EFFECT OF GASIFIER DIMENSION ON WOOD COMBUSTION THROUGH CFD

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"I hereby to declare that the work is my own except for quotations which have been acknowledged"

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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 modeling the biomass combustion inside the updraft gasifier. The project is design to study the effect of the gasifier dimension on wood combustion trough CFD. Using the typical design of gasifier, the model is modeled in 3-Dimensional. The result that obtained in this project is methane (CH_4) and carbon monoxide (CO). The carbon monoxide produced from new design is 628 ppm and methane is 83.6 ppm. The result show that the carbon monoxide is reduced 23.5% and methane is reduced 9.5% from the current design. From the result the small dimension of gasifier is able to reduce methane (CH_4) and carbon monoxide (CO).

ABSTRAK

Pembakaran kebuk adalah proses penghasilan bahan bakar daripada bahan organik contohnya bahan bakar asli yang dibakar dengan teliti pada suhu, tekanan dan keadaan atmosfera tertentu. Projek ini adalah membuat model pembakaran kebuk untuk bahan organik. Projek ini bertujuan untuk menkaji kesan dimensi ataupun saiz kebuk terhadap proses pembakaran kebuk menggunakan perisian CFD. Model kebuk pembakaran dimodelkan sebagai bentuk 3-dimensi.. Keputusan yang dicatat dari projek ini adalah karbon monoksida (CO) dan metana (CH_4). Karbon monoksida yang dihasilkan oleh rekaan baru adalah 628 ppm dan metana adalah 83.6 ppm. Keputusan menunjukkan pengurangan penghasilan karbon monoksida sebanyak 23.5% dan pengurangan penghasilan metana sebanyak 9.5% berbanding rekaaan asal. Daripadakeputusan yang di perolehi, kebuk pembakaran yang bersaiz kecil mampu mengurangkan penghasilan metana dan karbon monoksida.

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INTRODUCTION

1.1 Project Overview

1.1.1 Simulation in CFD

Nowadays, lots of computational fluid dynamics (CFD) simulations were conducted to study the effects of moisture in biomass, particle injection location, the burnout of different biomass particle sizes and many others characteristics of the biomass so that the prediction of the biomass combustion can be made.

This study is useful for future in designing a gasifier. Definitely coal gasifier and biomass gasifier are different things as coal char in gasification reactivity is significantly different from biomass reactivity.

1.1.2 Current Chamber (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 1.1 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 1.1. 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.

