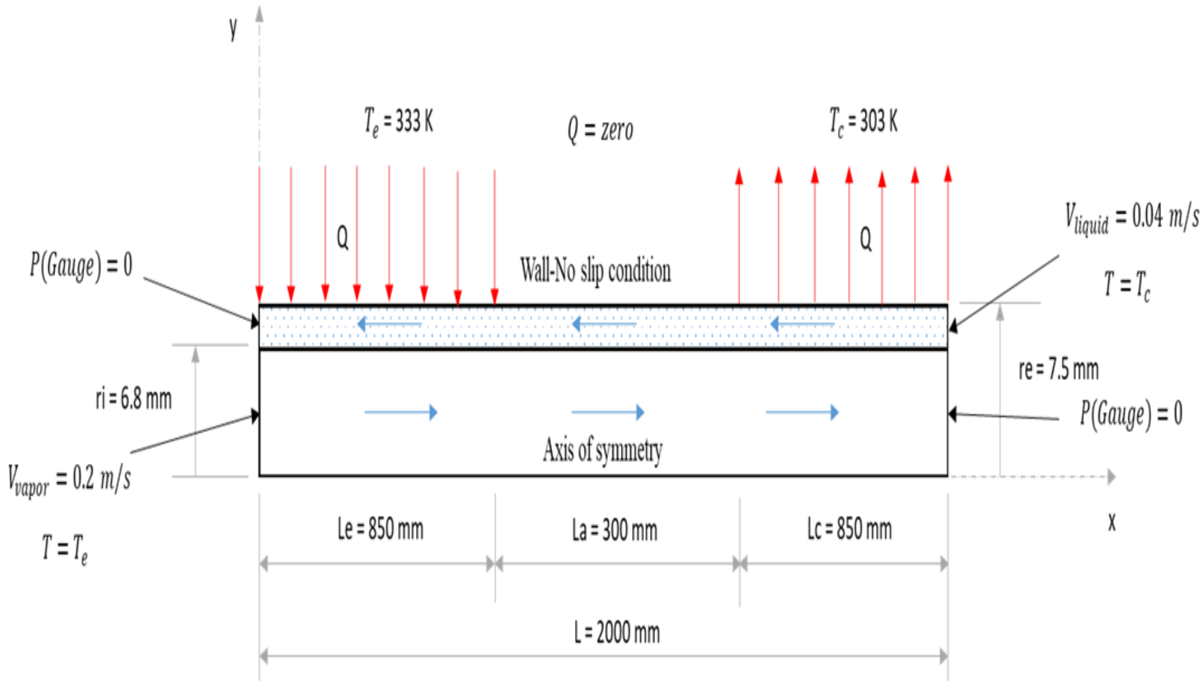

Fig. 3.2: Boundary conditions of a heat pipe.

3.3 Parametric Study: Two-dimensional Axisymmetric heat pipe

Table 3.1: Parametric Study for two-dimensional Axisymmetric heat pipe.

	Length (m)	**Evaporator/Condenser Length (mm)**	**Adiabatic Length (mm)**
Pipe 1	2	850	300
Pipe 2	1	425	150
Pipe 3	3	1275	450

3.4 Ansys Fluent Modeling

Ansys Workbench is used in industries and academia for computational fluid dynamics (CFD), finite element analysis (FEA), electromagnetic simulation and so on. Using different modules available in Ansys Workbench different computational analysis are performed [20], [21]. Ansys Fluent is widely used to study fluid flow and thermal analysis [22]–[25]. The model of the heat pipe is designed using ANSYS workbench,

- 2D, axisymmetric, steady, laminar, viscous problem.
- The regions of the model are evaporator, adiabatic wall, condenser, fluid zone, inlet, and outlet.
- Used three different fluids Water and Dowtherm and Water-Based Fe_2O_3 Nanofluid
- The properties of Water are in the Ansys library, but in this study, I defined Dowtherm and Water-Based Fe_2O_3 Nanofluid as new user-defined fluids in Ansys and entered their properties.

3.5 Properties of DOWTHERN

Table 3.2: Dowtherm fluid properties @ 187 ℃ (460K) [8].

Liquid phase	**Vapor phase**
Density ρ = 918.9 kg/m3	Density ρ = 0.72 kg/m3
Specific heat Cp = 2.040 $*$ 103 JT$kg.\ K$	Specific heat Cp = 1.628 $*$ 103 JT$kg.\ K$
Thermal conductivity = 0.1120 W/m K	Thermal conductivity = 0.0187 W/m K
Viscosity = 0.43*10−3 kg/m s	Viscosity = 0.00865*10^{-3} kg/m s

Table 3.3: Dowtherm fluid properties @ 197 °C (470 K) [8].

Liquid phase	Vapor phase
Density ρ = 909.6 kg/m3	Density ρ = 0.9464 kg/m3
Specific heat Cp = 2.071 $*$ 103 JT$kg.\ K$	Specific heat Cp = 1.657 $*$ 103 JT$kg.\ K$
Thermal conductivity = 0.1104 W/m K	Thermal conductivity = 0.0194 W/m K
Viscosity = 0.43*10−3 kg/m s	Viscosity = 0.00885*10−3 kg/m s

Table 3.4: Dowtherm fluid properties @ 77 °C (350 K) [8].

Liquid phase	Vapor phase
Density ρ = 1013.4 kg/m3	Density ρ = 0.00812 kg/m3
Specific heat Cp = 2.321 JT$kg.\ K$	Specific heat Cp = 1.2692 JT$kg.\ K$
Thermal conductivity = 0.1296 W/m K	Thermal conductivity = 0.01112 W/m K
Viscosity = 1.31*10^{-3} kg/m s	Viscosity = 0.00654*10^{-3} kg/m s

3.6 Thermo-physical properties of Nano fluids

The concentration, material, and size of nanoparticles have important roles in the heat transfer coefficient of Nano fluids. Thermal conductivity increases with large particle size, whereas viscosity increases with small particle size. Fluids are considered Nano fluids when their particle sizes range from 1 to 100 nm direct relation between the density of nanoparticles and the thermal conductivity of Nano fluids [1].

Thermal conductivity is an important property which has a major role in heat transfer with nanofluids. The Hamilton–Crosser correlation with an empirical scaling factor was used for the determination of the nanofluid effective thermal conductivity as follows: where the empirical scaling factor given by:

Thermal Conductivity:

$$K_{nf} = K_f \left[\frac{K_s + 2K_f - 2\emptyset\left(K_f - K_s\right)}{K_s + 2K_f + \emptyset\left(K_f - K_s\right)} \right] \tag{1}$$

n= 3 /Ψ is the shape factor that considers the effect of different particle shapes on thermal conductivity. Since the nanoparticles used in this investigation are spherical, the shape factor Ψ is 1.

