Enhancement Of Thermal Conductivity Using Nanofluids

Sivasubramanian.R[1], Ramachandran.N[2], Arun Kurien Reji[3], Karunakararaja.M[4]
[1, 2, 3, 4] Department of Mechanical Engineering
[1, 2, 3, 4] Sri Krishna College of Engineering and Technology, Coimbatore, Tamil Nadu, India.

Abstract- *The past decade has seen the rapid development of nanofluids science in many aspects. Number of research is conducted that is mostly focused on the thermal conductivity of these fluids. Nanofluids are new kinds of fluids engineered by dispersing nanoparticles in base fluids. This project involves analysis of thermal conductivity of Aluminium Oxide (Al2O3) nanoparticles dispersed in water in the volume fraction of 4%.Solar Water Heater is modelled using 'SOLID WORKS 2013' and is analyzed with the Al2O3-Water nanofluid using 'ANSYS 14' software. Initially the water is analysed with Solar Water Heater and an Outlet temperature of 355K is obtained. Water based Al2O3 nanofluid of volume fraction of 4% is then analysed with Solar Water Heater .We get a result of 30oC increase in the outlet temperature than that of water. Then the analysis results are compared with results of the theoretical calculation. Overall, this project can bring a motivation and experience , training to work under pressure , apply knowledge that have been gathered and soft skill ability like time management , planning the task , and negotiation skill to make sure this project goes smooth as planned and done at correct time.*

Keywords- Nano fluid, Solar water heater(SWH) pipe, heat transfer, temperature.

I. INTRODUCTION

Heat transfer is a discipline of thermal engineering that concerns the generation, use, conversion, and exchange of thermal energy and heat between physical systems. Heat transfer is involved in almost every sector of the economy. Heat transfer is classified into various mechanisms, such as thermal conduction, thermal convection, thermal radiation, and transfer of energy by phase changes.

The thermal conductivity which plays a vital role in field of determining the size of heat transfer applications. In order to reduce the size of the heat transfer applications the thermal conductivity must be increased. Nowadays thermal conductivity of heat transfer applications are enhanced by the introduction of nanofluids.

These nanofluids before being applied in heat transfer application are initially tested and analyzed, based on their results they are used in heat transfer applications.

II. LITERATURE REVIEW

Paisarn Naphon [4], Presented work on “Experimental investigation of titanium nanofluids on the heat pipe thermal efficiency” In the study the enhancement of heat pipe thermal efficiency with nanofluids with titanium particles was presented. The heat pipe with the de-ionic water, alcohol, and nanofluids (alcohol and nanoparticles) are tested.

Sarit K. Das a [3], Presented work on” Pool Boiling Characteristics of Nanofluids”, The paper investigates Nanofluid characteristics through experimental study of pool boiling in water–Al2O3 nano-fluids. The results indicate that the nano-particles have pronounced and significant influence on the boiling process deteriorating the boiling characteristics of the fluid.

Sarit K. Das a [3], Has done a paper on “Temperature Dependence of Thermal Conductivity Enhancement for Nanofluids”, from the paper it is has been observed that a 2 to 4 fold increase in thermal conductivity enhancement of nanofluids can take place over a temperature range of 21°C to 51°C. It is also has been observed that nanofluids containing smaller CuO particles show more thermal conductivity with temperature.

Li, C. H., Peterson, G. P [2], Has done a paper on” Experimental Investigation of Temperature and Volume Fraction Variations on the Effective Thermal Conductivity of Nanoparticle Suspensions”, The paper indicate that the nanoparticle material, diameter, volume fraction, and bulk temperature, all have a significant impact on the effective thermal conductivity of these suspensions. The paper had analyzed and discussed the unusual high effective thermal conductivity of nanofluids

D. Wen [2]., Presented a work on “Experimental Investigation in to Convective Heat Transfer of
Nanofluids at the Entrance Region under Laminar Flow

Conditions", The paper had investigated that particle migration in nanofluids flowing through a tube and its effect on heat transfer by using a theoretical model and they proposed that the presence of nanoparticles also affects the boundary layer development in pipe flows and hence heat transfer.

