THE STUDY ON HEAT DISTRIBUTION INSIDE THE COMBUSTION CHAMBER OF A GAS FIRED PYROLYSIS SYSTEM

AHMAD ZULFADZLI BIN AHMAD MURAD

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Faculty of Chemical & Natural Resources Engineering
Universiti Malaysia Pahang

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ABSTRACT

The ability of lignocelluloses materials to pyrolyze into bio-fuel depends on the amount of heat transferred supply to the biomass feed. Typically, by using fixed bed pyrolysis system, heat is supplied through the reactor wall. In this research, the effects of heat distribution inside the combustion chamber of direct fired pyrolysis system is studied to look the effectiveness heat transfer process from gas burner to the reactor. The experiment of different setting of fuel and air of gas burner was done. The settings are 16 mbar of fuel with 2.5 of air, 16 mbar of fuel with 5 of air, 16 mbar of fuel with 7.5 of air, 19 mbar of fuel with 2.5 of air, 19 mbar of fuel with 5 of air, and 19 mbar of fuel with 7.5 of air. The temperatures distributions of the furnace were investigated. The different type of the setting of fuel and air for gas burner will influence the heat distribution in the gas fired pyrolysis system. The results of the heat distribution of the furnace show similar pattern for 6 different setting but the temperature value were different. The best setting of fuel and air was gained by selecting the shortest time of the setting to reach 400 ºC of the temperature of the reactor. The 400 ºC is the temperature of pyrolysis process started. It was found that the best setting of fuel and air for gas burner is the setting of 19 mbar of fuel with 2.5 of air. The time taken to achieve pyrolysis temperature from the best setting is 25 minutes. The heat distribution patterns also have been reviewed and discussed in this research. This study provides clearer insight into the heat distribution of the gas fired pyrolysis system.

ABSTRAK

Kebolehan lignosellulosik untuk dipirolisiskan kepada bio minyak bergantung kepada kuantiti haba yang dipindahkan kepada sumber biojisim. Kebiasaannya, dengan menggunakan sistem pirolisis, haba yang dihasilkan melalui dinding reaktor. Dalam kajian ini, kesan penyebaran haba di dalam ruang pembakaran sistem pirolisis dipelajari untuk mengetahui keberkesanan peralihan haba di dalam sistem. Eksperimen dijalankan dengan membezakan tetapan bahan bakar dan peredam udara di dalam pembakar gas. Tetapannya ialah 16 mbar bahan bakar bersama 2.5 udara, 16 mbar bahan bakar bersama 5 udara, 16 mbar bahan bakar bersama 7.5 udara, 19 mbar bahan bakar bersama 2.5 udara, 19 mbar bahan bakar bersama 5 udara dan juga 19 mbar bahan bakar bersama 7.5 udara. Peredaran haba yang terhasil daripada bekas pembakaran dikaji. Tetapan bahan bakar dan juga peredam udara akan mempengaruhi taburan haba di dalam sistem pirolisis. Hasil kajian taburan haba terhadap system pirolisis, ia menunjukkan bentuk graf yang seragam bagi tetapan yang berlainan. Tetapi, suhu bagi setiap tetapan menunjukkan nilai yang berbeza. Tetapan bahan bakar dan peredam udara yang terbaik terhasil dengan memilih tetapan yang boleh meningkatkan suhu reaktor kepada 400 ºC dengan masa yang paling singkat. Pada suhu 400 ºC, proses pirolisis bermula. Melalui kajian, didapati tetapan bahan bakar pada nilai 19 mbar dan 2.5 udara menunjukkan keputusan yang terbaik. Masa yang diambil untuk mencapai suhu pirolisis daripada tetapan yang terbaik adalah 25 minit. Bentuk taburan haba juga di perhatikan dan di bahas dalam kajian ini. Kajian ini menjurus lebih dalam tentang taburan haba di dalam system api pirolisis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF SYMBOLS

