Faculty of Mechanical Engineering

STUDY ON TEMPERATURE DISTRIBUTION ON DIFFERENT COMBINATION OF LIQUID AND GASES FOR PLASMA GENERATION USING ANSYS FLUENT

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STUDY ON TEMPERATURE DISTRIBUTION ON DIFFERENT COMBINATION OF LIQUID AND GASES FOR PLASMA GENERATION USING ANSYS FLUENT

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DECLEARATION

"I hereby declare that this report entitled "Study On Temperature Distribution On Different Combination Of Liquid and Gases For Plasma Generation Using Ansys Fluent is the result of my own work except for quotes as cited in the references."

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APPROVAL

"I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for the award of Bachelor Degree in Mechanical Engineering (Hons)"

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Supervisor's Name : DR. FADHLI BIN SYAHRIAL

Date : ………………………

DEDICATION

To my beloved mother and father

ABSTARCT

Study on temperature distribution on different combination of liquid and gases for in liquid plasma refers to study on the generation, use, conversion of thermal energy generated by microwave oven to the reactor. Concept of microwave heat transfer is acquired. This study focuses on heat distribution in the reactor that will lead to generation of in liquid plasma after bubble is formed through evaporation process. Different combination of liquids and gases which are H_2O, Palm Oil with argon or helium gas are compared. This study also suggested ideal condition for in liquid plasma generation. Plasma is a type of ionized gas with radical species electron like OH, H_α, H_β that generated after bubble is formed during evaporation process. Temperature distribution indicates heat transfer to the reactor will be analysed by using ANSYS software and discussion is made on temperature contour generated. Design of the simulation is by placing copper electrode on PTFE platform and put inside a glass reactor covered by Teflon. Heat wave supplied to the system is microwave at a frequency of 2.45GHz at power rating of 750W. Liquid molecule will be breakdown by radical species electron and react chemically to form hydrogen gas. It is found that combination of palm-oil and argon gas has a good potential for the formation of in liquid plasma hence increase production of hydrogen gas. Result can be explained based on thermodynamic properties of the liquid and gas respectively.

ABSTRAK

Kajian mengenai pengedaran suhu pada gabungan yang berbeza dari cecair dan gas untuk plasma cecair merujuk kepada kajian tentang penjanaan, penggunaan, penukaran tenaga haba yang dihasilkan oleh ketuhar gelombang mikro ke reaktor. Konsep pemindahan haba gelombang mikro diperolehi. Kajian ini memberi tumpuan kepada pengagihan haba dalam reaktor yang akan membawa kepada penjanaan plasma cecair selepas gelembung terbentuk melalui proses penyejatan. Gabungan yang berbeza dari cecair dan gas yang H_2O, Minyak Sawit dengan argon atau gas helium dibandingkan. Kajian ini juga mencadangkan keadaan ideal untuk penjanaan plasma cecair. Plasma adalah sejenis gas terionis dengan elektron spesies radikal seperti OH, H_α, H_β yang dihasilkan selepas gelembung dibentuk semasa proses penyejatan. Pengagihan suhu menunjukkan pemindahan haba ke reaktor akan dianalisis dengan menggunakan perisian ANSYS dan perbincangan dibuat pada kontur suhu yang dihasilkan. Reka bentuk simulasi adalah dengan meletakkan elektrod tembaga pada platform PTFE dan dimasukkan ke dalam reaktor kaca yang diliputi oleh Teflon. Gelombang haba yang dibekalkan kepada sistem adalah gelombang mikro pada kekerapan 2.45GHz pada penarafan kuasa 750W. Molekul cecair akan pecah oleh elektron spesies radikal dan bertindak balas secara kimia untuk membentuk gas hidrogen. Telah dijumpai bahawa gabungan minyak sawit dan gas argon mempunyai potensi yang baik untuk pembentukan plasma cecair sehingga meningkatkan pengeluaran gas hidrogen. Keputusan boleh dijelaskan berdasarkan sifat-sifat termodinamik cecair dan gas masing-masing.

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Besides, I would like to express my gratitude towards my parents who give me mental and financial support to complete my study. Encouragement and support are crucial for me to keep moving forward while doing this project. They reminded to put in effort to produced quality work. Their support and encouragement is always my backbone when I face hurdles in my studies. I am pleased that my hard work paid off that I am able to finish this project on time

I would also like to thank to all my classmates that are doing final year project for encouraging and supporting each other by sharing our idea and thought during the information collecting phase when execution of the project. I also appreciate the willingness to share and discuss the problem and find the solution together. I would also like to thank my university, University Teknikal Malaysia Melaka (UTeM) for giving us the project so that we are able to improve our personal skills and are adapt more readily towards career in the future. Lastly, I would like to apologies if there are any imperfections and inadequacy in the project, I am looking forward for improvement in this learning process.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

There are several mechanisms in heat transfer which include conduction, convection and radiation. Conduction is where heat transferred through contact of atom, when solid object is heated atom vibrate about a fixed position colliding other atom which results in transfer of heat. Convection heat transfer takes place in fluids where the particles gain kinetic energy and move to transfer heat to particles with less energy. Radiation is the transfer of heat energy through electromagnetic field.

Heat transfer to the reactor will lead to generation of in liquid plasma at copper electrode tip region. In liquid plasma is formed when liquid become a type of ionized gas through conversion of neutral atoms or molecules to radical species electron like OH, H_α, $H_{\beta.}$ It will break down the molecule of liquid dipped to obtain hydrogen, carbon dioxide and other elements. In liquid plasma is widely used in water treatment, energy extraction and other biological application. Plasma is referred to fourth stage of matter where solid breaks down to become liquid then gas, when gas is further breaks down under constant heat supply it generates plasma. Hydrogen is mainly used for energy extraction.

Design of the simulation started by putting copper electrode on PTFE platform in a glass reactor covered with teflon. Simulation is done on different combination of liquid and gas to identified good potential criteria for in liquid plasma generation. Reactor is placed in microwave oven that will supply heat at a frequency of 2.45GHz at power rating of 750W, set up of this experiment will be designed in ANSYS software and characterization of the heat transfer to the copper electrode is analysed.

Heat is transferred to the reactor through radiation, reactor transfer heat to the water through conduction and heat is transfer to the electrode through convection. Plasma is generated at tip region of the copper electrode. There are factors that will affect the heat transferred and this leads to study of temperature distribution on different combination of liquid and gases to determine the effectiveness of heat transfer to the reactor with different combination. Simulation of the study is carried out by using ANSYS Fluent, it is approximated solutions of differential equations, it provides details of flow. The equations that can be solved by CFD includes steady, incompressible, laminar flow of a Newtonian fluid with constant properties and without free-surface effects.

Different temperature contour will be generated on different combination of liquid and gas. Analysis on the result obtained will be carried out to identify characteristic of heat transfer on the copper electrode under different parameters. Efficiency of the heat transfer to the copper electrode can be identified through this study.

1.2 Objectives

The objectives of the project are as follow:

I. To identify temperature distribution on different combination of liquid and gases for plasma generation using ANSYS Fluent.
II. To determine the ideal condition for plasma generation in the liquid.
III. To relate and explain result generated through simulation in ANSYS Fluent 16.0 with concept in heat transfer.

1.3 Problem Statement

Industry are having problems in identifying high efficiency sustainable energy harvesting. In liquid plasma technology is one the method of hydrogen fuel harvesting. However, efficiency of this technology remains doubtful. It can be affected by several factors where main factor is heat transfer. Types of fluid and dimension of the geometry set up can be a factor to the efficiency of the heat transferred. This study will study the effect of different combination of fluid to the rate of heat transfer by analyzing temperature distribution generated through the simulation.

1.4 Project Scope

Scope of project includes identification of the effectiveness of heat transfer on different combination of liquid and gases which are water liquid with argon and helium or palm-oil with argon and helium respectively for in liquid plasma generation using ANSYS Fluent simulation. This simulation is a steady state condition with define boundary condition that replicated from experiment done. Temperature distribution is affected by heat transferred to the reactor. Heat will be transferred from microwave oven to the reactor and bubble will be formed at region near to electrode tip. Ionization take place and in liquid plasma is developed. Ideal condition for generation of in liquid plasma is determined based on the analysis done.

1.5 General Methodology

In order, to study the temperature distribution on different combination of liquid and gases for in liquid plasma using ANSYS Fluent simulation. The simulation is visualized in a way that copper electrode will be placed on PTFE platform in a glass reactor covered with teflon. Reactor is placed in microwave oven that will supply heat at a frequency of 2.45GHz at power rating of 750W, set up of this experiment will be designed in ANSYS Fluent software and characterization of the heat transfer to the reactor is analysed.

CHAPTER 2

LITERATURE REVIEW

2.1 Plasma Introduction

Plasma can be referred to fourth state of matter after solid, liquid and gas(Horikoshi & Serpone, 2017), it is a layer of ionized gas formed through ionization process. Neutral atoms or molecule are converted into radical species electron and positive ion through the process. It is widely applied in industrial which can be used in water treatment, electronic chip manufacturing, energy extraction and many others. Plasma is generated at high temperature as the molecules dissociate to form a layer of freely moving gas that are made of charged particles, electrons and positive electron. Plasma is a good electric conductor with the presence of the freely moving charged particles and electron.

Plasma can be classified into either physics plasma or chemistry plasma. Physics plasma is generated when charged ionic species has adequate kinetic energy gained from high voltage electric power and break the bond of the sample resulting in energy extraction. Plasma physics refer to study of reaction on charged particles to electric and magnetic field. Nearest star to earth that is sun is one of the examples on occurrence of physics plasma. The high temperature of sun results in high energy particles which is an output from thermonuclear fusion reactions which keep the sun gaseous(Fridman & A. Kennedy, 2011). The visible boundary surface of the sun is known as solar atmosphere that can be divided into three regions, photosphere, chromosphere and corona. Photosphere is a layer of gases at temperature of 6000K, surrounding photosphere is reddish ring called chromosphere and outermost layer is known as corona. Ionosphere is a large natural blanket of plasma in the atmosphere which envelopes the earth from an altitude of approximately sixty kilometres to several thousand kilometres. Physics plasma research can be applied in various field which include astrophysics, controlled fusion, accelerator physics etc.

In chemical plasma, these chemically active free particles will decrease activation energy of the sample hence result in energy extraction or material removal. Chemistry plasma is also widely used in some industries which include electronics, lightning, metallurgy and others. According to Fridman, plasma chemical is that the reaction media become overheated when energy is uniformly consumed by the reagents into all degrees of freedom and hence high energy consumption is required to provide special quenching of the reagents(Fridmen, 2008). Most of the chemical plasma is generated through microwave-discharged. Electrons received energy and transmit the energy to all plasma components as electron has low mass and high mobility. Microwave discharged chemical plasma promotes high temperature which is around 3000K-5000K that lead to bond dissociation which results in optimal energy extraction and other chemical reaction. For this project, it is related to chemistry plasma where the focus is place in energy extraction from H_2O and Palm Oil Mill Effluent. H_2O contain hydrogen which is the source of energy, plasma contain radical species electron and positive ion to disassociate water molecule and extract the hydrogen gas from it.

` Besides, according to Horikoshi, characterization of plasma can be divided into two which are the high temperature plasma and low temperature plasma(Horikoshi & Serpone, 2017). Plasma generated can be thermal or non-thermal plasma. Plasma generated is different where high temperature with high energy density and low temperature with high chemical reactivity.

Thermal plasma technology emerged as an innovative and efficient method in material processing, material science field. Thermal plasma is refer to fully ionized gas generated at high pressure (>10kPa) by using either alternating current, direct current, radio frequency or microwave sources (Samal, 2017). Thermal plasma has high energy density and its heavy particles has common temperature with its electron. Plasma welding, cutting torches are common example of thermal plasma. Electron will oscillate more vigorous with enhancement of electric field, collision between electron lead to high internal energy. Plasma generated in this project is thermal plasma by using 2.45GHz with power supply of 750W.

Non-thermal plasma is defined as partly ionized gas compare to thermal plasma that is fully ionized gas which consists of electrons, positive and negative ions, neutral atoms and charged molecules. Non-thermal plasma has to low energy density and temperature difference between electron and heavy particle is large (Samal, 2017) as less energy used to generate non-thermal plasma. Non-thermal plasma processing has strong chemical reactivity to reduce or decompose particles, it is environment friendly. Other than that, non-thermal atmospheric-pressure plasma is a new innovative approach in medical field. Non-thermal atmospheric-pressure plasma is "cold plasma" generated under atmospheric pressure, there are several types of Non-thermal electric discharge which includes corona discharge, plasma jet and others.

In liquid plasma refers to plasma generated in the liquid phase. Plasma in liquid is generated as the dielectric breakdown of the liquid and turns into a type of corona, micro-bubbles and pale white light is observed to be formed surrounding the electrode. Dielectric breakdown of liquid refers to water molecule is polarized by electric field, positive and negative charge will be attracted to negatively and positively charge electric field as the electric field reduce, polarized particles is released forming a layer of ionized gas and electron. Previously, in liquid plasma is generated by high-voltage pulse but the technology has improved where the plasma can be generated through rapid heat transfer like radiation of heat generated through microwave, generation of in plasma liquid can be optimized by several factors like material, dimension, density, viscosity and temperature which is one of the objectives in this study.