Brinkman’s equation can be used for estimation of nanofluid viscosity:

$$\mu_{nf} = \mu_f (1 - \emptyset)^{-2.5} \tag{2}$$

Specific heat of nanofluid was estimated by equation:

$$C_{P_{nf}} = \frac{(1 - \emptyset)(\rho C_p)_f + \emptyset(\rho C_p)_s}{\rho_{nf}} \tag{3}$$

and the density of nanofluid was calculated from equation:

$$\rho_{nf} = (1 - \emptyset)\rho_f + \emptyset\rho_s \tag{4}$$

In my work

- ∅ Volume concentration, it is the particle volume fraction of the suspension (vol%) = 2%
- n is the empirical scaling factor = 3/Ψ
- Ψ the shape factor (in case of spherical nanoparticles Ψ=1

Note:

- ➢ BF base fluid
- ➢ NP Nano particles Using the previous equations to get the nanofluid properties as shown in the table below:

Table 3.5: Thermo-physical properties of Nano fluids.

Φ Volume concentration		0.02 & 0.04 & 0.06				
n is the empirical scaling factor		3				
Ψ the shape factor		1				
Material properties		**Density (kg/m3)**	**Specific heat coefficient (J/kg. K)**	**Thermal conductivity (W/m. K)**	**Dynamic viscosity (kg/m s)**	**Volume concentration**
Base fluid	Water-liquid	998.2	4181.7	0.6069	0.0008899	—
	Water-vapor	0.5542		0.0261	0.0000134	—
Nano particles	ɣ-Fe_2O_3	5242	679	161		—
Nano fluid using The Hamilton-Crosser Correlation	Water-Based Fe2O3 Nanofluid	1083.076	3842.644322	0.643631674	0.000936	0.02
		1167.952	3552.867534	0.68187595	0.000985515	0.04
		1252.828	3302.354069	0.721728222	0.001038775	0.06

3.7 Parametric Study: Three-dimensional Axisymmetric heat pipe

Table 3.6: Parametric Study for Three-dimensional Axisymmetric heat pipe.

	Length (m)	**Evaporator/Condenser Length (mm)**	**Adiabatic Length (mm)**
Pipe 1	2	850	300

Problem specifications:

The Case study will be 3D, axisymmetric, steady, laminar, viscous problem

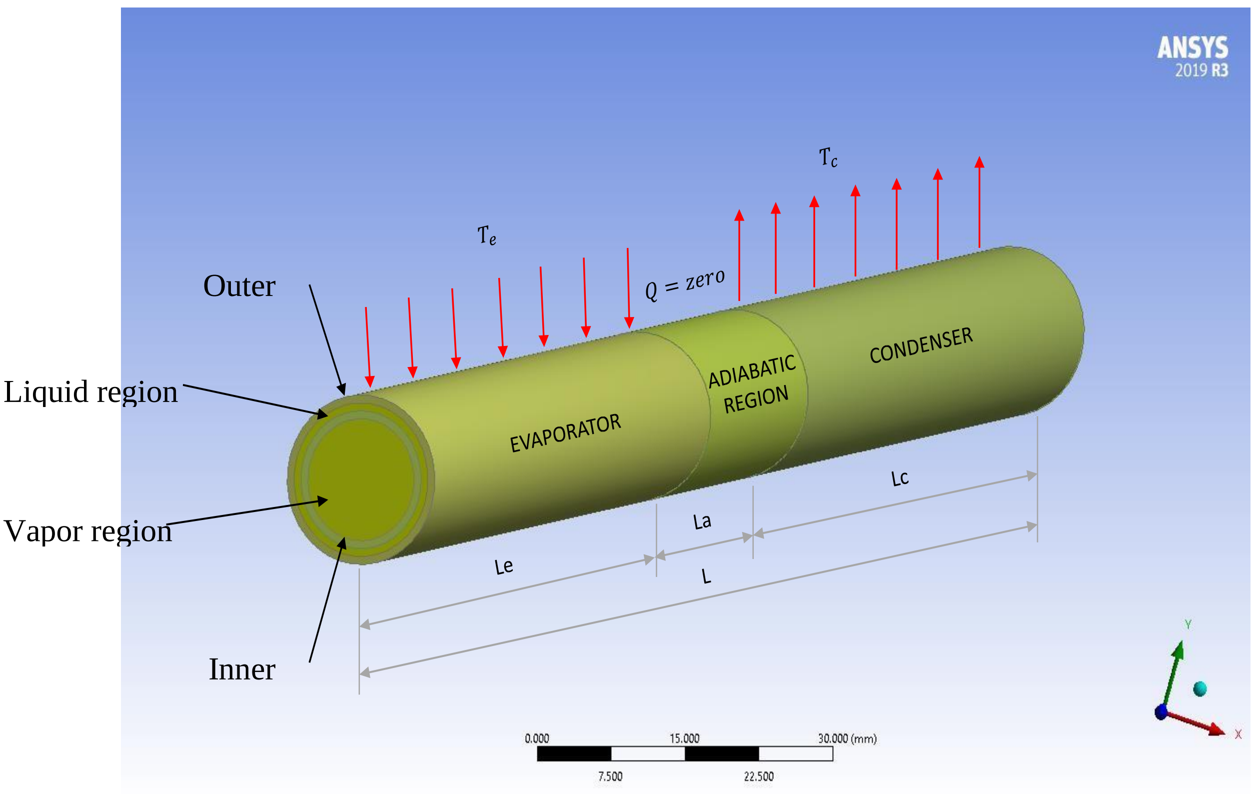

Fig. 3.3: Problem specifications.

