Faculty of Engineering

EXPERIMENTAL STUDIES ON BIOMASS COMBUSTION TO PRODUCE ENERGY

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Bachelor of Engineering with Honours
(Mechanical Engineering and Manufacturing System)
2005

UNIVERSITI MALAYSIA SARAWAK

R13a

BORANG PENGESAHAN STATUS TESIS

Judul: **EXPERIMENTAL STUDIES ON BIOMASS COMBUSTION TO PRODUCE ENERGY**

SESI PENGAJIAN: 2004 / 2005

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EXPERIMENTAL STUDIES ON BIOMASS COMBUSTION TO PRODUCE ENERGY

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This project is submitted in partial fulfilment of
the requirements for the degree of Bachelor of Engineering with Honours
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For my family and friends

ACKNOWLEDGEMENT

Many thanks to the supervisor Madam Shanti Faridah Salleh for all the guidance and commitment given throughout the completion of this project. The author also wish to thanks all his wonderful friends in being very supportive and helpful and giving some inspiration in doing the project. Also thanks to the people in the faculty especially to the technicians that helps to provide all the technical guidance needed and for willing to spent their time in giving supervision. The author would also like to express his gratitude for the never ending support, determination, and concern from the family member and giving help in any way they can. Lastly thank you again to all in making this project a success and God Bless.

ABSTRACT

The importance of biomass as an alternative source of energy is becoming more acknowledgeable among many researchers throughout the world. With the world natural resources lessen as time goes by, there is a need to find renewable sources. Many of the research found emphasize mainly on biomass in the eastern part of the world such as the wheat, cottons and also aquatic biomass. In this particular study, experiments will focus on the potential of tropical biomass. As Malaysia is well-known for its vast source of plants and agricultural activities, the wastes produced can be processed and utilized as a source of fuels and for electricity generation. The main objective of this project is to find out the calorific value of various biomasses using the method of direct combustion. In the end the result is compared with values obtained using the BOMB Calorimeter. This project will also measure the effectiveness of the combustion furnace and to discuss any weaknesses found for future improvement.

ABSTRAK

Kepentingan “*biomass*” sebagai sumber tenaga alternatif semakin mendapat perhatian daripada golongan penyelidik di seluruh dunia. Kuantiti sumber semulajadi bumi yang kian berkurangan menyebabkan permintaan terhadap sumber tenaga yang boleh diperbaharui meningkat. Banyak kajian yang telah dibuat lebih tertumpu kepada sumber ”*biomass*” yang terdapat di negara-negara barat contohnya seperti gandum, kapas dan juga ”*biomass”* akuatik. Dalam kajian yang dijalankan ini, eksperimen adalah lebih tertumpu kepada potensi sumber “*biomass”* tropika. Malaysia sememangnya terkenal dengan sumber tumbuhan yang banyak dan aktiviti pertaniannya, sisa-sisa pertanian tersebut boleh diproses dan digunakan sebagai bahan api dan untuk menjana tenaga elektrik. Objektif utama projek ini adalah untuk mendapatkan nilai kalori untuk pelbagai jenis ”biomass” menggunakan kaedah pembakaran secara langsung. Nilai yang diperolehi seterusnya akan dibandingkan dengan keputusan yand didapati menggunakn ”BOMB Calorimeter”. Projek ini juga akan mengukur keberkesanan kebuk pembakaran yang dibina dan membincangkan kelemahannya agar boleh diperbaiki di masa akan datang.

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C	Specific heat capacity of water, 4.2KJ/kgK
m	mass off water, kg
P	power, W
Q	energy, KJ
ΔT	temperature difference, K
T_o	initial water temperature
T_f	final water temperature

CHAPTER 1

INTRODUCTION

1.1 General

With the growing number of population in the world today, there is an urge to produce a lot more energy supply which ironically seems a bit hard as the earth natural resources continuously being exhausted. Most of the energy sources on earth are totally dependant on products of photosynthesis. Biomass is organic material which has stored sunlight in the form of chemical energy. Scientifically, biomass can generally be defined as any hydrocarbon material which mainly consists of carbon, hydrogen, oxygen and nitrogen. Sulfur is also present in fewer proportions [19].Biomass fuels include wood, wood waste, straw, manure, sugar cane, and many other by products from a variety of agricultural processes.

When burned, the chemical energy is released as heat and the wood burn in a fire place is a biomass fuel. It is a renewable energy resource comprising over 70 billion tons of annual production and about 1800 billion tons stored on the earth during 1980’s (Jones, 1989).What we now call biomass was the chief source of heating homes and other buildings for thousands of years. In fact, biomass continues to be a major source of energy in much of the developing world.