Nowadays, in liquid plasma is widely use in hydrogen extraction as hydrogen is an important energy source. This project is to study the temperature distribution on different combination of liquid and gases for in liquid plasma using ANSYS Fluent simulation refers to study of effectiveness transfer of thermal energy to the reactor, transfer of high amount of thermal energy will cause development of plasma tip region of the copper electrode which is known as in liquid plasma. Purpose of this study is to increase the efficiency of the heat transferred to the reactor with different combination of liquid and gases, by increasing the efficiency of the heat transferred volume of the plasma generated will be increased. Current technologies for hydrogen production include steam reforming of natural gas, coal gasification and water electrolysis. There are disadvantages in these technologies, steam reforming of natural gas produces low purity hydrogen, high air emission and requires high temperature that will lead to carbon formation.

2.2 Plasma Discharge Method

In liquid plasma can be generated by using different method which include microwave. Radio frequency, direct current, magnetron, dielectric barrier discharge (DBD). According to S. Nomura et. al applications of in plasma liquid include in synthesis of nanomaterials. Besides, in plasma liquid can be applied at energy extraction, water treatment and medical site for sterilization of medical equipment.

2.2.1 Dielectric Barrier Discharge (DBD)

Plasma generated by dielectric barrier discharge (DBD) developed by Fangmin Huang is through electrodes that covered by dielectric material to allow charge extinguishes before plasma arc is formed on the surface of electrodes. Discharge and extinguished takes place in interval with filamentary mode that carries weak current. However, the electron density and temperature generated has ability to disassociate and ionized the particles. DBD are widely used in industrials like sterilization of clinical materials, removal of volatile organic compounds from air, etc due to its low operation cost. Set up of dielectric barrier discharge include a DBD reactor and AC power source with frequency of 10-20kHz. There are reaction and cooling space in the reactor and silver paper is used to cover the high voltage electrode and ground electrode(Huang et al. 2010) to extinguishes the charge before the plasma arc is formed. Radical species electron produced during plasma discharge will reduce the particle of wastewater. The set-up of the experiment is shown in Fig. 2.1:

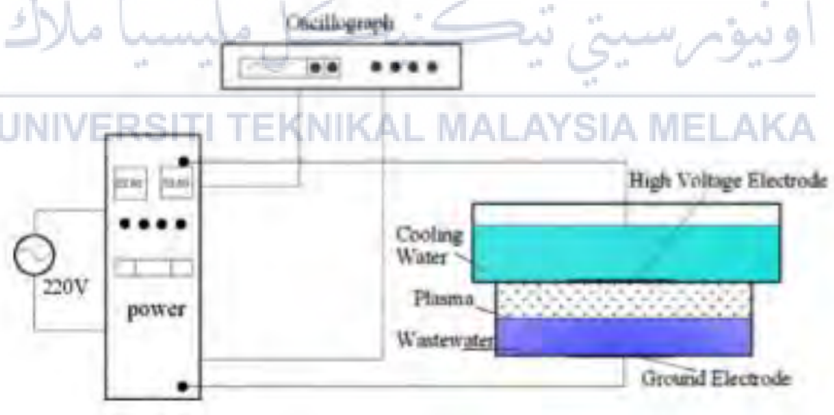

Figure 2.1 Set up of DBD plasma discharge by FangMin Huang et al.

2.2.2 Magnetron

Generation of plasma through magnetron is one of the latest technology that have vast applications in producing quality coatings(Ehiasarian et al., 2002). Magnetron plasma method refers to generation of plasma by sputtering gas ions without using target heating process which means it only involve vaporization of the material (Pratontep et al. 2005), plasma will be generated in vaporization process. However, the positive ions and electrons are confined in the plasma by magnetron mechanism is force out through electric field. The setup by Robert K. Waits. et al. is shown in Fig 2.2 below. This method consists of anode and cathode which anode is the surface to be coated and cathode is raw material to be vaporized. It uses magnet to enclose plasma to surface to be coated, magnetic field will promote more rapid electron collision. Magnetron cathode will ionize the target to escape into primary magnetic field and the negative ion is sputtered off by electric field impact to the surface to be coated. Magnetron plasma generation is based on two types of waveforms which are unipolar modes and bipolar modes. The difference between unipolar modes and bipolar modes is unipolar discharge voltage will become to zero compare to an overshoot in cathode voltage(Waits, 1978).

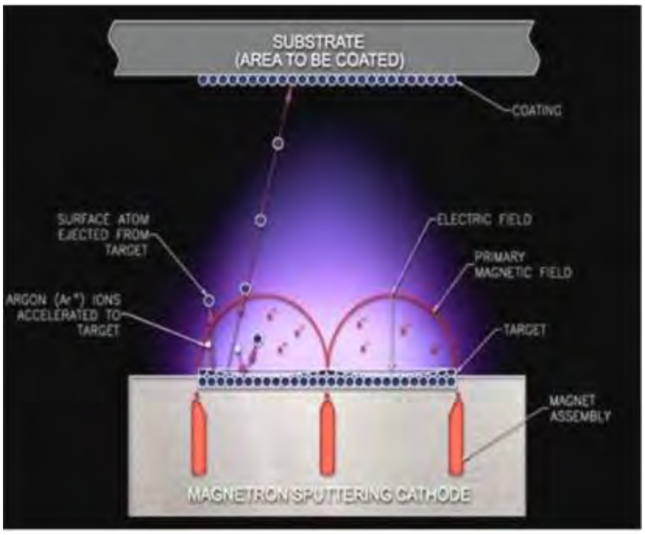

Figure 2.2 Magnetron plasma discharge

2.2.3 Microwave and radio frequency plasma generation

Based on the wave spectrum shown in Fig 2.3, different types of waves have different characteristics which include frequency and wavelength that affect the amount of energy transmitted by the wave.

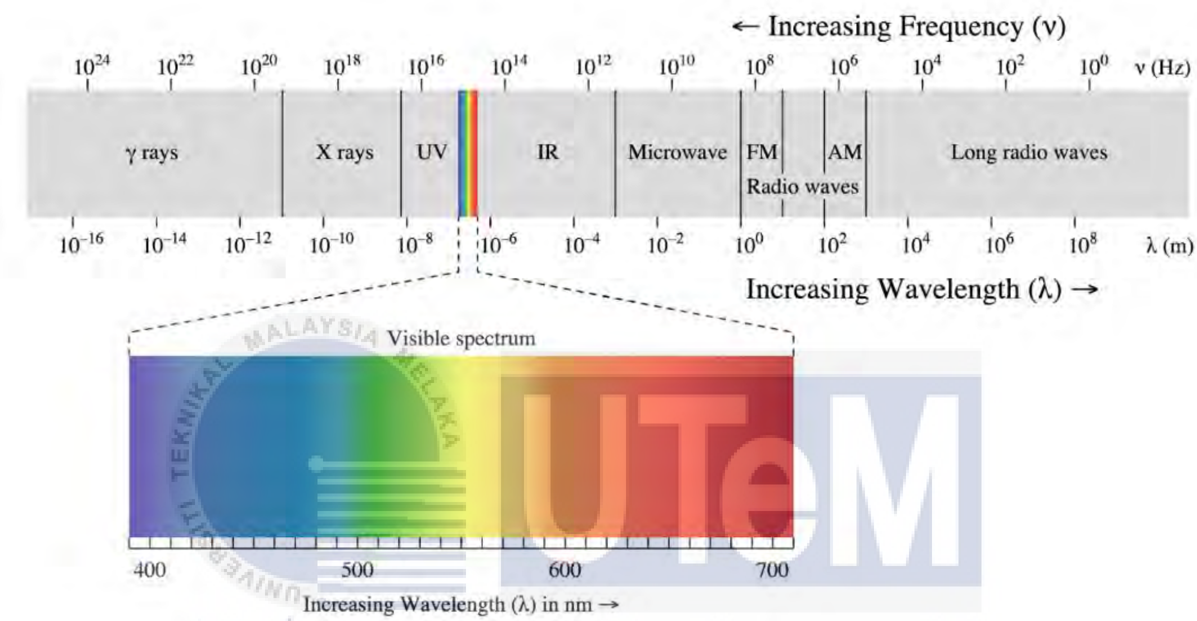

Figure 2.3 Wave Spectrum

In this stimulation, microwave will be used to transmit heat to the reactor as it has ability to transmit electromagnetic energy(Saltiel & Datta, 1999). By referring wave spectrum above microwave tends to transmit larger amount of energy with shorter wavelength based on Energy equation $E = \frac{hc}{\lambda}$ compare to radio frequency(Kent, n.d.). Plasma in microwave is generated through absorption of microwave energy by particles and further disassociate into positive ion and electron to form an electric field with high field intensity(Li et al. 2016). Example of microwave plasma generator set up by Dashuai Li et al. is shown in Fig 2.4:

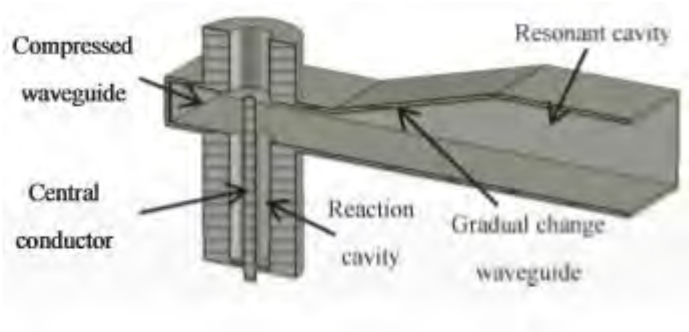

Figure 2.4 Set up of microwave plasma generator

Energy that carried by microwave is gathered at resonant cavity of the generator and electric field will be formed at waveguide, plasma will be ignited by central conductor. For this study, heat source is generated by microwave oven without direct supply of current to electrode for generation of plasma.

2.3 Application of in liquid plasma

In liquid plasma has a vast application in various field that include industry to biomedical field. In industry, it can be used to synthesize material or change a property of certain material and it can used to purified waste water effluent produce by industry in manufacturing process. In biomedical field, it can be used for certain treatment like wound healing and operation. Some of the application is discussed in this chapter.

2.3.1 Synthesizing nanoparticle

Latest research shown that in liquid plasma has vast application in medical field. In-liquid plasma can be used in wound treatment, skin related illness and even cancer as plasma has the ability of build- up, exodus of defect skin cells through impediment or revival of integrin receptors of the cell. According to Hong et al. plasma has ability to deactivate many types of microorganisms effectively with even type of drug safe skin. The types of plasma source that are used in medical field are plasma sources and dielectric barrier discharge(Omurzak et al., 2007).

Besides, there are two types of nanomaterial synthesizing using plasma which is direct discharge between electrode and other is through gas discharge between electrolyte(Horikoshi & Serpone, 2017). Fig 2.5 shows different set up of nanomaterial synthesizing using plasma between electrode and electrolyte.

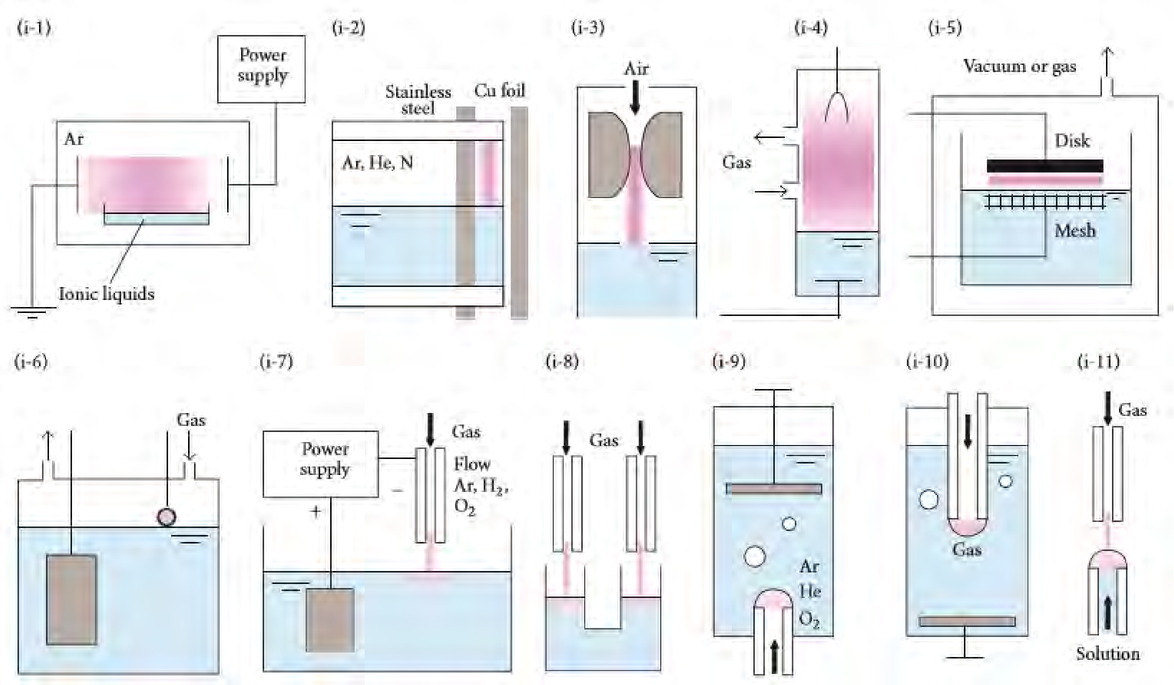

Figure 2.5 Nanomaterial Synthesis using Gas Discharge between an Electron and Electrolyte Surface by Genki Saito et al.

The first method is done as liquid is raw material for the nanomaterial. Ionic liquid will not be decomposed as temperature of plasma generated is low compare to other plasma discharge method but reduction of metal ion take place that lead to the synthesis of nanomaterial(Saito & Akiyama, 2015). The ionic liquid act as conductors between anode and cathode. Continuous supply of argon lead to generation of plasma. For example in situation 6, plasma will be generated at anode and react will ionise liquid to reduce aqueous metal salts to synthesis nanoparticles(Horikoshi & Serpone, 2017).