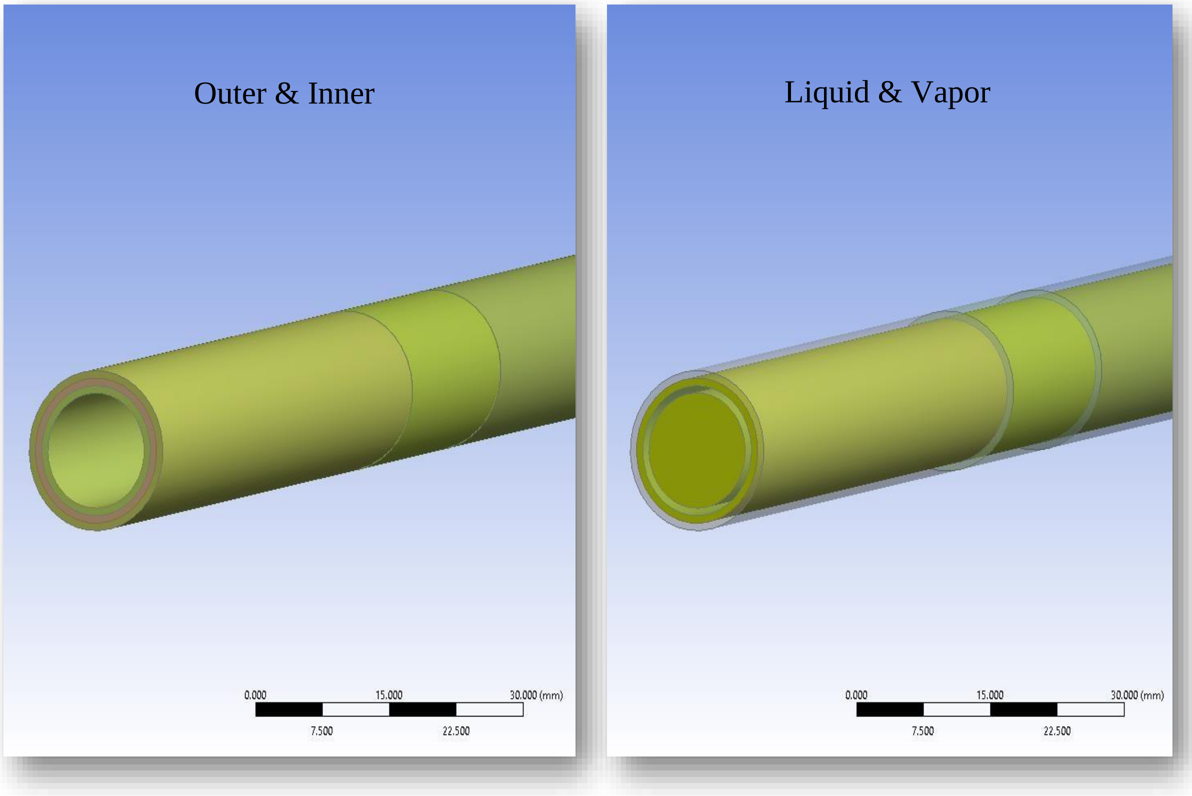

Fig. 3.4: Problem specifications

3.8 Boundary Conditions and Flow properties

The boundary condition for case that study three-dimensional pipe as shown below:

Pipe material used is copper, Total Pipe length = 2 M, Evaporator Region = 850 mm,

Adiabatic Region =300 mm, Condenser Region =850 mm

Outer pipe dimensions (Liquid domain): r_o =8mm, r_i =7.5 mm

Inner pipe dimensions (Vapor domain): r_o =6.8mm, r_i =6.3 mm

Vapor inlet velocity = 0.2 m/s, Liquid inlet velocity = 0.04 m/s

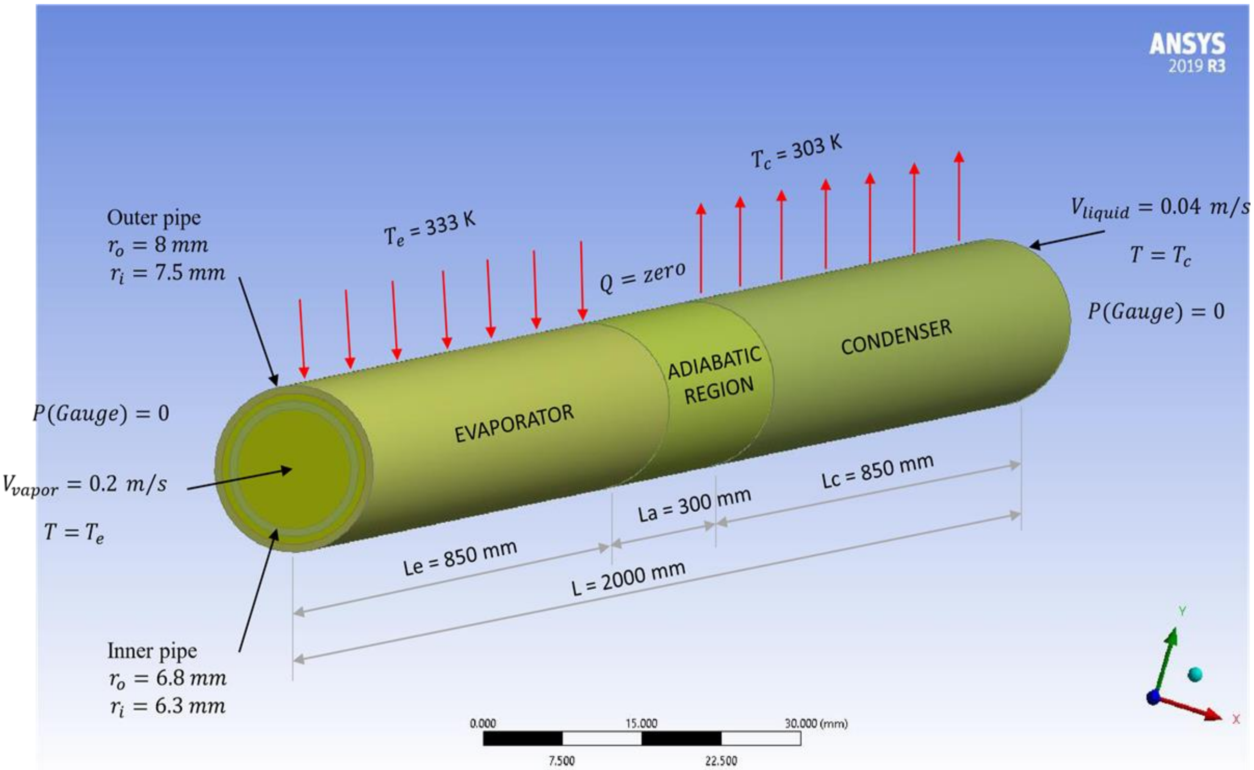

Fig. 3.5: Boundary condition and flow properties.

There are different assumptions that can be applied to a fluid. Fluids can be:

- Compressible $\rho \neq constant$, or incompressible $\rho = constant$.
- Viscous $\mu \neq 0$, or inviscid $\mu = 0$.
- Steady $u\cdot = 0$, or unsteady $u\cdot \neq 0$.
- Laminar (streamlined-low Re), or turbulent (Chaotic-high Re).
- Newtonian (shear stress is a linear function of strain rate), or non-Newtonian (shear stress is a nonlinear function of strain rate).

3.9 Governing Equations

The flow is assumed to be laminar due to Re<<<230, with the specified parameters and boundary conditions. Ansys Workbench solves the Navier-Stokes equation on the conservation of mass, momentum, and energy, the governing equations solved for simulations are as follows:

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho \vec{v}) = 0 \tag{5}$$

For an incompressible flow, equation (5) reduces to:

$$\nabla.\vec{v} = 0 \tag{6}$$

$$\frac{\partial(\rho \vec{v})}{\partial t} + \nabla.(\rho \vec{v}\vec{v}) = -\nabla p + \nabla.(\bar{\bar{\tau}}) + \rho \vec{g} + \vec{F} \tag{7}$$

where $\bar{\bar{\tau}}$ is the stress tensor, p is the static pressure, and $\rho\vec{g}$ is the gravitational body force. $\vec{F}$ May arise from resistances,

$$\frac{\partial(\rho h)}{\partial t} + \nabla.(\rho h \vec{v}) = -\nabla.[(k + k_t)\nabla T + S_h \tag{8}$$

where k is the molecular conductivity, k_t is the conductivity due to turbulent transport and S_h includes the defined volumetric.

