UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

CHARACTERIZATION OF HEAT TRANSFER PHENOMENON OF THE ELECTRODE WITH PLATE OVER THE TIP OF ELECTRODE FOR PLASMA GENERATION

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Bachelor in Mechanical Engineering

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KUGAISHAN A/L SUPPARMANIAM

A report submitted in partial fulfilment of the requirements for the degree of

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DECLARATION

I declare that this report entitled "Characterization of Heat Transfer Phenomenon on High Conductivity Round and Sharp-Tip-Shaped Tungsten Electrode" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : KUGAISHAN A/L SUPPARMANIAM

Date : …………………………………….

APROVAL

“I hereby declare that I have read through this report entitle “Characterization of Heat Transfer Phenomenon on High Conductivity Round and Sharp-Tip-Shaped Tungsten Electrode” and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Mechanical Engineering (Thermal-Fluid)”.

Signature : ....

Supervisor’s Name : DR. FADHLI BIN SYAHRIL

Date : ………………………………..

DEDICATION

To my beloved mother and father

ABSTRACT

Recently a new technology was developed to produce hydrogen which known as in liquid plasma. In this technology, the plasma is formed in liquid. Plasma is a state of matter that exist after gas is supplied to sufficient amount of heat. This technology works from the electrical energy. From the electrical energy source heat is generated at the electrode that was immersed in liquid. The liquid used are normally hydrocarbon, water and waste oil. As the heat is focused at the tip of the electrode, plasma is generated on the tip of the electrode. Then radical species is produced. After this radical species react with liquid few gases are formed such as hydrogen, carbon monoxide and carbon dioxide. This technology also can work in commercial oven. In this technology the use of waste oil is highly recommended as it is disposed and at the same time it is used to produce hydrogen gas. However, this technology consumes a lot energy. So, further studies need to be done regarding in liquid plasma technology to enhance the efficiency of heat transfer. In this project the type of electrode, addition of plate over the tip of electrode and type of liquid used for in liquid plasma was studied. This was done by simulating in the Computational Fluid Dynamic. The setup was changed for two models. The results were compared for the highest heat gain by comparing the maximum temperature over the electrode. If the temperature over the electrode tip is high, the liquid will change into gas and the high temperature will ease the formation of plasma. From the result, the maximum temperature over the tip of electrode was obtained for in liquid plasma when tungsten was used as electrode, plate was not added over the tip of electrode and dodecane was used as a liquid for in liquid plasma. The high maximum temperature indicates that the in-liquid plasma requires less energy to initiate plasma.

ABSTRAK

Baru-baru ini teknologi baru telah dibangunkan untuk menghasilkan hidrogen yang dikenali sebagai plasma cecair. Dalam teknologi ini, plasma terbentuk dalam cecair. Plasma adalah keadaan yang wujud selepas gas dibekalkan kepada jumlah haba yang mencukupi. Teknologi ini berfungsi dari tenaga elektrik. Dari haba sumber tenaga elektrik dihasilkan pada elektrod yang direndam dalam cecair. Cecair yang digunakan biasanya adalah gas asli, air dan minyak sisa. Apabila haba tertumpu di hujung elektrod, plasma dijana pada hujung elektrod. Kemudian spesies radikal dihasilkan. Selepas spesis radikal ini bertindak balas dengan beberapa cecair gas terbentuk seperti hidrogen, karbon monoksida dan karbon dioksida. Teknologi ini juga boleh berfungsi dalam oven komersial. Dalam teknologi ini penggunaan minyak sisa sangat disyorkan kerana ia dilupuskan dan pada masa yang sama ia digunakan untuk menghasilkan gas hidrogen. Walau bagaimanapun, teknologi ini menggunakan banyak tenaga. Oleh itu, kajian lanjut perlu dilakukan mengenai teknologi plasma cecair untuk meningkatkan kecekapan pemindahan haba. Dalam projek ini, jenis elektrod, penambahan plat di atas hujung elektrod dan jenis cecair yang digunakan untuk plasma cecair telah dikaji. Ini dilakukan dengan mensimulasikan dalam Computational Fluid Dynamic. Persediaan telah ditukar untuk dua model. Hasilnya dibandingkan dengan kenaikan haba tertinggi dengan membandingkan suhu maksimum atas hujung elektrod. Jika suhu di atas hujung elektrod adalah tinggi, cecair akan berubah menjadi gas dan suhu tinggi akan memudahkan pembentukan plasma. Dari hasilnya, suhu maksimum di atas hujung elektrod diperolehi dalam plasma cecair apabila tungsten digunakan sebagai elektrod, plat tidak ditambah di atas hujung elektrod dan dodekane digunakan sebagai cecair untuk plasma cecair. Suhu maksimum yang tinggi menunjukkan bahawa plasma dalam cecair memerlukan tenaga yang kurang untuk memulakan plasma.