Fig 2.6 shows 12 different set up of second method of nanomaterial synthesizing using plasma that is direct discharge between electrodes. In this method, raw materials are embedded in both electrode and electrolyte. In order-to generate high temperature spark or arc discharge is used to generate plasma.

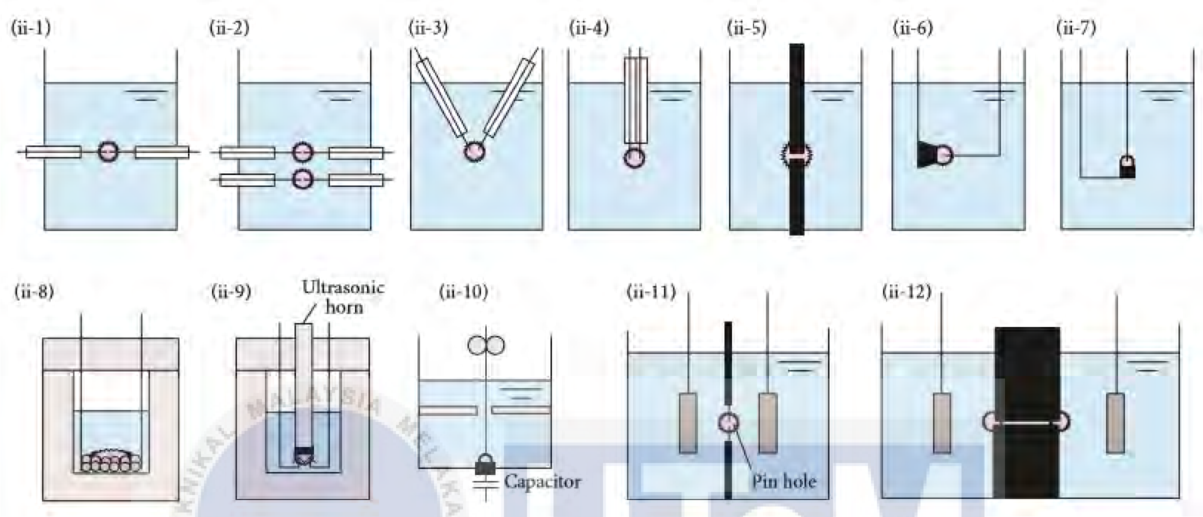

Figure 2.6 Nanomaterial Synthesis using Direct Discharge between Two Electrodes by Genki Saito et al.

In liquid plasma is used for synthesizing nanoparticle. Nano-particles of silver and platinum can be synthesised by microwave-induced plasma in liquid(Sato et al. 2011). For example, metallic silver can be generated by reducing rapidly and completely silver cation from silver nitrate using plasma source. To generate nanoparticles from plasma, reducing agents will not be used. The chemical species formed by the plasma act as reducing agent. For example, silver cation in pure water is reduced by hydrogen radical. The conductivity of pure water as needed for plasma generation in pulse wave is not necessary for microwave. This is due to the dielectric property of the pure water that can transmit microwave. The supply of breakdown voltage to water through microwave method is difficult. The water has high dielectric constant (80) and dielectric loss (10) so the microwave energy is easily absorbed into it. Due to these two reasons, lower pressure is applied to easy the form of plasma. However, to lower the pressure the process of evacuation system needs to be applied. This cost more than atmospheric pressure. Less contaminant is produced as the metal electrode itself is reduced to nanoparticle. So, a study was done to attempt in liquid plasma by microwave under atmospheric pressure. The study shows that the silver nanoparticles and platinum nanoparticles could be produced without using reducing agent and counter ion for metal ion. The formation of the metal nanoparticle is observed by the transmission electron microscopic.

2.3.2 Waste water treatment

The discharge of the pollutant from waste water of industries has adverse effect on human and aquatic life. Textile dying and treatment plant produces 17-20 % of industrial water pollution(Reddy & Subrahmanyam, 2012). Dyes are organic compound and designed to be chemically and photolytically stable(Sismanoglu et al. 2010). Since dyes contain toxic and may contain nondegradable amines, dyes need to be treated.in order to achieve that, advanced oxidation process (AOP) is the most effective method compared to remediation methods, ultrasonic degradation, corona discharge, metallic nanoparticles, titanium dioxide nanotubes, photo-Fenton, photocatalytic and sonolysis combined with ozonlysis. From the advanced oxidation process (AOP), various oxidant can be generated at the electric discharges at the water-gas interfaces. This discharge produces UV radiation, overpressure shock waves, and the formation of chemically active species. Highly oxidative species are produced from the interaction of the high energy electron. UV radiation, shock wave, ions, molecular species and reactive radicals are produced in water by electrical breakdown. Among these reactive species hydroxyl radicals, hydrogen peroxide and ultraviolet are major reactive species. This high energy can be obtained by plasma in liquid. So, advanced oxidation process (AOP) based on plasma can be generated.

2.3.3 Hydrogen Fuel production

Hydrogen is the source of energy that can be generated through various hydrocarbon sources like used engine oil, used cooking oil, Palm Oil Mill Effluent and etc by using various method like in liquid plasma. In liquid plasma able to purify waste water besides extracting energy by solidify carbon that can be turned into nanotechnology material. Shinfuku Nomura et al. generated in liquid plasma through 2.45GHz household microwave and able to produce hydrogen gas with purity of 66-81%(Nomura et al., 2009). In liquid plasma consists radical species electron that break down hydrocarbon bond and turns particles into useful substance through chemical reaction. Application of in liquid plasma has ability to reduce harmful effect of hazard waste to the environment. Fig 2.7 is the experimental setup by Shinfuku Nomura et al. where rated microwave oven output of 1260W.

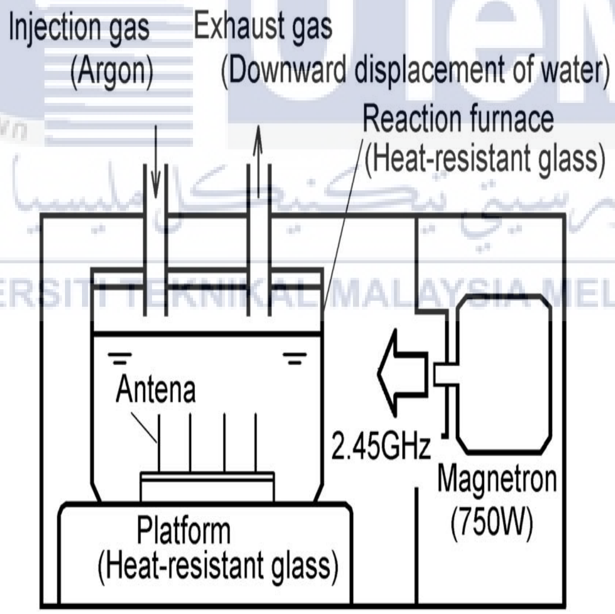

Figure 2.7 In liquid plasma reactor (Nomura et al., 2009)

Fig 2.8 shows schematic of receiving antennas immersed completely in the hydrocarbon and plasma generated will be at the tip of antennas. In this study, length of antenna L is set as λ/4, however the author is not certain whether it is optimal length for the antennas to receive the electric field.

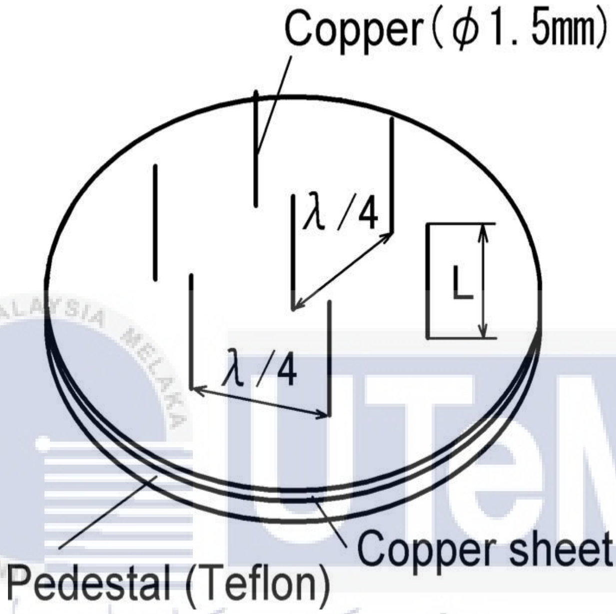

Figure 2.8 Microwave receiving antenna(Nomura et al., 2009)

Conversion of hydrocarbon oil sands to reusable compound can be done using various method which include catalytic technology by Depew et al. It uses hot water heated using microwave oven to extract bitumen(Depew et al. 2017). However, Depew et al. concluded that this method has some disadvantages which include low specific productivity, high metal capacity and large equipment size compare to advantages of in liquid plasma which has compact setup with low operation cost and high reliability. So catalytic technology has not been widely used in industry.

2.4 Microwave Heat Transfer

Typically, there are three types of heat transfer which are convection, conduction and radiation. Microwave heat transfer is classified as radiation heat transfer mechanism which has higher efficiency compare to typical types of heat transfer(Moreno et al. 2005). Microwave is a type of electromagnetic waves where it consists of positive and negative charge as shown in Fig 2.9 that will change direction rapidly. Heat transfer by electromagnetic waves does not involve mass exchange.

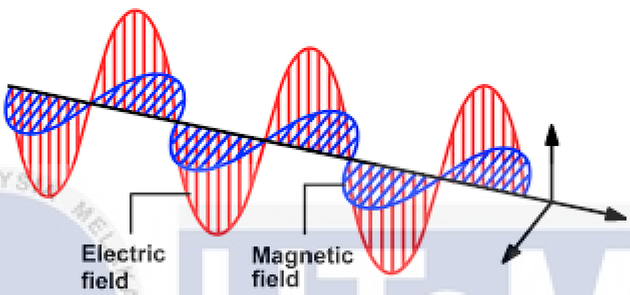

Figure 2.9 Electromagnetic wave

Heat is generated through dipole oscillation where polar molecule tends to align with radiative electromagnetic wave in a way that positive and negative polar molecule will be alligned to negative ion and positive ion carried by the electromagnetic wave respectively as demonstrated in Fig 2.10. The rate of heat transfer depends on dielectric properties of molecules which it will react more rapidly to electromagnetic field.

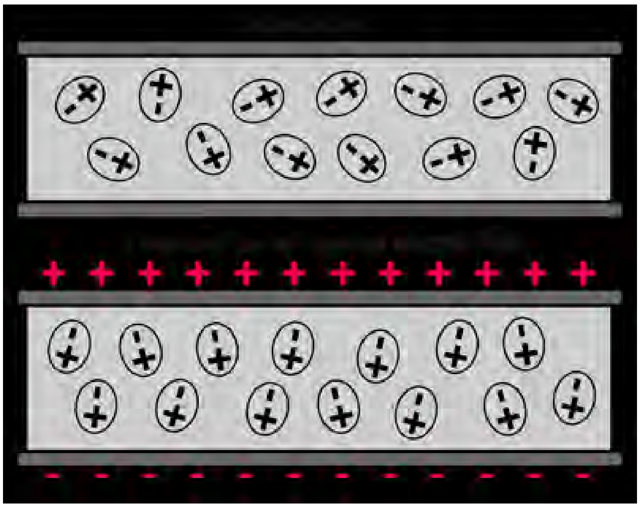

Figure 2.10 Illustration of dielectric arrangement

In microwave oven, microwave is generated by magnetron where electric energy supplied to the microwave oven is converted. Then, microwave is guided by wave guide and ejected on wall of microwave oven and it will be reflected by the wall to spread through the oven cavity. Electromagnetic wave will rapidly change its charge while propagate through polar molecules, polar molecules tend to align accordingly to microwave charge and this promote molecular movement that cause friction between it to produce heat. As a result, a more rapid heat transfer is obtained from microwave oven.

2.4.1 Microwave Application

Due to high energy content, microwave has a vast application in various field which include medical, industry, agriculture etc. In agriculture field it can be used to eliminant contaminant often cause by chemical fertiliser used by farmer for commercial agriculture purpose. Traditionally, elimination of contaminant in soil is through heated at high temperature using fire that will cause an increase of temperature at soil surface to increase evaporation rate at surface however, the inner surface of the soil remained contaminated. This phenomenon can be solved by applying microwave in soil purification process. Microwave able to purify soil through process named microwave-induced steam distillation. Soil contain water that is high dielectric constant which mean it will react to microwave and evaporate to become steam that will volatize the contaminant, this process will transform contaminant into gaseous form and discharged to collecting system deigned. This process is carried out at temperature below 100℃. To improve outcome of this process, it is repeated several times and soil is dampen before the process, elimination rate is increased when the humidity of the soil is high.

In oil and gas industry, microwave is used to separate emulsion, by-product of petroleum refining process. Emulsion refer to fine dispersion droplets from liquid which is insoluble. Previously, it is separated through filtration process or using chemical treatment to demulsify, this method is inefficient and hazardous to the environment when chemical is release into water. Klaila et al. uses microwave energy as an alternative source to filter emulsion to increase purification efficiency(Enzymes, 1973). As microwave is supplied to the system, emulsion is heated up and its property is changed, it become less viscous and neutralized when microwave induce its molecular rotation.

Depew et al. develop used of microwave for conversion and oxidation of methane, decomposition of polychlorinated hydrocarbons and bitumen. It can be recover using hot-water but it will result in high viscosity of its products which is difficult to be refined. Large amount of energy is deposited in microwave and heterogenous catalytic reaction(Depew et al. 1991) utilized it to heat up material with high dielectric loss under high temperature. High temperature allow reaction between catalyst by using microwave energy whereas for reagent that escaped from primary reaction will remain as rapid heat transfer by microwave, this process is less dependent to high pressure in vaporous locale and back reaction. There is other way of heavy oil recovery like using RF by Vermeulen et al. and the effectiveness of this technique is satisfying(Vermeulen & Chute, 1983).