Where, Cp, μ, ρ, k are constant material Cp specific heat, k thermal conductivity, ρ Density, μ viscosity

Chapter 4

Results and Discussion

4.1 Performance heat transfer for Heat pipe for Two-dimensional Axisymmetric:

Simulations were performed for water, DOTHREM and water-Based Fe203 Nanofluid and the results explain below:

Solution Results for case 1 when used water as working fluid

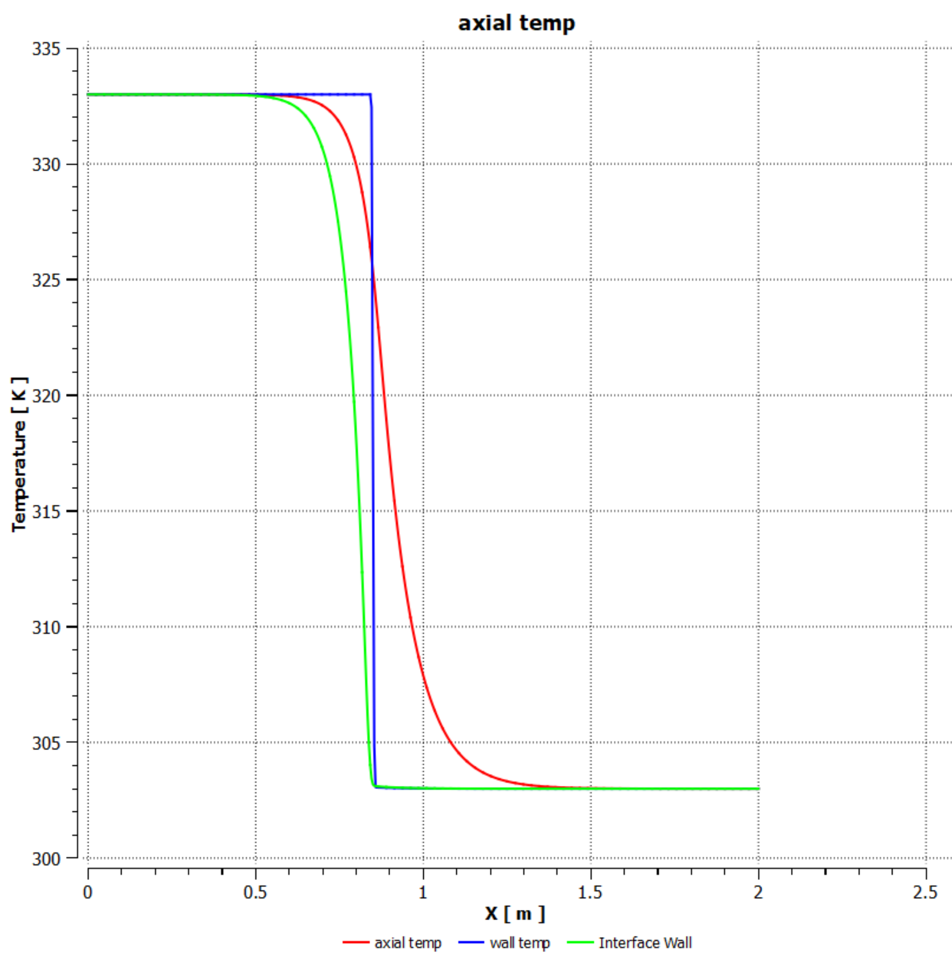

Fig. 4.1: Variation of Axial Temperature along Centerline, Interface wall, and upper.

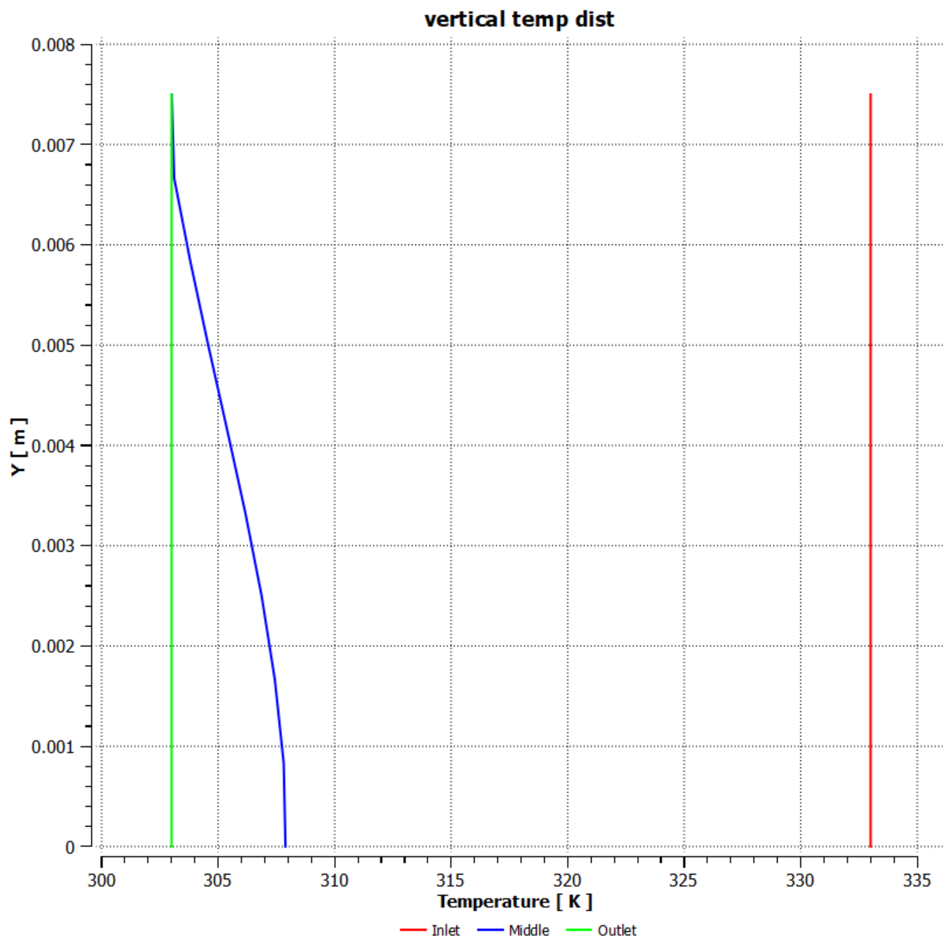

Fig. 4.2: Vertical temperature variation at pipe Inlet, Middle, and Outlet.

The Fig. 4.2 shows the temperature at inlet was 333 K but the temperature decreases to 303 K at outlet when used water.