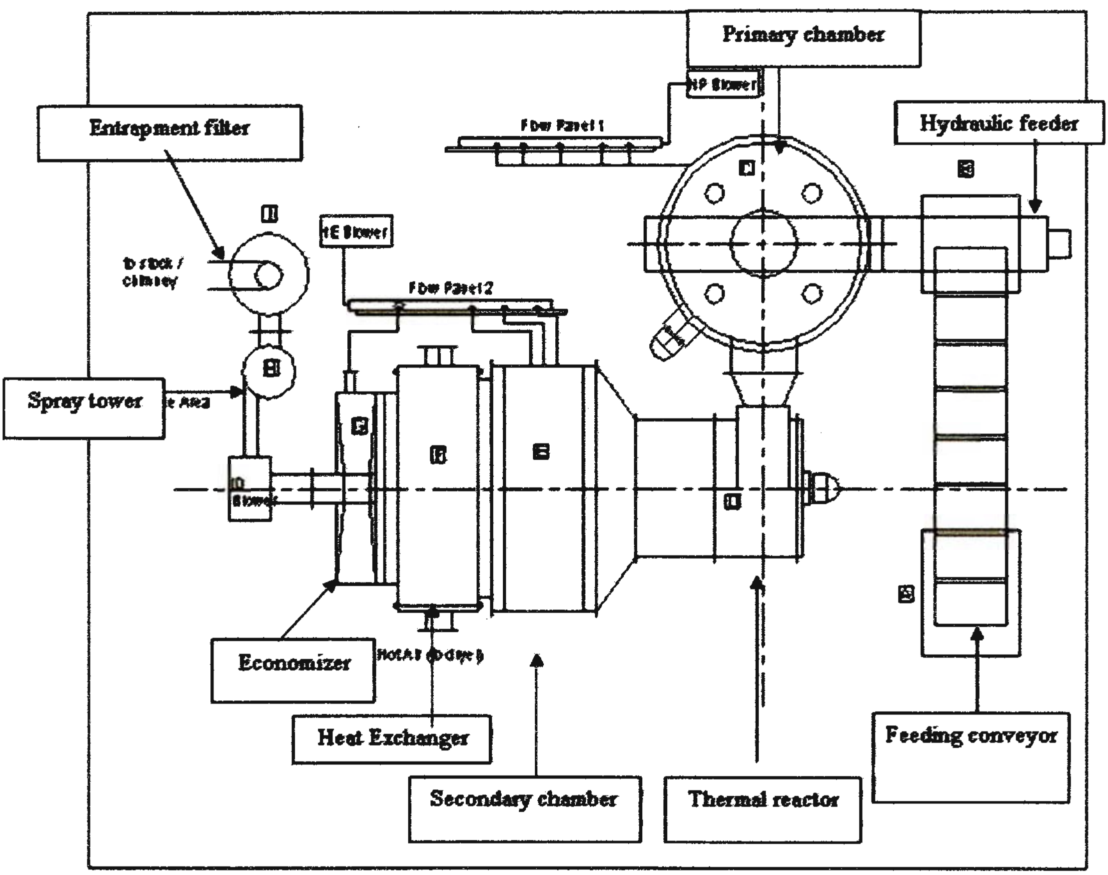

Figure 1.1: Two stage incinerator (source: Aziz A. A. *et al.*, 2002)

1.2 Problem Statement

The current primary chamber is designed based on rule of thumb without extensive working through numerical studies and experimental work. Hence, a further study needs to be done to optimize the current chamber's performance in terms of the product gases released.

The main factor in this project is, to reduce the product gases released by the biomass (after burned in the gasifier). So the simulation on wood combustion needs to be done using the CFD in determining the effect of shape of the gasifier in reducing carbon monoxide and methane.

1.3 Objective

The objectives of this project are:

- To design a new one gasifier (updraft gasifier) which use biomass waste as the fuel through CFD..
- To analyse the effect of the gasifier's dimension on the product released such as carbon monoxide and methane
- To compare the shape of the new one gasifier with the existing gasifier on how it influent the producing of methane and carbon monoxide.

1.4 Scope

The scopes of this project are:

- Draw two different gasifier's dimension or shape on updraft gasifier through Gambit software
- Simulate the wood combustion on each design
- Compare the effects of both design with the current design in terms of carbon monoxide and methane produced.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Biomass gasification means incomplete combustion of biomass resulting in production of combustible gases consisting of Carbon monoxide (CO), Hydrogen (H_2) and traces of Methane (CH_4). This mixture is called producer gas. Producer gas can be used to run internal combustion engines (both compression and spark ignition), can be used as substitute for furnace oil in direct heat applications and can be used to produce, in an economically viable way, methanol. The methanol, which is an extremely attractive chemical is useful both as fuel for heat engines as well as chemical feedstock for industries. Since any biomass material can undergo gasification, this process is much more attractive than ethanol production or biogas where only selected biomass materials can produce the fuel. (Reed *et al.,* 1982)

2.2 Definition of Gasifier

The production of generator gas (producer gas) called gasification, is partial combustion of solid fuel (biomass) and takes place at temperatures of about 1000 °C. The reactor is called a gasifier. The combustion products from complete combustion of biomass generally contain nitrogen, water vapor, carbon dioxide and surplus of oxygen. However in gasification where there is a surplus of solid fuel (incomplete combustion) the products of combustion are Figure 2.1 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. Thus the key to gasifier design is to create conditions such that biomass is reduced to charcoal and, charcoal is converted at suitable temperature to produce CO and H_2. (Skov *et al.,* 1974)

