Faculty of Engineering

# EXERGY ANALYSIS OF BIOMASS FROM AGRICULTURAL WASTE

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This project report attached here to, entitled **"Exergy Analysis of Biomass From Agricultural Waste"** prepared and submitted by **Chong Kok Hing** as a partial fulfillment of the requirement for the degree in Bachelor of Engineering with Honours in Mechanical and Manufacturing System is hereby read and approved by:

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**PN. SHANTI FARIDAH SALLEH**        **Date**

**Supervisor**

**To my dearest brothers and sisters, and family**

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# ABSTRACT

This main idea of this thesis is to perform an exergy analysis of biomass on agricultural wastes.  Exergy analysis is a powerful tool to figure out how much energy is destroyed not only in quantity but in quality as well.  Thus engineer can improve the combustion system by minimize the energy destroyed.  This exergy analyses were perform on bomb calorimeter, as a prototype for other closed system. Before perform exergy analysis, experiments were conducted on few agricultural wastes in natural state and dry state to determine its heating value.  The equation in this analysis can be use to perform exergy analysis in any closed system.

# ABSTRAK

Idea utama tesis ini adalah untuk mengkaji exergy analisis dalam bidang biomass dari sisa pertumbuhan.  Exergy analisis bukan sahaja merupakan alat yang cekap untuk menyelidik tenaga yang dimusnahkan dalam kuantiti tetapi juga dalam kualiti. Dengan itu, jurutera dapat meningkatkan efisien sistem pembakaran dengan minimumkan tenaga yang dimusnahkan.  Exegy analisis ini dijalankan dalam bomb kolorimeter, sebagai model bagi sistem tertutup.  Sebelum exergy analisis dijalankan, terdapat beberapa eksperimen dilaksanakan untuk sisa pertumbuhan yang bertujuan untuk mencari nilai pembakarannya.  Formula yang digunakan dalam analisis ini boleh dijadikan sebagai rujukan untuk semua sistem tertutup.

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# Nomenclatures

| | | |
|---|---|---|
| C | - | Specific heat, kJ/Kg.K |
| d | - | Diameter, m |
| f | - | Formation of the compound form |
| G | - | Total Gibbs function, H – TS, kJ |
| g | - | Gravitational, $m/s^2$ |
| H | - | Total enthalpy, U + PV, kJ |
| HHV | - | Higher heating value, kJ/kmol fuel |
| h | - | Specific enthalpy, u + Pv, kJ/kg |
| $h_o$ | - | Specific enthalpy at the dead state, kJ/kg |
| I | - | Irreversibility |
| i | - | Specific irreversibility, kJ/kg |
| $k_e$ | - | Specific kinetic energy, kJ/kg |
| LVH | - | Low heating value, kJ/kmol fuel |
| m | - | Mass, kg |
| P | - | Pressure, kPa |
| $P_o$ | - | Surroundings pressure, kPa |
| pe | - | Specific potential energy, kJ/kg |
| Q | - | Total heat transfer, kJ |
| $\dot{Q}$ | - | Heat transfer rate, kW |
| $Q_k$ | - | Heat transfer through the boundary at temperature $T_k$ at location k |
| S | - | Total entropy, kJ/K |
| $S_o$ | - | Specific entropy at dead state, kJ/K.kg |

| | | |
|---|---|---|
| $T$ | - | Temperature, $^oC$ or K |
| $T_k$ | - | Temperature at location k |
| $T_o$ | - | Surroundings temperature, $^oC$ or K |
| $t$ | - | Time, s |
| $X_{ke}$ | - | Exergy of kinetic energy, kJ/kg |
| $X_{pe}$ | - | Exergy of potential energy, kJ/kg |
| $U$ | - | Total internal energy, kJ |
| $U_o$ | - | Specific internal energy at the dead state, kJ/kg |
| $u$ | - | Specific internal energy, kJ/kg |
| $V$ | - | Velocity, $m/s^1$ |
| $V_o$ | - | Specific volume at the dead state, $m^3/kg$ |
| $v$ | - | Specific volume, $m^3/kg$ |
| $W$ | - | Total work, kJ |
| $\dot{W}$ | - | Power, kW |
| $W_{rev, in}$ | - | Reversible work input, kJ |
| $W_{rev, out}$ | - | Reversible work output, kJ |
| $W_{surr}$ | - | Surroundings work, kJ |
| $W_u$ | - | Useful work, kJ |
| $W_{u, in}$ | - | Useful work input, kJ |
| $W_{u, out}$ | - | Useful work output, kJ |
| $X_{heat}$ | - | Exergy transfer by heat, kJ |
| $\dot{X}_{mass}$ | - | Exergy transfer by mass flow rate, kJ/kg.s |
| $X_{pv}$ | - | Exergy of flow work, kJ/kg |
| $z$ | - | Elevation of the system relative to a reference level in the environment |