III. NANOFLUIDS

- A Nanofluid is a fluid containing nanometer-sized particles, called nanoparticles.
- These fluids are engineered colloidal suspension of nanoparticles in a base fluid.
- The nanoparticles used in nanofluids are typically made of metals, oxides etc
- Common base fluids include water, ethylene glycol and oil.
- Common nanoparticles are Al2O3,ZnO,TiO2

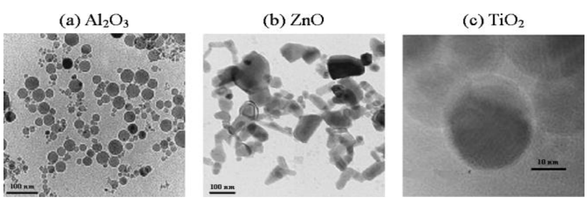

Figure 1. Common Nanoparticles

1. PREPARATION OF NANOFLUIDS:

Basically three different methods are available for preparation of stable nanofluids and are listed below:

a) BY MIXING NANOPARTICLE WITH BASE FLUID

In this method, the nanoparticles are directly mixed in the base liquid and thoroughly stirred. Nanofluids prepared in this method give poor suspension stability, because the nanoparticles settle down due to gravity, after a few minutes of nanofluid preparation. The time of particle settlement depends on the type of nanoparticles used, density and viscosity properties of the host fluids.

b) BY ACID TREATMENT OF BASE FLUIDS

The PH value of the base fluid can be lowered by adding a suitable acid to it. A stable Nanofluid with uniform particle dispersion can be prepared by mixing nanoparticles in an acid treated base fluid. But acid treated nanofluids may cause corrosion on the pipe wall material with prolonged usage of nanofluids. Hence acid treated base fluids are not preferred for preparation of Nanofluids even thoughformation of stable nanofluids is possible with such base fluids.

c) BY ADDING SURFACTANTS TO BASE FLUIDS

In this method a small amount of suitable surfactant, generally one tenth of mass of nanoparticles, is added to the base fluid and stirred continuously for few hours. Nanofluids prepared using surfactants will give a stable suspension with uniform particle dispersion in the host liquid. The nanoparticles remain in suspension state for a long time without settling down at the bottom of the container.

2. BROWNIAN MOTION ON NANOFLUIDS

- It is the random motion of particles suspended in a fluid resulting from their collision with the quick atoms or molecules in the gas or liquid.
- The term "Brownian motion" can also refer to the mathematical model used to describe such random movements, which is often called a particle theory.
- This transport phenomenon is named after the botanist Robert Brown.

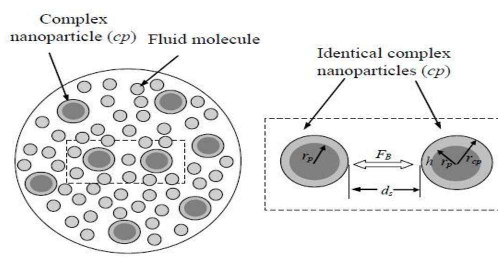

Figure 2. Concept of Brownian Motion on Nanofluids

3. ADVANTAGES OF NANOFLUIDS

- High specific surface area and therefore more heat transfer surface between particles and fluids
- High dispersion stability with predominant Brownian motion of
- particles.
- Reduced pumping power as compared to pure liquid to achieve
- equivalent heat transfer intensification.
- Reduced particle clogging as compared to conventional slurries, thus promoting system miniaturization.
- Adjustable properties, including thermal conductivity and surface wet ability, by varying particle concentrations to suit different applications.

4. APPLICATIONS OF NANOFLUIDS

- Electronics cooling
- Defence

- Space
- Nuclear systems cooling
- Heat exchanger

IV. BENEFITS OF USING SOLAR WATER HEATER

- A 100 litres capacity SWH can replace an electric geyser for residential use and saves 1500 units of electricity annually.
- The use of 1000 SWHs of 100 litres capacity each can contribute to a peak load saving of 1 MW.

1. MODELING OF SWH

The Modeling of Solar Water Heater is done using The Solid Works 2013.The Dimensions of The Solar Water Heater are Measured from the existing Solar Water Heater.

a. DIMENSIONS OF SWH

Table 3. Dimensions of SWH

S. NO	OBJECT	DIMENSION
1	Length of Pipe	1000mm
2	Inner Diameter of Pipe	30mm
3	Outer Diameter of Pipe	40mm
4	Length of Fin	20mm
5	Breadth of Fin	1000mm
6	Thickness of Fin	2mm

b. MATERIALS OF FIN & PIPE

The fin which is used to increase the heat transfer from the surfaces is made of Aluminum and the pipe which provides path for fluid flow through them is made of copper

c. WIRE FRAME MODEL OF SWH (WITH FIN)

