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EFFECT OF AIR ARRANGEMENT ON WOOD COMBUSTION THROUGH CFD

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This thesis report submitted to Faculty of Mechanical Engineering in partial fulfill of the requirement of the award of Bachelor's Degree of Mechanical Engineering (Automotive)

Faculty of Mechanical Engineering
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May 2008

“I hereby to declare that the work is my own except for summaries and quotations which have been duly acknowledge”

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ACKNOWLEDMENT

I would like to express my gratitude and appreciation to my supervisor, Pn. Ernie binti Mat Tokit for her valuable suggestion and advice throughout the project. She also help in obtaining the reference and read through the manuscript of this report. From her guide and support, my work become easy and I really appreciate it. Thanks again to her.

Thanks should also be forwarded to all my family, friends, and other people which help me to finished out this reports. Not forget to the Universiti Teknikal Malaysia, Melaka that give opportunities to do this project and for all staff that gives cooperation on this work. Thanks to all.

ABSTRACT

Gasification is a process that makes a fuel from organic materials such as biomass by heating them under carefully temperature, pressure and atmospheric conditions. The project is about the adjustment of air arrangement of nozzle of updraft gasifier using FLUENT software. Using the typical design of gasifier, the model is produced in 3-Dimensional to obtained better result and analysis. Gambit software was used as a designing tool before exporting it to the FLUENT software. This project was done to reduce the emission produce gases especially methane (CH_4) and carbon monoxide (CO). Two design of gasifier are design with different arrangement to obtained better result. Using FLUENT software to calculate the result and emission inside the gasifier after combustion. The result obtained show that the proposed design able to reduce the emission in term carbon monoxide (CO) that is 260 ppm and methane (CH_4) that is 29.9 ppm. The temperature obtained also show increment that is 1017^oC at the exhaust outlet. The error obtained shows that decrement in all aspect that is 68.3% for carbon monoxide, 67.5% for methane and 52.7% for temperature. Finally, future investigation is also suggested in this study for more accurate result using computational fluid dynamic (CFD) software.

ABSTRAK

Pembakaran kebuk adalah proses penghasilan minyak daripada bahan organik contohnya bahan bakar asli yang dibakar dengan teliti pada suhu, tekanan dan keadaan atmosfera tertentu. Projek ini adalah mengenai perubahan pada sususan masukan udara kebuk pembakaran jenis masukan atas menggunakan perisian FLUENT. Dengan menggunakan rekabentuk kebuk pembakaran yang biasa, model ini dihasilkan didalam 3-dimensi untuk mendapatkan keputusan dan analisis yang lebih baik. Perisian Gambit digunakan sebagai alat merekebentuk sebelum dimasukkan kedalam perisian FLUENT. Projek ini dihasilkan bertujuan untuk mengurangkan asap yang dihasilkan terutama metana (CH_4) dan karbon monoksida (CO). Dua rekaan kebuk pembakaran yang berlainan susunan masukan udara direka untuk mendapatkan keputusan yang lebih baik. Penggunaan perisian FLUENT adalah untuk mengira keputusan dan asap yang berada didalam kebuk pembakaran. Keputusan menunjukkan rekaan bentuk yang baru berupaya mengurangkan asap yang dihasilkan iaitu karbon monoksida (CO) 260 ppm dan metana (CH_4) sebanyak 29.9 ppm. Suhu juga menunjukkan peningkantan iaitu 1017^{o}C pada keluaran ekzos. Peratusan perbezaan juga menunjukkan penurunan bagi semua aspek dengan 68.3% bagi karbon monoksida, 67.5% bagi metana dan 52.7% bagi suhu. Kajian lanjutan dicadangkan untuk mendapatkan keputusan yang lebih tepat menggunakan perisian Dinamik Bendalir Berbantu Komputer (CFD).

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INTRODUCTION

1.1 Overview

The requirements of energy are slightly high nowaday due to the rapid industrialization and improvement of standard of living. Thus the usage of biomass as an alternative solution has came commercialized all around the world. Industrial waste has become a major concern in dealing with this problem especially in ecosystem or in other word, controlling the pollution nowadays. Substantial quantities of waste of biomass that produced by the industry are burned to produce heat for wood drying and other applications, and the combustion process can lead to the generation of significant concentrations of power. As 90 % of the world's population is expected to reside in developing countries by 2050, biomass energy is likely to remain a substantial energy feedstock. The usage of wood as one source of energy was important because:

i) It transform the waste component into usable substance
ii) It slow down the depletion of primary resource in industrial production
iii) It reduce the pollution that occur to this world and nature

The concept of marketing the biomass energy has a huge potential in Malaysia considering that the country has an abundant supply of waste that can be used to generated energy. In wood industry, a large amount of wood waste can be burned to generate electricity in the wood processing industry itself. This can automatically save cost and produce more output if these concepts are use widely.

