Numerical Study Of Nanofluids Assisted Thermoelectric Air Conditioner

by

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22591

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
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in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

____
(Dr Khairul Habib)

UNIVERSITI TEKNOLOGI PETRONAS
BANDAR SERI ISKANDAR, PERAK
January 2020

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

AHMAD SYAHIR BIN SAIFUDDIN

ABSTRACT

The effect of various type of nanofluids on thermoelectric cooling performance has been investigated numerically. This paper described the effect of nanofluids is used to assist the thermoelectric cooler for heat dissipation at the hot side to improve cooling performance the thermoelectric module. ANSYS Fluent is used to model and simulate the flow of nanofluids in minichannel Heat sink attached to the thermoelectric module hot side. The model described is validated with prior experimental study. The selected nanofluids are TiO_2/water, $Si0_2$/water, TiO_2/EG and $Si0_2$/EG, the volume concentration of nanoparticles for each nanofluids varies from 0.01%, 0.02% and 0.04%. The results of present work show that TiO_2/water with 0.04% volume concentration as a coolant lead to highest COP of thermoelectric air conditioner. Numerical findings show that increase in volume concentration, improves thermal conductivity and thermal effectiveness between coolant and heatsink.

ACKNOWLEDGEMENTS

First and foremost, praise and gratitude to the lord, the Almighty, for his showers of blessings during my research. I want to express my sincere thanks to my supervisor, Dr Khairul Habib for the invaluable guidance, encouragement and critics throughout this project. Working and learning under your guidance was a great pleasure and respect. Thank you to all supportive lecturers in Mechanical Engineering Department for their opinion during the progress of the project in the university. Next, I would like to thank all the personnel and technicians for their support and commitment upon completing the project. I am immensely blessed and grateful to my parents for their devotion, their prayers and their unending encouragement. Also, I express my thanks to my friends for helping me until this project complete successfully.

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ABBREVIATIONS

COP	Coefficient of Performance
NTEAC	Nanofluids assisted thermoelectric air-conditioner
TEM	Thermoelectric Module
TEC	Thermoelectric Cooler
EG	Ethylene Glycol
CFD	Computational fluid dynamics

NOMENCLATURES

G'	Factor of Geometric (cm)
I	Current (A)
V_{in}	Voltage (V)
N	Number of elements of thermoelectric used in TEM
Q_{cold}	Heat absorb at cold surface (W)
Q_{hot}	Heat released at hot surface (W)
K_{TE}	TEM thermal conductance
S_{TE}	TEM Seebeck Voltage (V/K)
R_{TE}	TEM electrical resistance (Ω)
Z	Figure of Merit (K^{-1})
P_{TE}	Power input for TEM (W)
C_p	Specific heat capacity (J/kg K)
T	Temperature (K)
T_{cold}	Cold side temperature (K)
T_{hot}	Hot side temperature (K)
ΔT	$T_{hot} - T_{cold}$
V	Velocity (m/s)

CHAPTER 1

INTRODUCTION

1.1 Background Of Study

Specific liquids are used as coolants in different purposes for heat transfer since these liquids have a lower thermal conductivity than common solids. To transfer heat rapidly and more effectively with minimum fluctuations in temperature, scientists are working to integrate small particles into liquids. A mixture of colloidal nanoparticles and base fluids when uniformly dispersed and stably in base fluids called nanofluids, Can impressively improves the thermal properties of base fluids to boost the rate of heat transfer. Research indicates that Al_2O_3-water nanofluids and the thermal conductivity improvement is observed to 87% at 293K for 50wt.% [1].

Several years back, thermoelectric cooling technology is one of high performance, low energy consumption devices. The physical thermoelectric properties depend on the temperature of the heating and cooling sides[2]. Thermal resistance network designed to reflect the efficiency coefficient (COP).

Thermoelectric cooling is used to control the temperature of electronic devices thermally, including processors. TEC fixes the perceived problem of dissipation of heat of electronic areas. Thermoelectric advances are becoming faster as the basic science of thermoelectric is becoming well known.

In this project, nanofluids used as heat dissipation fluid for hot-side thermoelectric cooling, as the thermoelectric module degrades as it exceeds maximum temperature different. The heat transfer between the nanofluids and thermoelectric hot side is demonstrating in ANSYS Fluent.

1.2 Problem Statement

The performance of thermoelectric cooler will reduce when the different temperature at the hot side and cold side exceed the maximum different temperature specification which is 67 ° C. Application of nanofluid as a heat dissipation fluid improves cooling performance of thermoelectric cooler[3]

The heat dissipation between the TEM and nanofluids is quite specific challenging along the way. The stability nanoparticles affect the thermophysical properties, respectively.

1.3 Objectives

The objectives of this project are as below:

i. To study the thermal physical properties and select the suitable nanofluids for heat dissipation in thermoelectric cooling.
ii. To develop a simulation model of thermoelectric module and nanofluids as a coolant using ANSYS software.
iii. To analyse the performance of thermoelectric cooling by using nanofluids as a coolant numerically.

1.4 Scope Of Study

i. This work is focused on the effects of the thermophysical properties, thermal conductivity, density, specific heat capacity and concentration of nanoparticles, in enhancing the cooling performance of TEC.

ii. The simulation of heat transfer between thermoelectric module hot side and nanofluids is analysed using CFD simulation (Ansys Fluent).

CHAPTER 2

LITERATURE REVIEW

2.1 Preparation Of Nanofluids

Nanofluids are diminish colloidal suspensions of nanoparticles in a base fluid showing extremely good efficiency improvement in heat transfer in multiple applications. However, the preparation and stabilizing of nanofluids is still a major concern as the properties of nanofluids rely on the stability of the suspension[4]. There are two way of nanofluids synthetization which are single step and two step method[5].The single step method involves preparing the nanoparticles directly inside a liquid volume while the two step method involving the dispersion of dry nanoparticles into a liquid base[6]. Figure 2.1 shows the preparation of nanofluids using magnetic stirring. Metal-oxide nanofluids is suitable to prepare using two step method. So, we will use the two-step method for this project to synthesize nanofluids according to nanofluid selection.

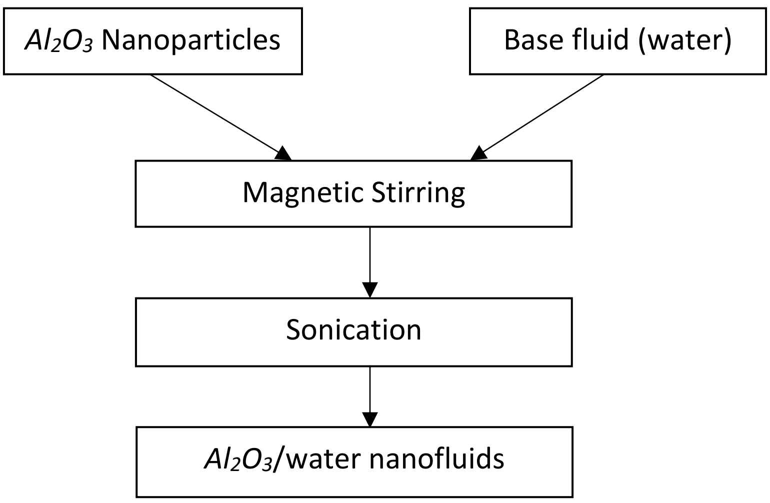

Figure 2.1: Preparation of nanofluids

The main dilemma in preparing the nanofluids is on the stability because it is dependent on surface forces acting between particles, the general technique for enhancing nanofluids stability is to add surfactants, which induce electrostatic or steric revulsion between nanoparticles, thereby abstain from aggregation[2]. The base fluid might be a low-viscous liquid including water, refrigerant or a high-viscous liquid such as ethylene glycol, mineral oil or a combination of various fluid forms[7].