Sugar cane, a good example of a biomass crop, can be found in many part of the world. The chief commercial product, sugar, is extracted from the cane by removing the juice; the remainder of the plant, called "bagasse", still contains the chemical energy of the sun. As with any biomass, bagasse produces heat when burned. Although, the efficiency of photosynthesis to convert solar energy into usable energy is low averaging 1% in good condition (Hall, 1989). Facts show that biomass is providing no less than one-third of the developing countries energy needs [8]. Biomass can be converted into three main types of products, namely electrical/heat, transportation fuel and chemical feedstock. It is indeed important to do experiments that as such can give information of the biomass energy generation capabilities so that further utilization and development can be done.

There are many sources of biomass in the world as long as the forest still exists. The sources can either be extracted directly from natural resources or wastes and residues from industries. Researchers characterize the various types of biomass in different ways but one simple method is to define four main types, namely woody plants, herbaceous plants/grasses, aquatic plants, manures [16].

1.2 Objectives of the Project

This project is a continuation of a research being done earlier that purposed to find the calorific value of three chosen biomass sources which are palm oil, coconut shell and rice husks. However the results are being obtained theoretically using existing formulas and calculation methods. In the end, the result obtain from this project will be compared to the theoretical values and any differences will be discussed. The objectives of this study are:

1. To find out the calorific value for various types of biomass.
2. To design a furnace for the burning process.
3. To compare the result obtained from the experiment with theoretical values

1.3 Report Overview

The first part of this report will discussed about facts on various matter related to biomass sources, experiments, it significant and potential on becoming the next source of energy. Most of the previous experiments done are on the methods of conversion such as pyrolysis, gasification and also chemical conversion where modifications are made for enhancing or increasing the efficiency of the methods. Also described, are the criteria of the selected specimens of biomass used for the experiment. Among the factors involved are the moisture content of the specimen, the content of carbon, and their suitability for the conversion processes.

In the methodology section, it will mostly describe the experiment procedures of the conversion process. In this section also is described about the construction of the chamber for the conversion process. Method to obtain the calorific values and also some of the calculation required will also is shown in this section.

For the results and discussion, it is mainly to compare the result from the experiment with the theoretical values obtained from previous experiment. Discussion is made for the values difference and the inaccuracy of the experiment that can help to improved results in the future. Conclusion and recommendation will be made based on the results obtain in the experiment and with reference to other previous research.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Biomass is often called ‘bioenergy’ or ‘biofuels’. It is the plant material derived from the reaction between CO_2 in the air, water and sunlight, via photosynthesis, to produce carbohydrates that form the building blocks of biomass. Typically photosynthesis converts less than 1% of the available sunlight to stored, chemical energy [17]. For small scale domestic application, the fuel usually takes the forms of wood pellets, wood chips and wood logs, which the pellets form are more preferable with its low moisture content, high energy density and easier to handle despite it cost the most expensive than the other two [18]. Unlike fossil fuels, biomass is renewable in the sense that only a short period of time is needed to replace what is used as an energy resource.

2.2 Source of biomass

2.2.1 Byproducts and Residues

The production of biomass for nonfuel application can also produce secondary products or byproducts and the residues [10]. The residues can also be obtained from post-harvest processing, that are the rice husks, sugar cane and food processing residues. These offer cheap resources since the production costs are borne by the primary products. The availability of the residues is determined by the availability of the primary products and proper management of forest thinning and harvesting.

2.2.2 Urban Wastes

Biomass wastes from urban areas include industrial especially from wood processing factories, commercial, animal wastes or manures, domestic refuse and sewage sludge or municipal biosolids. In some situation, these may have to be treated first to reduce the toxicity before being used. This however, is not being done very often and only in a few of the developed countries since the collection of the sources especially the sewage sludge is rather unpleasant and unhealthy and depending on the energy policy of countries. Every waste counts including lumber, wood pallets and crates, tree and brush trimmings and other organic materials. Foods, leftovers mainly from restaurants can be disposed for biomass energy.

2.2.3 Agricultural Residues

Agricultural waste biomass can be obtained more during a certain time of the year where harvesting takes place. But still, in an equatorial climate in Malaysia where lots of plantation and crops are grown continuous supply of residues are of no concern. Crops such as rice, palm oils, coconuts, corns and sugar canes can be easily obtained. Biomass usage for energy generation is still new in Malaysia and there is no large scale project is being done on biomass energy utilization. The husks or the shell are still only being use traditionally for cooking and heating. As mention earlier, plant type's biomass can be divided to woody plants, herbaceous plants/grasses, aquatic plants and manures. Within this categorization, herbaceous plants can be further subdivided into those with high- and low-moisture contents. Apart from specific applications or needs, most commercial activity has been directed towards the lower moisture-content types, woody plants and herbaceous species and these will be the types of biomass investigated in this study. Aquatic plants and manures are intrinsically high-moisture materials and as such, are more suited to 'wet' processing techniques.