ºC	-	degree Celsius
%	-	percent
µV/ ºC	-	microvolt per degree Celsius
Btu	-	British Thermal Units
cm/s	-	centimeter per seconds
CO_2	-	Carbon Dioxide
EFB	-	Empty Fruit Bunches
FFB	-	Fresh Fruit Bunches
H_2		Hydrogen
Kg	-	kilogram
kW	-	kilowatt
LPG	-	Liquid Petroleum Gas
mbar	-	milibar
mm	-	milimeter
ms	-	Milliseconds
MJ/kg	-	Mega joule per kilogram
MPa	-	Mega Pascal
Mtoe	-	Million tones of oil equivalent
MW	-	Megawatt
CH_4		Methane
R & D	-	Research and Development
s	-	Seconds
t/hr	-	tones per hour
TJ	-	Tera Joule
W/m^2	-	watt per meter square
wt%	-	percent weight

CHAPTER 1

INTRODUCTION

1.1 Research Background

All fossil fuels in the world are nonrenewable, and as such they will eventually be depleted. As they are based on finite resources and their distributions are heavily localized in certain areas of the world, they will become expensive. Further, energy generation from fossil fuels require combustion, thus damaging the environment with pollutants and greenhouse gas emission. In order to sustain the future of the world with a clean environment and no depletive energy resources, renewable energy is the obvious choice. Renewable energy sources include: solar energy, wind energy, geothermal energy, biomass, and hydrogen. Most renewable energy, except for geothermal energy, comes directly or indirectly from the sun. Benefits of renewable energy are numerous and they include: (Sunggyu Lee, 2007)

1. Environmental cleanness without pollutant emission
2. Non depletive nature
3. Availability throughout the world
4. No cause for global warming
5. Waste reduction
6. Stabilization of energy costs

7. Creation of jobs

The renewable energy sources are expected to exhibit the largest change in total energy supply between now and 2030. Nowadays, renewable energy is growing importance in satisfying environmental concerns over fossil fuel usage and its contribution to the greenhouse effect. Palm oil waste and other form of biomass are some of the main renewable energy sources that available and provide the only sources of renewable liquids, gaseous and solid fuels. Palm oil waste and biomass can be used in variety ways to provide energy: (A.V. Bridgewater *et al*.1999).

1. By direct combustion to provide heat for use in heating, for steam production and hence electricity generation.

2. By gasification to provide a fuel gas for combustion for heat, or in an engine or turbine for electricity generation.

3. By fast pyrolysis to provide a liquid fuel that can substitute for fuel oil in any static heating or electricity generation application .The liquid can also be used to produce a range of specialty and commodity chemicals.

Rising income and growing populations have increased energy demand. Energy is required in almost all aspect of everyday life including agriculture, drinking water, lighting health care, telecommunication and industrial activities. Presently, the demand of energy is met by fossil fuels (i.e. coal, petroleum and natural gas). However, at the current rate of production the world production of liquid fossil fuel (petroleum and natural gas) will decline by the year 2012 (Sumiani Yusof, 2004).

Nowadays, the serious pollution through all over the world is mainly causes by the transportation and factories. The world has become highly alerted to the global warming problem. The major greenhouse gas is CO_2, large quantities of which are produced by combustion of fossil fuels by coal being a major contributor. Thus, there is a great demand in using bio fuel instead of fossil fuel energy. Disadvantages of fossil fuel derived transportation fuels beside others problem such as greenhouse gas emissions, pollution, resource depletion, unbalanced supply demand relations, are strongly reduced or even absent with bio transportation fuels (M.Steinberg, 2003).

Renewable energy nowadays is growing importance in supporting environmental concerns over fossil fuel usage. Palm oil and other forms of biomass including energy crops and forestry wastes and agriculture are some of the important renewable energy resources. All of these can be the only source of renewable liquid, gaseous and solid fuels. Biomass is known as the renewable energy that mainly derived from the agriculture or forestry sector. Today, various forms of biomass are consumed all over the world for energy generation. Biomass provides a clean, renewable energy source that could dramatically improve the environment, economy and energy security. The use of these materials will depend on state of the art, economic and technologies that are used to transform them into manageable products. One of the valuable biomass in Southeast Asia is derived from the palm oil which is usually in empty fruit bunches (Mohamad Aziz Zakiran, 2009).

Malaysia is looking forward in industrial and development sector that need sustainable energy resources. Biomass fuels and residues can be converted to energy via thermal, biological and physical processes. Each process area is described with the greatest emphasis on the technologies that are attracting the most attention in the research and demonstration arenas (A.V.Bridgewater, 2000). Thus, instead of spending a large amount of money in treatment of palm oil waste, why not we used the waste as feed to produce a valuable product such as bio oil.