2.2 Application Of Nanofluids In Heat Transfer Enhancement

Study on enhancing heat transfer via nanofluids and device assisted by nanofluids also Gained huge global exposure over the last decade due to their numerous stunning properties[8]. Nanofluids could be characterized as a nanoparticulated fluid with a nanometer size and a base fluid. The heat transfer properties of nanofluids will indeed be superior than ordinary heat transfer fluids because of the existence of high thermal conductivity nanoparticles usually made up carbon nanotubes, metal oxides and carbides. Owing to its thermophysical characteristics, nanofluid can thus be widely used in most research activities in recent decades in relation to heat transfer enhancement that serves the principal purpose of its use. Table 2.1 shows critical analysis of nanofluids in heat transfer enhancement in various paper.

Table 2.1: Summary of critical analysis of nanofluids as coolant

Authors	Base Fluid	Nanoparticles	Volume Concentration	Result and remarks
(Ahammed et al., 2016)[9]	Water	Al_2O_3	0.1%, 0.2%	The higher the concentration of nanofluids, the higher thermal effectiveness.

(Hashimoto et al., 2020)[10]	Water/Ethylene Glycol	SiO_2	0.02%, 0.05%, 0.1%	The coefficient of heat transfer increases with increased concentration of nanoparticles.
(Fares et al., 2020)[11]	Water	Graphene	0.2%	Heat exchanger thermal efficiency improve by 13.7% compare to conventional fluid.
Mukherjee et al., 2020) [5]	Water	Al_2O_3, TiO_2	0.25%, 0.5%, 1.5%	Al_2O_3 achieved 44% thermal conductivity enhancement and 21% enhancement of transient heat transfer performance.

(Ghanbarpour et al., 2014) [1]	Water	Al_2O_3	3% - 50%	The rise in thermal conductivity and viscosity varies from 11% to 87% and 181% to 300%, accordingly.
(Keshavarz Moraveji et al., 2013) [12]	Water	TiO_2, SiC	0.8%, 1.6%, 2.4%, 3.2%, 4%	Increase in particle concentration, improve the heat transfer coefficient.

2.2 Application Of Thermoelectric Cooling

Thermoelectric Cooler (TEC) technology has gained good attention for its compact design, working silence, highly reliable, eco-friendliness and absence of mechanically moving components. TEC includes of Semiconductor p-type and n-type parts, electrically connected in sequence. As direct current flows via the circuit and causes temperature differences between sides of the TEC. As a result, one side of the TEC, defined as the cold side, is cooled while its opposite side, which called the hot side, is heated at the same time [13]. Table 2.2 shows summary of application of thermoelectric cooling and cooling method at hot side.

Table 2.2: Summary of application of TEC and cooling method at hot side

Authors	Application	Cooling method at hot side	Result and remarks
(Irshad et al., 2015) [14]	Air- Conditioner	Air Cooling	Achieved maximum COP of 0.679 and 498.6 W cooling capacity.
(Ahammed et al., 2016)[9]	Water chilling	Water, Al_2O_3/water	Highest COP of 1.69 achieved when Al_2O_3/water used a coolant compare to water 1.2.
(McNally et al., 1936)[15]	Electronic devices cooling	Air Cooling	Highest cooling capacity achieved 57 watts at 6 A input current.
(Shoeibi et al., 2020)[16]	Water Chilling	Water Cooling	The efficiency of solar still improved 76.4% using thermoelectric cooling.
(Sun et al., 2017) [17]	Electronic devices cooling	Water Cooling	Cooling capacity improved 73.54% compare to air cooling.

CHAPTER 3

METHODOLOGY

3.1 Project Management

Project management is a critical element to scheduling and planning the research flow under the time limit.

3.1.1 Research Techniques

Gathering the information is necessary for starting the analysis in order to get a project overview. Reading materials related to the research through books, conference articles, and online journals can provide the necessary information for the analysis to be performed. For instance, topics related to thermoelectric air conditioner, heat transfer enhancement via nanofluids and minichannel heatsink.

Other than that, It is essential to consult with lecturers and experts in the research field to ensure that the research achieves the goals.

3.1.2 Project Activities

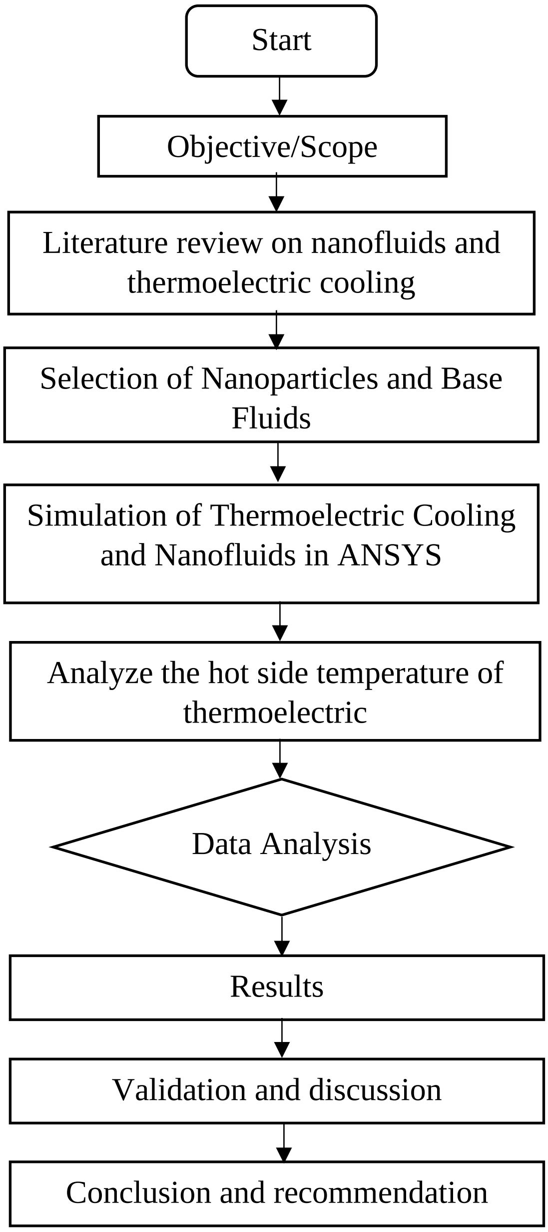

Figure 3.1: Project activities flow chart

3.1.3 Project Gantt Chart

Table 3.1: Project Gantt chart of FYP 1

No	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Literature Review on Nanofluids and Thermoelectric Air Conditioner														
2	Selection of nanoparticles and base fluids							★							
3	Construction of Methodology														
4	Research on numerical modelling between nanofluids and TEC														
5	Identify the equations used in fluid flow analysis of nanofluids in TEC											★			
6	Simulation in Ansys of nanofluids and TEC														