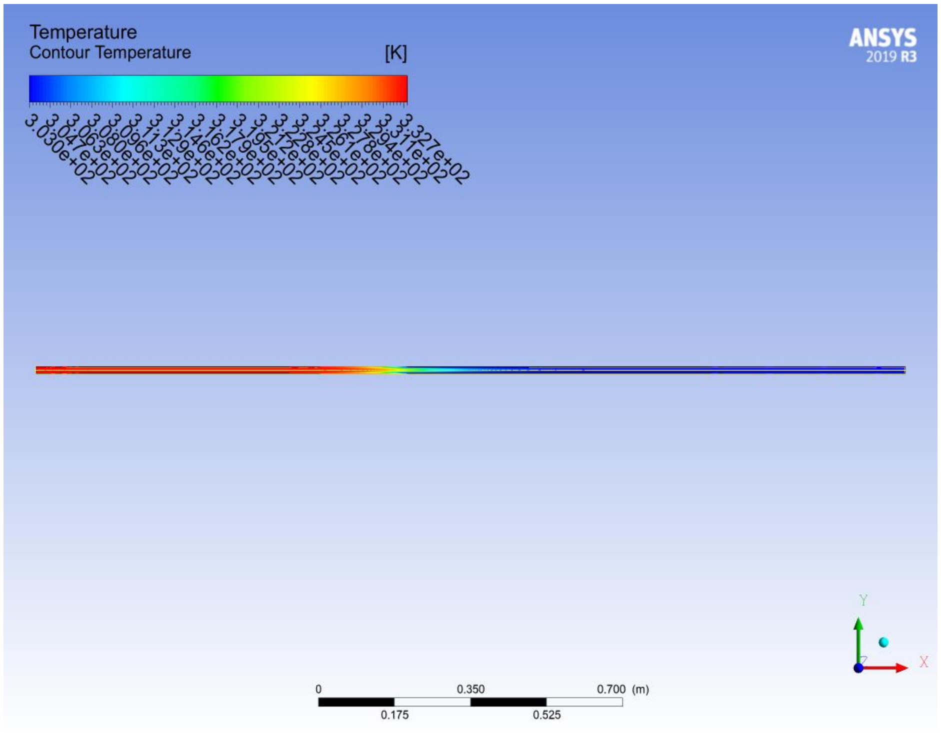

Fig. 4.3: Contour shows the temperature along the heat pipe.

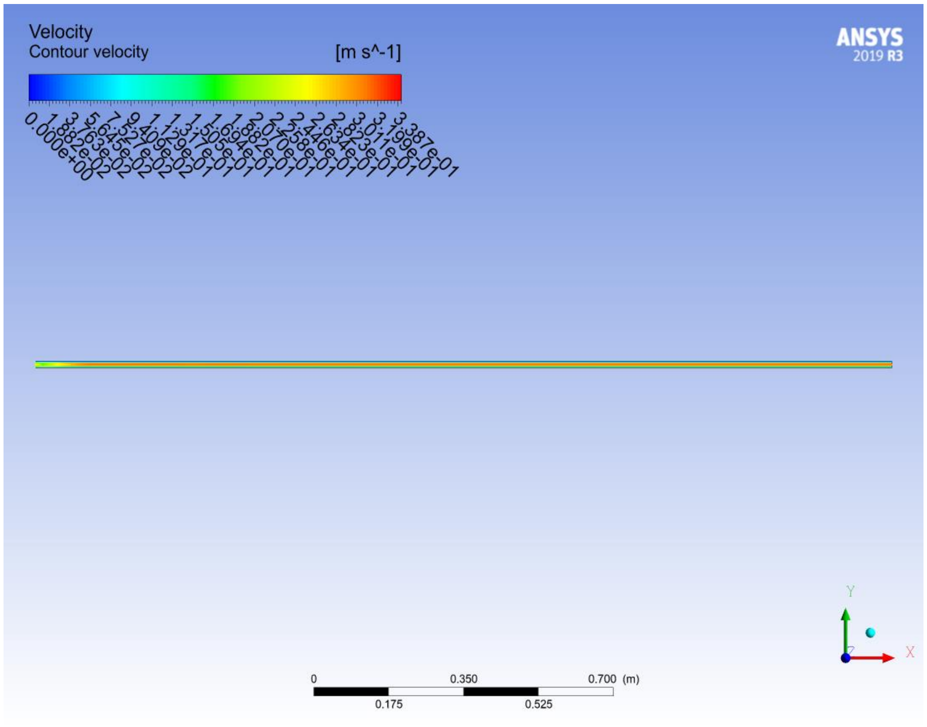

Fig. 4.4: Contour shows the velocity along the heat pipe.

Table 4.1: Parametric study cases, and all results for Pipe 1.

<table>
<tr><th>Fluid</th><th>Case No.</th><th>Vapor inlet velocity (mTs)</th><th>Liquid inlet velocity (mTs)</th><th>Evaporator Temperature (K)</th><th>Condenser temperature (K)</th><th>Nano particles concentration n</th></tr>
<tr><td rowspan="3">Water</td><td>1</td><td rowspan="9">0.2</td><td rowspan="9">0.04</td><td>333</td><td>303</td><td>–</td></tr>
<tr><td>2</td><td>340</td><td>303</td><td>–</td></tr>
<tr><td>3</td><td>350</td><td>303</td><td>–</td></tr>
<tr><td rowspan="3">Dowtherm</td><td>4</td><td>460</td><td>430</td><td>–</td></tr>
<tr><td>5</td><td>470</td><td>430</td><td>–</td></tr>
<tr><td>6</td><td>350</td><td>303</td><td>–</td></tr>
<tr><td>Water-Based</td><td>7</td><td>333</td><td>303</td><td>0.02</td></tr>
<tr><td>Fe_2O_3</td><td>8</td><td>333</td><td>303</td><td>0.04</td></tr>
<tr><td>Nanofluid</td><td>9</td><td>333</td><td>303</td><td>0.06</td></tr>
</table>

Table 4.2: Parametric study cases, and all results for Pipe 2.

Fluid	**Case No.**	**Vapor inlet velocity (mTs)**	**Liquid inlet velocity (mTs)**	**Evaporator Temperature (K)**	**Condenser temperature (K)**	**Nano particles concentration**
Water	10	0.2	0.04	333	303	–
	11			340	303	–
	12			350	303	–
Dowtherm	13			460	430	–
	14			470	430	–
	15			350	303	–
Water-Based Fe_2O_3 Nanofluid	16			333	303	0.02
	17			333	303	0.04
	18			333	303	0.06

Table 4.3: Parametric study cases, and all results for Pipe 3 at 2D.

Fluid	**Case No.**	**Vapor inlet velocity (mTs)**	**Liquid inlet velocity (mTs)**	**Evaporator Temperature (K)**	**Condenser temperature (K)**	**Nano particles concentration**
Water	19	0.2	0.04	333	303	– – –
Dowtherm	20			460	430	– – –
Water-Based Fe_2O_3 Nanofluid	21			333	303	0.06

All results for heat performance are shown for 21 cases studies above at evaporator and condenser temperatures columns for only two-dimensional studies at Ansys Fluent with boundary conditions.

