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EFFECT OF FUEL MOISTURE CONTENT ON SOLID WASTE COMBUSTION

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This report is submitted to
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Faculty of Mechanical Engineering
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"I hereby declared that this thesis titled
'Effect of Fuel Moisture Content on Solid Waste Combustion ' is the result of my own effort except as clearly stated in references the source of reference".

Signature : ____________________________
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Date : ____________________________

Dedicate to my family and to all Malaysians.

Malaysia Boleh.

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ABSTRACT

This project is entitled 'Effect of Fuel Moisture Content on Solid Waste Combustion'. Nowadays, people produced large amount of waste, either in the form of solid, liquid or gas everyday. These wastes can be treated in various methods according to its categorization. Gasification process is a popular method which is not only able to burn up the waste, but also have the potential to generated energy. Wood waste which came from various industries makes up a large amount of the solid waste. In order to obtain the maximum efficiency with the minimum production of product gases, this project is aim to determine the optimum operating parameters of moisture content in solid waste combustion. The scopes of this report are running of experimental work under various operating parameters which is fuel moisture content, determination of temperature distribution at the axial and outlet of the gasifier, determination of the ignition front velocity and ignition front rate and analysis on gasifier performance. Several samples of different moisture contented wood wastes are used for combustion in this research. Thermocouples and data logger are used in temperature measurement. From experimental work results, the temperature distribution of all fuel moisture samples can be observed except the wood waste sample with highest fuel moisture content which is failed to observe. The optimum operating parameter for wood waste combustion is identified at fuel moisture content of 13.04%. In combustion at this 13.04% fuel moisture content, the gasifier shows the greatest performance.

ABSTRAK

Projek ini bertajuk "Kesan Kelembapan Pada Pembakaran Bahan Buangan". Pada masa kini, banyak bahan buangan, samada dalam bentuk pepejal, cecair dan gas dihasilkan setiap hari. Bahan buangan ini boleh dirawat berdasarkan kategorinya. Proses gasifikasi merupakan satu cara untuk membakar bahan buangan dan juga berpotensi menghasilkan tenaga melalui pembakaran. Bahan buangan pepejal kayu dari pelbagai industri telah membentuk sebahagian besar jumlah bahan buanagan pepejal. Projek ini bertujuan menentukan operasi parameter yang optimum bagi kandungan kelembapan dalam kayu buangan yang berfungsi sebagai bahan api. Masalah dalam projek ini ialah pernentuan keberkesanan pembakaran maximum dengan penghasilan gas produk yang mimimum. Antara skop laporan ini ialah penggunaan kandungan kelembapan sebagai operasi parameter, penentuan taburan suhu di bahagian masuk dan keluar alat gasifikasi, penentuan pemecutan api pembakaran dan analisis pada kecekapan gasifier. Pelbagai langkah digunakan untuk pelaksanaan ujian ini iaitu penggunanan beberapa contoh kayu buangan yang berbeza kandungan kelembapan dalam pembakaran serta penggunaan pengukur haba dan 'data logger' dalam pengukuran taburan haba. Menurut keputusan eksperimen, taburan suhu untuk semua contoh kayu buangan yang berbeza kandungan kelembapan dapat diperhati dengan jelas kecuali contoh kayu buangan yang berkandungan kelembapan yang paling tinggi tidak dapat diperhati dengan jelas. Operasi parameter yang optimum bagi kandungan kelembapan dalam kayu buangan yang berfungsi sebagai bahan api didapati adalah kelembapan sebanyak 13.04%. Gasifier menunjukkan kecekapan yang tinggi pada pembakaran kayu buangan berkandungan kelembapan sebanyak 13.04%.

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LIST OF NOMENCLATURE

UTeM	Universiti Teknikal Malaysia Melaka
M_i	Initial, moist mass
M_f	Final, dry mass
LCV	Lower Calorific Values
ϕ	Equivalence ratio
V	Actual air velocity
d	Diameter of blower outlet
A	Area of blower outlet
Q	Actual air flow rate
P	Density of air
$(\frac{A}{F})_{actual}$	Actual air fuel ratio
$(\frac{A}{F})_{stoichio}$	Stoichiometric air fuel ratio
AFT	Adiabatic flame temperature

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Problem

Nowadays, consumers have produced many wastes. This is because of the progression of human civilization. This waste may in the form of solid, liquid and gas as well as either biodegradable or non biodegradable resulting from human and animal activities, that are useless, unwanted, or hazardous. Solid waste can be divided to several types namely garbage, rubbish, ashes, industrial wastes, agricultural wastes and may more others (Wikipedia, 2009). Due to different types of solid waste, different methods are invented and used to reduce the solid waste volume. Among the methods are automotive shredder residue (ASR), gasification, in-vessel composting and pyrolysis.

