I hereby, declare I had read through this thesis entitled “Effect of Air Velocity on Solid Waste Combustion” and I agree that this thesis had fulfilled the quality and scopes that worth it to award Degree of Mechanical Engineering (Structure-Material).

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Supervisor’s Name	: …………………………
Date	: …………………………

EFFECT OF
AIR VELOCITY AND EQUIVALENCE RATIO ON
SOLID WASTE COMBUSTION

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This report is submitted to
Faculty of Mechanical Engineering
University Teknikal Malaysia Melaka
In Partial Fulfillment for Bachelor of Mechanical Engineering
(Structure & Material)

Faculty of Mechanical Engineering
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APRIL 2009

"I hereby declared that this thesis titled
'Effect of Air Velocity and Equivalence Ratio on Solid Waste Combustion ' is the result of my own effort except as clearly stated in references the source of reference".

Signature : ____________________

Name of Author : ____________________

Date : ____________________

Special dedication to my late and loving father, Andrew Wong Kiong Ming who passed away last year. He will always be remembered. Dedication as well to my mother whom, also had taken good care of me. Not forgetting as well both my brothers, who had been with me all this while.

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2009

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ABSTRACT

Our world currently produced large and increasing amount of waste, either in the form of solid, liquid or gas. These wastes can be treated in various methods according to its classification. One of the most popular methods is the gasification process which is not only able to burn up the waste, but also have the potential to generated energy. Therefore, this project is aim to determine the optimum operating parameters of a gasifier for different air velocity with wood as the solid waste. The gasifier's mode of operation had been determined in the project. The problem to be solved is to obtain the maximum effiency with the minimum production of product gases. Among the scope in this report is running of experimental work using various air velocity as the operating parameter as well as the determination of the gasifier mode operation from the equivalence ratio. The temperature distribution at the axial and outlet of the gasifier and the gasifier's performance will also be determine. Several methods are used in conducting this test such as variation of the blower air intake and outlet's diameter to produce different air velocity and the usage of both thermocouples and data logger in temperature measurement . Anemometer is used in determined the air velocity. There are five air velocities used in the project namely 0 m/s, 3 m/s, 4 m/s, 5m/s and 6 m/s. The optimum operating parameter obtained in this project is 4 m/s, which has equivalence ratio of 0.32. It also has maximum axial temperature of 710.61°C and 354.63°C at the outlet temperature. Meanwhile, the performance of the laboratory scale UTEM gasifier does have variations from actual industrial gasifier.

ABSTRAK

Dunia kita telah menghasilkan banyak bahan buangan, samada dalam bentuk pepejal, cecair dan gas. Bahan buangan ini boleh dirawat berdasarkan klasifikasinya. Antara teknik rawatan yang paling popular ialah proses gasifikasi di mana teknik ini bukan sahaja membakar bahan buangan tersebut, tetapi juga berpotensi menghasilkan tenaga. Sehubungan itu, projek ini bertujuan menentukan operasi parameter yang optimum bagi pelbagai halaju udara dengan, dengan kayu sebagai bahan api. Mode operasi gasifikasi juga telah ditentukan dalam projek ini. Masalah dalam projek ini ialah pernentuan efiksen maximum dengan penghasilan gas produk yang mimimum. Antara skop laporan ini ialah penggunaan ujian pelbagai halaju udara sebagai operasi parameter serta penentuan mode operasi dari nisbah keseimbangan. Taburan suhu di bahagian masuk dan keluar alat gasifikasi juga akan ditentukan. Pelbagai langkah telah digunakan untuk pelaksanaan ujian ini termasuk variasi kemasukan udara dan diameter muncung udara untuk kesan halaju yang berbeza dan penggunaan pengukur haba dan 'data logger' dalam pengukuran taburan haba. Anemometer juga telah digunakan dalam menentukan halaju udara tersebut. Sebanyak lima halaju udara yang dijalankan dalam projek ini iaitu 0 m/s, 3 m/s, 4 m/s, 5 m/s dan 6 m/s. Optima operasi pembolehubah dalam projek ini ialah 4 m/s yang mempunyai nisbah keseimbangan 0.32. Ia juga mempunyai suhu bahagian masuk yang maksima, 710.61°C dan suhu maksima bahagian keluar pada 354.63°C. Manakala prestasi alat gasifikasi UTEM yang berskala makmal mempunyai ketidaksamaan dengan alat gasifikasi yang digunakan dalam industri.