Amongst the thermo-chemical conversion technologies, biomass gasification has attracted the highest interest as it offers higher efficiencies in relation to combustion. Gasification is a partial oxidation process at elevated temperatures around 500ºC to 1400ºC that results in producer gas consisting of carbon monoxide (CO), Hydrogen (H_2), carbon dioxide (CO_2), methane (CH_4), traces of higher hydrocarbons such as ethane and ethene, water vapour, nitrogen as the air is the oxidizing agent and various contaminants such as small char particles, ash, tar and oil.

"Gasification of biomass is primarily done in fixed and fluidized beds. The fixed bed gasifiers are suitable for small-scale applications and the fluidized bed configurations are cost effective in large-scale applications that generate over 15 MWe"(Barker, 1996). This paper will presents the review of the effect of air arrangement on wood combustion process through CFD to reduce the production of CO and CH_4 release by the gasifier.

1.2 Problem Statement

In the presence of air, heat causes organic materials to burn. Burning or oxidation is what typical gasifier do. The burning of waste in gasification causes well-known negative environmental and public health effects. Gasification facilities produce gas primarily carbon monoxide (CO), hydrogen (H_2), methane (CH_4), carbon dioxide (CO_2), hydrocarbon oils, char and ash.

The previous gasifier is design without experimental work and produces a big amount of emission. Thus, this project was proposed to investigate and reduce the amount of carbon monoxide and methane produce by the biomass after burned in the gasifier. So the simulation on wood combustion need to be done by using the CFD in determines the air arrangement of the gasifier in reducing carbon monoxide and methane.

1.3 Objective

The objective of this study is:

i) To design a new model of gasifier which used biomass waste that is wood as a combustion particle
ii) To analysis the effect of air nozzle arrangement on reducing carbon monoxide and methane
iii) To compare two type of gasifier with different nozzle arrangement and how it influent the producing of methane and carbon monoxide

1.4 Project Scope

The scope of this project work generally involved the following:

i) Literature review specifically on updraft gasifier and wood combustion process
ii) Draw 2 different gasifier with different air nozzle arrangement on updraft gasifier through Gambit software
iii) Simulate 2 different nozzle design of wood combustion using FLUENT 6.1
iv) Compare the effect of both design with current design in term of carbon monoxide and methane produced

CHAPTER II

LITERATURE REVIEW

2.1 Introduction of Gasifier

Gasifier is a process that makes a fuel gas from organic materials such as biomass by heating them under carefully controlled temperature, pressure, and atmospheric conditions. A key to gasification is using less air or oxygen than is usually found in the firebox of a boiler. The fuel product of gasification is called biogas or fuel gas, which can be used to run power generator such as internal combustion engine and external combustion engine.

The fixed bed gasification system consists of a gasifier with a gas cooling and cleaning system. The fixed bed gasifier has a bed of solid fuel particles through which the gasifier 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. Mostly these fixed bed gasifier were 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" (Carlos *et al.* 1988).

"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 "(Carlos, 2006).

2.1.1 Two Stage Incinerator

In early 2000, a group of engineers from Universiti Teknologi Malaysia developed a modular two-stage incinerator system (throughput of 1000kg/h) with output of 5MW to incinerate biomass wastes (Aziz A. A. *et al*. 2002). Figure 3.1 shows the top view of overall incinerator placed in Universiti Teknologi Malaysia's laboratory on approximately 74m^2 floor areas. The system is modular in concept and consists of several major components as shown in Figure 3.1. It is made up of i) a primary combustor, ii) a thermal oxidizer, iii) a secondary combustor, iv) a heat exchanger, v) an economizer, vi) a gas cleaning train, vii) a waste conveyor, viii) a control room, ix) gas supply lines and x) an exhaust extractor.