Besides, microwave can be used to purify coal by reducing its ash and sulphur content. 98% ash and 66% sulphur able to be reduced through this process, the process include removal of NOx from flue gas and NOx-is absorbed by laden carbon until it is thoroughly reduced.

Other than that, microwave can be applied in quarry operation and construction site. Previously, quarry operation applied method like bombing, high water pressure, mechanical chisel etc. These methods are not environment friendly as it produces dust and sound pollution to surrounding. To overcome the problem, microwave can be applied in quarry operation with high dielectric loss factor (high relative permittivity) properties to ensure microwave is able to permittable into the rocks. Microwave has high energy to crush rock rocks contain water crystallization that able to react vigorously with microwave. Constant supply of microwave will lead to internal thermal stresses and crack the rock. In construction site, it can be used to remove contaminated concrete such as ^{235}U and ^{238}U. for both application, size of the rock and concrete can be controlled by manipulating microwave frequency, microwave is an efficient and environment friendly solution.

Microwave is also used to dispose harmful radioactive contaminated waste, commonly it is disposed in glass which has leakage potential that will cause adverse effect to environment and human health. Aubert et al. has used this method to melt radioactive ashes(Aubert et al. 1993). Microwave is guided to melt ashes by prevent it from corroding glass layer. It is protected by circulating water in cooling jacket for the waveguide to cool down before radioactive waste in contacts with wall. At the same time, solidified waste material consisting radioactive properties can be injected to a stainless-steel drum which is in resonant cavity form that is attached with microwave generator and melted the waste material in drum at temperature of 1100℃.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In methodology, the series of stages done to complete the project objective are described. Every stage will be explained in more detail in this chapter. The flow and process can be clearly overview by a flow chart and Gantt chart, Gantt chart is produced by using Microsoft excel where the task and duration is shown. The project begins with planning, information collecting on the study to ensure objectives are achieved.

Methodology discusses about the process and method involved to achieve objectives of the project. It includes problem statement, information collecting in literature review, project flow and in methodology, follow by discussion where the results are analysed and compared before it come to conclusion. All the chapters included in the project are to ensure the objective is acquired.

3.2 Methodology Flow Chart and Gannt Chart

Flow chart is a diagram showing the steps and process to do the project from the beginning to the end whereas Gantt chart shows the timeline of the project from week 2 to week 15. Gantt chart is important to manage the task according to schedule that have plan from the starting from the project so that the project can be complete on time.

The study is about in liquid plasma generation in microwave oven as microwave oven is low cost and convenient for hydrogen production. It is applicable in industrials for compact hydrogen production(Nomura et al., 2009). The study is analysis based on engineering view where heat transfer to the reactor is studied to increase efficiency of the system. Simulation is done by using ANSYS Fluent software. The parameters involved like shape of electrode tip, height and diameter of electrode are obtained from the journal(Nomura et al., 2009) to study the effectiveness of heat transfer of the experiment done by Nomura et al. However, there are no studies on heat transfer on this experiment. Verification is done based on theory and other related studies on microwave heat transfer.

The activities include designing domain in ANSYS Fluent software where the geometry is set up in the software. Boundary conditions involve in this study is tuned and result is generated. Detail of steps taken are shown in Fig 3.1.

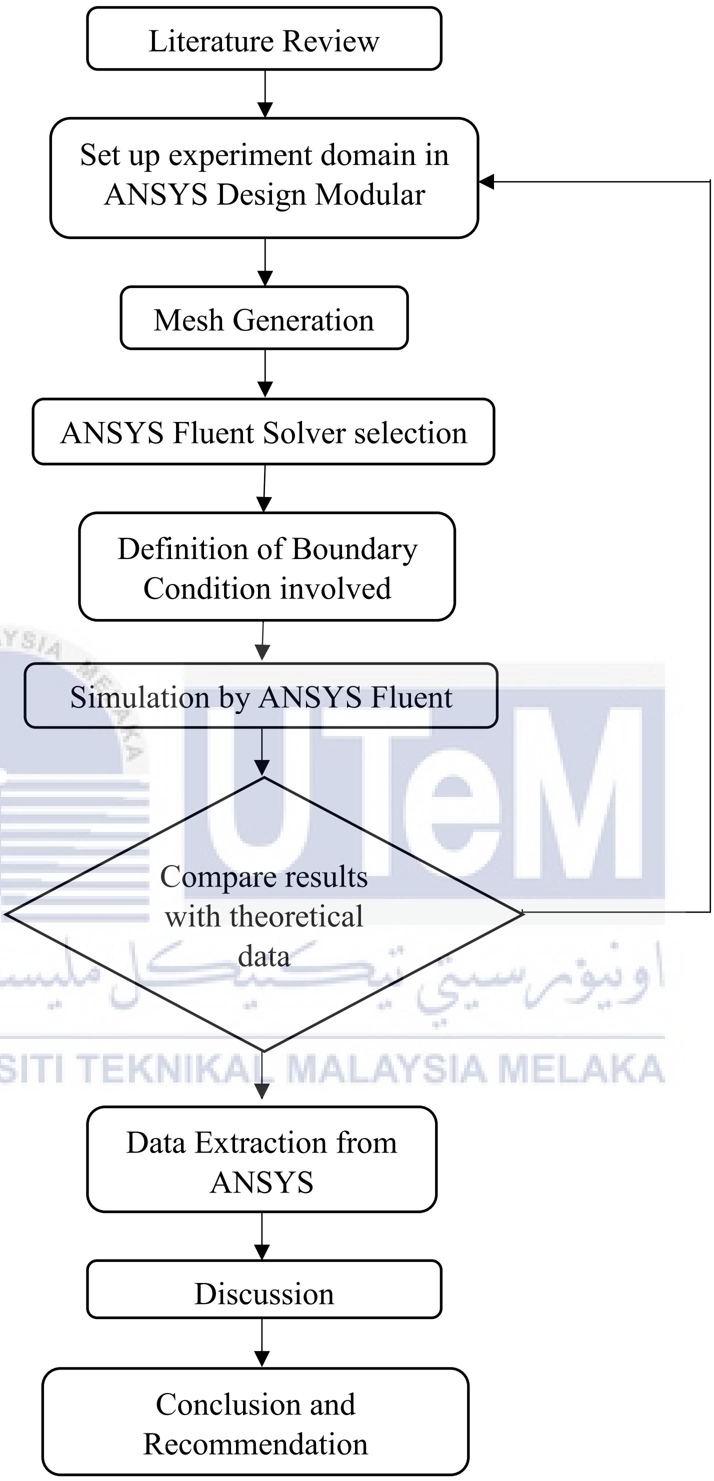

Figure 3.1 Flow Chart of this Study

3.3 Literature Review

Literature review is a process of collecting information that related to the diploma project, it usually refers to the study and analysis the previous researches that have been done. The information is mostly from journal, thesis, patent and others. Literature review will provide proposal on the objective and finding for current project, it is either an innovation or improvement from previous research.

In this title, characterization of heat transfer phenomenon on high conductivity round and sharp-tip copper electrode where literature review contains the plasma introduction, types of discharge for plasma, application for plasma, microwave radiation and high conductivity metal. Furthermore, the method used to generate result of stimulation that is ANSYS Fluent is also discussed in this chapter. All the information collected from the references is relevant and it will narrow down the scope of our finding.

3.4 ANSYS Fluent CFD Simulation

For simulation part of this study, ANSYS Fluent 16.0 software is used to generate result to carry out analysis. ANSYS Fluent is software used to model fluid flow by applying Partial Differential Equations (PDE) and has ability to discretize PDE into algebra problem (Taylor Series) for simulation validation. Reason ANSYS Fluent was chosen to carry out the simulation as it has several benefits to attain objectives of this study. ANSYS Fluent has design function where set up of an experiment can be designed in ANSYS Fluent and carried out analysis instead of setting up the experiment physically which are costly and non-effective. It provides high-fidelity database for interrogation of flow field. There are also Governing Equations that embedded in ANSYS Fluent which include Continuity Equation, Equation of motion, Navier-Stokes Equation etc. These mathematical modelling represent physical problem of a study. In-order-to generate solution for a study, there are several steps which start with discretization and linearization follow by assembly of system of algebraic equations and lastly solve the equation to generate results.

3.4.1 Geometry

Geometry is set up ANSYS Fluent Design Modular. Parameter stated in Table 3.1 were used to create the model for this simulation. Geometry set up include platform holding copper electrodes immersed in reactor with fluid domain filled with gas in the remaining cavity. Centre electrode is situated at centre of the platform and the other electrodes are 13mm away from the centre electrode and thickness of reactor wall is 2mm. Geometry set up is shown in Fig 3.2. The objective is to obtain temperature distribution at region around the tip of electrodes.

Table 3.1 Table of geometry dimension

Parts	Diameter(mm)	Height(mm)
Copper electrodes	3	20
Reactor	84	81
Platform	60	10
Gas	84	21

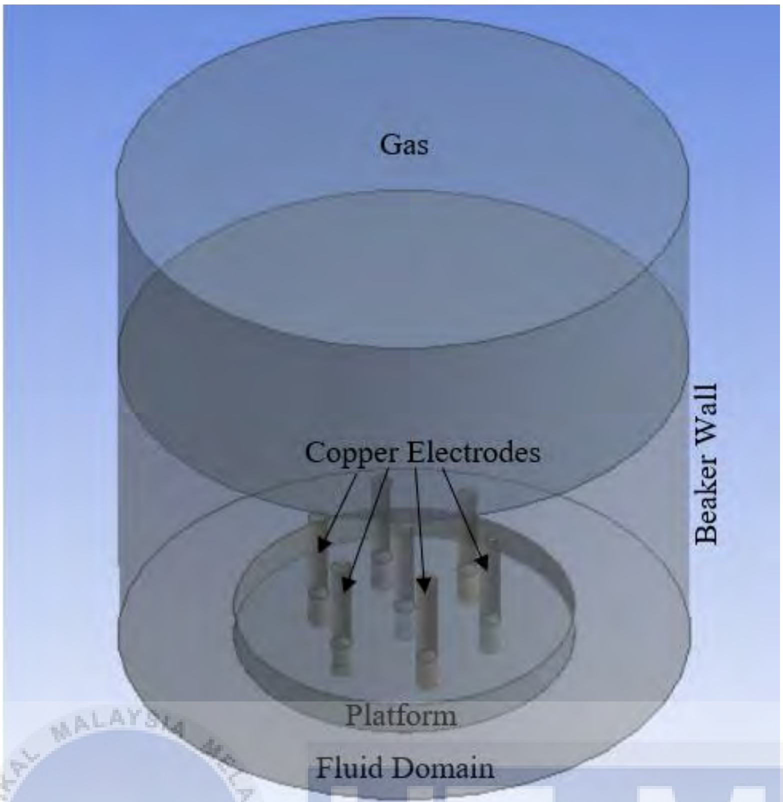

Figure 3.2 Geometry set up for simulation

3.4.2 Meshing

Accuracy of CFD simulation result is depend on quality of mesh on the set up. There are several parameters that can indicate quality of mesh of a simulation. Skewness indicates quality of a mesh. For tetrahedral mesh, skewness should be kept below 0.95. This simulation has skewness of 0.85 which is in accordance to accurate result generation. Skewness value above 0.95 will cause difficulties for solution to converge and require adjustment of solver controls. Besides, mesh size also affects accuracy of result. Higher mesh size indicates more vectors is involved in partial derivatives computation in governing equations. Mesh is refined using high smoothness, higher smoothness results in higher mesh size.

Table 3.2 Number of mesh node in each part

Domain	Nodes	Elements
copper_electrodes	18473	82859
gas	37408	34185
platform	3984	2877
water_fluid	95416	528649
All Domains	155281	648570

3.4.3 Boundary Condition SETUP

The type of solver used is pressure base with absolute velocity formulation and steady state time as there is no rate of change in heat supply with time to the system. The Models used in this simulation is laminar with scalable wall Fn as this simulation only does not involve any flow. Scalable wall Fn is applicable for arbitrary fine meshes, it takes every details of boundary layer into consideration when resolving. Boundary conditions involve in this study is tabulated in Table 3.3. Glass wall is defined as energy source as heat is transfer to wall before it is transfer into internal region with lower temperature. Initialization Methods used in this simulation is Hybrid Initialization and calculation is done at 1000 iterations.

Table 3.3 Boundary condition involve in the simulation

BOUNDARY	BOUNDARY TYPE	THERMAL CONDITION	HEAT GENERATION RATE W/m^3
Copper Electrodes	Wall	Convection	0
Gas	Wall	Convection	0
Platform	Wall	Convection	0
Water Fluid	Wall	Convection	0
Beaker Wall	Wall with thickness 2mm	Conduction	100000

3.5 Microsoft Excel

Data obtained from the simulation will be transfer to Microsoft Excel and graph will be plotted based on parameter manipulated. The results are then compared and analysis to proceed to discussion part. Generation of graph is important to see clearly how manipulated variables affect the responding variables of the study.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, data extracted from ANSYS Fluent will be analysed and discuss in detailed. The main purpose of this simulation is to study temperature distribution in region around copper electrode tip at initial stage for in liquid plasma formation. The simulation done based on four main conditions with two types of fluid domain combining with two types of gas injected into the experimental domain respectively. Types of liquid include water liquid and palm-oil, gas types include argon and helium. This study focuses on temperature distribution at region around electrodes tip with different types of fluid and gas combination to identify optimum condition for in liquid plasma formation.