★ Project Key Milestone

Table 3.2: Project Gantt Chart of FYP2

No	Details/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Literature Review on Numerical Study of Nanofluids and Thermoelectric Air Conditioner.	■	■	■	■	■	■	■							
2	Develop equations used in fluid flow analysis of nanofluids assisted thermoelectric air conditioner.	■	■	■											
3	Model the thermoelectric air conditioner in ANSYS.	■	■	■	■ ★	■	■								
4	Mesh the geometry						■	■							
5	Run the simulation.							■	■	■	■	■ ★	■	■	
6	Analyze the results.										■	■	■	■	
7	Validate the results.												■	■ ★	
8	Conclude the results												■	■	■ ★
9	Discussion and recommendation												■	■	■

★ Project Key Milestone

3.2 Thermoelectric Air Conditioner Description

Figure 3.2 shows a proposed schematics diagram of nanofluids assisted thermoelectric Air conditioner. Minichannels heatsink used to aid the coolant dissipate heat from thermoelectric hot side. Minichannel heatsink is attached to the thermoelectric module's hot side. The specifications of the aluminum minichannel heatsink are given in the Table 3.3. The coolant flows through the heat sink and contains the heat which is transmitted from the thermoelectric modules' hot side. The heat exchanger transports the hot coolant to drain the added heat and return to the coolant tank.

To measure the cooling load, a test room with a scale of 2 m× 2 m× 2 m is used. The cooling load of the room was calculated with value 170 W. It was noted that 26 W of input power to thermoelectric module can produce 40 W of cooling power. Therefore, to ensure adequate cooling, the number of TEMs needed for a cooling load of 170 W was 5 units, That could provide cooling power of up to 200 W in the configuration offered, which was slightly larger than the cooling load needed.

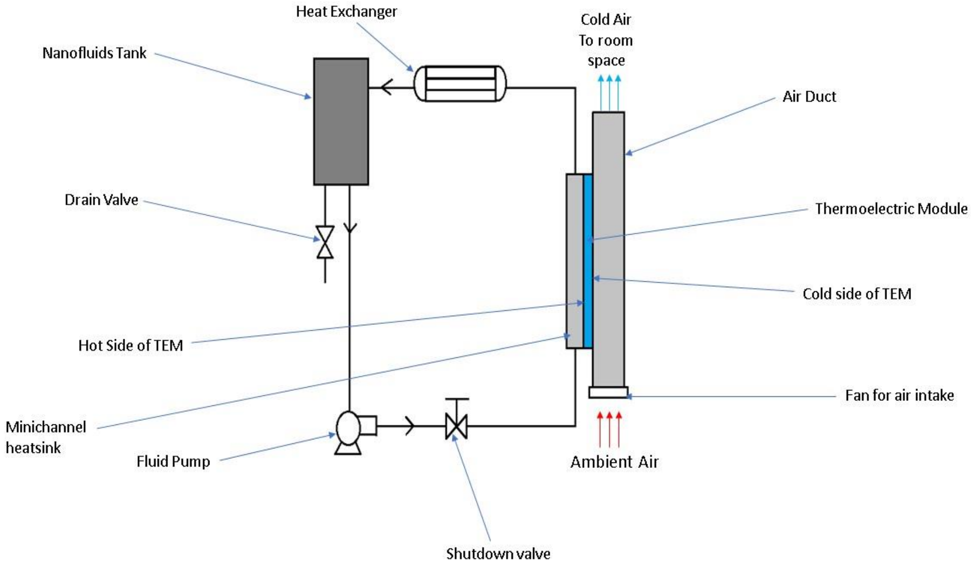

Figure 3.2: Schematics diagram of NTEAC

Table 3.3: Specification of minichannel heatsink[9]

Specifications	Value
Channel width, W_{ch} (m)	0.00145
Channel height, H_{ch} (m)	0.001
Base thickness, t_b (m)	0.0005
Fin width, W_{fin} (m)	0.0005
Hydraulic diameter, D_h (m)	0.001184

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3.3 CFD Modelling Process

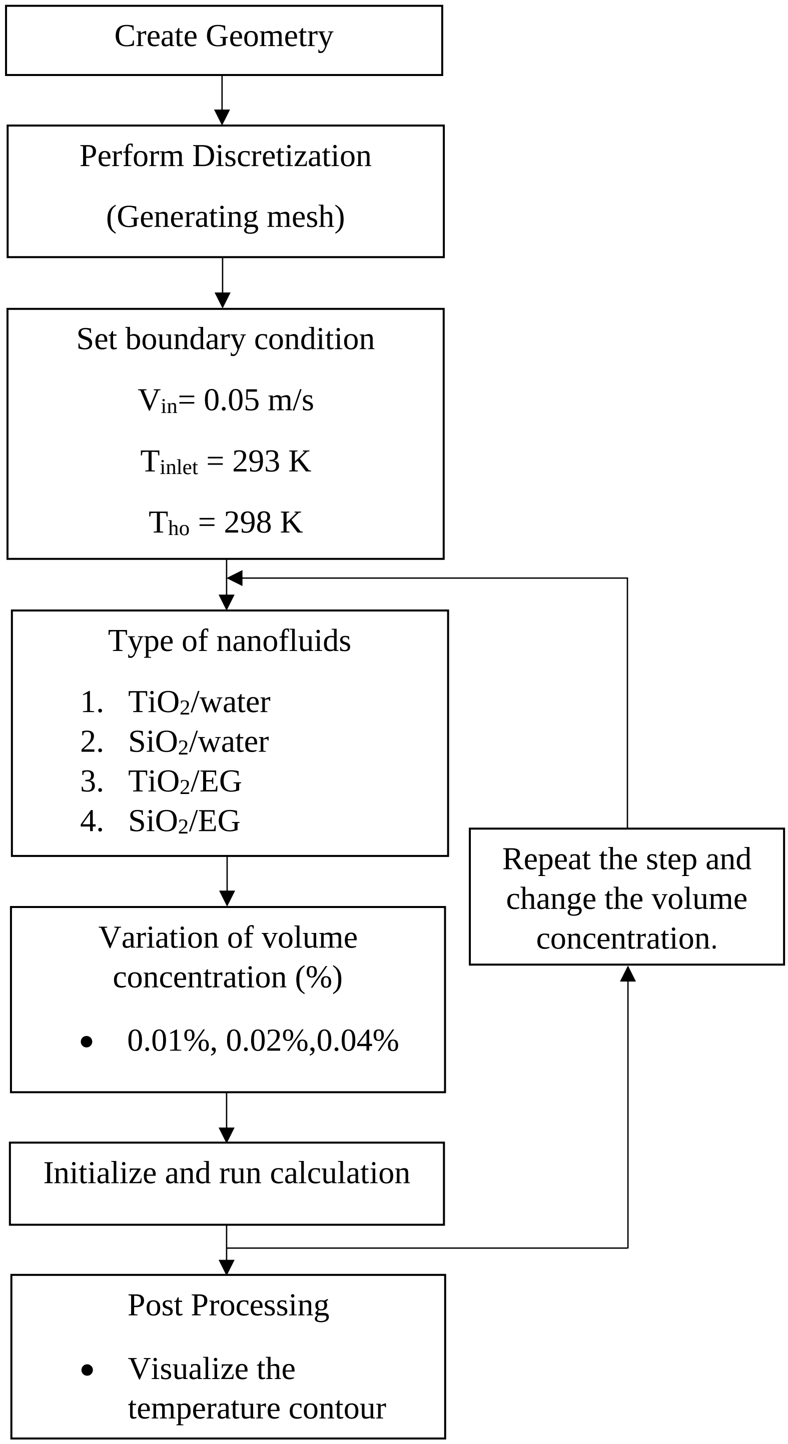

Figure 3.3: Process of CFD Modelling

3.4 Simulation Model

3.4.1 Design Of Geometry

Figure 3.4 shows the geometry of minichannel heatsink affixed to the thermoelectric hot-side design in design modeler ANSYS fluent. The geometry shown in figure consist of minichannel heatsink, thermoelectric module and air duct. The geometry shows the minichannel heatsink attached to the Thermoelectric hot side for heat dissipation and improve thermoelectric cooling power. Various nanofluids is used as the cooling fluids. Table 3.4 shows the domain type and material that being declare in ANSYS for each body part in the geometry.