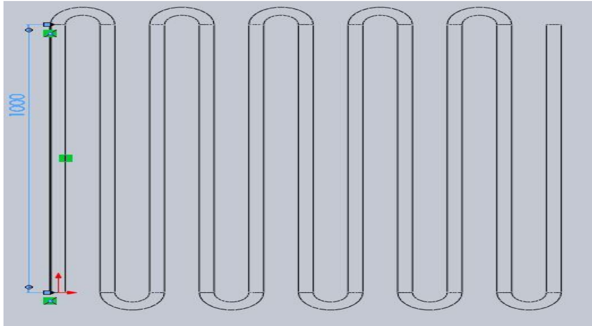

Figure 3. Wire Frame Model of SWH(With Fin)

d. 3D MODEL OF SOLAR WATER HEATER(WITH FIN)

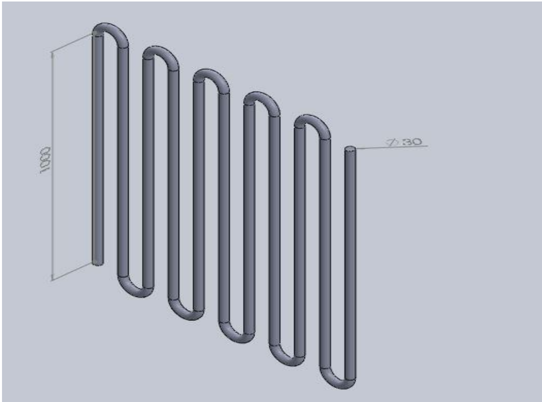

Figure 4. 3D Model of Solar Water Heater (With Fin)

e. WIRE FRAME MODEL OF SWH (WITHOUT FIN)

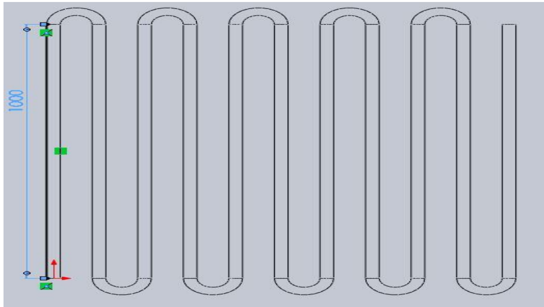

Figure 5. Wire Frame Model of SWH(Without Fin)

f. 3D MODEL OF SOLAR WATER HEATER (WITHOUT FIN)

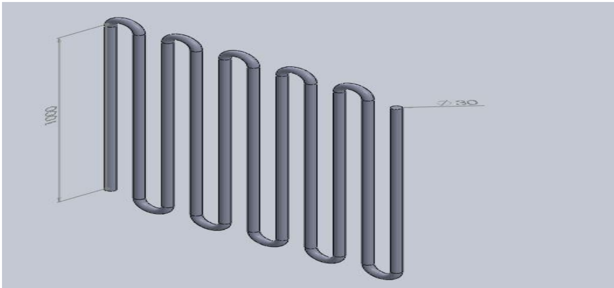

Figure 6. 3D Model of Solar Water Heater(Without Fin)

As per the measured dimensions, the Solar Water Heater is modeled using The "SOLID WORKS 13" software. Both Solar Water Heater with fin & without fin are modeled. The 3D model & wire frame model of Solar Water Heater with fin & without fin are shown in the figures.

V. COMPUTATIONAL ANALYSIS

The Computational Analysis of Solar Water Heater is done using "ANSYS WORKBENCH 14"

1. MESHING

Mesh generation is one of the most critical aspects of engineering simulation. Too many cells may result in long solver runs, and too few may lead to inaccurate results. ANSYS Meshing technology provides a means to balance these requirements and obtain the right mesh for each simulation in the most automated way possible.

2. MESH MODEL(WITH FIN)

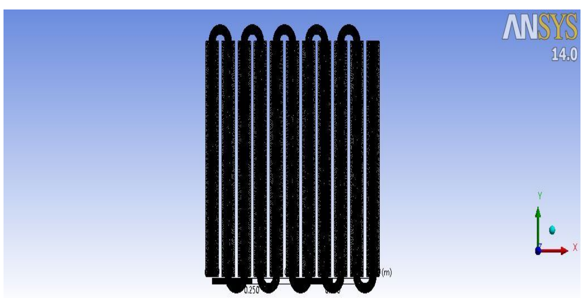

Figure 7. Mesh Model of Solar Water Heater (With Fin)

MESH MODEL(WITHOUT FIN)