# Greek Letters

| | | |
|---|---|---|
| $\Delta$ | - | Finite change in quantity |
| $\varphi$ | - | Stream availability, kJ/kg |
| $\eta_{II}$ | - | Second law efficiency, % |

# Subscripts

| | | |
|---|---|---|
| ch | - | Chemical |
| el | - | Elements in the compound |
| gen | - | Generation |
| in | - | Input |
| out | - | Output |
| ph | - | physical |
| rev | - | Reversible |
| surr | - | Surroundings |
| sys | - | System |
| 0 | - | Dead state |
| 1 | - | Initial or inlet state |
| 2 | - | Final or exit state |

# Superscripts

| | | |
|---|---|---|
| · (dot) | - | Quantity per unit time |
| ¯ (bar) | - | Quantity per unit mole |
| $^{o}$ (circle) | - | Standard reference state |

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction to Biomass

Most of the fuel that using by our world today is limited. Therefore there is an urgency to find the solution before the problem become worst. Nowadays many research and technology proved that biomass is the answer for our non-renewable fuel resource. Biomass is totally renewable resource. The toxic emissions is dramatically reduce due to the biodisel is using oxygenated if compare to petroleum diesel. Biofuels and biodiesel become the primary biofuels today because they can substitute for gasoline and diesel or blended with them to reduce greenhouse gas build-up. Biomass currently supplies over 3% of the U.S. total energy consumption.

## 1.2 Introduction to Exergy

Exergy, which is also called the availability. The main purpose of exergy analysis is to detect and evaluate quantitatively the causes of the thermodynamic imperfection of thermal processes. Exergy analysis can, therefore, give information about the possibilities of improving thermal processes.

Exergy analysis is highly effective method of analysis for thermal processes because it can provide the information that cannot be obtained from energy analysis alone. Furthermore, exergy analysis is a tool for identifying the types, locations and magnitudes of thermal losses. Identification and quantification of these losses allows us to evaluate and improve the design of a thermodynamic system.

The exergy of the system is defined as the maximum shaft work that could be produced by the composite of the system and a specified reference environment that is assumed to be infinite in equilibrium an ultimately to enclose all other system.
In particular, exergy analysis takes into account the different thermodynamic values of work and heat. The exergy transfer associated with shaft work is equal to the shaft work. The exergy transfer associated with heat transfer, however depends on the temperature level at which it occurs in relation to the temperature of the environment.

### 1.3 Biomass Resources

There are many types of biomass resources that can be found from the earth. That is form agriculture waste, wood wastes, municiple sludge waste, wood wastes, other energy crops. According to Wrixon *et al* (1993), the main biomass resources form Europe is agriculture waste. Where else the wood wastes contribute the smallest amount. Figure 1.1