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d	=	Diameter
A	=	Area
v	=	Velocity
Q	=	Volumetric flow rate
ρ	=	Density
Φ	=	Equivalence Ratio

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CHAPTER 1

INTRODUCTION

1.1 Solid Waste

Despite of the progression of our humankind civilization, we have produced many wastes. This waste may in the form of solid, liquid and gas as well as either biodegradable or non biodegradable. Solid waste can be divided to several types namely garbage, rubbish, ashes, industrial wastes, mining wastes, agricultural wastes and may more others. Due to different types of solid waste, different methods are invented and used. Among the methods are automotive shredder residue (ASR), gasification, in-vessel composting, pyrolysis and so on.

A research conducted on waste generation by the local government department in Ministry of Housing and Local Government, shows that our Malaysian local authorities and waste management consortia have to handle approximately 17,000 tonnes of municipal solid waste everyday throughout the country. Rapid developments and industrialization in Malaysia had caused a demand for a better and more efficient waste management strategy. In this matter, the solid waste gasification is an effective method to reduce the solid waste volume in Malaysia.

According to Lefcort, M.D, (1995), gasification is a special case of pyrolysis. It involves the process of converting 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, the work will emphasize 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.

The equipment that used to convert the solid fuel is solid waste gasifier. The solid fuels such as wood waste, saw dust briquettes and agro-residues are converted into a gaseous fuel through a thermo-chemical process. This resultant gas is very useful to produce heat which in turn applied in power generation applications. There are three type of gasifiers namely downdraft, updraft and crossdraft, which is classified according to the way air or oxygen is introduced into it.

In the gasification process, one of the factors that affected the combustion efficiency is the gas velocity. Combustion process required high amount of gases for reaction. Increasing the gas velocity too will increase the combustion rate, as we see of a burning house during a windy day. However, too strong wind too may put the fire out. Therefore, there is a certain gas velocity for the optimum combustion to take place. This research is done to determine the specific gas velocity and as well as the equivalence ratio that is associated to it.

1.2 Objective

1. To determine the optimum operating parameter of a gasifier for different air velocity.
2. To determine the gasifier mode operation which is either in pyrolysis, gasification or combustion.

1.3 Work Scopes

1. To run experimental work under various air velocity.
2. To determine the gasifier mode operation from equivalence ratio value.
3. To determine the axial and outlet flame temperature distribution in the gasifier.
4. To determine the gasifier performance

1.4 Problems Statement

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 air velocities to get the suitable axial flame temperature.

1.5 Significant of Study

A laboratory scale of the updraft gasifier is used in this research. The updraft gasifier operated with the air passing through the biomass from bottom while the combustible gases come out from the top of the gasifier. The combustion rate in the updraft gasifier can be affected by the turbulence in it. The turbulence in the furnace is mainly involved the velocity of the air intake. The air velocity plays an important role as it is associated with the amount of reactant gases and product gases. It also will determine the burning rate of the combustion process. Therefore, this research will study on the effect of air velocity and equivalence ratio on solid waste combustion.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Christine and Gable, S. (2008) in http://alternativefuels.about.com described that the gasification is an exothermic reaction between a high carbon fuel and a carefully controlled and limited supply of oxidizer, together with heat, pressure, and steam to convert materials directly into a gas composed primarily of carbon monoxide and hydrogen. Gasification is also identified as a type of pyrolysis. However, the pyrolysis involved the destructive decomposition of wood waste into charcoal, oils, tars and gas when the pyrolysis occurred at below 593 °C or 1,100°F. However in gasification, there are no formation of oil, tar and charcoal byproducts as all the solid wood waste is converted to the burnable gas of mainly carbon monoxide, hydrogen and methane.

Both the process of the pyrolysis and gasification is shown in the Figure 2.1 and Figure 2.2 below. In Figure 2.1, the pyrolysis occurred without sufficient air and yields products of hydrogen (H_2), tars and methane (CH_4). As for the gasification in Figure 2.2, excess air with oxygen (O_2) and steam is introduced and able to convert all char into products of hydrogen (H_2), carbon oxide (CO) and carbon dioxide (CO2).