As we know, people are depending on energy that generates from fossil fuel. But, this great geology with fossil fuel sources cannot be sustainable for the eternity. The available fossil fuels sources now only can survive for another 20 to 30 years (Hisyam, 2006). Currently, Malaysia faced this scenario; the growing demand of technology and becoming developed nation by 2020, limited fossil fuel reserves, only 30–40 years and net oil importer from 2040 and the major challenges to overcome this problem; fuel security, electricity sales price, renewable energy power purchasing agreement, financing assistance, lack of promotion, conventional vs. renewable energy power plant and subsidy for conventional energy (Mohamed et.al., 2006).

Based on simple calculation, oil palm biomass has a total energy potential of about 15.81 Mtoe (million tonne of oil equivalent). Taking the efficiency of 50%, the energy generated from oil palm biomass may reach almost 8 Mtoe. In the year 2006, Malaysia's energy demand is 40.4 Mtoe (million tonne of oil equivalent) this means that oil palm biomass can provide almost 20% of the total energy demand in Malaysia. If all the 8 Mtoe energy produced by oil palm biomass is converted into energy replacing petroleum crude oil, Malaysia can save up to about RM 7.5 billion per year. Therefore, this clearly shows the potential of oil palm biomass as one of the major source of energy in Malaysia. Its renewable nature makes it even a more important energy source (S.H Shuit, 2009).

Malaysia government need fully supports re-biomass based power generation through various initiative and promotion program such as biogen since biomass resources is big potential for Biomass Power Co-Generation and beside that Malaysia can develop and expand the market profitability through new technology and lower production cost to overcome the challenges (Hamdan, 2004).

1.2 Pyrolysis Process

Pyrolysis is thermo-chemical process whereby dry and comminuted biomass is heated in the relative absence of air and oxygen. Depending on the process condition the major product could be bio-oil, a liquid fuel, or substantial quantities char, a solid fuel or a non- condensable gaseous product which can also be burnt as fuel through its calorific value (Lim *et.al*, 2004).

From the process, three main products are formed is char (solid), pyrolitic oil (liquid) and gaseous fuel. The by-products are methane, hydrogen, carbon monoxide, and carbon dioxide. The pyrolysis of common materials like wood, plastic and clothing is extremely important for fire safety and fire fighting (Salman Zafar, 2009).

Pyrolysis is thermal decomposition occurring in the absence of oxygen. It also always the first step in combustion and gasification .It also can be divided by three, first is fast pyrolysis, intermediate pyrolysis and slow pyrolysis .Pyrolysis process usually produce char, bio-oil, and gas. The production of this product is depending on the manipulated parameter that is residence time and temperature. The crude pyrolysis fuel approximates to biomass in elemental composition (Bridgewater, 2003).

Pyrolysis shows potential route to upgrade the organic waste to value added fuels and renewable chemicals. For woody feedstocks, temperatures around 500^0C together with short vapour residence times are used to obtain bio-oil yields of around 70%, along with char and gas yields of around 15% and set the alternative way to produce oil (N.Abdullah, 2009).

1.3 Problem Statement

So based on previous Empty Fruit Bunch Fast Pyrolysis Process, it used electricity for heating part (Daan Assink,2007).The energy conversion of heat by electric will only have 40% of efficiency which is not efficient (A.H Jafar, 2008). Increasing price and decreasing source of fossil fuel also is problem to our world today (S.H Shuit, 2009). By developing direct fired pyrolysis system, the energy conversion of heat will be improved. But, with the new direct fired pyrolysis system, there are several weaknesses. The study about ability of this system to produce product can be studied.

So this research, it uses direct heat in fast fired pyrolysis by firing to give optimum conversion of heat to the system. In order to get optimum heating in the system, there are several things that must be done. The method is by adjusting the setting of fuel and air. So with the various setting of fuel and air, it will give the best heating condition that will be used in gas fired pyrolysis system (Luis E Juanico, 2008).

The pyrolysis process temperature is in the range of 450^0C - 550^0C (N. Abdullah, 2008). For this research, the setting of fuel and air that produced the fastest temperature to achieve the pyrolysis process temperature will be selected as the best setting. So the best setting of fuel and air can be use as permanents setting for further research of this system.

1.4 Objectives

The objectives of this work are stated as follows:

1. To study the heat distribution pattern inside the combustion chamber of the Gas Fired Pyrolysis System.

2. To determine the best setting of fuel and air that can achieve the pyrolysis process temperature in the shortest time.