Discussion on this study is divided into four main sections. First will be explaining theory related in this study. Second will be explanation on temperature contour obtained from each simulation result. Thirdly, will be comparing optimum conditions for hydrogen production using in liquid plasma method based on result temperature obtained. Lastly, suggestion and conclusion will be made based on analysis done.

4.2 CFD Simulation Description

Simulation done as a basic concept on temperature distribution at region around the copper electrodes tip. This is important to ensure set-up of all components are at optimum specification for the formation of in liquid plasma.

Radiation takes place when microwave oven radiates microwave from its magnetron, dielectric properties of glass(reactor) causing its molecules to arrange according based on microwave charge causing an increase in temperature at outer wall of reactor. As there is a change in medium, microwave did not penetrate further, conduction takes place instead from outer wall of reactor to inner wall of reactor. Then convection takes place from inner wall to water and copper electrodes.

Solution is solved by Standard Second Order Upwind scheme for Momentum and Semi Empirical Pressure (SIMPLE) with Turbulence Dissipation Rate and Kinetic energy. From the simulation, graph of temperature versus distance along line plot is presented where temperature at each point can be determined from the graph.

From result generated, the plane generated only slice through three copper electrodes as other electrodes are identical. Three lines named Line1, Line2 and Line3 are also generated along vertical axis of the midpoint of each electrode to the top of reactor as shown in Fig 4.1 to study the temperature distribution across each boundary. Graph of temperature against distance along the Y-axis.

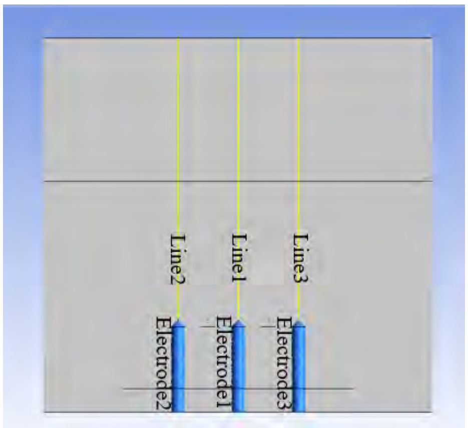

Figure 4.1 Lines representing respective electrodes in results generation

A plane is generated at XY plane at the origin slicing reactor into half as shown in Fig 4.2 to study temperature contour in every part inside the reactor.

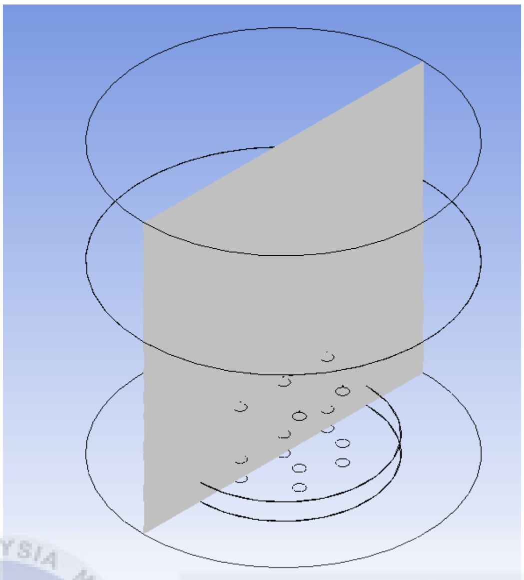

Figure 4.2 Plane 1 slicing at XY plane

4.3 Related Concept

There are few theories that related to this study which include thermal diffusivity, thermal conductivity, Ideal Gas Law and others. Result of the simulation also based on few parameters like density, specific heat capacity and others that will be discussed further.

4.3.1 Density

Density is defined as mass per volume. Density has an effect in heat transfer, density tends to decrease with increasing temperature(Hsu, 2014). As temperature increase, heat is transfer into molecules of matter causing molecules to vibrate more rapidly causing an increase in volume. Density is related to the concept of thermal diffusivity.

According to thermal diffusivity which can be represented by equation below, thermal diffusivity is inversely proportional to density. Thermal diffusivity increases as density decrease which means the rate of heat transfer from high temperature to low temperature region is high when density of the material is low.

$$\alpha = \frac{k}{\rho C_p}$$

Where $k = thermal\ conductivity\ of\ material$, $\rho = density\ of\ material$ and $C_p = specific\ heat\ capacity\ of\ material$

4.3.2 Specific Heat Capacity

Specific heat capacity is defined as the amount of heat energy required to raise temperature of a unit mass by 1°C. Specific heat capacity can be divided into two types which are specific heat at constant volume and specific heat at constant pressure. The properties that specific heat capacity depend on are temperature and pressure. For gases at low pressure, it tends to behave in ideal gas behaviour has relationship with water. Amount of heat absorb by a unit mass of substance is depend on its specific heat capacity as and the temperature change. It can be represented by formula below,

$$E_h = cm\Delta T$$

Wher$E_h = Heat\ energy$, $m = mass\ of\ substance$ and $\Delta T = change\ in\ temperature$

Temperature indicates the magnitude of kinetic energy transfer to molecules causing transfer of energy at a unit mass. Temperature change increase while heat capacity decrease if heat energy supplied to a unit mass is kept constant. Material with lower specific heat capacity tends to have higher temperature change compare to material with high specific heat capacity.

4.3.3 Thermal Conductivity

Thermal conductivity, the rate of heat transferred by conduction through cross section of an area of a material. According to Fourier's Law of Conduction, conduction can be represented by formula below,

$$Q_{cond} = \frac{kA_s(T_s - T_\infty)}{L}$$

From the formula, it is known that convection heat transfer coefficient, k is inversely proportion to the change of temperature between surface temperature and surrounding temperature sufficiently far from the surface when heat transfer and surface area is kept constant.

4.3.4 Viscosity

Viscosity of a fluid is defined as the resistance to deform according to shape of container. Viscosity is a significant parameter affecting heat transfer rate of a fluid, it related to wall shear stress that affects the temperature. Wall shear stress is defined as friction force per unit area of the fluid to velocity gradient and friction force will be generated. Fluid wall shear stress which can be represented by equation 1 below. Friction force generated over surface of water produce heat and magnitude of friction force can be represented by equation below.

$$\tau_w = C_f \frac{\rho V^2}{2}$$

$$F_f = C_f A_s \frac{\rho V^2}{2}$$

Where C_f is the friction coefficient/skin friction coefficient.

Fluids involved in this study are palm oil and water liquid, water liquid is Newtonian fluid but not palm oil, palm oil is classified as Non Newtonian Fluid.(Keshvadi et al. 2011). Viscosity of Newtonian Fluid tends to decrease with temperature whereas viscosity of gases tends to increase with temperature as shown in Fig 4.3, the graph of viscosity against temperature below. However, this relationship is only applicable Newtonian Fluid.

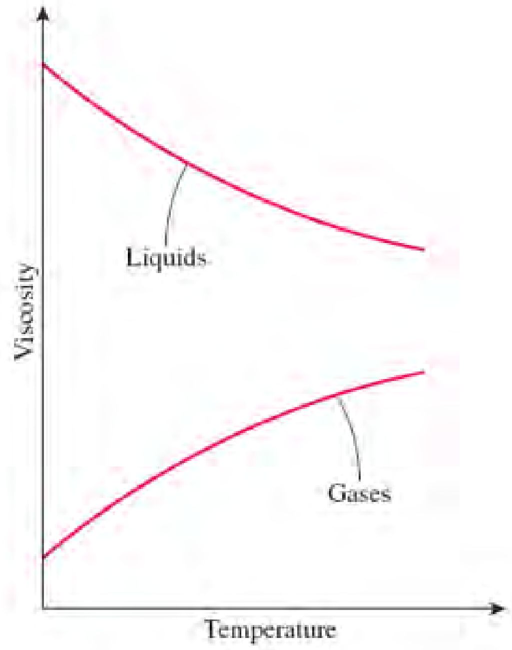

Figure 4.3 Graph of viscosity against temperature

Non-Newtonian Fluid is defined as fluid viscosity that is not constant and will vary with shear rate. Based on research done by Abdelraziq IR et al. viscosity tends to decrease with increasing temperature (IR & TH, 2015). Research conducted by Nik et al. states that palm oil is classified as pseudoplastic fluid/shear thinning fluid which is a type of Non-Newtonian Fluid(Wan Nik et al. 2013).

Fig 4.4 shows relationship between viscosity and types of fluids, for shear thinning fluid shear rate increase with decreasing viscosity.

Figure 4.4 Relationship between viscosity and shear rate

From the shear stress formula below,

$$\tau = \boldsymbol{\nu} \times \boldsymbol{\gamma}$$

Where $\tau = shear\ stress$, $\nu = density$ and $\gamma = shear\ rate$

Shear rate is directly proportional to shear stress and shear stress is directly proportional to friction coefficient which cause an increase in temperature. However, ANSYS Fluent will take in consideration of all the thermal properties but only take viscosity into consideration to obtain the temperature distribution.

4.3.5 Ideal Gas Law

Function of helium or argon gas injected into the reactor it acts as fuel promote to assist generation of in liquid plasma at region around the tip of copper electrodes. For natural plasma like aurora light, lightning that take place in the atmosphere it used up the inert gases like argon and helium that present in atmosphere to form natural plasma. Formation of natural plasma is replicated in this study where inert gas act as fuel for plasma generation. Other than that, it also can be explain using Ideal Gas Law. According to Ideal Gas Law $PV = mRT$, pressure is directly proportional to temperature. Temperature will increase if pressure increase when volume is kept constant. Ideal gas law is derived from Boyle's Law and Charles Law. It is represented by formula $P = mRT/V$ and $P = \left(\frac{nR}{V}\right)T$ respectively. In this simulation, volume is kept constant and types of gas manipulated will absorb heat from microwave oven and increase in temperature forming a region with high pressure. High pressure in the reactor will cause liquid temperature to raise easily hence it has good potential to promote generation of plasma in liquid at region around tip of electrode.

4.4 Results Data

Fig 4.5 shows temperature contour generated and Table 4.1 shows temperature at each line along Y-axis. It shows a highest temperature of 393.6K at water region and lowest temperature of 322.5K at the base. Highest temperature concentrated above tip of copper electrodes. From the simulation generated, temperature distribution at water region is large.

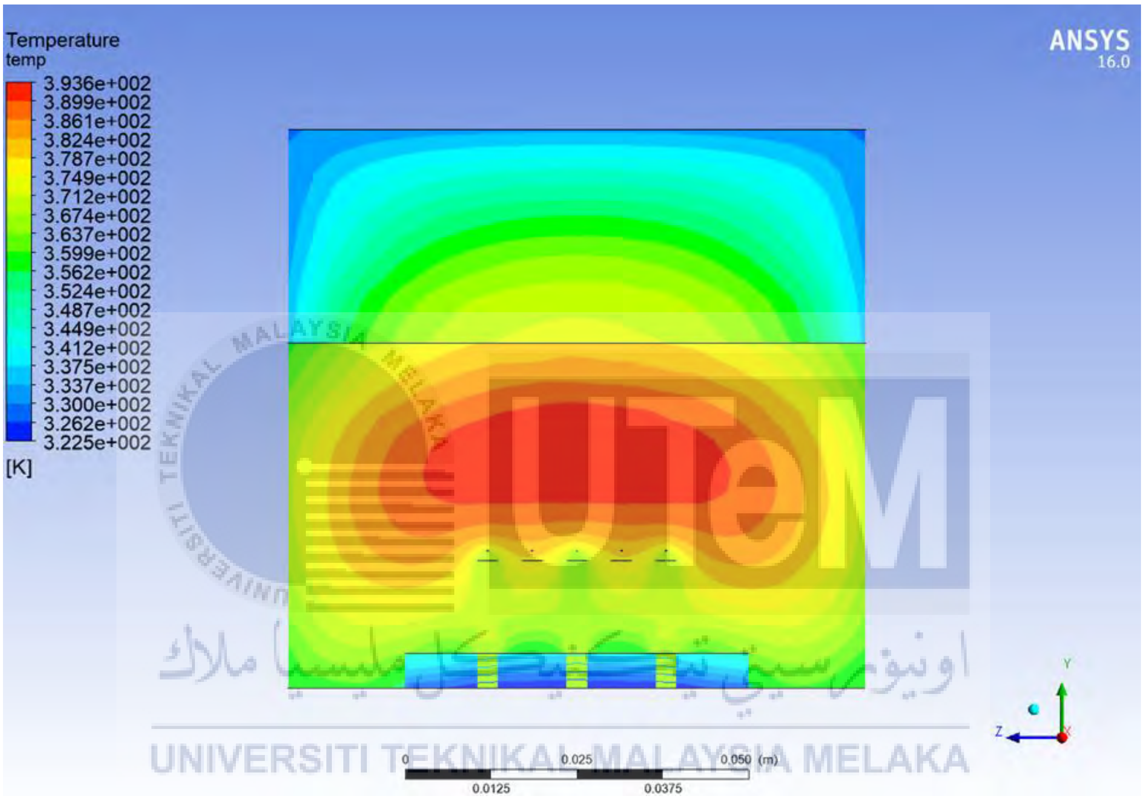

Figure 4.5 Simulation result of water liquid with argon gas

Table 4.1 Temperature along Y-axis at each line for water liquid with argon gas

Y [m]	Temperature [K]				Region
	Line1	Line2	Line3	Average	
0.00	365.30	367.29	367.30	366.94	Copper Electrode
0.01	365.52	367.52	367.53		
0.02	366.01	368.01	368.02		
0.03	390.00	390.12	390.19	384.18	Water
0.04	393.17	391.84	392.08		
0.04	385.30	383.68	384.12		
0.05	371.04	369.39	369.21		
0.06	363.37	361.63	361.43	348.18	Gas
0.07	350.52	349.33	349.19		
0.08	332.88	332.64	332.61		
Average	368.31	368.14	368.17		

Fig 4.6 shows graph of temperature along Y-axis. The trend of the temperature shows region with highest and lowest temperature. All three lines shows a slight increase in temperature from 0m to 0.02m, this shows that tip of the electrodes has higher temperature than its body. Then, temperature increase constantly to its peak at 393.7K at water region before dropping as approaching to water surface at 0.05m to 370K. Temperature continue to drop constantly along Y-axis at gas region to temperature of 368K. Lowest temperature is seen at the platform.