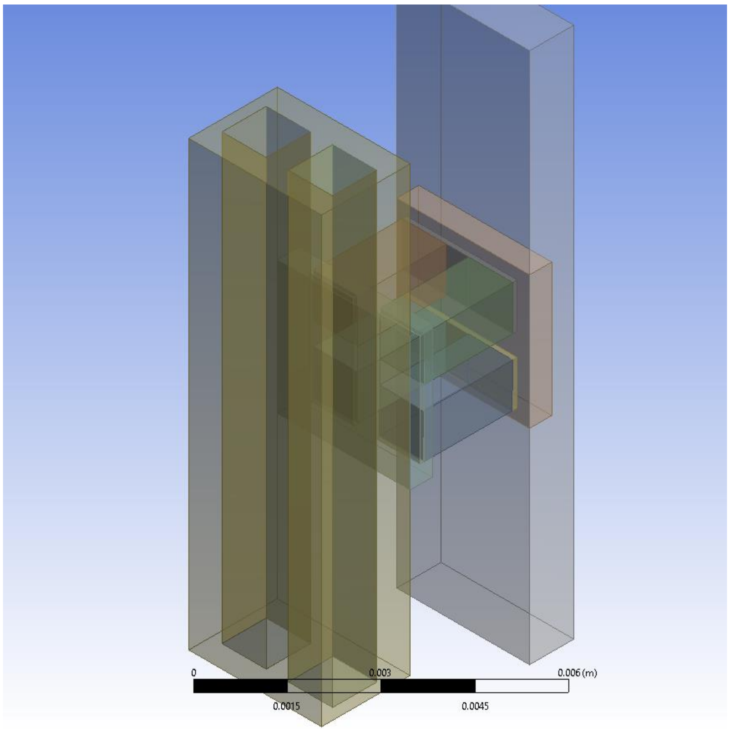

Figure 3.4: Design of geometry in design modeler

Table 3.4: Declared material ANSYS Fluent [7]

Body Part	Domain type	Material
Air Duct	Fluid	Air Ideal Gas
Copper	Solid	Copper
Ceramic	Solid	Aluminum Oxide
Minichannel Heatsink	Solid	Aluminum
Pleg	Solid	Bismuth Telluride
Nleg	Solid	Bismuth Telluride
Fluid	Fluid	Nanofluids

3.4.2 Meshing Of Geometry

Meshing forms a crucial aspect of the simulation phase in which Complex geometries are categorized into basic elements that can be used as discrete local simplifications of the greater domain. The mesh affects simulation precision, convergence, and the simulation speed. Besides, as meshing usually occupies a large portion of the time it takes for simulation outcomes to be obtained, the quicker and more efficient the meshing devices, the more precise the solution is. Figure 3.5 show size of element of 0.1 mm in the meshing part in ANSYS fluent.

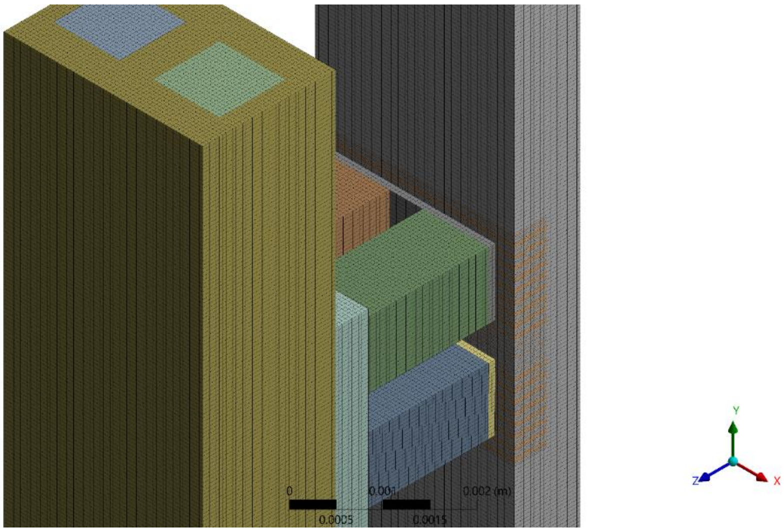

Figure 3.5: Meshing of Geometry

3.5 Numerical Analysis

The system was modelled by using ANSYS Fluent and ANSYS Thermal Electric. This software will measure how much heat can be dissipated by the fluid flow within the minichannel heatsink from the thermoelectric hot side. The thermoelectric modules used in the simulation are specified in Table 3.5. The initial temperature of the hot side of thermoelectric module is set to T_{hot} = 25 ºC.

Table 3.5: Specification of thermoelectric[9]

Specifications	Value
Dimension (mm)	40 x 40 x 3.5
N	127
I_{max} (A)	8.5
V_{max} (V)	14.4
Q_{max} (W)	72
ΔT_{max} (ºC)	67
R_{TE} (Ω)	1.31
S_{TE} (V/K)	0.048
K_{TE} (W/ ºC)	0.71

3.5.1 Thermoelectric Cooler

A TEM's heating and cooling capacity comprised four forms of heat which are Peltier cooling (Q_{PEC}), Peltier heating (Q_{PEH}), Joule heat (Q_{JH}) and Fourier heat (Q_{FH}) given as follows:

$$Q_{PEC} = S_{TE} I T_{cold} \quad (1)$$

$$Q_{PEH} = S_{TE} I T_{hot} \quad (2)$$

$$Q_{JH} = S_{TE} I T_{hot} \quad (3)$$

$$Q_{FH} = K_{TE} (T_{hot} - T_{cold}) \quad (4)$$

By using the above equation, a TEM can describe the heating and cooling power as:

$$Q_{cold} = S_{TE} I T_{cold} - 0.5 I^2 R_{TE} - K_{TE} \Delta T \quad (5)$$

$$S_{TE} = 2N\alpha \quad (6)$$

$$R_{TE} = 2N\sigma / G' \quad (7)$$

$$K_{TE} = 2N\kappa G' \quad (8)$$

$$Q_{hot} = S_{TE} I T_{cold} + 0.5 I^2 R_{TE} - K_{TE} \Delta T \quad (9)$$

$$V_{in} = (S_{TE} \times (T_{hot} - T_{cold})) + (I \times R_{TE}) \quad (10)$$

The electrical power input of a TEM is provided by:

$$P_{TE} = \alpha I (T_{hot} - T_{cold}) + I^2 R_{TE} \quad (11)$$

$$Z = \frac{S^2{}_{TE}}{R_{TE}\ K_{TE}} \quad (12)$$

The COP of TEC can be given by:

$$COP_{TE\ cooling} = \frac{Q_{cold}}{P_{TE}} \tag{13}$$

3.5.2 Estimation of nanofluids thermophysical properties

Suppose the nanoparticles are have been well distributed throughout the base fluid, the distribution of particles can be assumed uniform in the whole system, The thermophysical properties of the mixtures can be measured using certain classical formulas as normally used for dual phase flow. Thermophysical properties of base fluids and nanoparticle are given in the Table 3.6 and Table 3.7 respectively. They used the following equations to estimate the thermal conductivity, density and specific heat of nanofluids at different concentrations[18].