According to the research on waste generation in Malaysia, Malaysia local authorities and waste management consortia have to handle approximately 17,000 tones of municipal solid waste everyday throughout the country (Nadzri, 2002). Rapid developments and industrialization in Malaysia require a better and more efficient waste management strategy. Solid waste gasification is an effective method to reduce the solid waste volume in Malaysia.

Solid waste gasifier is the equipment that used to convert solid fuel such as wood waste, saw dust briquettes and agro-residues into a gaseous fuel through a thermo-chemical process. The resultant gas can be used for heat and power generation applications. Since there is an interaction of air or oxygen and biomass in the gasifier, they are classified according to the way air or oxygen is introduced in it. There are three types of gasifiers namely downdraft, updraft and crossdraft.

Gasification is a process that converts carbonaceous materials into carbon dioxide and hydrogen by reacting the raw material at high temperature with controlled oxygen and steam. Gasification is a very efficient method for extracting energy from many different types of organic materials. In this research, we emphasized on the gasification of wood waste. The resources of wood waste include construction fields, furniture industries, paper industries, old furniture and so on. These solid wood wastes are usually left to decompose naturally in the dumpsites. However, in case the solid waste is burnt with the right method, it has the potential to generate electricity. This is a beneficial situation as it not only reduce the solid waste but also as an alternative for energy source.

In the gasification process, one of the factors that affected the combustion efficiency is the moisture contents. Besides, the different moisture contents also may affect the burning rate of solid waste fuels, total burning time and ignition delay. This research is done to determine the specific moisture contents that are associated to solid waste combustion.

1.2 Objective

- To determine the optimum operating parameters of a gasifier for different fuel moisture content.

1.3 Scopes

i. To run experimental work under various operating parameters which is fuel moisture content.
ii. To determine the temperature distribution in the gasifier.
iii. To determine the ignition front velocity and ignition front rate in variation of fuel moisture content.
iv. To analyse gasifier performance.

1.4 Problems Statements

No extensive work on the gasifier through experimental or simulation work. Hence this study is done to analyze the performance of the gasifier with various fuel moisture content in order to get the maximum efficiency and the least CO and NO_x gases released.

1.5 Significant of Study

The combustion process in the furnace is mainly involved the variation in fuel moisture contents. The moisture contents play an important role as it is associated with the amount of reactant gases and product gases. It also determines the burning rate and total burning time of the combustion process. Therefore, this research study on the effect of moisture contents on solid waste combustion.

The updraft gasifier is used in this research and as the classification implies updraft gasifier has air passing through the biomass from bottom and the combustible gases come out from the top of the gasifier.

CHAPTER 2

LITERATURE RIVIEW

2.1 Gasification Process

Gasification is a process that converts carbonaceous materials, such as coal, petroleum, solid waste, or biomass, into a burnable gas by reacting the raw material at high temperatures with a controlled amount of oxygen. The burnable components of the gas are, typically, carbon monoxide, hydrogen and methane. A common name for this gas is "producer gas". The word "gasification" conjures up visions of alchemy, i.e., changing common metals into gold; in the present case, dirty hog fuel is changed into a burnable gas. Over the last one hundred years, the popularity of gasification has had its ups and downs. Before natural gas was plentiful, or even available, cities built "gas works" to make "city gas" of various varieties for lighting and cooking. At the beginning of this century, before the arrival of spreader stokers and traveling grates, a number of utility boilers were built with coal gas producers (hence the name "producer gas") instead of furnaces.

During World War II, trucks and automobiles in occupied Europe were fuelled with producer gas from on-board wood gasifiers which used, primarily, dried blocks of wood. The latest surge of interest in gasification occurred during the oil shortages of the 1970's occasioned by the Yom Kippur War in 1973 and the fall of the Shah of Iran in 1978. Today, the main interest in wood waste gasification is primarily in Europe. There, projects are underway to demonstrate that it is possible to gasify wood waste and use the resultant, cleaned, pressurized producer gas to fuel a gas turbine and generate electricity without using a boiler. The installations are expensive and hard to justify with the low cost of natural gas world wide. (Lefcort, M.D 1995)

2.1.1 Gasification of Wood Waste

The combustion of wood waste always includes a stage of gasification. For example, the case of a fresh log placed on top of a stack of logs already burning in a fireplace. The new log hisses while its moisture is driven off; the heat of evaporation coming from the already burning logs in the fireplace. After the log has dried tongues of flame can be seen extending upward, along the length of the log. With time the number of tongues of flame increases. Finally, the flames die out and now, fissured, black log glows red and yellow as it slowly burns down to a grey, powdery ash. In this fireplace example, the tongues of flame are burning forms of producer gas. The fissured log is made up of fixed carbon. It so happens that typical bone dry wood is composed of between 75% and 80% volatile matter and 20% to 25% fixed carbon (Lefcort, M. D 1995). In other words, if a piece of bone dry wood is placed in a suitably hot, oxygen-free chamber, 75% to 80% of its mass will volatilize. It also so happens that the fixed carbon in the remaining 20% to 25% mass fraction contains about 50% of the wood's initial Btu's. Hence, converting wood into charcoal increases the energy density by a factor of between 2 and 2.5 (Lefcort, M. D 1995)
. This is the reason why, particularly in the third world where, frequently, fuel must be transported on one's back, wood is often converted into charcoal before it is delivered to end users for heating purposes.