1.5 Scope of Works

This work is essentially an experimental study to identify the effectiveness of the fabricated pyrolysis system to transfer heat energy to the biomass materials to allow the pyrolysis process to take place. The work scope involves:

1. Modifying existing system with temperature probes at strategic position inside the reactor and combustion chamber.

2. Taking measurements at 5 different setting points in combustion chamber.

3. Run the experiment on the system with different setting of fuel and air of gas burner.

4. Study the temperature distribution pattern of every different experiment.

1.6 Rationale and Significance

For this research, it shows that the direct fired pyrolysis system is the suitable pyrolysis system compared to the other complex and large scale pyrolysis system. This direct fired pyrolysis system is a portable system that can be mobilized to the place near the sources of biomass such as palm oil plantation. With this system, it produces low cost of transportation. It is because this system can be located at palm oil plantation compared to the large scale plant that located far from the palm oil plantation. Besides that, this direct fired pyrolysis system can easily use with low technical skills. So it make easier to run this system compared to the complex plant that need high technical skills to run the plant.

During the research, knowledge about heat distribution of the gas fired pyrolysis system can be gained. Besides that, the energy saving skills also can be practice in this research. The technical elements on controlling and handling the equipment such as gas burner also can be gain in this research.

So there are some experiments to get the optimum setting of fuel and air of gas burner in the gas fired pyrolysis system. The experiment will cover on the gas burner with controlling the settings of the fuel and air and to make sure the temperature in the furnace and reactor achieve the pyrolysis process temperature in the shortest time.

Hence, in the end of this experiment, the best setting of fuel and air of gas burner can be selected. So after all aspects covered, it will accomplish this research well.

CHAPTER 2

LITERATURE REVIEW

2.1 Thermal conversion processes of biomass.

Biomass can be converted chemically into more valuable product and fuel energy. There are some technologies that can convert biomass into energy and higher product value. Gasification, combustion and pyrolysis are three main processes for thermal conversion. Those processes will produce fuel gas, heat and bio fuel as their products respectively. So the figure below showed the thermo chemical and biomass products.

As summarized in Figure 2.1, thermal conversion processes include direct combustion to provide heat, for steam production and hence electricity generation. Gasification also provides a fuel gas that can be combusted, generating heat, or used in an engine or turbine for electricity generation. The third alternative is fast pyrolysis that provides a liquid fuel that can substitute for fuel oil in any static heating or electricity generation application.

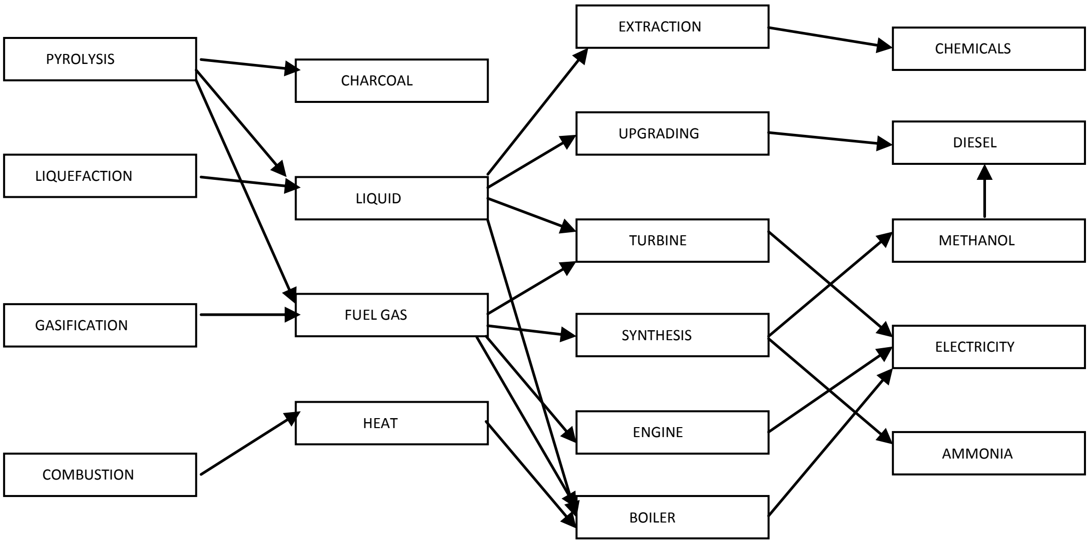

Figure 2.1: Thermochemical biomass processes and products (Bridgewater, 2000).