4.2 Performance heat transfer for Heat pipe for Three-dimensional Axisymmetric:

Simulations were performed for water, DOTHREM and water-Based Fe203 Nanofluid and the results explain below: Solution Results for case 22 when used water as working fluid

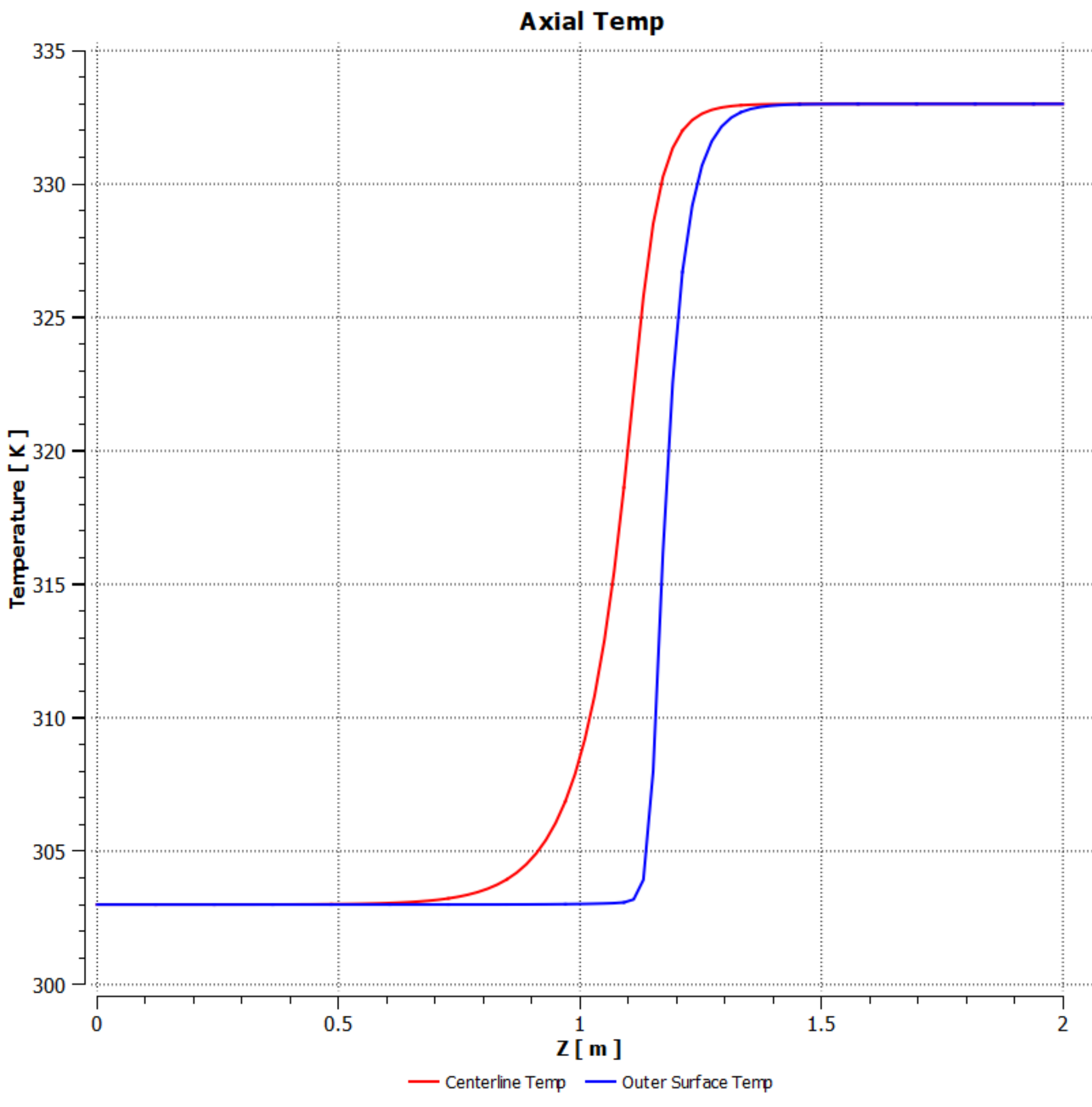

Fig. 4.5: Variation of Axial Temperature along Centerline and centerline.

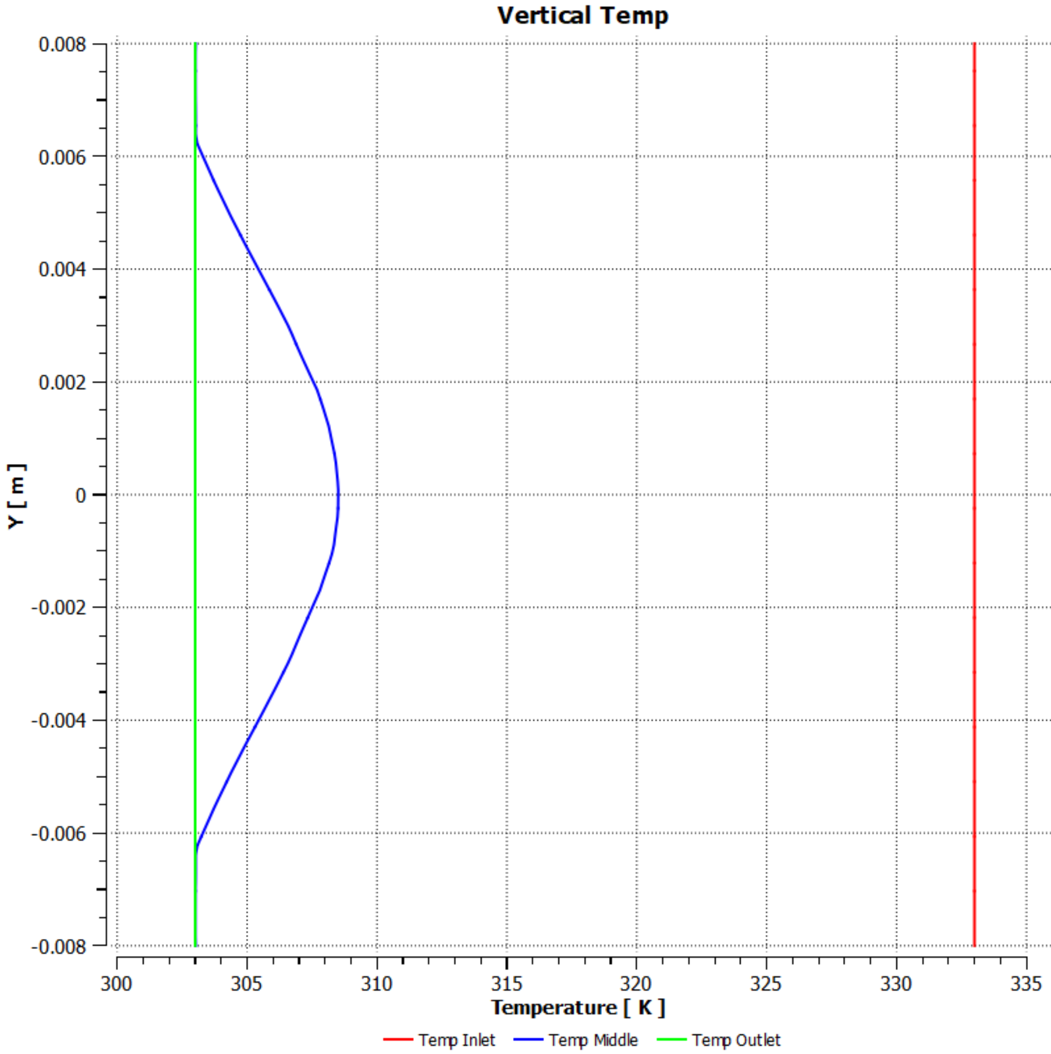

Fig. 4.6: Vertical temperature variation at pipe Inlet, Middle, and Outlet.