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CHAPTER 1

INTRODUCTION

1.1 Project background

Hydrogen gases are one of the most abundant gas on the earth. Hydrogen is used in many applications such as aerospace application, glass purification, petroleum refining and used as a coolant in power plant generator. One of the technologies used to produce hydrogen is by in liquid plasma. In this technology, plasma is generated in liquid at high temperature. This liquid then decomposed into gas by thermal decomposition according to molecules in liquid and several other gases as a by-product.

Plasma is fourth state of matter that exists when gas is heated under high temperature. Vaporization or decomposition of raw material into gases phase occurs due to the high temperature of plasma (Rahim et al., 2015). After that, due to simultaneous nucleation and quenching ultrafine particles are formed. For in liquid plasma, plasma is generated at the area where the heat is accumulated which is usually over the tip of electrode. At the beginning of the plasma formation, the liquid is changed to radical species. Then this radical species reacts with liquid to form gases. For example, in liquid water the radical species formed are OH radical, H alpha, H beta and many other radial species. These radical species then react with water molecules to form hydrogen, carbon monoxide, carbon dioxide and many other gases.

For produce hydrogen gas by in liquid plasma, the target material should contain hydrogen. The target material or liquid that are commonly used to produce hydrogen by in liquid plasma are water, alcohol, and oil. So, the best material to use for in liquid plasma is waste oil. By using waste oil, the hydrogen gas can be produced while disposing the waste oil. One of the examples of waste oil that can be used in this country is palm oil waste.

The plasma can be formed using two methods. First is directly heating the electrode from the heat source. Second is heating the electrode through microwave radiation. To study about the in liquid plasma, the plasma was generated in commercial microwave oven with a supply of 750 watts power and 2.45 Hz frequency for experiment. However, to prevent from any losses due to the experiment, computational fluid simulation using Ansys Fluent shall be done. For in liquid plasma to be efficient the studies shall be done to reduce heat losses, focuses the heat formed over the tip of the electrode, and to increase the formation of hydrogen gases. By being more efficient, the electrode requires less heat energy to form plasma compared to the existing in liquid plasma. In other word by reducing the required heat energy, the cost for the formation of hydrogen gas can be reduced. There are a lot of improvement can be done for in liquid plasma to be efficient. For this study, the heat formed for the initiation of plasma over the tip of the electrode was investigated. To generate plasma, liquid have to formed as gas. Then after the further increase in temperature, the gas will turn to plasma. So, in order to initiate plasma, the liquid has to exceed the boiling point. In this study, three different condition were compared by comparing the temperature formed over the tip of the electrode. The three conditions are in-liquid plasma for tungsten and copper electrode without plate over the tip of electrode, in-liquid plasma with and without plate over the tip of electrode and in-liquid plasma with plate over the tip of electrode with water and dodecane as a liquid. The comparison was based on the maximum temperature that can be formed from same heat transfer rate which is 750W. Figure 1 below shows one of the in liquid plasma.