2.3 Biomass Conversion

The conversion of biomass to energy encompasses a wide range of different types and sources of biomass, conversion options, end-use applications and infrastructure requirements [18]. Biomass can be converted into useful forms of energy using a number of different processes. Factors that influence the choice of conversion process are: the type and quantity of biomass feedstock; the desired form of the energy, i.e. end-use requirements; environmental standards; economic conditions; and project specific factors [19]. In many situations it is the form in which the energy is required that determines the process route, followed by the available types and quantities of biomass. Biomass can be converted into three main products: two related to energy — power/heat generation and transportation fuels and one as a chemical feedstock.

Conversion of biomass to energy is undertaken using two main process technologies: thermo-chemical and bio-chemical/biological. Mechanical extraction (with esterification) is the third technology for producing energy from biomass. Within thermo-chemical conversion four process options are available: combustion, pyrolysis, gasification and liquefaction. Bio-chemical conversion encompasses two process options: digestion (production of biogas, a mixture of mainly methane and carbon dioxide) and fermentation (production of ethanol).

2.3.1 Direct Combustion [18]

The burning of biomass in air i.e. the combustion process is used over a wide range of outputs to convert the chemical energy stored in biomass into heat, mechanical power or electricity using various equipments such as stoves, furnaces, boilers, steam turbines and generator. It is the traditional form of energy production from biomass providing the main sources of energy for more than half of the world's population. The feedstock for direct combustion should be dry that is consisting of more than 85% dry matter (Jones, 1989). Wetter feedstock may be burned, but combustion efficiency will be reduced as some of the energy produced is used to evaporate the moisture and combustion will be less complete. The design of combustion devices will determine the completeness of combustion and efficiency of heat transfer. A wide range of devices is available ranging from open fires and simple stoves to large scale fluidized-bed furnaces. For some devices it may be necessary to process the feedstock before direct combustion involving drying or mechanical treatment such as chipping, chopping or grinding to improve combustion efficiency.

2.3.2 Gasification

Gasification is the conversion of biomass into a combustible gas mixture by the partial oxidation of biomass at high temperatures, typically in the range 800–900 °C [10], [17].There are four primary types of biomass-gasification reactor systems have been developed: fixed bed reactors, bubbling fluid-bed reactors, circulating fluid-bed reactors and entrained flow reactors (Bain *et* al., 2000). This type of conversion is more suitable for biomass with moisture content in the range 0 to 30% but still not all the suitable biomass will produce a desirable result. More details on the moisture content of biomass will be explained in the later part of this chapter. There are a few types of gasification process as shown in the next page.

ADVANTAGES	DISADVANTAGES
Downdraft - Simple conception and proven for certain fuels - Simple construction - High rate of conversion - Relatively clean gas if appropriate gas used	- Homogeneous fuel and of a significant size - Size of installations very limited (350 kWe) - Possibility of fusion of ash in the reactor grill causing blocking - Low moisture content of fuels necessary - High maintenance costs (wear)
Updraft - Simple and robust construction - High heat output - Greater flexibility in terms of moisture content of primary material	- Low temperature of flue gases with the risk of condensation - Gases laden with tar - Unsuitable for electricity production
Dense fluidised bed - Good control of temperatures - High reaction speeds - Good contact solid/gas - Relatively simple and operational construction - No size limits - Catalytic treatment in the bed possible	- Minimum size to be economical (20MWe) - High level of particles in gases - Loss of fuel with ashes by entrainment limiting outputs - Requires small sized particles - Low moisture content <20% - Sensitive to granulometric division - Level of tar moderate to high
Circulating fluidised bed - Good control of temperature and reaction speed - High tolerance with regard to fuel (type, size) - Moderate level of tar in gases - High conversion rate - No size limits	- High level of particles in the gases - Low moisture content < 20% - Minimum size to be economical (20 MWe) - Loss of fuel with ashes - Requires small sized particles for maximum benefit of properties
Entrained beds - Good contact solid gas/mixture - Vitrifaction of ash - No size limits - High conversion rate - Clean gas with regard to tar	- High biomass preparation costs - High temperature gives good quality gas but low PCI - Limited fuel inventory - Very strong minimum size (>50 MWe)

Table 2.1 Advantages and Disadvantages of Various Gasification Processes

(Extracted from www.reslab.com)

2.3.3 Pyrolysis

Pyrolysis is an endothermic process that heats organics materials to high temperature without oxygen resulting in the breakdown of these organic materials into their various components (Cheremisinof and Morresi, n.d.). The temperature is around 400 to 1000 °C and at these temperatures there is no oxygen and organic materials will produce different composition of these three product which are gas (hydrogen, methane, carbon dioxide, carbon monoxide), liquid (water, oil, organics), and solid mainly carbon and ash. The gases, liquids and solids are generated depending on parameters such as final temperature, residence time, heating rate, gas environment and initial biomass properties [9]. Sometimes, off-gas may also exist. Off-gas is vapors that are emitted from extraction and treatment systems. These vapors can either be discharged directly to the