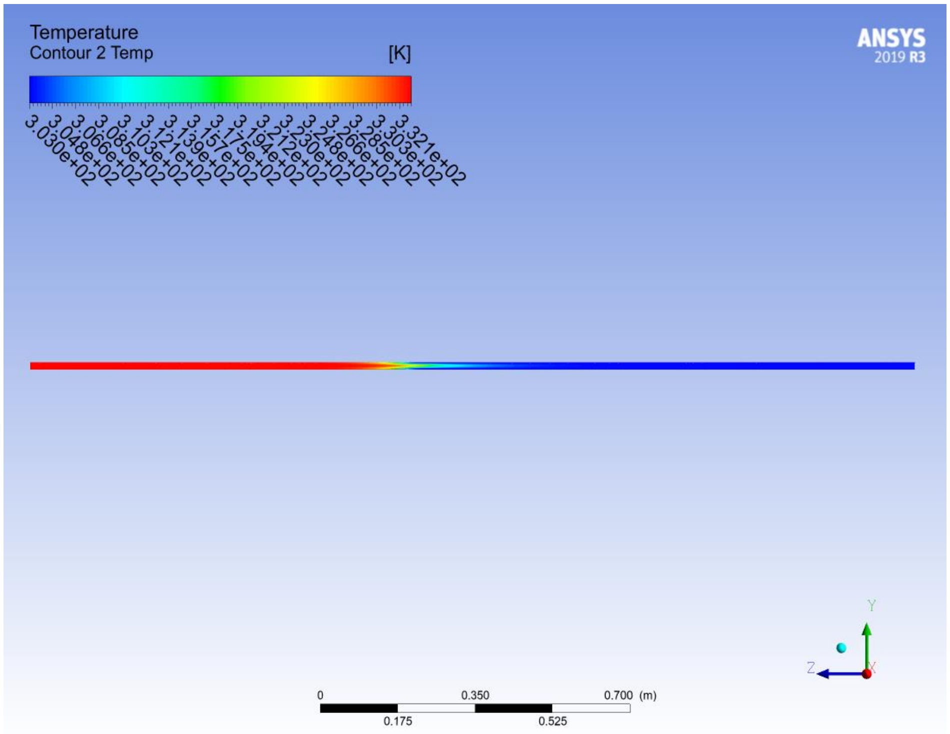

Fig. 4.7: Temperature contour.

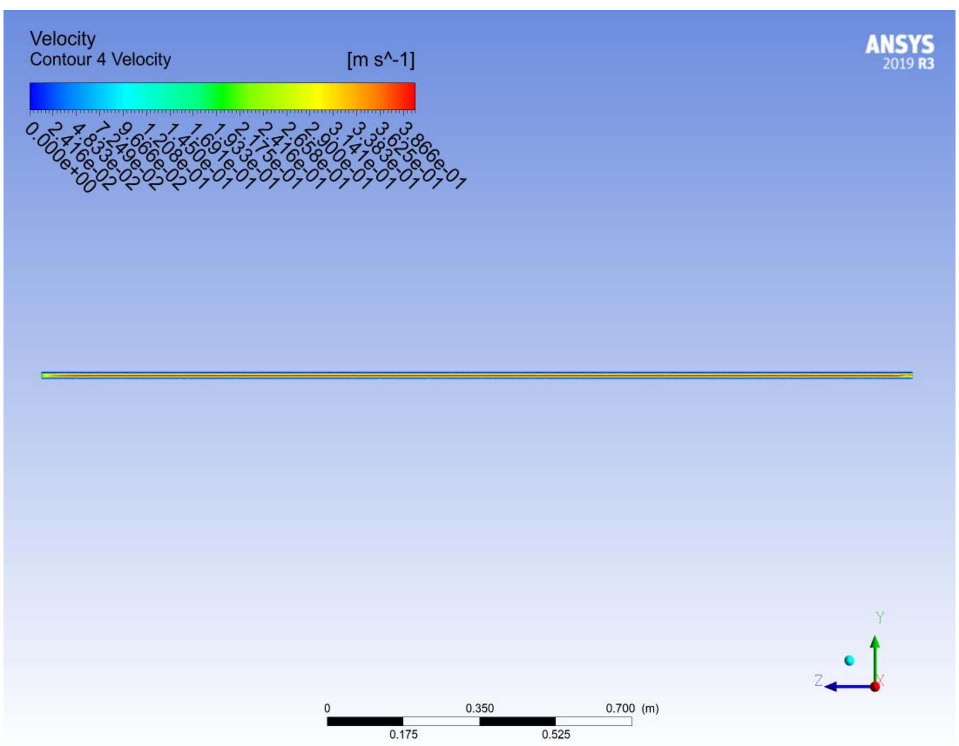

Fig. 4.8: Velocity contour.

4.3 Comparison between the three fluids

Water DOTREM Nanofluid

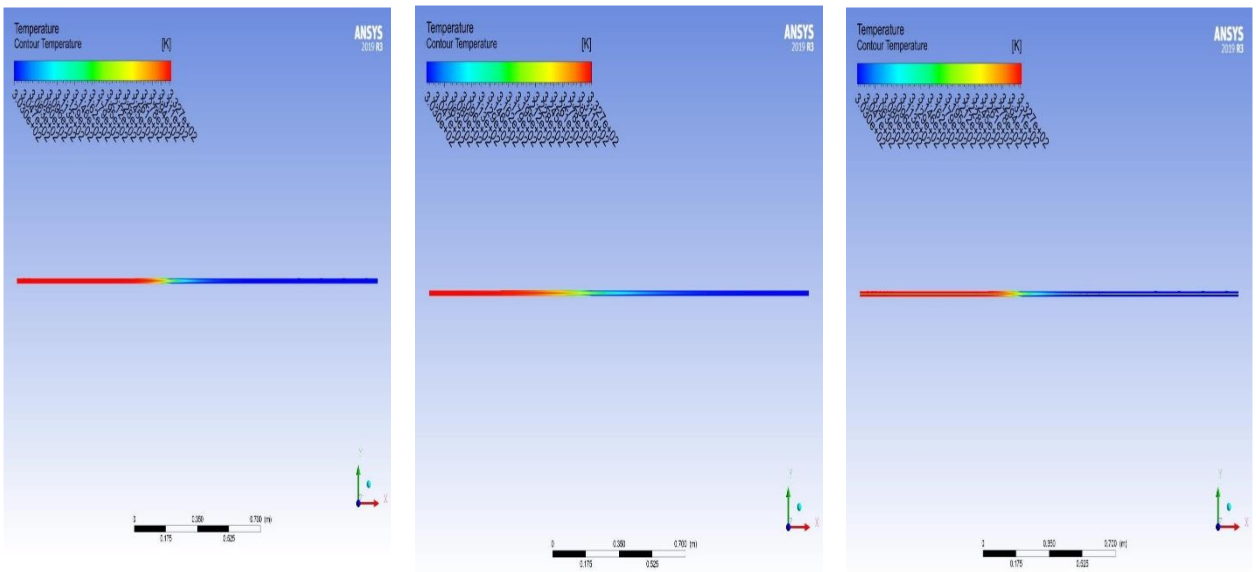

Fig. 4.9: Contour shows the temperature along the heat pipe for all fluid.