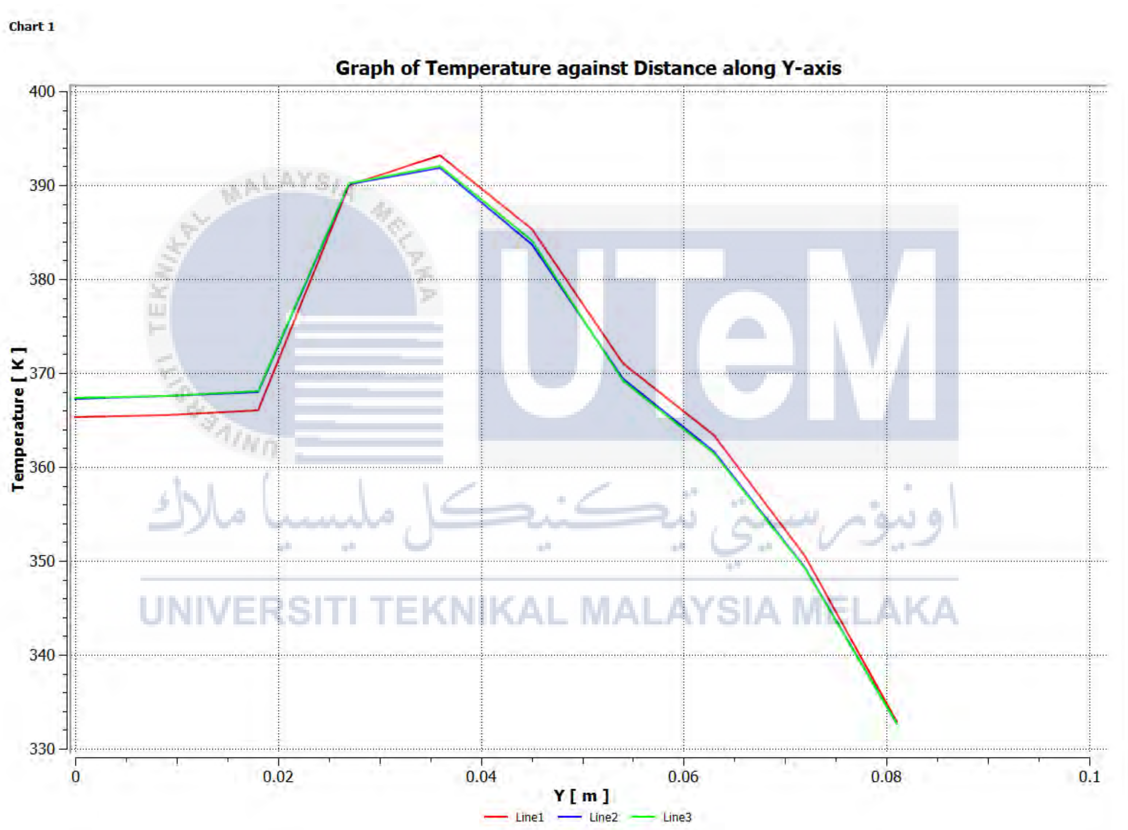

Figure 4.6 Graph of temperature against distance along Y-axis for water liquid and argon gas

Fig 4.7 shows the temperature contour generated and Table 4.2 shows the temperature at each line along Y-axis. It is clearly shown that highest temperature is concentrated at water region around copper electrode tip at temperature of 384K. It is clearly shown that gas region at the beaker mouth has lowest temperature at 303.4K.

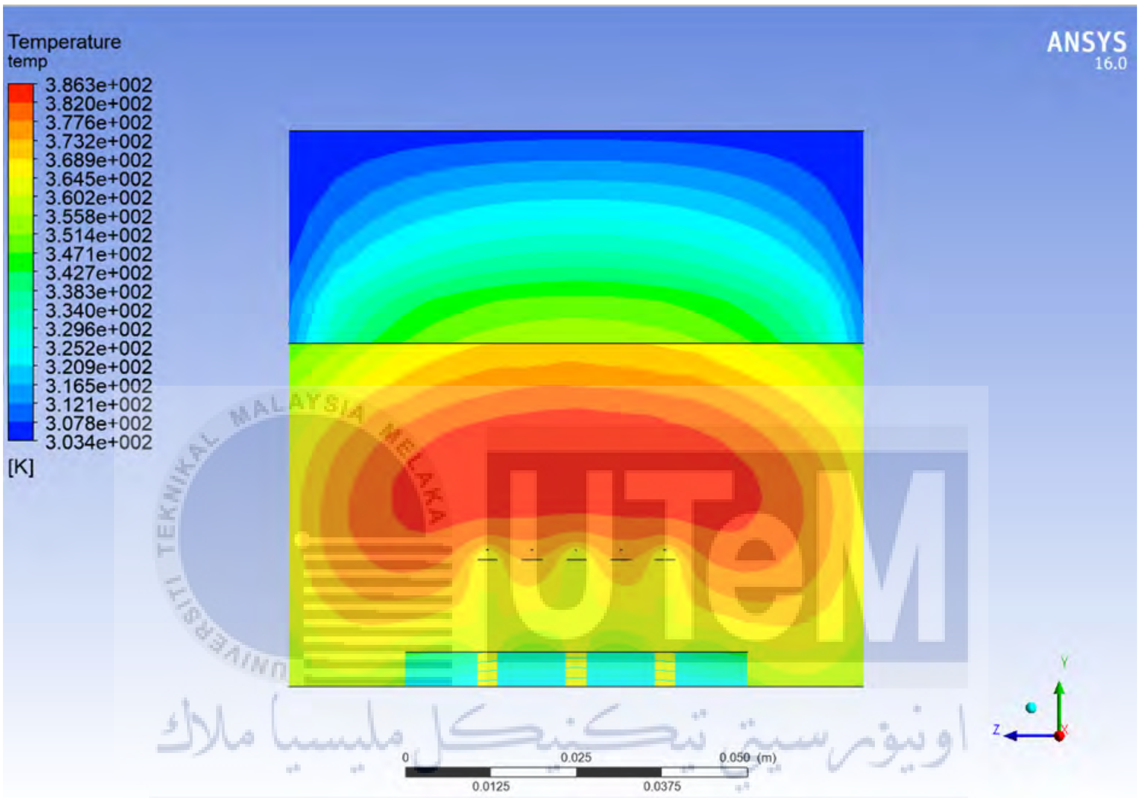

Figure 4.7 Simulation result of water liquid with helium gas

Table 4.2 Temperature along Y-axis at each line for water liquid with helium gas

Y [m]	Temperature [K]				Region
	Line1	Line2	Line3	Average	
0.00	361.82	364.09	364.07	363.6	Copper Electrode
0.01	362.02	364.30	364.28		
0.02	362.44	364.72	364.70		
0.03	383.95	384.25	384.33	373.36	Liquid Region
0.04	385.37	384.15	384.42		
0.04	375.74	374.05	374.58		
0.05	351.03	349.31	349.11		
0.06	334.82	333.15	332.94	319.34	Gas Region
0.07	319.39	318.31	318.17		
0.08	305.94	305.70	305.67		
Average	354.25	354.20	354.23		

From the graph plotted as shown in Fig 4.8, it is shown that Line1 which represent electrode 1 has temperature of 334.71K which is lower than 336.35K at Line2 and Line3 which represent electrode 2 and 3 respectively at position Y=0m.

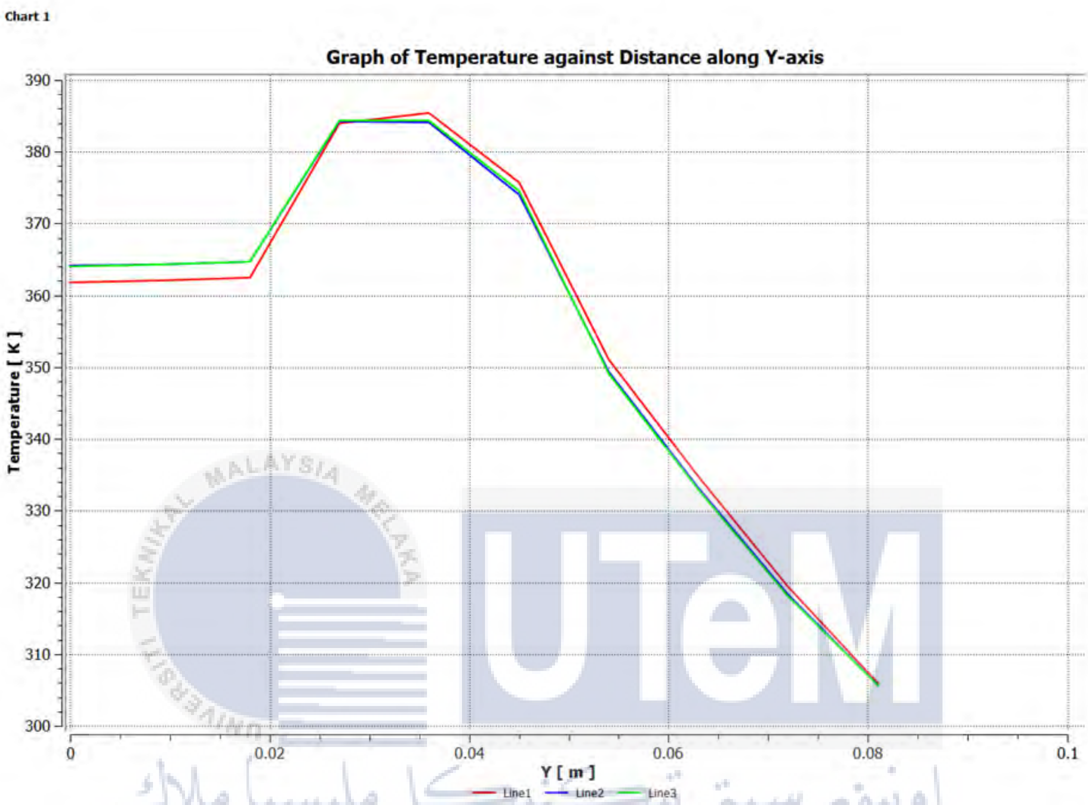

Figure 4.8 Graph of temperature against distance along Y-axis for water liquid and helium gas

Electrode temperature shows a very mild increase from its body to its tips. Temperature increase constantly to highest temperature of 385K at Y=0.036m before starting to drop sharply as approaching water liquid surface. At gas region, temperature continues to drop constantly from Y=0.05m to 0.081m to a temperature of 303.4K.

From the temperature distribution as shown in Figure 4.9 above, highest temperature 459.34K is at Y=0.04m in palm oil region whereas lowest temperature is 304.77K at Y=0.08m at gas region. Table 4-3 shows temperature at each line along Y-axis. It is shown that temperature at palm oil is concentrated where heat does not widely spread widely at water region.

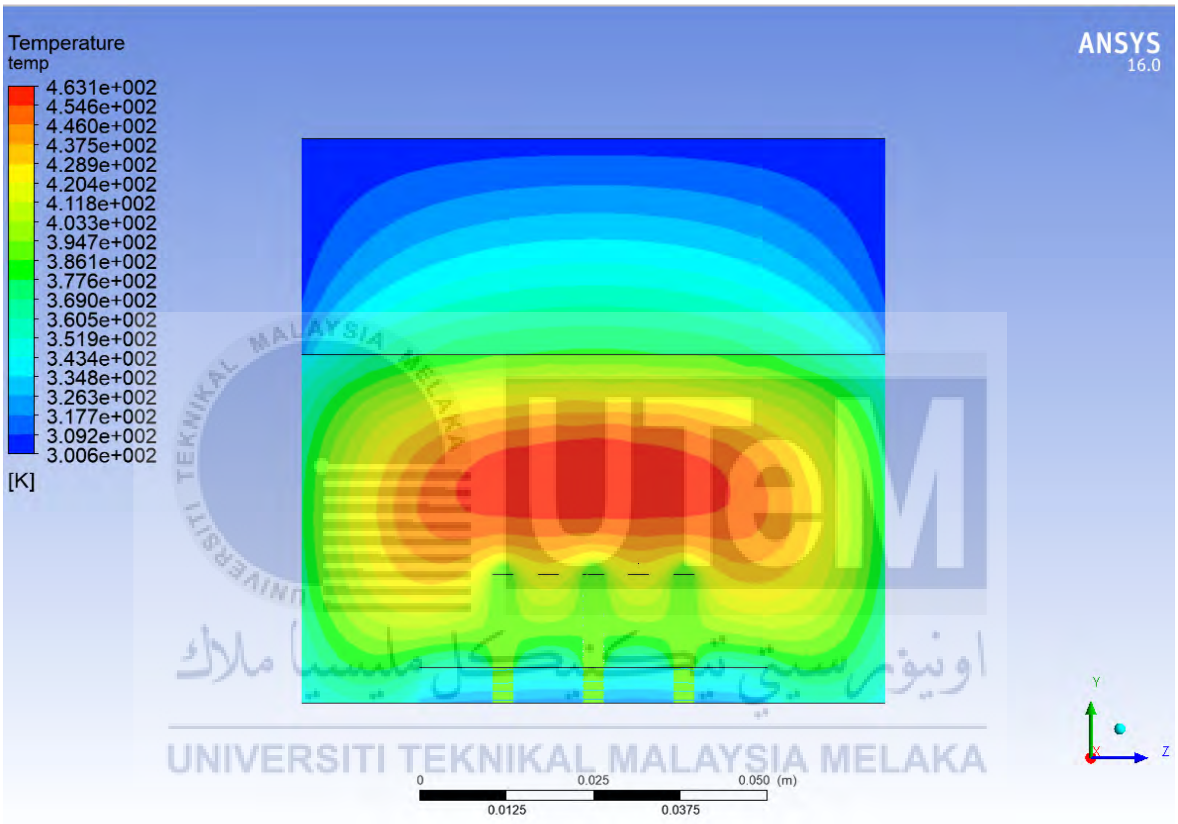

Figure 4.9 Simulation result for palm oil and argon gas

Table 4.3 Temperature at each line along Y-axis for palm oil and argon gas

Y [m]	Temperature [K]				Region
	Line1	Line2	Line3	Average	
0.00	386.25	389.28	389.14	388.46	Copper Electrodes
0.01	386.39	389.42	389.29		
0.02	386.80	389.85	389.71		
0.03	456.10	455.09	455.21	424.14	Palm-oil
0.04	459.34	455.33	454.75		
0.04	419.11	415.97	415.41		
0.05	369.54	366.92	366.86		
0.06	343.82	341.22	341.18	322.73	Gas
0.07	322.75	321.04	321.02		
0.08	304.77	304.38	304.38		
Average	383.49	382.85	382.70		