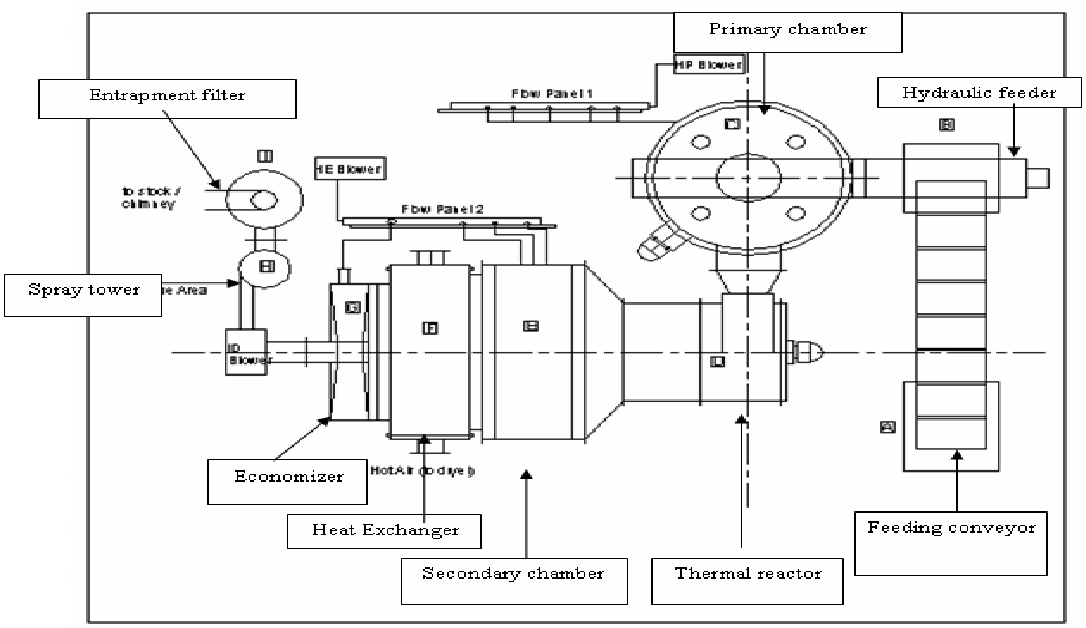

Figure 2.1: Top view of Universiti Teknologi Malaysia (UTM) Two stage incinerator
(Abdul Aziz A.A. *et al*, 2002)

The primary chamber is located beside thermal reactor and hydraulic feeder. The primary chamber is and updraft gasifier with 1.875m height and 1.945 m width. Primary chamber is used to burner the waste that feed by the hydraulic feeder. The combustion takes part thus the produced gasses will flow into the thermal reactor and thus continue it flow until the end of the process.

2.2 Definition of Gasifier

Gasification is the gas production process that produces from the combustion in a gasifier. Complete combustion process generally contain nitrogen, carbon monoxide, water vapor and surplus of oxygen. However in gasification where there is a surplus of solid fuel for the incomplete combustion products are combustible gases like Carbon Monoxide (CO), Hydrogen (H_2) and traces of Methane and non useful products like tar and dust. The production of these gases is by reaction of water vapor and carbon dioxide through a glowing layer of charcoal.

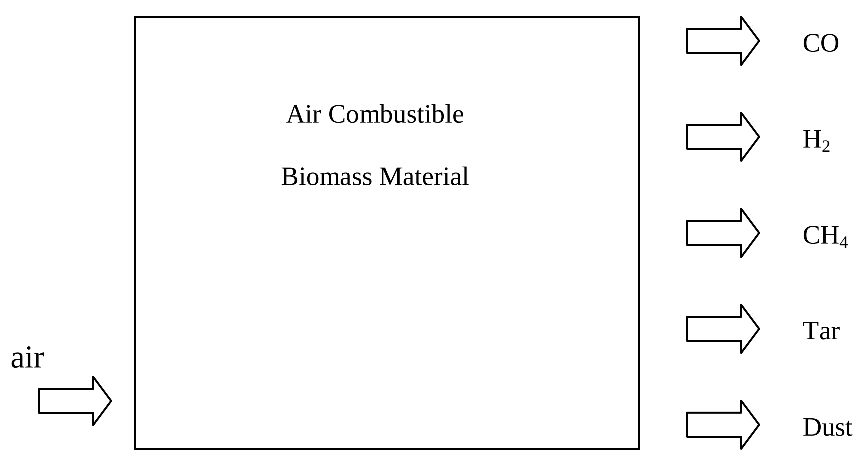

Figure 2.2: Product of Combustion in Gasifier (Carlos, 2006)

2.3 Fixed Bed Gasifier

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 in example updraft, downdraft, crossdraft and two stage gasifier. The downdraft gasifiers are Imbert type that is gasifier with throat and open core type that is 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" (Bridgwater *et al.* 1995).