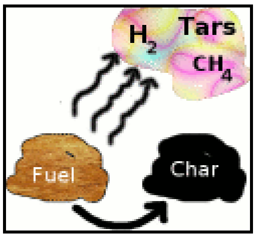

Figure 2.1: Pyrolysis of carbonaceous fuels char

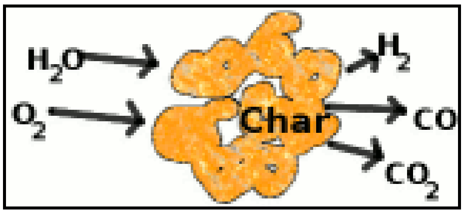

Figure 2.2: Gasification of char

(Source: http://en.wikipedia.org/wiki/Gasification)

Mainly the raw materials used in gasification are coal, petroleum-based materials, and organic materials. The raw material or feedstock can be prepared and fed, either in dry or slurried form, into a sealed reactor chamber called a gasifier. In the gasifier, the feedstock is subjected to high heat, pressure, and controlled amount of oxygen. The environment in the gasifier is either oxygen-rich or oxygen-starved environment. However, oxygen is not required in mostly commercial gasification technologies.

Gasification produces three primary products, namely hydrocarbon gases (syngas), hydrocarbon liquids (oils) and char (carbon black and ash). The syngas is primarily carbon monoxide and hydrogen (≥85 percent) and smaller quantities of carbon dioxide and methane. Both syngas and oil has the potential in generation of electricity and other wide usages.

2.1.1 History of gasification

The history of gasification dated back to mid-1800's and had undergo a long history of development. It is initially used to produce 'town gas' from coal for heating, cooking and lightning purpose. This 'town gas' is later substituted by natural gas after the founding of the gas fields. The break-out of World War II had caused fuel shortages in Europe. This leads the Europeans to return to gasification-powered energy to power their motor vehicles. Thus, wood gas generators named Gasogene or Gazogene is introduced. After the war, demand for liquid fuels remained and the German engineers made a successful production of synthetic liquid fuel from gasified coal.

In the 1970's the U.S. government launched a large industrial scale gasification projects due to the Arab Oil Embargo and the "energy crisis". From this development came the first Integrated Gasification Combined Cycle (IGCC) electric generating plant. Presently, several IGCC power plants are operating throughout the world. And crude oil price spikes and geopolitical instabilities in major oil-producing countries have generated serious interest in using gasification for GTL (Gas To Liquid) synthetic fuel processes.

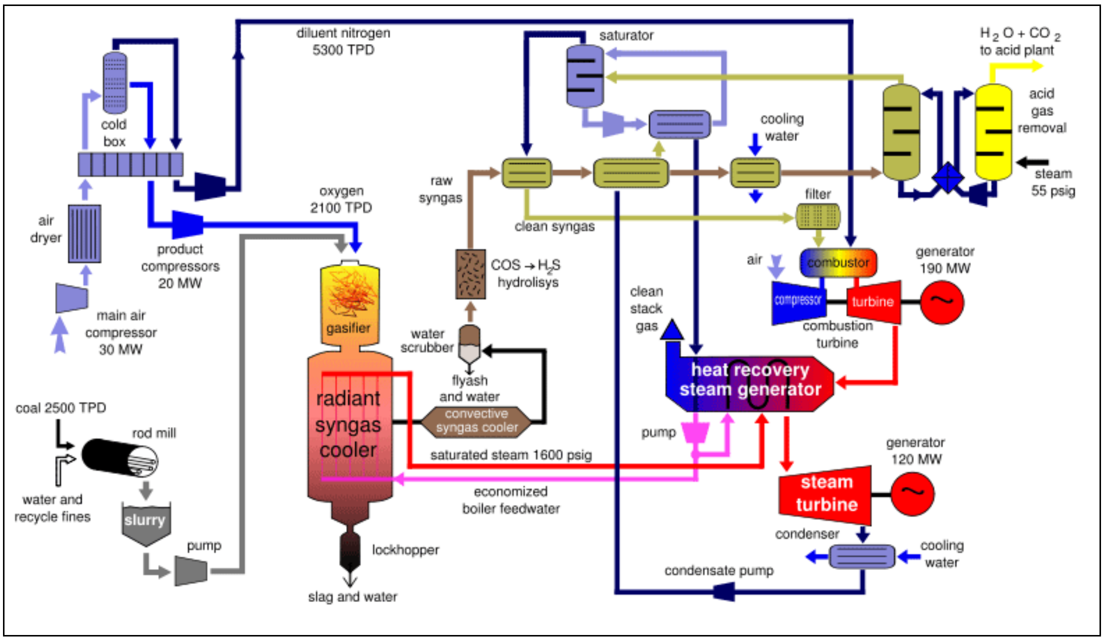

Figure 2.3: Integrated Gasification Combined Cycle, or IGCC

(Source: http://en.wikipedia.org/wiki/Integrated_Gasification_Combined_Cycle)