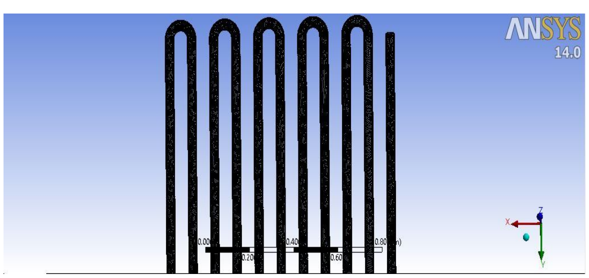

Figure 8. Mesh Model of Solar Water Heater (Without Fin)

3. PROPERTIES OF WATER FLUID

Table 4. Properties of Water Fluid

SNO	PROPERTIES	VALUE
1.	Density	1000Kg/m^3
2.	Specific Heat	4182 J/Kg-K
3.	Thermal Conductivity	0.6 W/m-K
4.	Viscosity	0.001003 Ns/m^2

4. ANSYS CALCULATION

The Calculation is done using ANSYS by setting up the parameters of the water fluid. The following setup is made

SETUP FOR WATER FLOW THROUGH SWH

Table 5. Setup for water flow through SWH

S.NO	PARAMETER	VALUE
1.	Fluid	Water
2.	Flow	Laminar
3.	Fluid Velocity	0.64m/s
4.	Inlet Temperature	300K
5.	Back Flow temperature	300K
6.	Pipe Material	Copper
7.	Fin Material	Aluminum
8.	Heat Flux of Pipe	1000W/m^2
9.	Number of iterations	300

5. RESULTS FOR WATER FLOW THROUGH SWH(WITH FIN)

On solving the ANSYS setup various, results are obtained they are as follow

a. AREA RESULTS

Table 6. Area Results

S.NO	OBJECT	AREA(m^2)
1.	Inlet	0.00069
2.	Outlet	0.00069
3.	Fins	1.00651
4.	Pipe	1.52571