$$k_{nf} = k_{bf}\left[\frac{\left(k_p + (n-1)k_{bf} + (n-1)\varphi(k_{bf} - k_p)\right)}{\left(k_p + (n-1)k_{bf} + \varphi(k_{bf} - k_p)\right)}\right] \tag{14}$$

$$\rho_{nf} = (1 - \varphi)\,\rho_{bf} + \varphi\rho_p \tag{15}$$

$$(C_p)_{nf} = \frac{(1-\varphi)\left(\rho C_p\right)_{bf} + (\varphi)\left(\rho C_p\right)_p}{\rho_{nf}} \tag{16}$$

For viscosity calculation of nanofluids, the correlation has been used[19]:

$$\mu_{nf} = \mu_{bf}\,(1 + 39.11\varphi + 533.9\varphi^2) \tag{17}$$

Table 3.6: Thermophysical properties of base fluids[20]

Properties	Water	Ethylene-glycol
Thermal Conductivity (W/mK)	0.6316	0.256
Dynamic Viscosity (N s/m^2)	6.56 x 10^{-4}	0.021
Density (kg/m^3)	991.8	1126
Specific heat capacity (J/kg K)	4178.6	2354

Table 3.7: Thermophysical properties of selected nanoparticles[5], [21]

Properties	TiO_2	SiO_2
Thermal Conductivity (W/mK)	11.7	1.3
Density (kg/m^3)	4000	2200
Specific heat capacity (J/kg K)	683	740

3.6 Boundary Condition

For thermoelectric boundary condition, at input power 26 W initial value at hot side temperature is set to T_{hot} = 25 ºC.

For minichannel heatsink, the inlet temperature and velocity of coolant is set to a constant value which is:

T_{in} = 293 K

V_{in} = 0.05 m/s

The flow is often believed to be thermally fully formed at the channel outlet, as the temperature gradient change along the stream path at the channel outlet is typically relatively low.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Model Validation

To ensure the numerical model is valid, the model is verified with available experimental result from Ahammed et al., 2016 [9]. The heat flows from the hot side to the heat sink wall. According to the simulation results, the hot side temperature of TEC and the maximum wall temperature of minichannel heatsink using water as coolant been recorded and compared with experimental results. Figure 4.1 shows the temperature of hot side and maximum temperature of wall of minichannel heatsink. The percentage different is 2.78%.

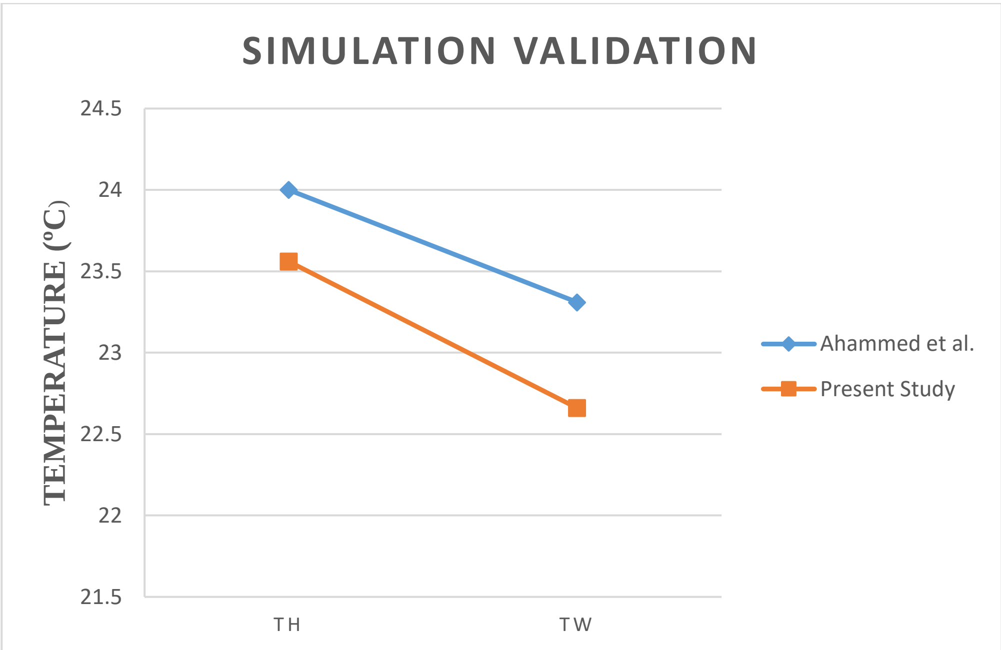

Figure 4.1: Temperature at hot side and wall of minichannel heatsink

4.2 Coefficient Of Performance Of Thermoelectric Cooler.

Figure 4.1 shows the change of COP of the thermoelectric cooling module in the variation of nanofluids and nanofluids concentration. Certainly, it is shown that the COP rises with increased concentration of nanoparticles. The highest COP of thermoelectric cooler is 1.4821 when TiO_2/water used the coolant at an input power of 26 W, with volume concentration of 0.04 %. The COP decreased to 1.4657 when SiO_2/EG as the working fluids under the same input power.