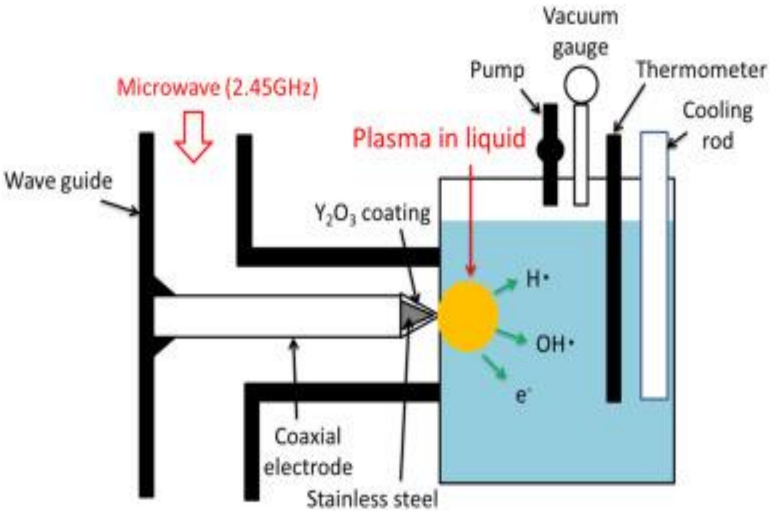

Figure 1: Example of in liquid plasma formed from microwave radiation(Rahim et al., 2015).

1.2 Problem statement

In liquid plasma technology consumes a lot of electrical energy which can be very costly. This happens due to several losses that occurs during the process. Apart from that, rate of hydrogen gas produced also should be increased. Moreover, the percentage of hydrogen gas from all gases that is accumulated from the in liquid plasma production is less. If these problems can be encountered, the in liquid plasma technology will be more efficient. To achieve that few improvements can be done. Firstly, the type of electrode used can be changed with electrode that can produce more heat. This electrode should be cheap and has high thermal conductivity. Then adding plate over the tip of the electrode can hold the hydrogen gas from spreading throughout the liquid. However, heat transfer for addition of plate over the tip of electrode should be investigated. Furthermore, the type of liquid also can affect the temperature over the tip of electrode.

1.3 Objectives

The objectives of this project are:

1. To investigate the heat transfer for copper and tungsten electrode under microwave heating.
2. To investigate the effect of adding plate over the tip of electrode on the heat transfer under microwave heating.
3. To investigate the effect of type of liquid on the heat transfer under microwave heating.

1.4 Scope

This project mainly concerns to increase the efficiency of the in liquid plasma. So, the important part that need to do improvement is the type of electrode used, addition of plate over the tip of electrode, and type of liquid used. The electrode material, addition of plate over the tip of electrode and type of liquid plays important role in heat transfer to form plasma. Thus, these properties need to be studied and improved to increase the efficiency.

1.5 General Methodology

To study the heat transfer over the tip of electrode, computation fluid simulation must be generated. The simulation is set to transfer heat from 2.45 Hz and 750 W microwave radiation. The simulation is visualized such a way that convectional microwave oven consists of beaker filled with liquid and fully covered with Teflon on top of the beaker. In water consist of electrode, stainless steel base and metal plate over the tip of electrode for in-liquid plasma with plate. So, the radiation from through the microwave oven to the beaker glass, conduction through the glass beaker, and convection and conduction through liquid to the electrode can be determined through the simulation result. Since Ansys Fluent cannot solve the Maxwell's equation, the study was constrained to heat transferred over the tip of electrode. This simulation is done four times using two different model. Each for different condition of in-liquid plasma.

CHAPTER 2

LITERATURE REVIEW

2.1 Plasma

Movement of atoms and molecules of a matter caused by the energy obtained by the matter changes its form into liquid. If the matter receives further energy, the matter will eventually change into gas. If the matter receives further energy, the atoms and molecules of the matter forms into electrons and ions. This is the fourth state of matter which is called plasma. Earth's temperature and pressure is not favourable condition for the formation of plasma. However, in the universe most of matters are in the form of plasma(D'Agostino et al., 2005).