b. CONTOURS OF STATIC TEMPERATURE

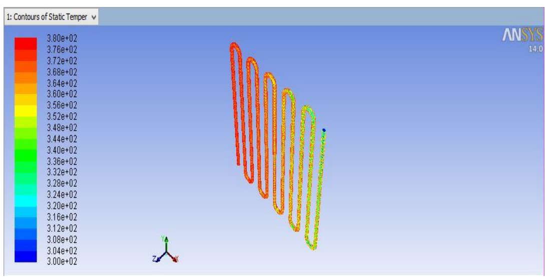

Figure 9. Contours of static Temperature

c. CONTOURS OF TOTAL TEMPERATURE

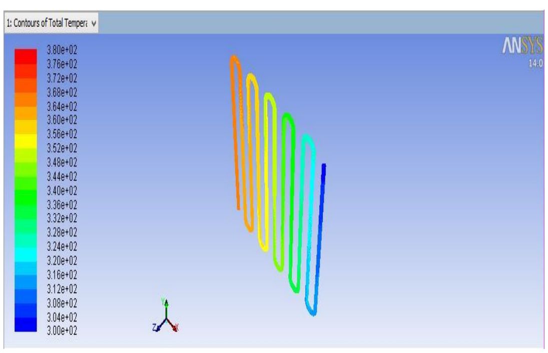

Figure 10. Contours of Total Temperature

d. CONTOURS OF RELATIVE TEMPERATURE

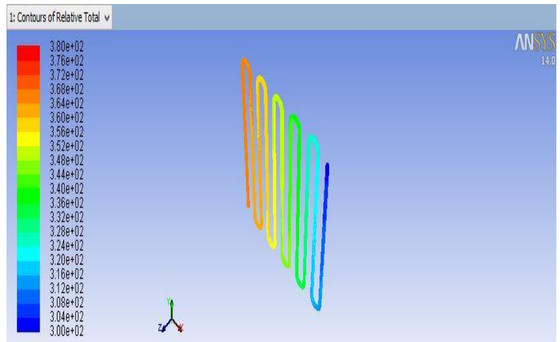

Figure 11. Contours of Relative Temperature

6. RESULTS FOR WATER FLOW THROUGH SWH(WITHOUT FIN)

On solving the ANSYS setup various, results are obtained they are as follows

a. CONTOURS OF STATIC TEMPERATURE

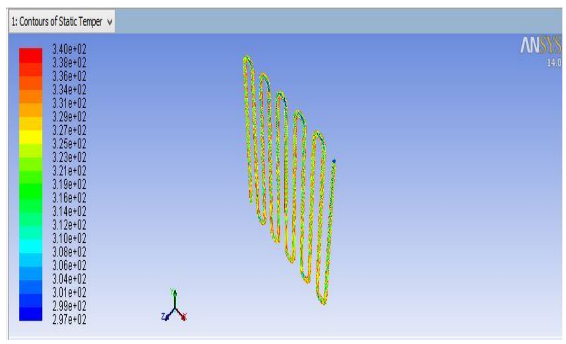

Figure 12. Contours of static Temperature

b. CONTOURS OF TOTAL TEMPERATURE

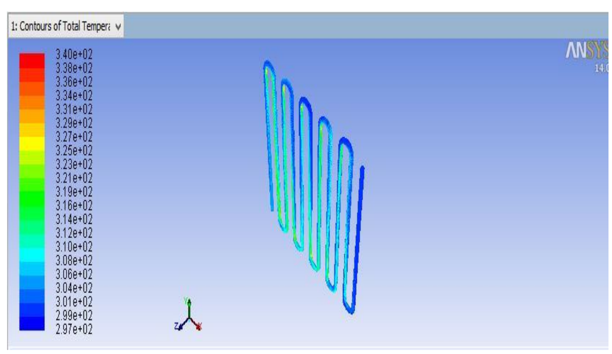

Figure 13. Contours of Total Temperature

c. CONTOURS OF RELATIVE TEMPERATURE

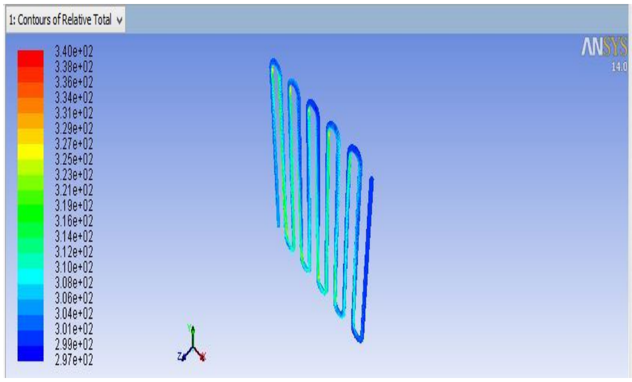

Figure 14. Contours of Relative Temperature

d. PROPERTIES OF AL_2O_3-WATER NANOFLUID

Table 7. Properties of Al_2O_3-Water Nano fluid

S.NO	PROPERTIES	VALUE
1.	Density	997Kg/m^3
2.	Specific Heat	4170 J/KgK
3.	Thermal Conductivity	0.6862 W/mK
4.	Viscosity	0.000855Kg/ms
5.	Volume Fraction	0.04

7. SETUP FOR AL2O3-WATER NANOFLUID FLOWTHROUGH SWH

Table 8. Setup for Al2O3-Water Nanofluid flow through SWH

S.NO	PARAMETER	VALUE
1.	Fluid	Water
2.	Flow	Laminar
3.	Fluid Velocity	0.64m/s
4.	Inlet Temperature	300K
5.	Back Flow temperature	300K
6.	Pipe Material	Copper
7.	Fin Material	Aluminum
8.	Heat Flux of Pipe	1000W/m^2
9.	Number of iterations	300

8. RESULTS FOR AL2O3-WATER NANOFLUID FLOW THROUGH SWH (WITHFIN)

The following results were obtained for the analysis of Al2O3-Water Nanofluid flow through SWH