Water Dowtherm Nanofluid

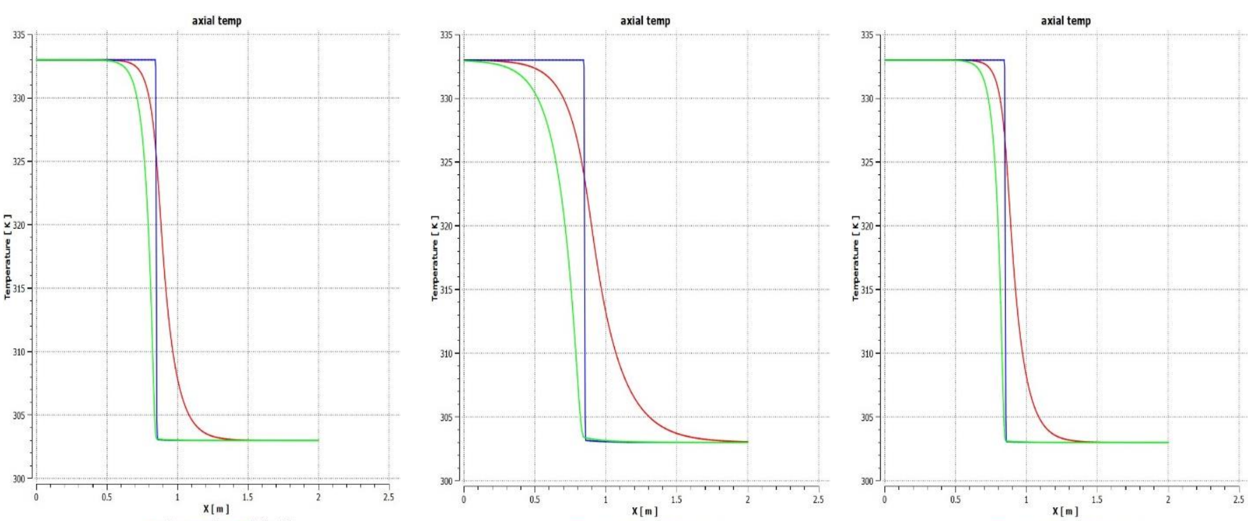

Fig. 4.10: Axial temperature variation at pipe Inlet, Middle, and Outlet for all fluid.

Water Dowtherm Nanofluid

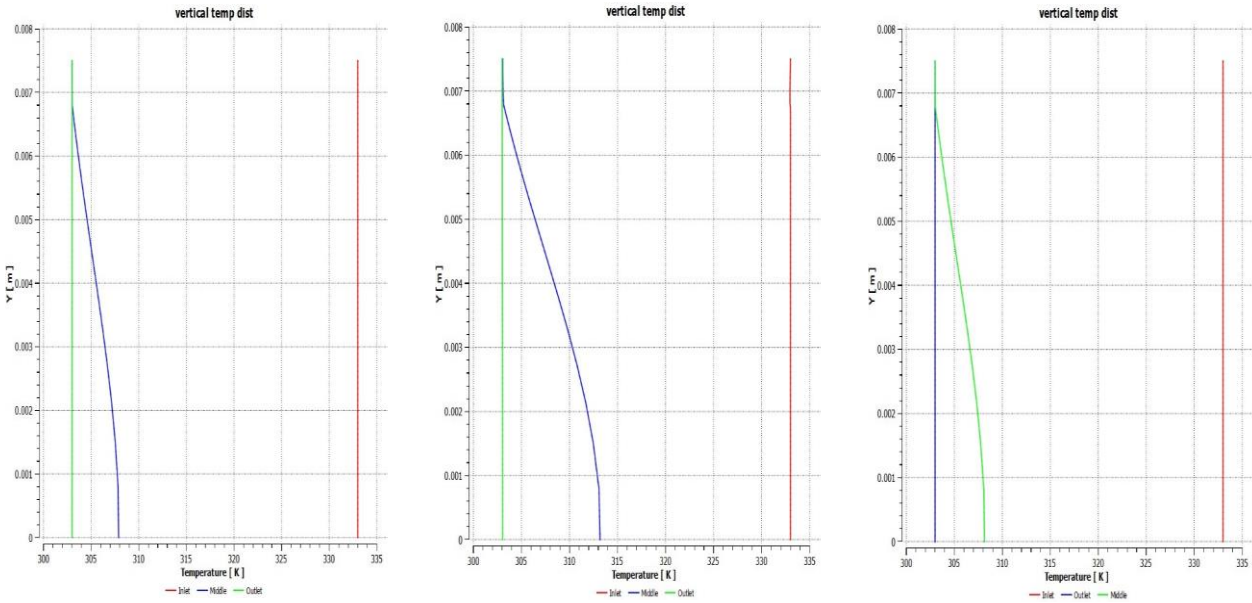

Fig. 4.11: Vertical temperature variation at pipe Inlet, Middle, and Outlet For all fluid.

Table 4.4: Parametric study cases, and all results for Pipe 3 at 3-dimensional.

Fluid	**Case No.**	**Vapor inlet velocity (mTs)**	**Liquid inlet velocity (mTs)**	**Evaporator Temperature (K)**	**Condenser temperature (K)**	**Nano particles concentration**
Water	**22**	**0.2**	**0.04**	**333**	**303**	**–**
						–
						–
Dowtherm	**23**			**460**	**430**	**–**
						–
						–
Water-Based Fe_2O_3 Nanofluid	**24**			**333**	**303**	**0.06**

Chapter 5

Conclusion

In the present work, the heat transfer of double pipe counter flow is investigated using ANSYS Workbench. 2D as well as 3D analyses are conducted including three different fluids: water, DOWTHERM, and water-based nanofluid. The pipe external section is divided into three regions: evaporator, adiabatic and condenser regions. A heating and cooling temperatures are defined to the evaporator and condenser, respectively. The liquid and vapor are supplied to the pipe in opposite directions based on the defined inlet velocity. In the 2D analysis, the pipe is solved as axisymmetric problem. A parametric analysis is conducted to study the effect of changing the pipe length as well as the nano fluid concentration on the pipe thermal performance with total of 24 different analyses and case studies. The DOWTHERM performance outweigh the water performance in point of view of the cooling length. The DOWTHERM can reserve his low temperature for a wider range comparing to the water. The presence of nano fluids enhanced the water thermal performance, and its volume fraction can affect the heat transfer performance, but this effect is negligible. The change of pipe length has no effect in the present analyses because I kept the relative length of the pipe zones along with the boundary conditions fixed. When comparing between the 2D and 3D analyses, a negligible difference is detected in terms of thermal temperature which is about 0.227 % in case of water and 0.0455 % in case of Dowtherm.

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