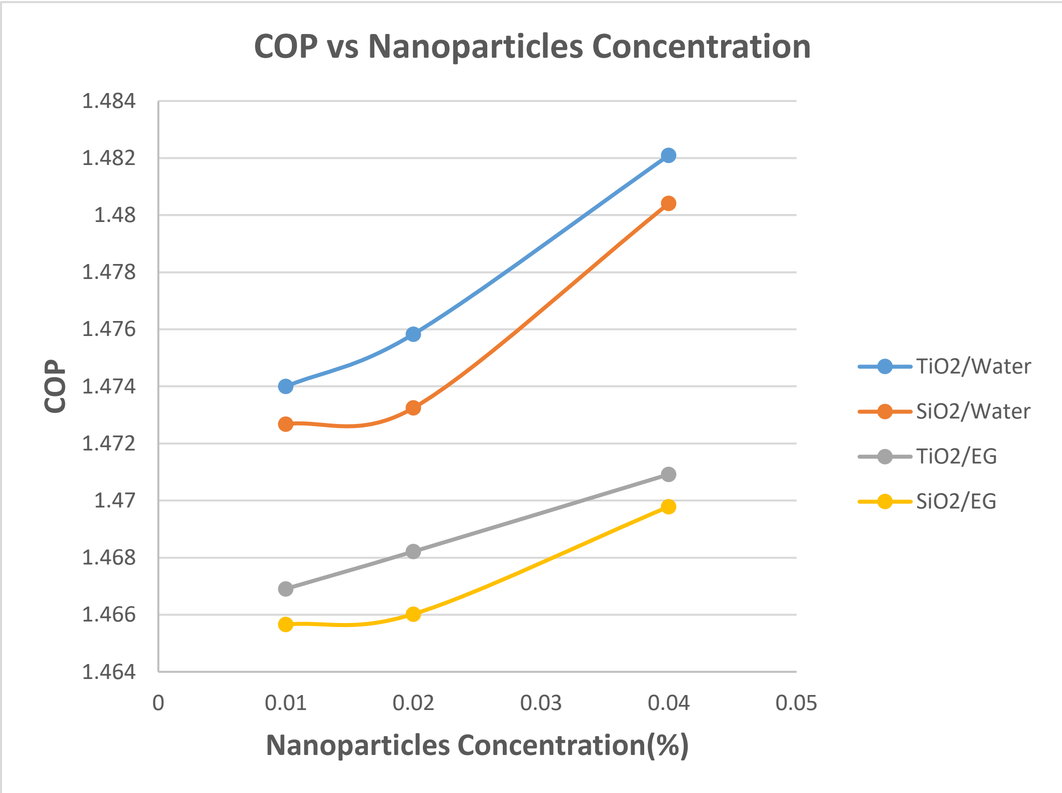

Figure 4.2: Various COP at various concentration of coolant

4.3 Cooling Capacity

Figure 4.2 presents the variation of cooling capacity against volume concentration of nanoparticles. It was found that, as the concentration of the coolant increase, the cooling power (Q_c) increases. These findings showed that this would increase the cooling power by regulating the temperature at TEC's hot side using nanofluids as the coolant. The cooling power increase from 42.31 watt to 42.52 watt for TiO_2/water cooling at 0.01% and 0.04% volume concentration, respectively.

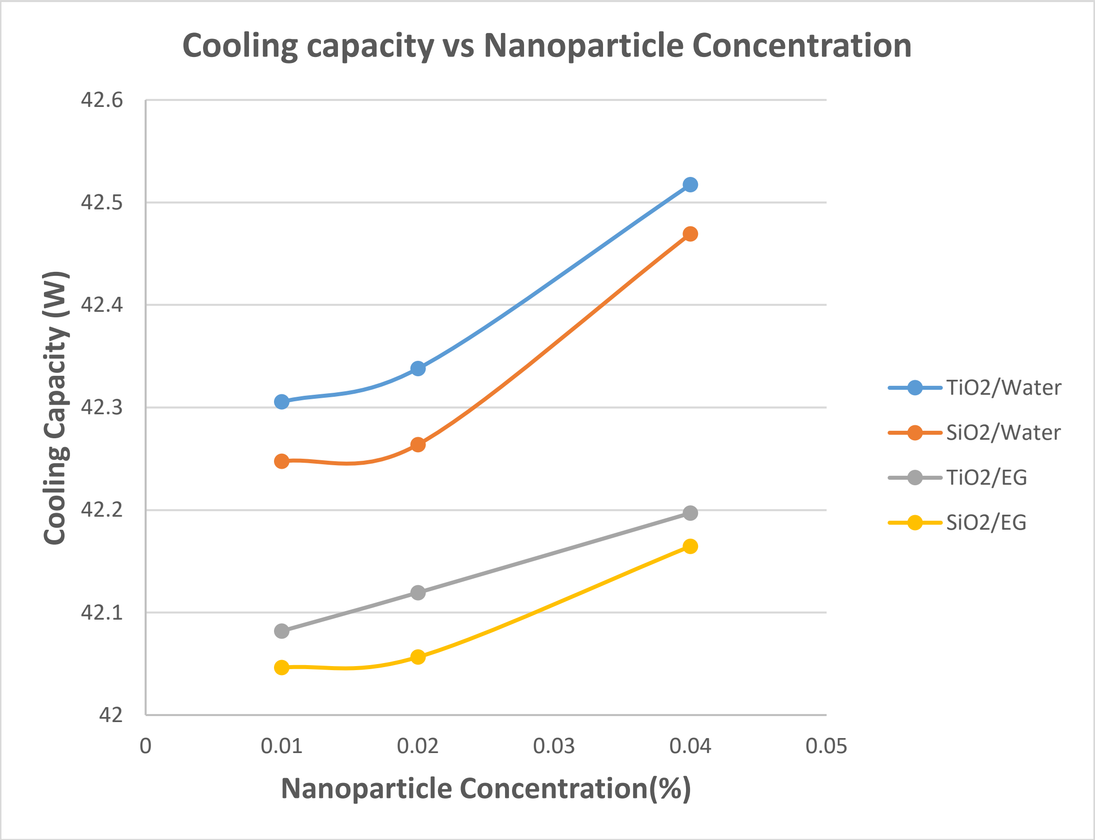

Figure 4.3: Cooling capacity against volume concentration of nanoparticles

Figure 4.4 compares the cooling power (Q_c) of the TEC for cooling cases at 26 watt of input power. The cooling capacity depends on the temperature of cold side, reducing the temperature of hot side will improve the system cooling. Therefore, the lower the temperature at the cold side, the higher the cooling power. It is observed from the figure TiO_2/water nanofluid cooling method produces the highest cooling power, which means the most efficient cooling of all method. Also, it seen that nanoparticles dispersed in water as based fluid produce better cooling compare to Ethylene Glycol as base fluid. That is because of the inclusion of nanoparticles to improve thermal conductivity of the base fluids.

Having a low cooling capacity for EG base fluids does not make it a bad coolant. For a winter condition air conditioner, EG base fluid will be better than water because of the low freezing point. EG as base fluids also have a low specific heat capacity, it enables a mixture of glycol to bring heat away much faster than water.