From the graph plotted as Fig 4.10, trend of temperature variation of the simulation is determined. Temperature at copper electrode is constant from its body to tip. Then, temperature spike up at palm-oil region to highest temperature at 459.3K. As Y distance increase and approach palm oil surface, temperature start to drop drastically. At gas region, temperature continue to drop as distance Y increased at a steady rate. Line2 and line3 which represent electrode 2 and 3 respectively shows similar trend whereas electrode 1 has lower temperature at Y=0m compare to electrode 2 and 3.

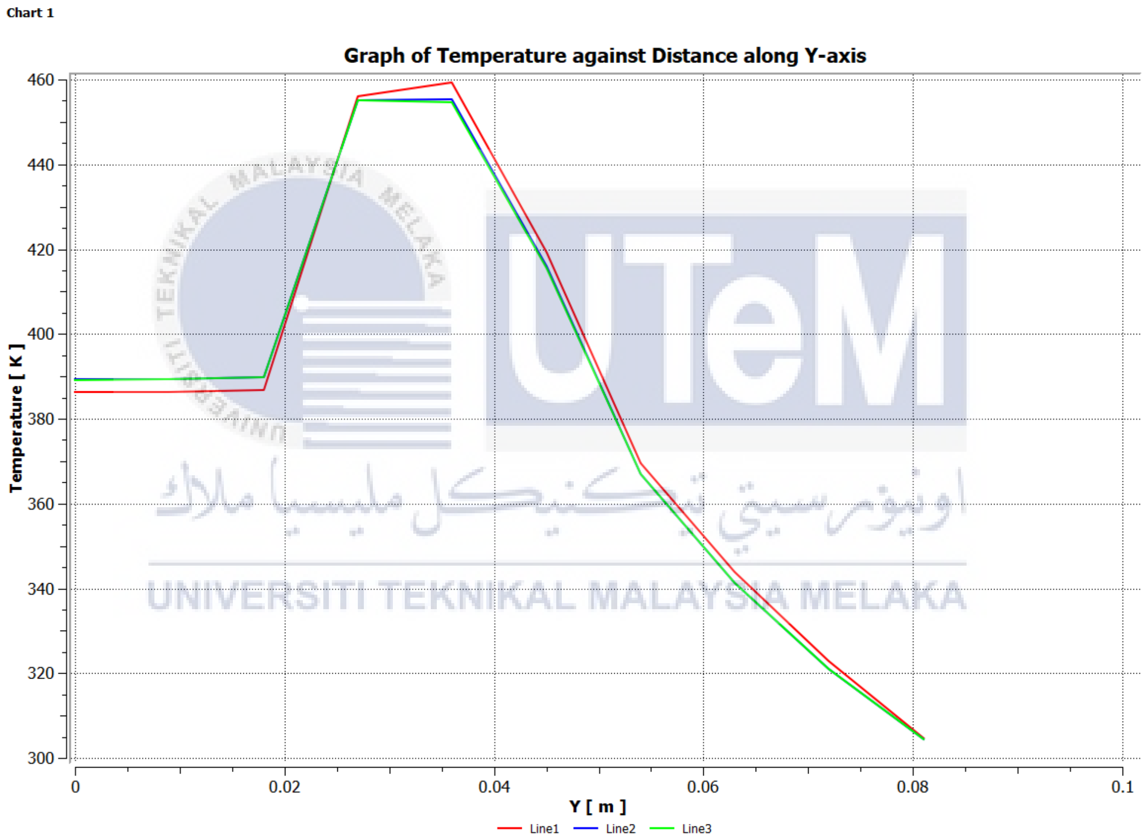

Figure 4.10 Graph of temperature against distance along Y-axis for palm oil with argon gas

Fig 4.11 above shows simulation result of palm-oil with helium gas and Table 4.4 shows temperature at each point along each line along the Y-axis. The highest temperature is at 454.1K at fluid domain region whereas lowest temperature is 315.4K at the platform and helium gas region. From the contour, it is indicated that only small amount of heat is transfer to gas region.

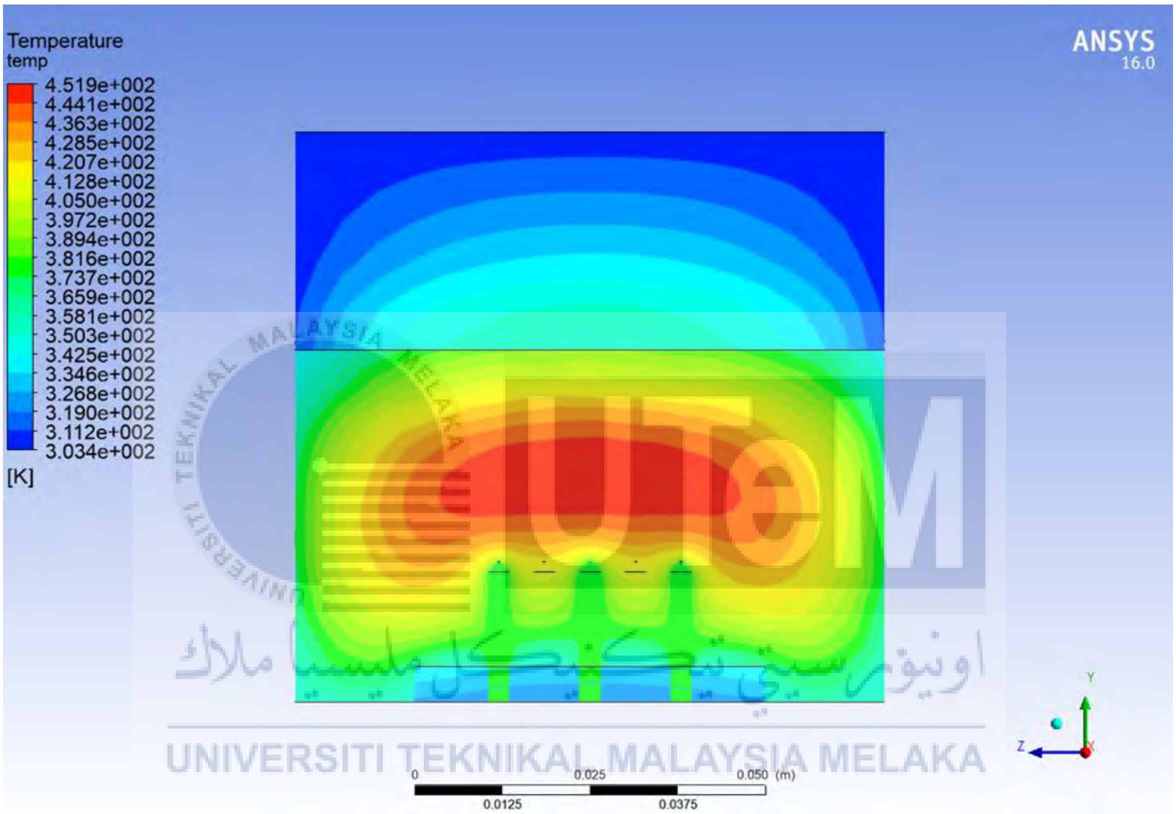

Figure 4.11 Simulation result for palm oil with helium gas

Table 4.4 Temperature at each line along Y-axis for palm oil with helium gas

Y [m]	Temperature [K]				Region
	Line1	Line2	Line3	Average	
0.00	374.50	378.91	378.91	377.7	Copper Electrode
0.01	374.69	379.10	379.11		
0.02	375.07	379.49	379.50		
0.03	444.89	445.18	445.42	413.01	Water Region
0.04	447.70	444.16	445.07		
0.04	411.09	407.18	409.44		
0.05	353.73	351.29	351.03		
0.06	336.11	334.00	333.74	319.8	Gas Region
0.07	319.88	318.60	318.44		
0.08	306.01	305.74	305.71		
Average	374.37	374.36	374.64		

Fig 4.12 shows graph of temperature against distance along Y-axis. It is clearly seen that temperature at electrodes are kept constant at 375K for electrode 1 and 380K for electrode 2 and 3. Temperature spike up constantly at water region to maximum temperature of 454.4K at Y=0.03m which is 0.01m from electrode tip. Temperature starts to drop towards palm-oil surface to 360K. At helium gas region, temperature drop constantly from 370K to 320K.

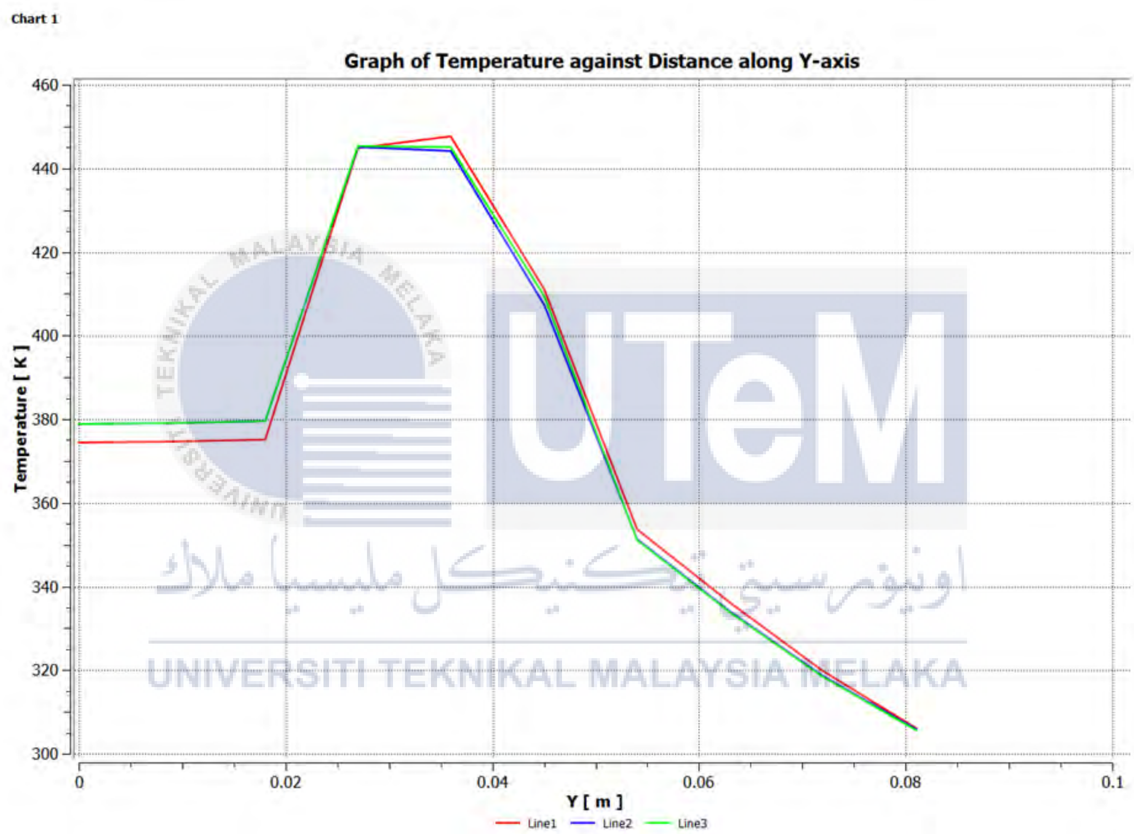

Figure 4.12 Graph of temperature against distance along Y-axis for palm oil with helium gas

4.5 Discussion

Table 4.5 show summarization of average temperature in each component in the reactor. However, platform is not included as platform is not the point of interest and material used for platform is thermal insulator, the material used is PTFE. Heat transfer to thermal insulator is small and negligible.