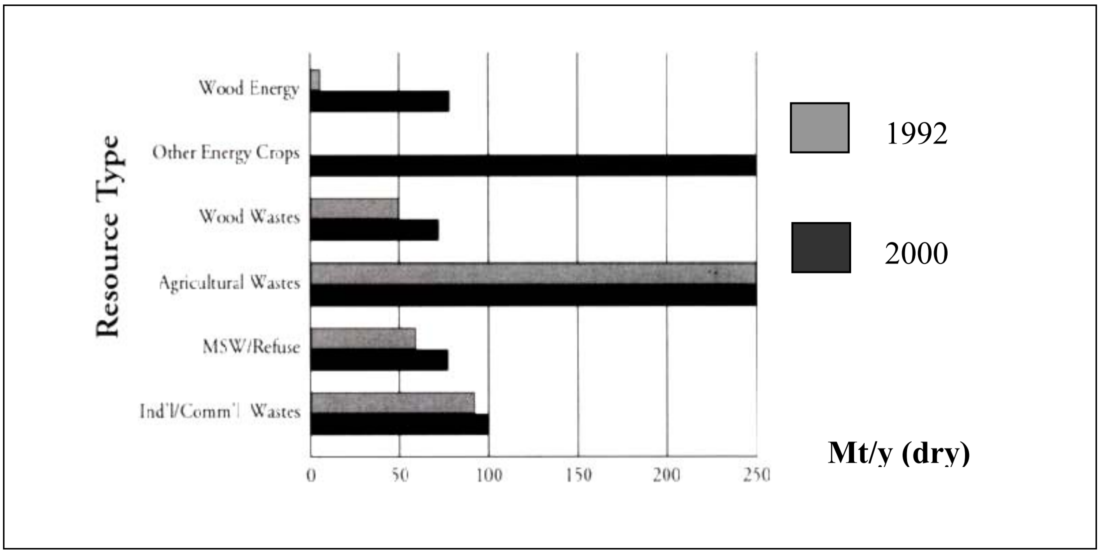


**Figure 1.1: European Biomass Resources (Mt/y (dry)**

Source: Wrixon *et. al* (1993), Renewable Energy- 2000

## 1.4 Type of biomass conversion

The energy of electricity power form biomass can be converted through three common methods, which are incineration, pyrolysis, and gasification.

Fluid bed system is one type of the incineration, which is a vessel, contains inert granular material that expands and acts theoretically as a fluid when gases are injected up through the material bed from nozzles. Fluid bed system operates within temperature from 750-1000° C, which can handle liquid, sludge, solid, and gases. It offers nearly isothermal operation.

Pyrolysis is a destructive distillation affected by the application of heat in an insufficiency of oxygen to yield gaseous, liquid (after cooling),and solid product. (Walter R. Niesen, 1995) [1]

Gasification is the cleanest, most efficient combustion method. Gasification system consists of a gasifier, a gas cleaning system and an engine generator system to convert the biomass material fed into the gasifier into electricity


Figure 1.2 Illustration for gasification process.

## 1.5 Problem Statement

The first law of thermodynamics deals with the quantity of energy and asserts that energy cannot be created or destroyed. The first law also gives no information about direction which it merely states that when one form of energy is converted into another, identical quantities of energy are involved regardless of feasibility of the process. The second law of thermodynamics, however, deals with the quality of energy. It is concerned with the degradation of energy during a process and the lost opportunities to do work. The exergy method of analysis overcomes the limitations of the first law of thermodynamics. The exergy analysis is based on both the First and the Second Laws of Thermodynamics. Exergy analysis can clearly indicate the locations of energy degradation in a process that may lead to improved operation. The main purpose of exergy analysis is to identify the causes and to calculate the true magnitudes of exergy losses.

## 1.6 Introduction to the Project

This project is about exergy analysis of biomass from agriculture wastes through conversion of incineration. The project not only carry out the calorific value for the agriculture waste such as paddy, palm oil, but also the exergy analysis in the bomb calorimeter.

The research begins with recognizing the potential agriculture wastes in Sarawak. Then proceed to the study of potential energy and moisture content that affect exergy through laboratory work. Literature review about exergy concept and a case study of exergy is carried out to give more understanding.

## 1.7 Objectives

The objectives of the project are given as follows:-

a) To identify the heating value of the potential biomass agricultures.

b) To develop an understanding and the exergy analysis of biomass from agriculture wastes on the bomb calorimeter.

c) To evaluate the efficiency of bomb calorimeter with paddy straw, palm oil leaves.

## 1.8 Scopes of the Project

The scopes of the project are as follows:-

a) The biomass form agriculture waste for this research was focused on paddy straw, palm oil leaves, and coconut leaves. The main reason is these three components are the major contribution agricultural activity in Malaysia, and it vast availability.

b) Literature review on the application of exergy analysis of biomass form agriculture wastes on closed system device- bomb calorimeter.