a. CONTOURS FOR STATIC TEMPERATURE

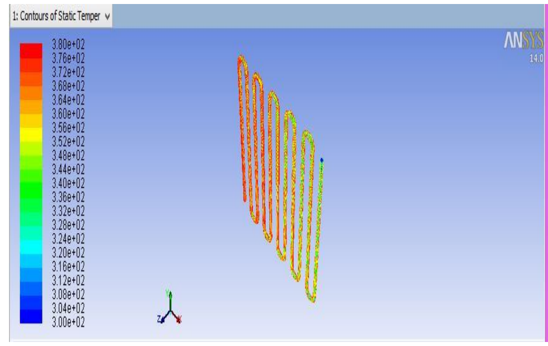

Figure 15. Contours for Static Temperature

b. CONTOURS FOR TOTAL TEMPERATURE

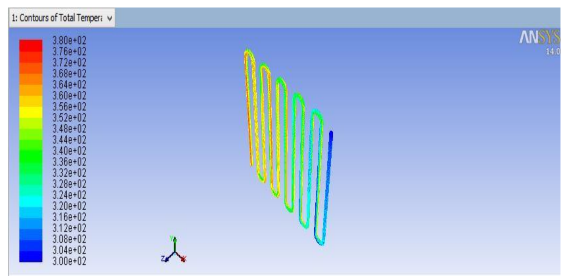

Figure 16. Contours for Total Temperature

c. CONTOURS OF RELATIVE TEMPERATURE

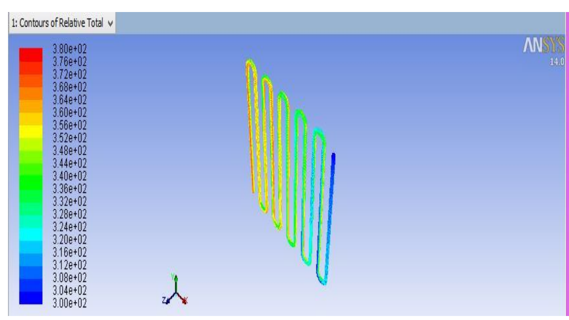

Figure 17. Contours for Relative Temperature

9. RESULTS FOR AL_2O_3-WATER NANOFLUID FLOW THROUGH SWH (WITHOUT FIN)

The following results were obtained for the analysis of Al_2O_3-Water Nanofluid flow through SWH

a. CONTOURS FOR STATIC TEMPERATURE

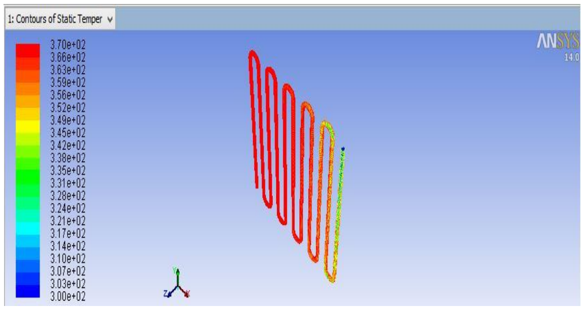

Figure 18. Contours for Static Temperature

b. CONTOURS FOR TOTAL TEMPERATURE

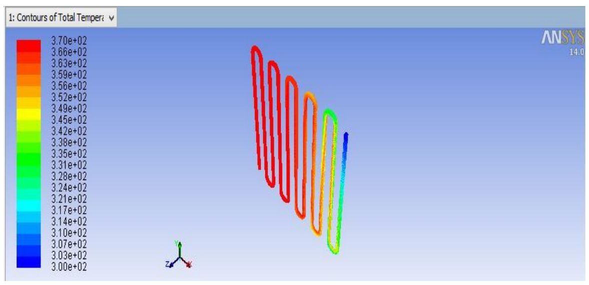

Figure 19. Contours for Total Temperature

c. CONTOURS OF RELATIVE TEMPERATURE

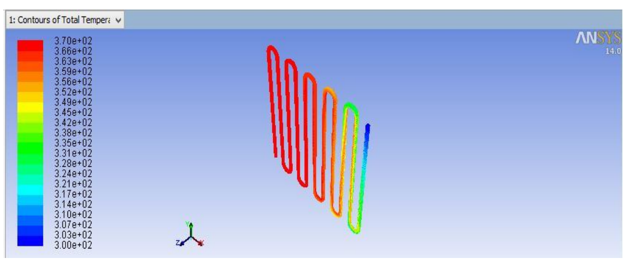

Figure 20. Contours for Relative Temperature

VI. THEORETICAL CALCULATION FOR NANOFLUID

The Properties of the nanofluids are theoretically calculated

6.1.1 PROPERTIES OF ALUMINUM NANOPARTICLES

Table 9. Properties of Aluminum Nanoparticles

S.NO	PROPERTY	VALUE
1.	Specific heat	765J.Kg/K
2.	Density	1000Kg/m^3
3.	Thermal conductivity	0.6W/m-K
4.	Dynamic viscosity	1.519x10^{-3}

6.1.2 PROPERTIES OF WATER FLUID

Table 10. Properties of Water Fluid

S.NO	PROPERTY	VALUE
1.	Specific heat	765J.Kg/K
2.	Density	3970Kg/m^3
3.	Thermal conductivity	40W/mK