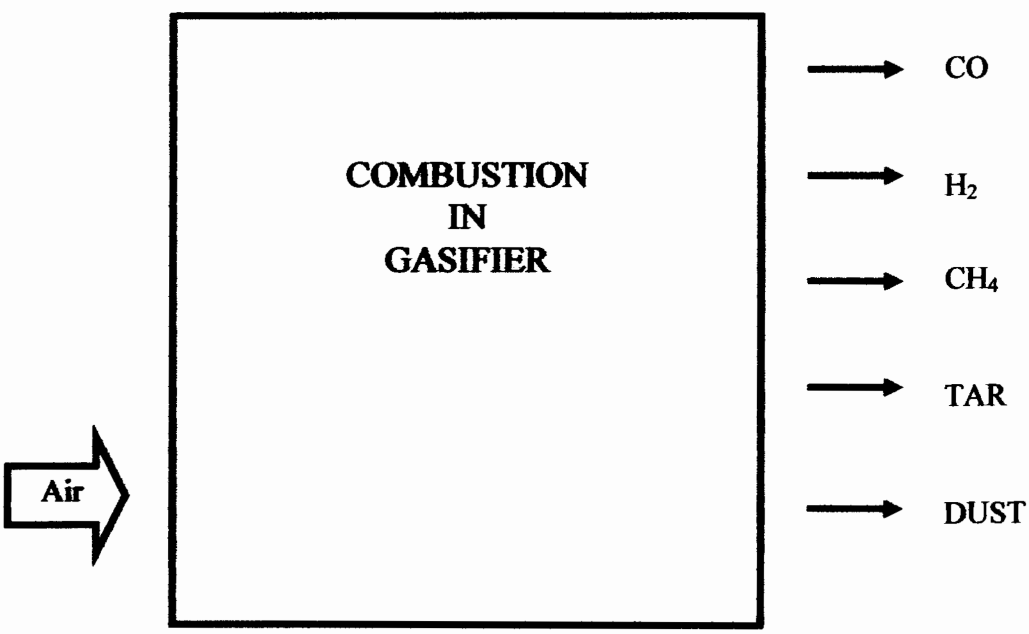

Figure 2.1: Product of combustion in a gasifier. (Source: Skov *et al.,* 1974)

2.3 Type of Gasifier

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 there are: downdraft, updraft and crossdraft. 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. Similarly in the downdraft gasifier the air is passed from the tuyers in the downdraft direction.

2.3.1 Updraft Gasifier

Also known as counterflow gasification, the updraft configuration is the oldest gasifier; it is still used for coal gasification. Biomass is introduced at the top of the reactor, and a grate at the bottom of the reactor supports the reacting bed. Air or oxygen and/or steam are introduced below the grate and diffuse up through the bed of biomass and char. A complete combustion of char takes place at the bottom of the bed, liberating CO_2 and H_2O. These hot gases (~1000 °C) pass through the bed above, where they are reduced to H_2 and CO and cooled to 750 ^{0}C. Continuing up the reactor, the reducing gases (H_2 and CO) pyrolyse the descending dry biomass and finally dry the incoming wet biomass, leaving the reactor at a low temperature (~500 °C). (Reed *et al.,* 2001)

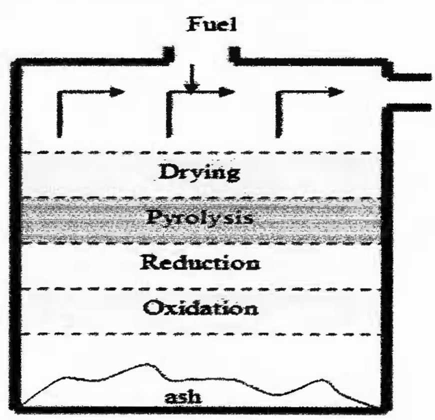

Figure 2.2: Updraft Gasifier (Source: S. Chopra and A. Jain, 2007)

2.3.2 Downdraft Gasifier

The downdraft gasifier or throated downdraft gasifier features a cocurrent flow of gases and solids through a descending packed bed, which is supported across a throat. The biomass fuel enters through the hopper and flows down, gets dried and pyrolysed. A lower overall efficiency and difficulties in handling higher moisture and ash content are common problems in small downdraft gas producers. The time (20-30 minutes) needed to ignite and bring plant to working temperature with good gas quality is shorter than updraft gasifier. This gasifier is preferred to updraft gasifier for internal combustion engines. With slight variation almost all the gasifiers fall in the above categories. The choice of one type of gasifier over other is dictated by the fuel, its final available form, its size, moisture content and ash content. Table 2.1 lists therefore, the advantages and disadvantages generally found for various classes of gasifiers (S. Chopra and A. Jain, 2007).