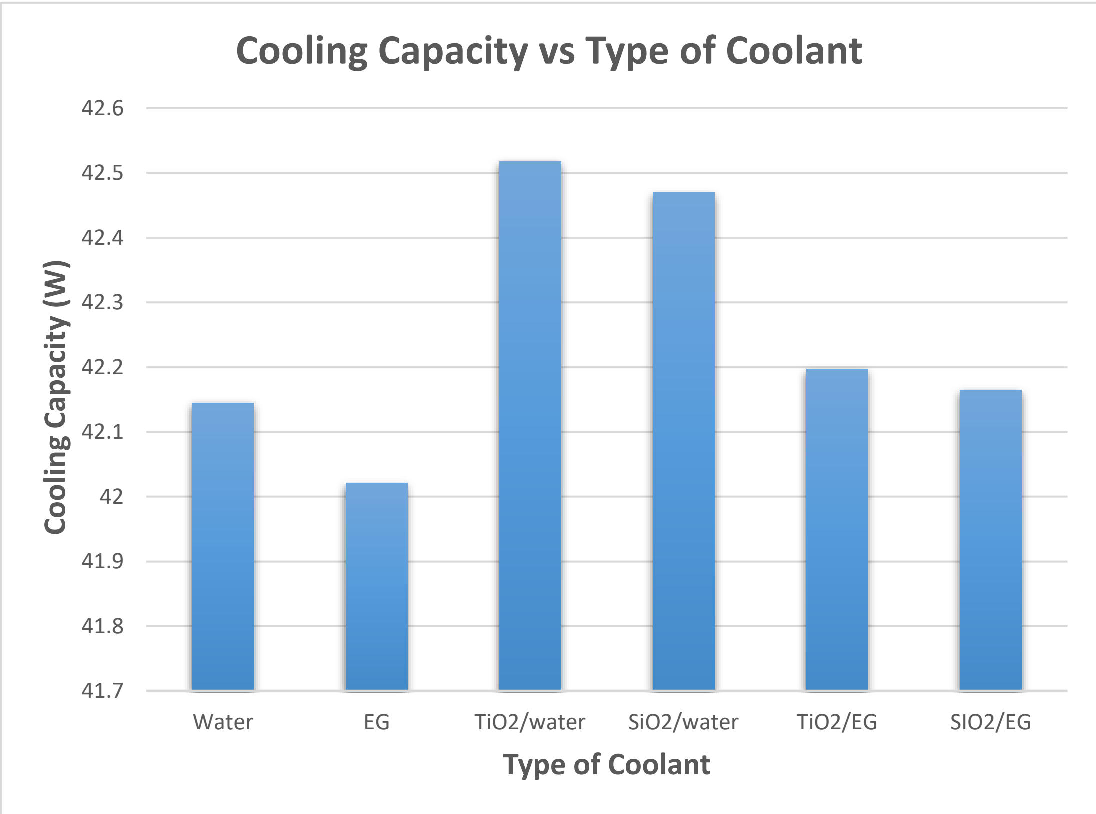

Figure 4.4: Cooling capacity against type of coolant.

4.5 Thermal Effectiveness Of Minichannel Heatsink

The thermal effectiveness between the minichannel heatsink and nanofluids is important to analyses. Figure 4.5 shows variation of the minichannel heatsink thermal effectiveness as a function of the nanoparticles volume concentration. The velocity inlet is set to be constant at 0.05 m/s. Thermal effectiveness is measure by observed the wall of heat sink base temperature. The result shows nanofluid with water as base fluids shows higher thermal effectiveness. It also seen that increase of volume concentration increase the thermal effectiveness.

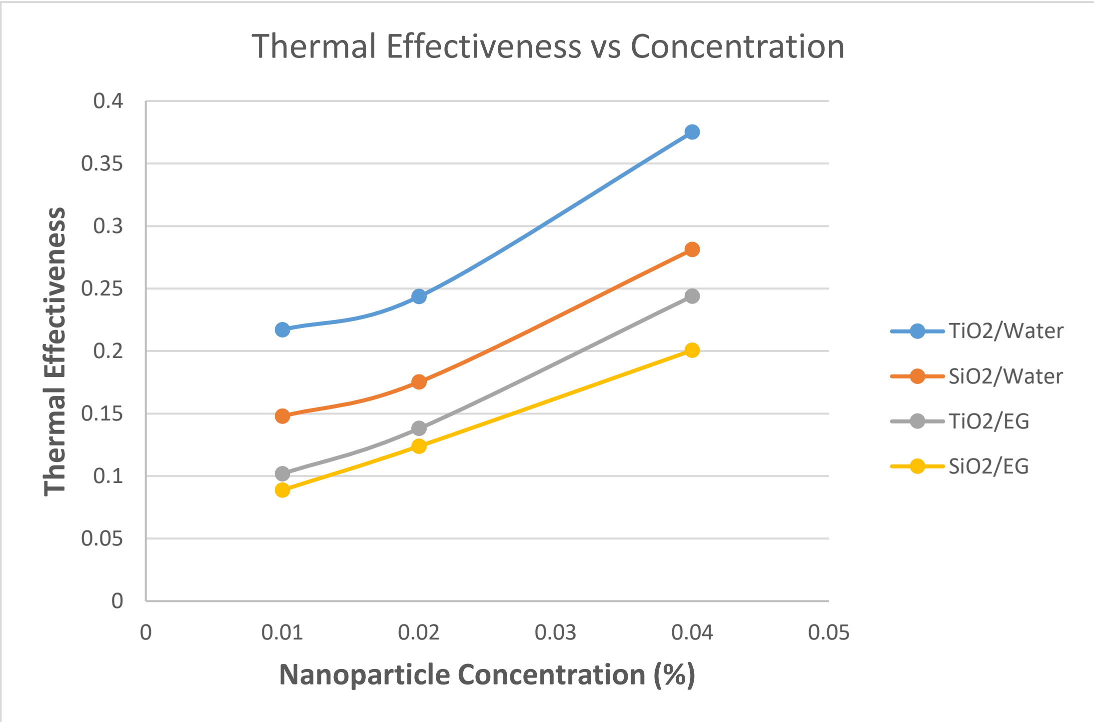

Figure 4.5: Thermal Effectiveness as a function nanoparticle volume concentration

4.6 Thermoelectric Dimensionless Figure Of Merit (ZT) At Hot Side

Dimensionless figure of merit (ZT) is defined to measure the thermoelectric performance. Figure 4.6 shows variation value of ZT as a function of nanoparticle volume concentration. The higher the volume concentration of Nanoparticle, the lower the value of ZT. This occurs because the more heat will dissipate at the hot side of thermoelectric cooling module. The simulation shows the worst ZT at the hot side, produce the highest cooling. The joule heating at the hot side is transfer to the heatsink. It shows, optimizing local ZT towards highest value not necessarily optimum for maximum cooling. The lowest ZT is shown by TiO_2/water cooling at 0.04% volume concentration which is 0.7304.

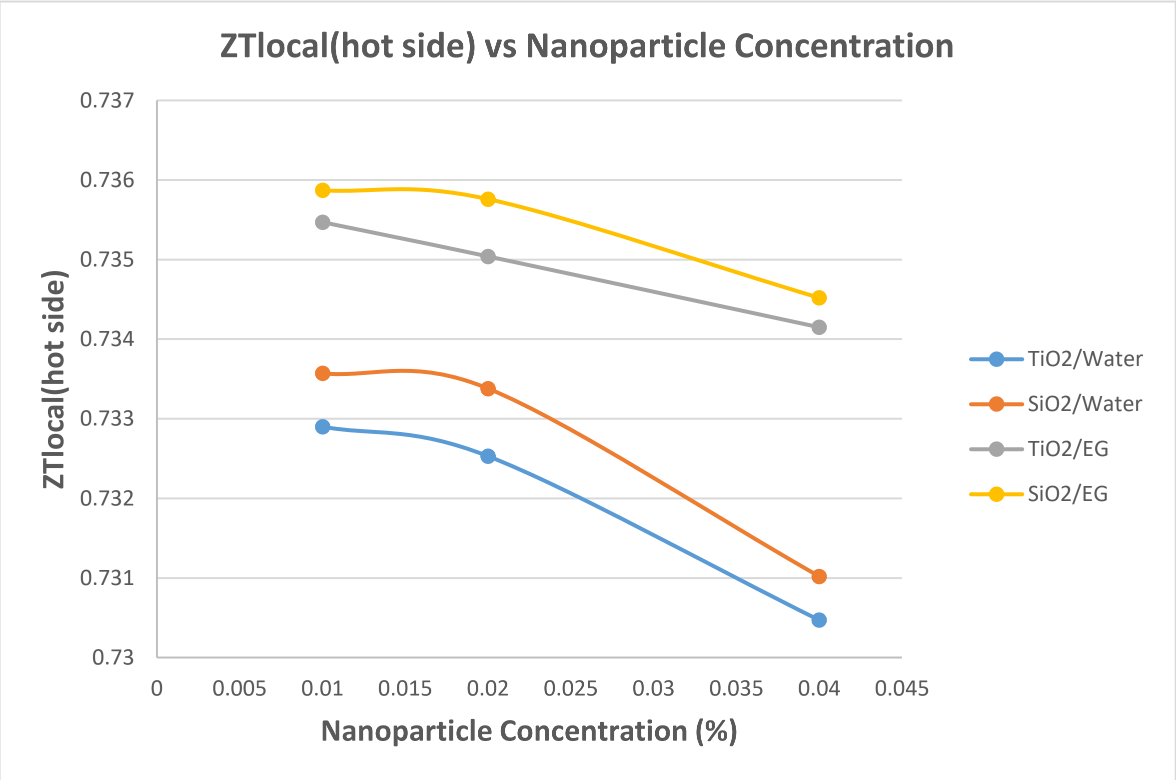

Figure 4.6: ZTlocal at hot side as a function of nanoparticle volume concentration