6.1.3 DENSITY CALCULATION OF NANOFLUID

$\rho_{nf}=\phi\rho_{np}+(1-\phi)\rho_f$

$\phi = 0.04$

$\rho_{nf}=(0.04x3970)+(1-0.04)1000$

$\rho_{nf} = 1118.8 Kg/m^3$

6.1.4 SPECIFIC HEAT CALCULATION OF NANOFLUI

$$Cp_{nf} = \frac{\phi\rho_p Cp_p+(1-\phi)\rho_f Cp_f}{\rho_{nf}}$$

$$Cp_{nf} = \frac{(0.04x3970x765)+[(10.04)x1000x4178x10^3]}{1118.8}$$

$Cp_{nf} = 3693.56 J/KgK$

6.1.5 DYNAMIC VISCOSITY CALCULATION OF NANOFLUIDS

$$\mu_{nf} = \left(\frac{\mu_f}{(1-Ø)}\right)^{0.25}$$

$$\mu_{nf} = \frac{(1.519x10^{-3})^{0.25}}{(1-0.04)^{0.25}}$$

$\mu_{nf} = 0.1994\ Ns/m^2$

6.1.6. KINEMATIC VISCOSITY OF NANOFLUIDS

$$\upsilon_{nf} = \frac{\mu_{nf}}{\rho_{nf}}$$

$\upsilon_{nf} = 0.1994/1118.8$

$\upsilon_{nf} = 1.725x10^{-3}\ m^2/s$

6.1.7 THERMAL CONDUCTIVITY CALCULATION OF NANOFLUID

$$k_{nf} = \left(\frac{[40+(2x0.60) + [2(40-0.6)0.04]0.6}{[40+(2x0.6)] - [40-0.6]0.04]} \right)$$

k_{nf} = [40+(2x0.60) + [2(40-0.6)0.04] 0.6 [40+ (2x0.6)] - [40-0.6]0.04]

k_{nf} = 23.77 W/mK

6.2.1 CALCULATION FOR NANOFLUID FLOW THROUGH SWH6.2.1PRANDTL'S NUMBER CALCULATION OF NANOFLUI

$Pr = \frac{\mu_f}{\rho_f \ \alpha_f}$

$= \left[\frac{1.519x10^{-3}}{1000x1.6x10^{-6}} \right]$

Pr = 0.949

6.2.2 REYNOLD'S NUMBER CALCULATION OF NANOFLUIDS

$Re = \frac{UD}{\upsilon}$

$Re = \frac{0.64}{1.728x10^{-4}}$

Re = 111.1

6.2.3 NUSSET NUMBER CALCULATION OF NANOFLUIDS

Nu = $\{0.35+(0.56)(Re)^{0.52(}Pr^{0.3)}\}$

Nu = $\{0.35+(0.56)(111)^{0.52(}0.945^{0.3)}\}$

Nu =6.37

6.2.4 HEAT TRANSFER CO-EFFICENT CALCULATION OF NANOFLUIDS

$Nu = \frac{hD}{k}$

$6.37 = \frac{h \ x \ 0.03}{23.7}$

h = 5035 W/m^2K

6.2.5 MASS FLOW RATE CALCULATION OF NANOFLUIDS

ṁ = ρ.A.C

= 111.8 × [(π/4) ×(0.03)^2] × 0.

ṁ = 0.506 kg/s

6.2.7 OUTLET TEMPERATURE CALCULATION (NANOFLUID FLOW WITH FIN)

Q = ṁ Cp ΔT

Q = ṁ C_p (T_o-T_i)

= 0.506 × 3698.56 × (T_o-27)

= 1871.96 × (T_o-27) W----------(1)

Q = h A ΔT

= 5035 × 0.8 × (T_w- T_m)

= 5035× 0.8 × {107- [(T_i + T_o)/2]}

= 430996 - 54378 - 2014 T_o W----(2)

Equating (1) & (2)

1871.96 × (T_o-27) =430996 -54378- 2014 T_o

3885.96 T_o =427160

T_o =109.92^{O}C

T_o =382.92 K

6.2.8 OUTLET TEMPERATURE CALCULATION (NANOFLUID FLOW WITHOUT FIN)

Q = ṁ Cp ΔT

Q = ṁ C_p (T_o-T_i)

= 0.506 × 3698.56 × (T_o-27)

= 1871.96 × (T_o-27) W------(1)

Q = h A ΔT

= 5035 × 0.6 × (T_w- T_m)

= 5035× 0.6 × {107- [(T_i + T_o)/2]}

= 323247 – 40783.5 – 1510.5 T_o W-------(2)

Equating (1) & (2)

3382.46 T_o =333006.42

T_o=98.45^{O}C

T_o=371.45 K

6.3 CALCULATION FOR WATER FLOW THROUGH SWH

6.3.1 REYNOLD'S NUMBER CALCULATION

$Re = \frac{UD}{\upsilon}$

$Re = \frac{0.64 \times 0.03}{1.728x10^{-4}}$

Re = 1.8 ×10^{-5}

6.3.2 MASS FLOW RATE CALCULATION

ṁ = ρ.A.