The advantage of fast pyrolysis is that it can directly produce a liquid fuel, which is beneficial when biomass resources are remote from where the energy is required since the liquid can be readily stored and transported. Although slow pyrolysis is well known and an established process, for instance in charcoal production, fast pyrolysis is still under development. A review of direct thermal liquefaction was produced by Elliott et al. and a survey of commercial and advanced technologies for both pyrolysis and gasification completed in 1994 (Bridgwater, 2000).

Each will give different range of product either gas, solid or liquid. Physical conversion involved densification; more easily handled such as briquettes particles, palletized fuel and fuel logs. These involve extrusion process of biomass particles with or without binder at higher pressure and later carbonized to obtain charcoal material (Ani, 2006).

2.1.1 Gasification Process

Gasification, which is a means to convert fossil fuels, biomass and wastes into either a combustible gas or a synthesis gas for subsequent utilization, offers the potential both for clean power and chemicals production. This will provides an international review of the technology and its applications, covering:

1. Gasification units that can be fired with coal, coal with biomass and wastes, refinery residues and natural gas.
2. Gasification both for power generation and the associated production of chemicals and fuel gases, with emphasis on the issues of coal gasification for advanced power generation.
3. Research and Development needs towards clean coal power generation based gasification technologies (Andrew J.Marchener, 2005).

Today, any major technology development effort is almost always supported by computational fluid dynamics (CFD) and/or other design calculation schemes. There are independent submodels for fluid dynamics, particle dynamics, heat transfer, coal conversion chemistry, and chemistry in the gas phase (Stephen Niksa, 2004).

There are four types of gasifier are currently available for commercial use now days counter-current fixed bed, co-current fixed bed, fluidized bed and entrained flow. The advantage of gasification is that the synthesis gas is a better fuel than original solid biomass, and can stored and transport more easily. Syngas may be burned directly in internal combustion engines, used to produce methanol and hydrogen, or converted via the Fischer-Tropsch process into synthetic fuel. Gasification can also begin with materials that are not otherwise useful fuels, such as biomass or organic waste. In addition, the high-temperature combustion refines out corrosive ash elements such as chloride and potassium, allowing the clean gas production from otherwise problematic fuels (D.J Wilhelm, 2001).

The future of biomass electricity generation lies in biomass integrated gasification/gas turbine technology, which offers high-energy conversion efficiencies (Ayhan, 2006). From environmental and economic viewpoints, new ways of hydrogen production, using a renewable and non-polluting source is the processes of biomass gasification. Since plants fix the CO_2 from the atmosphere during their growth, the concentration of carbon dioxide in the atmosphere would remain constant if biomass is used (Jale *et.al.* 2007). Generally, gasification process surely can be selected as an effective way to produce the renewable fuel energy.

2.1.2 Combustion Process

Combustion processes are controlled by fluid-dynamic, thermodynamic and composition variables. Among them the temperature is the most representative in characterizing the process. It is common to distinguish the combustion processes in dependence of their temperature: in this sense a rough classification of combustion processes divides them as occurring at either low or high or intermediate temperature. This is, indeed, a loose way of classifying such complex processes, and usually needs at least additional specification of the stage of the process considered. There is further complexity when there is more than one temperature relevant to the combustion process. For instance, processes designed to control both the minimum and the maximum temperatures are hard to be described when the two temperatures are changed in opposite directions. It could seem an incongruity to refer to a process as developing at low temperature when the reactants are preheated at relatively high value (Antonio Cavalerie, 2004).

Combustion of biomass represents a renewable form of energy and its consumption is likely to increase over the forthcoming years, as countries are looking for opportunities to reduce emissions of greenhouse gases through their climate change programmes. In the year 2005 the ‘‘Biomass Action Plan’’ of the European Commission set the target of increasing biomass use from about 289,000 TJ in 2003 to about 628,000 TJ in 2010, because of many advantages of biomass over conventional fossil energy sources, such as ‘‘low costs, less dependence on short-term weather changes, promotion of regional economic structures and provision of alternative sources of income for farmers’’ (L. Rigamonti *et al*. 2009).

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