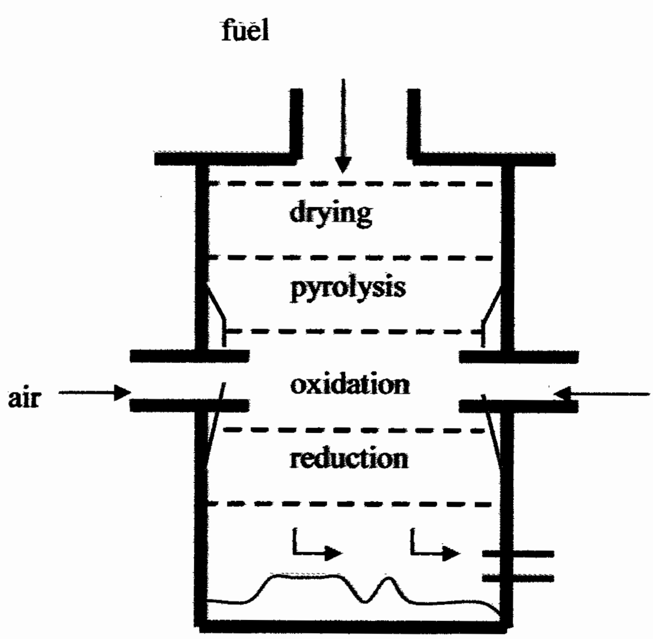

Figure 2.3: Downdraft Gasifier (Source: S. Chopra and A. Jain, 2007)

2.3.3 Crossdraft Gasifier

Crossdraft gas producers, although they have certain advantages over updraft and downdraft gasifiers, they are not of ideal type. The disadvantages such as high exit gas temperature, poor CO_2 reduction and high gas velocity are the consequence of the design. Unlike downdraft and updraft gasifiers, the ash bin, fire and reduction zone in crossdraft gasifies are separated. These design characteristics limit the type of fuel for operation to low ash fuels such as wood, charcoal and coke. The load following ability of crossdraft gasifier is quite good due to concentrated partial zones which operates at temperatures up to 2000 ^{o} c. Start up time (5-10 minutes) is much faster than that of downdraft and updraft units. The relatively higher temperature in cross draft gas producer has an obvious effect on gas composition such as high carbon monoxide, and low hydrogen and methane content when dry fuel such as charcoal is used. Crossdraft gasifier operates well on dry air blast and dry fuel.

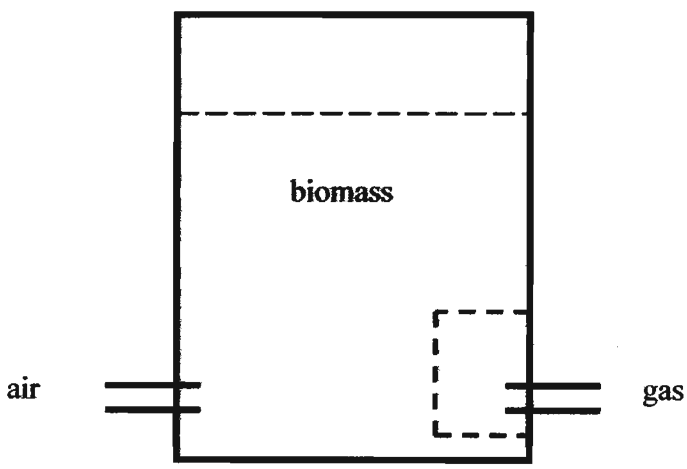

Figure 2.4: Crossdraft Gasifier (Source: S. Chopra and A. Jain, 2007)

2.3.4 Advantages and Disadvantages of Gasifier

Table 2.1: Advantages and Disadvantages of Gasifiers (Source; S. Chopra and A. Jain, 2007)

Sr. No.	Gasifier Type	Advantage	Disadvantages
1.	Updraft	- Small pressure drop - good thermal efficiency - little tendency towards slag formation	- Great sensitivity to tar and moisture and moisture content of fuel - relatively long time required for start up of IC engine - poor reaction capability with heavy gas load
2.	Downdraft	- Flexible adaptation of gas production to load - low sensitivity to charcoal dust and tar content of fuel	- Design tends to be tall - not feasible for very small particle size of fuel
3.	Crossdraft	- Short design height - very fast response time to load - flexible gas production	- Very high sensitivity to slag formation - high pressure drop

2.4 Gasification

Four distinct processes take place in a gasifier as the fuel makes its way to gasification are:

a) Drying of fuel

b) Pyrolysis

c) Combustion

d) Reduction

Though there is a considerable overlap of the processes, each can be assumed to occupy a separate zone where fundamentally different chemical and thermal reactions take place. Figure 2.5 shows schematically an updraft gasifier with different zones and their respective temperatures.