$= 1000 \times [(\pi/4) \times (0.03)^2] \times 0.64$

$\dot{m} = 0.452$ kg/s

6.3.3 OUTLET TEMPERATURE CALCULATION (WATER FLOW WITH FIN)

$Q = \dot{m}\, Cp\, \Delta T$

$Q = \dot{m}\, C_p (T_o - T_i$

$= 0.452 \times 4178 \times (T_o - 27)$

$Q = 1890.1 \times (T_o - 27)$ W----(1)

$Q = h\ A\ \Delta T$

$= h \times [\ (\pi/4) \times (0.03)^2\ ] \times (\ T_w - T_m\ )$

$= 2457.2 \times 0.8 \times (T_w - T_m)$

$= 2457.2 \times 0.8 \times \{107 - [(T_i + T_o)/2]\}$

$= 210336.32 - 26537.76 - 982.88\ T_o$ ----(2)

Equating (1) & (2)

$1890.1 \times (T_o - 27)$ W $= 210336.3226537.76 - 982.88\ T_o$ W

$2872.98\ T_o = 234831.26$

$T_o = (234831.26 / 2872.98)$

$T_o = 355$ K

6.3.4 OUTLET TEMPERATURE CALCULATION (WATER FLOW WITH OUT FIN)

$Q = \dot{m}\, Cp\, \Delta T$

$Q = \dot{m}\, C_p (T_o - T_i)$

$= 0.452 \times 4178 \times (T_o - 27)$

$Q = 1890.1 \times (T_o - 27)$ W----(1)

$Q = h\ A\ \Delta T$

$= h \times [\ (\pi/4) \times (0.03)^2\ ] \times (\ T_w - T_m\ )$

$= 2457.2 \times 0.8 \times (T_w - T_m)$

$= 2457.2 \times 0.8 \times \{107 - [(T_i + T_o)/2]\}$

$= 157752.24 - 19903.32 - 737.16\ T_o$ W--(2)

Equating (1) & (2)

$1890.1 \times (T_o - 27)$ W

$= 157752.24 - 19903.32 - 737.16\ T_o$ W

$2627.26\ T_o = 188881.62$

$T_o = 71^{O}C$

$T_o = 344$ K

6.4 COMPARISON OF RESULTS

Table 11. Comparison of Results

S.NO	USING WATER WITH OUT FIN	USING WATER WITH FIN	USING NANO FLUIDS WITH OUT FIN	USING NANO FLUIDS WITH FIN
INLET TEMPERATURE (°C)	27	27	27	27
OUTLET TEMPERATURE (°C)	71	82	97	107

VII. CONCLUSION

All the results are concluded on the basis of the analysis result and the theoretical calculation result, the thermal conductivity is enhanced using nanofluids

This chapter summarizes the conclusion drawn in this report. Nanofluids are dilute colloidal suspensions with nano-sized particles. The nanoparticles more suspended in the fluid and it also increases the stability of nanofluid. Effect of Heat transfer enhancement is even more than Base fluid.

REFERENCES

[1] Das, S. K., Putra, N., Roetzel, W., Pool Boiling Characteristics of Nanofluids, International Journal of Heat and Mass Transfer, 46 (2003)

[2] Das, S. K., et al., Temperature Dependence of Thermal Conductivity Enhancement for Nanofluids, Transactions of the ASME Journal,125 (2003)

[3] Keblinski, P., et al., Mechanism of Heat Flow in Suspension Nanosized Particles (Nanofluid), International Journal of Heat and Mass Transfer, 45 (2002)

[4] Li, C. H., Peterson, G. P., Experimental Investigation of Temperature and Volume Fraction Variations on the Effective Thermal Conductivity of Nanoparticle Suspensions, Journal of Applied Physics(2006)

[5] Wen, D., Ding, Y., Experimental Investigation in to Convective Heat Transfer of Nanofluids at the Entrance Region under Laminar Flow Conditions, International Journal of Heat and Mass Transfer (2004)

[6] Bang, I. C., Chang, S. H., Boiling Heat Transfer Performance and Phenomena of Al2O3-Water Nanofluids from a Plain Surface in a Pool, International Journal of Heat and Mass Transfer (2005)

[7] Paisarn Naphon., Experimental investigation of titanium nanofluids on the heat pipe thermal efficiency, International Communications in Heat and Mass Transfer (2008)