However, by applying high electric power into a gas, plasma can be created in the earth surface. Depending on the pressure intensity, the plasma formed can be low temperature, non-equilibrium plasma or an equilibrium thermal plasma. Among these, non-equilibrium plasma formation that can be created in many ways for technology applications, are much interested. This is because in non-equilibrium plasma, the electron gas will be at high temperature which about 10000 K, while keeping the gas molecules and ions cold which is about 300 K. The covalent chemical bonds of the gas molecules can be broken by the chemical reaction from the hot electron gas which has high energy. This will eventually lead to energy transferred from the collision. To optimize the technology application involving plasma a few characteristics must be considered which is the choice of gas or gas mixture, technique of energy input, and reactor geometry

2.1.1 Plasma in liquid

Plasma can be created through ionization of gases. This can be accomplished by thermal energy or electric field(Pavón, 2008). When the thermal energy reaches ionization energy, atoms breaks into smaller matter. That huge amount of energy is sufficient to defeat the binding force in the atoms. This is achieved by the electron which at the higher state of atoms and molecules that receive energy from in elastic collision of particles. While the plasma formation by electric field is achieved by using high intensity electromagnetic source from the surrounding. The ions and extra electron are created by the alternating electromagnetic that accelerate and collide inelastically the free electron with molecules in the gas. These phenomena is called as Townsend avalanche When the microwave radiation is continuously supplied, the liquid over the tip of electrode will achieve an energy beyond its dielectric limit. This will cause it to fell into an electrical break down stage which can be identified from the spark formation that will eventually form into plasma. The plasma is formed over the tip of electrode because the electromagnet wave that penetrate in to metal will causes it to move electron. These electrons will be concentrated at the sharp tip as it has no other places to go. These electrons will create more heat by colliding each other. Moreover, these electrons will cause more collision among ions and electrons in the liquid as it attracts positive ions and repels electrons. Apart from that, some liquids will have magnetic effect when electromagnetic wave pass through or in contact with them.

2.2 Dielectric

A dielectric material can act as capacitor when the material is placed between two electrodes that is connected to current. So, there is no direct current conductivity throughout the two electrodes and the material can store charge. About several years the prediction of moisture content in material such as in cereal grains is determined by their dielectric properties(S. O. Nelson, 1977). After the dielectric properties of cereal grains was reported, much more data and information are available and these information are used for the further evaluation of dielectric property(S. Nelson, 1991). Microwaves will react with material based on their dielectric property. Microwave will tend to react more with higher lossy material. This finding enables the microwave to be used for many other purposes. For example, the idea of dielectric implemented in joining the ceramics or polymers. The conventional method involves in heating the interface through layers by conduction to attach it. However, this method consumes a lot of time and energy. While by using microwaves, the heating can be focused particularly at the interface. This can be accomplished by incorporating higher lossy material at the interface(Venkatesh & Raghavan, 2004). Then the heating of material particularly high at the higher lossy material makes it possible to start a chemical reaction that is not possible to occur in conventional heating. One of the examples of this is in-liquid plasma.

The ability of dielectric material to store charge is called permittivity, ε. However, this permittivity is not influenced by the material's dimension. The relative permittivity is the permittivity of material in relative to the permittivity of free space and called as dielectric constant(Gabriel et al., 1998). The ability of the dipoles of dielectric material to move from their original orientation affects the dielectric polarisation. Thus, the higher the permanent dipole moments, the higher the material's dielectric constant. For solid the dielectric constant is different from liquid and gas due to the restriction to move freely. For solid due to the restriction the molecular rotation is difficult to be achieved. Thus, the rotation of molecules due to the electric field is not contributing dielectric constant. But for liquid and gases the molecules responses with changing electric field which occurs 10^6 seconds or higher.