2.3.1 Updraft Gasification System

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 robust than other fixed bed gasifiers because it is less sensitive to variations in size and quality of biomass. In an updraft 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 (Carlos, 2006).

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.

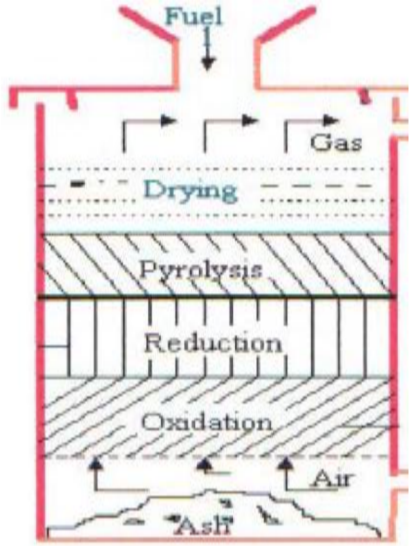

Figure 2.3: Updraft Gasifier (Bridgwater *et al.* 1995)

The producer gas from updraft gasifier has high amount of tar and is therefore mostly used in thermal applications. Payne (1993) investigated the performance of an updraft gasifier used in conjunction with a combustor for grain drying. Maize cobs of varying moisture content (9-46 %) were gasified in the gasifier with primary air as the gasifying medium. The producer gas was then completely combusted with secondary air and the exhaust gas mixed with the ambient air and used directly for drying the grain.

"For successful operation the biomass fuel had moisture content less than 50 %, ash less than 10 % of dry matter with minimum softening point of ash above 1190 ºC. Above 50 % moisture content the producer gas contained lot of tar aerosols. The producer gas generated from gasification of wood chips of 41 % moisture content consisted of 30 % CO, 11 % H_2, 3 % CH_4, 7 % CO_2, and 49 % N_2 with HHV of 6.2 MJ/Nm^3. The tar content of dry producer gas was in the range 50–100 g/Nm^3. The gasifier proved to be economically feasible for small heating systems" (Bridgwater *et al.* 1995).

2.3.2 Downdraft Gasification System

The downdraft gasifier or throated downdraft gasifier features a co current flow of gases and solids through a descending packed bed, which is supported across a constriction or throat. The biomass fuel enters through the hopper and flows down, gets dried and pyrolysed before being partially combusted by the air entering at the nozzles. The throat allows maximum mixing of gases in high temperature region, which aids tar cracking. Below the constriction or 'throat' the combustion gases along with tar pass through the hot char and are reduced to primarily CO and H_2.

The gasifier can handle uniformly sized biomass fuels having moisture content and ash content less than 20 % and 5 % respectively. The throated downdraft gasifier is generally used for gasification of woody biomass of uniform sizes and shapes (blocks) as they flow smoothly through the constricted hearth. "The producer gas from downdraft gasifier has lesser tar-oils (<1 %), higher temperature (around 700ºC) and more particulate matter than that from an updraft gasifier. The physical limitations of biomass particle size limit the capacity of the throated downdraft gasifiers to 500 Kw (Bridgwater, 1995).

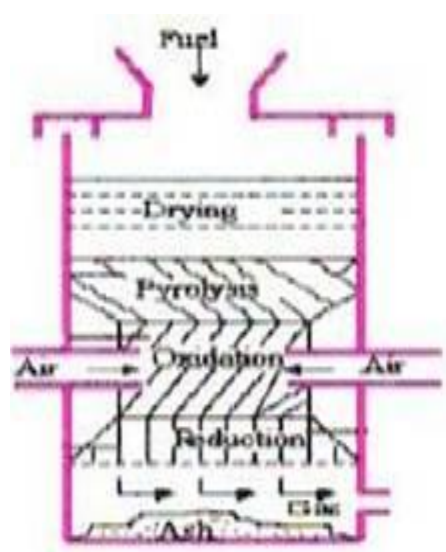

Figure 2.4: Downdraft Gasifier (Bridgwater *et al.* 1995)