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."

Signature: ……

Author : LAM CHEE SHENG

Date : ……

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)"

Signature :…….....

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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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_{β}. 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:

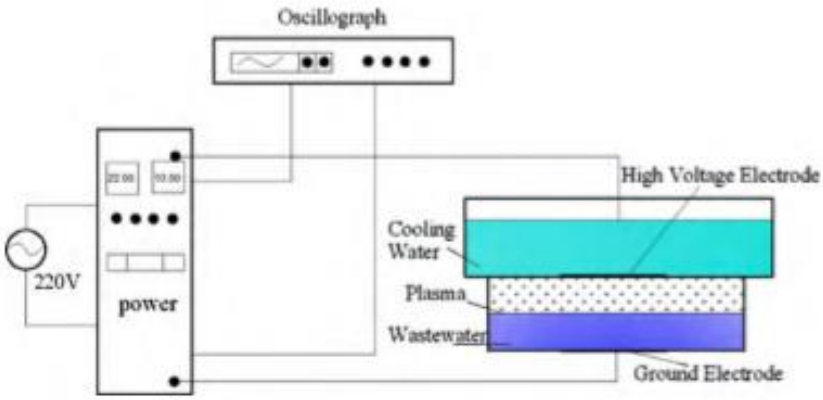

Figure 2.1 Set up of DBD plasma discharge by FangMin Huang et al.

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).

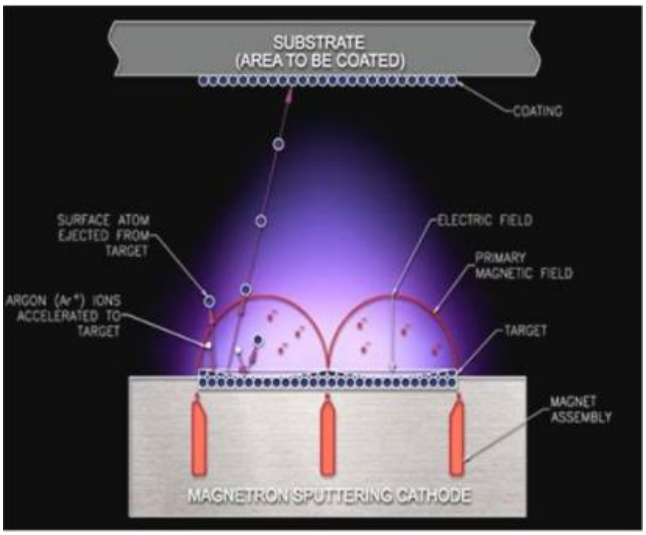

Figure 2.2 Magnetron plasma discharge