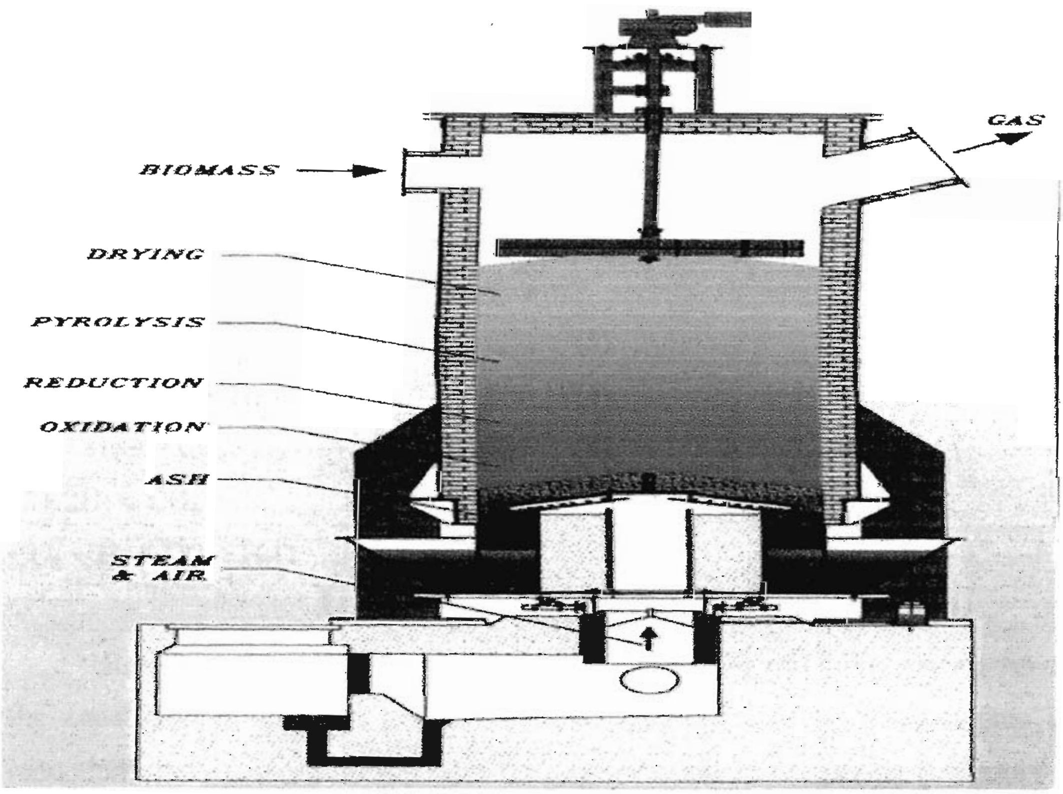

Figure 2.5: Updraft gasifier (combustion process). (Source: S. Chopra and A. Jain, 2007)

2.4.1 Combustion Zone

The combustible substance of a solid fuel is usually composed of elements carbon, hydrogen and oxygen. In complete combustion carbon dioxide is obtained from carbon in fuel and water is obtained from the hydrogen, usually as steam. The combustion reaction is exothermic and yields a theoretical oxidation temperature of 1450^0C (Schapfer *et al.*, 1937). The main reactions, therefore, are:

$C + O_2 = CO_2$ (1)

$2H_2 + O_2 = 2H_2O$ (2)

2.4.2 Reduction Zone

The products of partial combustion (water, carbon dioxide and uncombusted partially cracked pyrolysis products) now pass through a red-hot charcoal bed where the following reduction reactions take place. (Solar Energy Research Institute, 1939-1945)

$C + CO_2 = 2CO$ (3)

$C + H_2O = CO + H_2$ (4)

$CO + H_2O = CO + H_2$ (5)

$C + 2H_2 = CH_4$ (6)

$CO_2 + H_2 = CO + H_2O$ (7)

Reactions (3) and (4) are main reduction reactions and being endothermic have the capability of reducing gas temperature. Consequently the temperatures in the reduction zone are normally $800\text{-}1000^0C$. Lower the reduction zone temperature (~ $700\text{-}800^0C$), lower is the calorific value of gas.