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Thermoelectric air conditioner with nanofluid cooled minichannel heatsink is numerically study for cooling performance. Thermophysical properties of TiO_2/water, TiO_2/EG, SiO_2/water and SiO_2/EG is study for heat dissipation fluid at hot side thermoelectric cooler and enhance cooling performance.

The simulation of fluid flow between nanofluids, minichannel heatsink and thermoelectric module is develop using ANSYS fluent. The cooling performance thermoelectric cooler being analyse using nanofluids as a coolant in numerical analysis.

The highest COP reached by thermoelectric air conditioner is 1.482 for 0.04% of volume concentration of TiO_2/water as coolant. The result show increment of 2.71% in COP compared to water. The thermal effectiveness of the cooling system improves with increased volume concentration of nanoparticles. The result prove that nanofluids enhance efficiency and cooling performance of thermoelectric.

5.2 Recommendation

The stability of nanofluids is not considered in this project because it cannot be calculated using simulation. The simulation show, EG as base fluid have a lower COP compare to water. Low freezing point and high boiling point make EG a better coolant compare to pure water. The low specific heat capacity of EG make it carries the heat much faster than water. It is recommended to mix EG with water as base fluid because of the high viscosity of pure EG, will need to boost the flow rate and increase energy consumption. This could contribute to wear of the equipment. It is important to determine the exact the minimum glycol concentration required to maintain device performance.

The thermal comfort and humidity of the test room also not considered because the simulation only focus on heat dissipation by nanofluids at the hot side thermoelectric cooler. In the exact calculation stage, Verification of numerical findings with experimental results is highly recommended with exact parameters and variables in order to obtain the appropriate accuracy of the outcome of this project.

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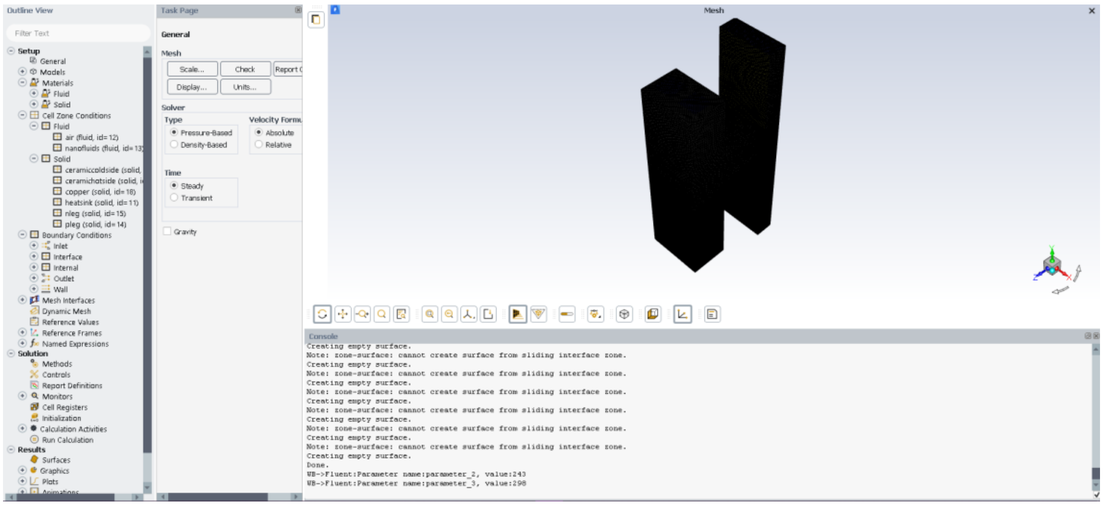
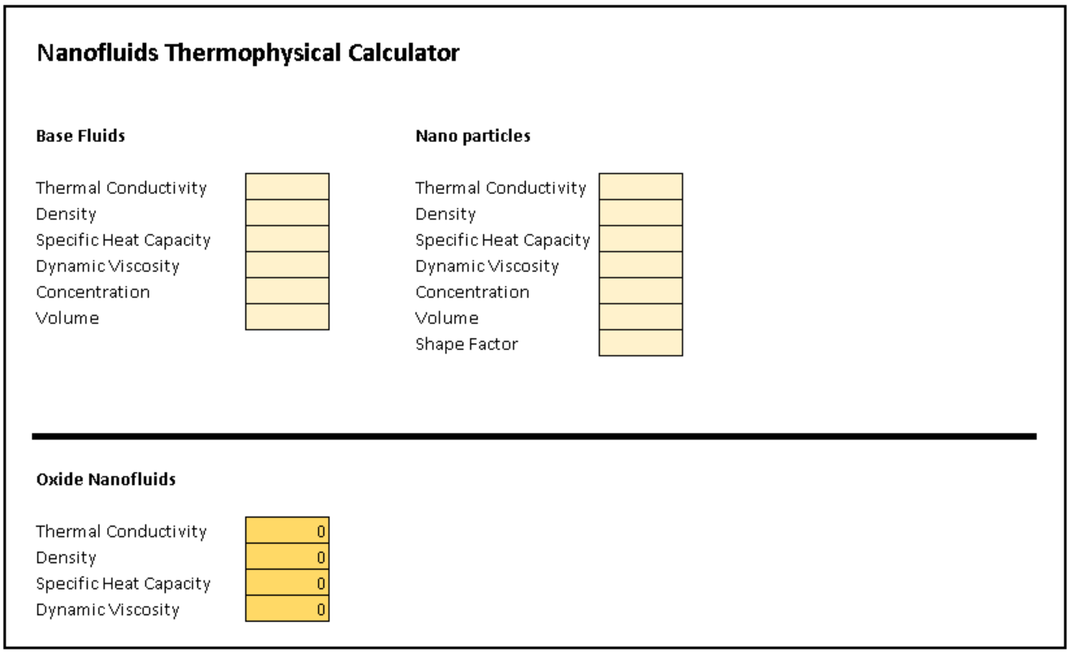
APPENDICES

Appendix 1: Diagram of ANSYS setup



Appendix 2: Nanofluids thermophysical properties calculator in excel



Appendix 3: Thermoelectric Calculator in Excel

INPUT VALUE	
Delta T (K)	10
Current (A)	4.5
Tc (K)	287.182
Th (K)	297.182
Treduction (K)	3.116

	OUTPUT VALUE	
Qc	41.667562	W
Qh	82.395062	W
Pte	28.6875	W
COPte	1.452464035	
Vin	6.375	V

Appendix 4: Post-Processing in ANSYS FLUENT