2.2 Stoichiometric Combustion

Stoichiometric Combustion is a process which burns all the carbon (C) to (CO_2), all hydrogen (H) to (H_2O) and all sulphur (S) to (SO_2).

The combustion reaction can be expressed as:

$$[C+H\ (fuel)] + [O_2 + N_2\,(Air)] \rightarrow [CO_2 + H_2O + N_2\,(Heat) \qquad (2.1)$$

Also known as the ideal fuel ratio, the stoichiometric ratio is the chemically correct mixing proportion. When burned, it consumes all the fuel and air without any excess left over. To determine the percent excess air or excess fuel at which a combustion system operates, you have to start with the stoichiometric air-fuel ratio. The fuel-air ratio is the proportion of fuel to air during combustion.

If insufficient amount of air is supplied to the burner, unburned fuel, dust, smoke, and carbon monoxide exhausts from the boiler. This results in heat transfer surface fouling, pollution, lower combustion efficiency, flame instability and a potential for explosion.

Boilers generally operate at an excess air level to avoid inefficient and unsafe conditions. This excess air level also provides protection from insufficient oxygen conditions caused by variations in fuel composition in the fuel-air control system.

Typical optimum values of excess air levels are shown here for various fuels. If the air content is higher than stoichiometric, the mixture is said to be fuel-lean whereas if the air content is less, the mixture is fuel-rich.

2.3 Fixed Bed Gasifier System

The first commercial updraft (fixed bed) gasifier was installed in 1839, when Bischaf patented a simple process for gasifying coke. The first attempt to use producer gas to fire internal combustion engine was carried out in 1881. The downdraft gasifiers were used for power generation and automotive applications before and during the Second World War. After the Second World War, availability of cheap fossil fuels led to decline of producer gas industry. The interest in biomass gasification was renewed after the energy crisis of 1970s'. The technology began to be perceived as a relatively cheap indigenous alternative for small scale industrial and utility power generation, especially in developing countries that suffered from high petroleum prices and had sufficient sustainable biomass resources (Stassen and Knoef, 1993)

The fixed bed gasifier has a bed of solid fuel particles through which the gasifying media and gas move either up or down. It is the simplest type of gasifier consisting of usually a cylindrical space for fuel and gasifying media with a fuel feeding unit, an ash removal unit and a gas exit. It is made up of firebricks, steel or concrete. In the fixed bed gasifier the fuel bed moves slowly down the reactor as the gasification occurs. The fixed bed gasifiers are of simple construction and generally operate with high carbon conversion, long solid residence time; low gas velocity and low ash carry over. In fixed bed gasifiers tar removal is a major problem, however recent progress in thermal and catalytic conversion of tar has given credible options. The fixed bed gasifiers are being considered to be of average strength for small-scale heat and power applications. The gas cleaning and cooling system normally consists of filtration through cyclones, wet scrubbers and dry filters (Riva 2006).

2.4 Types of Fixed Bed Gasifier System

There are many types of fixed bed gasifiers with varying schemes for both reactor design and reaction media. The fixed bed gasifier can be classified according to the ways in which the gasifying agent enters the gasifier i.e. updraft, downdraft, crossdraft and two stage gasifier. The downdraft gasifiers are Imbert type (gasifier with throat) and open core type (throatless). The gasifying media may be air, steam, oxygen or a mixture of these and the producer gas may be used in thermal (heat gasifiers) or engine (power gasifiers) applications. The composition of producer gas and the level of contamination vary with the biomass, type of gasifier and operating conditions (Stassen and Knoef, 1993).

2.4.1 Updraft Gasification Systems

(i) Principle

The updraft gasifier is the oldest and simplest form of fixed bed gasifier. It can handle biomass fuels with high ash (up to 15 %) and high moisture content (up to 50 %). It is more influential than other fixed bed gasifiers because it is less sensitive to variations in size and quality of biomass. In an updraft (counter current) gasifier, biomass fuel enters from the top of the reaction chamber and the gasifying media or agent (air, O_2 or mixture) enters from the bottom of the unit from below a grate. The fuel flows down slowly through the drying, pyrolysis, gasification and combustion zones. The ash is removed from the bottom. The updraft gasifier has high thermal efficiency as the sensible heat of the producer gas is recovered by direct heat exchange with the entering feedstock, which is dried, and pyrolysed before entering the gasification zone. The producer gas exits at low temperature (80-300 ºC) and contains an abundance of oils and tar (10-20 %) since the products of the pyrolysis and drying zone are directly drawn into it without decomposition. The dust content in the producer gas is low due to low gas velocities and filtering effect of feed in drying and pyrolysis zones. (VTT, 2002).