Table 4.5 Average temperature at each region with different combination of liquid and gas

Combination	Temperature [K]		
	Copper Electrode	Liquid Region	Gas Region
Water liquid with Argon Gas	366.94	384.18	348.18
Water liquid with Helium Gas	363.6	373.36	319.34
Palm oil with Argon Gas	388.46	424.14	322.73
Palm oil with Helium Gas	377.7	413.01	319.8

In the first and second simulation, fluid domain in the reactor is fixed as water liquid to determine the effect of argon and helium gas to water. Argon gas yield higher temperature than helium gas and based on Ideal Gas Law concept discuss earlier, argon temperature become higher resulted from increasing pressure in the reactor. Less heat will be transfer to gas region from liquid region as heat tends to transfer from high temperature region to low temperature region. Similar result is yield when palm oil is fixed as liquid domain. This phenomenon of argon gas yield higher temperature than helium gas can be explained based on thermal characteristics of both argon gas and helium gas. Comparison of thermal characteristics of both types of gas is summarized in the Table 4.6,

Table 4.6 Thermal properties of argon and helium gas

	Argon	Helium
Density (kg/m3)	1.6228	0.1625
Cp (j/kg.K)	520.64	5193
Thermal Conductivity (W/m.K)	0.0158	0.152
Viscosity (kg/m.s)	2.125e-5	1.99e-5

Based on thermodynamic properties of these gas argon has lower heat capacity compare to helium gas, helium gas needs higher amount of heat energy to increase in 1̊C compare to argon. In term of specific heat capacity, argon has lower specific heat capacity than helium which means temperature will go up faster in argon gas. Argon gas will be used up chemically under high temperature to initiate in liquid plasma. This justified argon has better quality in order to promote generation of in liquid plasma.

Studies between heat transfer on different types of fluid are conducted. Based on the mean temperature at the fluid region, it can be said that palm oil can achieve higher temperature than water. For water liquid, highest temperature contour shows temperature of 393.17K whereas simulation for palm oil yield highest temperature of 459.34K. This phenomenon can also be explained based on thermal properties of palm oil and water liquid. Table 4.7 shows thermodynamics property of fluid involve in this simulation. Properties of the decides outcome of temperature contour. As heat penetrated to the reactor, material with own's respective thermodynamics property will absorb different amount of heat and generate different temperature distribution.

Table 4.7 Thermal properties of water liquid and palm oil

	Water liquid	Palm oil
Density (kg/m3)	998.2	890.1
Cp (j/kg.K)	4182	1861
Thermal Conductivity (W/m.K)	0.6	0.1721
Viscosity (kg/m.s)	0.001003	86.97

Retrieve from(LIPICO Technologies, 2018)

It can be explained in term of specific heat capacity of both types of liquids. Palm oil has lower specific heat capacity than water, palm oil has 1861J/kg.K compare to water that has 4200J/kg.K. This mean that palm oil needs less heat to raise in 1̊C compare to water and palm oil will get heated more easily than water liquid.

In addition, based on temperature contour generated, it is found that water liquid has bigger spread of heat compared to palm oil. This is cause by the difference of thermal diffusivity of both liquids. Thermal diffusivity relates thermal conductivity, density and specific heat capacity of matter. Material with larger thermal diffusivity resulted with higher rate of heat transfer whereas material with smaller thermal diffusivity indicates that most of the heat is absorbed by the material but small amount of heat is conducted further. Palm oil has lower thermal diffusivity than water liquid that is why heat is more concentrated in palm oil is smaller compare to water. To generate in liquid plasma, it is preferable for liquid that can trap heat as heat is concentrated, bubble will be formed more easily and generate plasma.

Water liquid is Newtonian-Fluid whereas palm oil is Non-Newtonian Fluid. Both of this liquid cannot be compared directly in term of viscosity. Instead it can be said that Newtonian has constant viscosity without changing with shear stress rate whereas Non-Newtonian Fluid does not have constant viscosity, the viscosity varies with shear rate. Viscosity decrease as a result of increasing temperature causing shear rate and shear stress to increase. When shear stress increase, friction force increase. Heat is generated from friction force. With constant viscosity, shear rate and shear stress remained.

Latent heat of vaporization is defined as heat energy needed to vaporise one mole of liquid at its boiling point. Water has heat of vaporization of around 2260kJ/kg which is lower than palm oil. This indicates that bubble is easier to form as vaporization take place at faster rate. Bubble will form after liquid starts to vaporise. However, palm oil has lower thermal diffusivity. Palm oil will absorb and retain heat from conducted further than water. Rate of heat conduction between water molecules is higher which cause heat will be more distributed. Moreover, palm oil is suitable suited as palm oil has impact on environment, if energy is extracted from palm oil it can reduce the effect of palm oil on environment as its chemical property is changed.

Other than that, graph of temperature against Y-axis distance, the trend shows that electrode 1 has lower temperature than electrode 2 and 3. This is because electrode 1 is situated at the centre of reactor surrounded by 6 other electrodes, the 6 electrodes that surround electrode 1 is the thermal resistance that slow down heat transfer to electrode 1. Heat is absorbed by copper electrodes at the outer region before transferring to electrode 1. Thermal resistance depends on geometry and thermal properties of the medium which can be represented by the formula $R_{conv} = 1/hA_s$. Higher thermal resistance will affect effectiveness of heat transfer in the reactor.

From temperature contour generated it is shown that heat is concentrated at middle of the liquid region as temperature is highest at the region. This phenomenon is cause by adiabatic compression. Adiabatic compression can take place at a closed volume as assume in this study which reactor is considered as complete close volume. Adiabatic compression is a type of heat transfer mechanism that can be relate to "the piston effect" where heat from outer boundary push the heat to interior of the fluid causing heat accumulated at interior region of the fluid(Wunenburger et al. 2000). Comparing to conventional heat diffusion, adiabatic compression takes place at a faster. Heat accumulate at the region will promote initiation of in liquid plasma at the tip of copper electrodes.

Based on temperature distribution at gas region, it is show that temperature drop as distance along Y-axis increase. Highest temperature of gas region is near liquid surface, this is because heat will be released from liquid region. Heat energy get weaker as distance along Y-axis increase. Molecule losses its kinetic energy and cause the reduction in rate of heat transfer.

4.6 Validation

Based on study conducted T. Ishijima et al. water temperature will increase by 20K(Ishijima et al. 2010) from initial temperature. Therefore, from result simulated, difference between highest temperature and lower temperature at liquid region is determined to determine percentage of error. From the simulation done, percentage error is determined from formula below.

$$Percentage\ Error = \frac{Increase\ of\ temperature - 20}{20K} \times 100\%$$

$$= \frac{22.76K - 20K}{20K} \times 100\% = 13.78\%$$

However, the increase of temperature is not consistent. This is because temperature increase is taken without taking consideration of time frame. Increase in temperature is the difference of water temperature at water liquid and argon gas combination obtained from final-result of the simulation. To be accurate, increase in water temperature should be taken within a time frame and determine increase in temperature within the time frame.

As discussed earlier, materials have their respective thermal diffusivity. Thermal diffusivity is also calculated to prove that each liquid and gas stated has higher or lower thermal diffusivity respectively. Following are the calculations,

$$\alpha_{water} = \frac{0.6}{998.2 \times 4182}$$

$$= 1.4373 \times 10^{-7}$$

$$\alpha_{palm-oil} = \frac{0.1721}{1861 \times 890.1}$$

$$= 1.038 \times 10^{-7}$$

$$\alpha_{argon} = \frac{0.0158}{1.6228 \times 520.64}$$

$$= 1.87 \times 10^{-5}$$

$$\alpha_{helium} = \frac{0.152}{5193 \times 0.1625}$$

$$= 1.80 \times 10^{-4}$$

Assumption made in this simulation is whre this case is simulated in an ideal condition where there are no heat or mass transfer out of the system and it is completely seal. The gas injected has 100% purity. In real case, it is unable to achieve ideal condition where there will be heat transferred out of the system and gas injected to reactor also contain other mixture. This study applies convection, conduction and radiation heat transfer, it does not involve dipole oscillation.

Other than that, graph of gas viscosity against temperature is plotted in Fig 4.13 to ensure it is in accordance with theoretical concept. Temperature attain by gas will increase if viscosity of the gas is high when constant heat is supplied. Argon gas has viscosity of $2.13 \times 10^{-5}\ kg/m.s$ while helium gas has viscosity of $1.99 \times 10^{-5}\ kg/m.s$, it obtained the same trend when it is combined with water and palm oil where argon yield higher temperature that helium. The trend obtained is in accordance with theoretical concept.

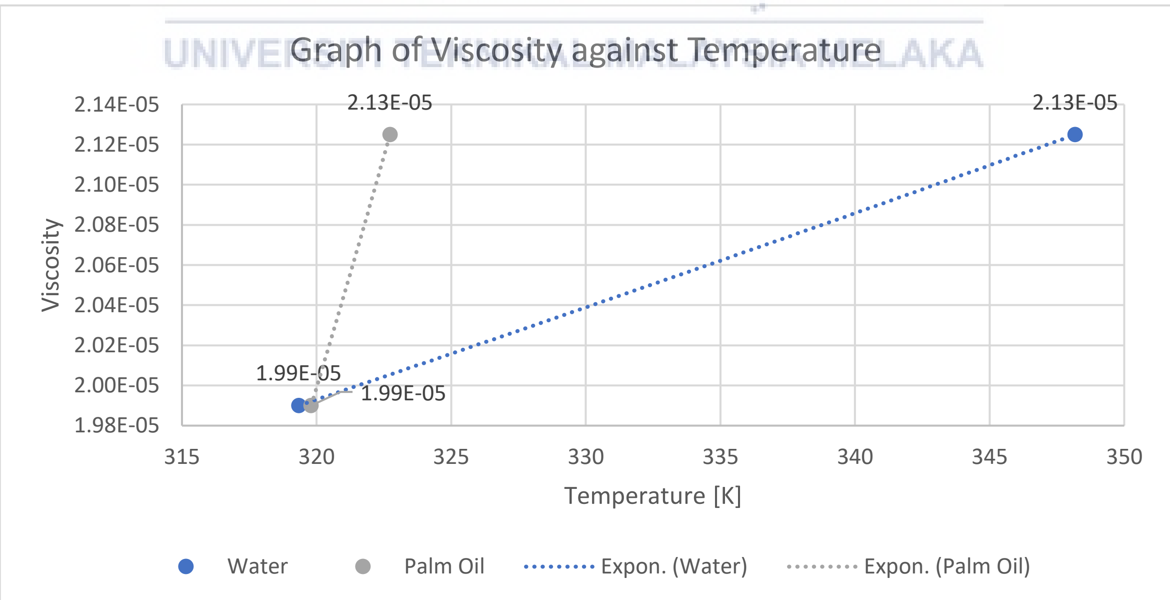

Figure 4.13 Graph of gas viscosity against temperature

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, in liquid plasma has a vast application renewable energy field. Through literature done it is found that there are many types of plasma with own's strength and weakness respectively depending on suitability on different situation. Besides, set up of experiment to generate plasma in liquid can be vary by researchers. Temperature distribution at reactor is studied through an assumption of direct heat discharge from microwave oven, assumption is predicted based on literature review done. Phenomenon on the temperature contour in reactor generated from simulation is discussed. Graph of temperature against distance along Y-axis is plotted to study the trend of temperature difference in the reactor. Table of temperature at each region, copper electrodes, water and gas are tabulated to identify the suitability of each matter in generation of in liquid plasma. Through the analysis based on result obtained from the simulation, temperature of argon gas and helium gas is first compared under water liquid. Argon has average temperature of 341.47K whereas helium has an average of 319.8K. It is further confirmed by using palm oil where result also shows argon has higher temperature. Study also done on different liquid, water liquid and palm oil. By comparing the highest temperature obtained in both liquid palm oil has higher temperature than liquid. Palm oil records highest temperature of 423.18K when argon is injected into the reactor whereas water liquid records at 384.18K when argon gas is injected into the reactor. Besides, it is found that heat distribution in water liquid is more segregated than palm oil which is not suitable for in liquid plasma generation as heat need to be concentrated for bubble to form. Then, it is found that combination of argon gas and palm oil is best combination for formation of plasma at region of copper electrode tip. Other than that, use of palm oil for energy extraction help to conserve the environment as some of it is disposed to the environment without proper process and cause harmfulness to the ecosystem. The highest temperature yield at simulation with palm oil is 459.3K compare to water which is 393.6K. It is proved that types of gas injected into the reactor affects highest temperature achieve in the control volume which is in accordance to Ideal gas Law. Highest temperature yield at combination of palm oil with argon gas is 459.3K compare to combination of palm oil with helium gas that yield 451.9K. Higher temperature will promote formation of bubble and cause ionization process that lead to formation of in liquid plasma.

5.2 Recommendation

For further study, simulation can be done on other CFD simulation software like COSMOL to compare with result generated through ANSYS Fluent for further verification. Other than that, geometry and dimension of the reactor, electrodes and other components can be manipulated to identify the effect of geometry on the heat transfer by analysing temperature distribution. To generate more accurate result, electromagnetic wave simulation can be done on as electromagnetic wave has different mechanism of heat transfer compare to heat transfer by convection, conduction and radiation. Simulation of heat transfer on other waste product can be done to study the effectiveness to extract hydrogen fuel from it and in order to preserve the environment.

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APPENDIX

Appendix A

No.	Action Plan Description	Deadline	PROJECT EXECUTUION PERIOD														
			2018														
			WEEK	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1.	PSM I Briefing		PLAN														
2.	PSM Title Selection and Confirmation		PLAN														
3.	Title Introduction Study		PLAN														
4.	Literature Review		PLAN														
5.	Progress Report Submission		PLAN														
6.	Methodology		PLAN														
7.	Report Inspection by Supervisor		PLAN														
8.	Preliminary Data		PLAN														
9.	Preliminary Data Analysis		PLAN														
10.	Conclusion		PLAN														
11.	Draft Report Submission		PLAN														
12.	Seminar and presentation PSMII		PLAN														