COMPUTATIONAL STUDY ON THE EFFECT OF TEMPERATURE IN FLUIDIZED BED GASIFIER

NORELYANI BINTI BAHROM

A report submitted in fulfillment of the
requirements for the award of the degree of
Master of Mechanical Engineering

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

JUNE 2013

To my parents for their love, support encouragement.

To my families, siblings, friends and lecturers especially Assoc. Prof Dr Kahar bin Osman, for their guidance through the whole process for this project.

ACKNOWLEDGEMENT

A big thanks and appreciation to my supervisor, Assoc. Prof Dr Kahar bin Osman for the guidance, encouragement, ideas and advices through the whole process in completing my master project. Without him, this project might be quite impossible to be completed. I am very grateful and I have learnt a lot from this project. A lot of thank for all the lecturers that had helped me to complete this project.

Special thank goes to my family and siblings that had support me since the first year of my study in UTM Skudai. I would not be able to success in this project without their persistence in giving me moral support and also financial support.

I would like to thank course mate and friends who have helped me a lot is this project. They had taught me the value of time, friendship, ethics and many more. Besides, their existence through this project had encouraged me to complete my work successfully.

Thanks to TNB research center at Bangi especially Dr. Nor Fadzilah Othman for her help, guide and advice during the progress of this study.

ABSTRACT

Fluidized bed gasifier which is excellent in temperature control was selected to be modelled in ANSYS FLUENT. Temperature is one of the important hydrodynamic parameter in developing the large-scale industrial power plant. Study will be emphasized on three different temperatures where each of them was expected to give different view on the effect within the gasifier. Results of gases composition were compared with existing experimental data from the pilot scale gasifer in TNBR, Bangi. Distribution of gas and solid phase temperature in the gasifier has been studied by considering the heat generated from each process. Using Eulerian Eulerian approach, different phases of solid and gas is being treated mathematically in computational fluid dynamic (CFD). Chemical reaction for heterogeneous and homogenous is the key for this computational study. For the three case studies, result has shown that the gas temperature was evenly distributed as it reaching up to the gasifier outlet and carbon monoxide (CO) composition is observed to be decreasing to zero quantity as it moves towards the upper part of the gasifier.

ABSTRAK

Fluidized bed yang sangat berkesan dalam kawalan suhu telah dipilih untuk dimodelkan menggunakan *ANSYS FLUENT*. Suhu merupakan salah satu hidrodinamik parameter yang penting dalam membangunkan loji kuasa industri. Kajian akan diberi penekanan kepada tiga suhu yang berbeza di mana setiap daripada suhu tersebut ia dijangka akan memberikan pandangan yang berbeza tentang kesan dalam penggas. Keputusan komposisi gas dibandingkan dengan data eksperimen yang sedia ada dari penggas skala perintis di TNBR, Bangi. Pengagihan suhu pada fasa gas dan pepejal dalam penggas telah dikaji dengan mengambil kira haba yang dihasilkan daripada setiap proses. Menggunakan pendekatan Euler Euler, fasa pepejal dan gas dirawat secara matematik dalam pengiraan dinamik bendalir (CFD). Tindak balas kimia untuk *heterogenous* dan *homogenous* adalah kunci untuk kajian ini. Bagi tiga kajian kes, keputusan telah menunjukkan bahawa suhu gas adalah sama rata sehingga ia keluar dari penggas dan komposisi gas karbon monoksida (CO) diperhatikan berkurangan sehingga kuantiti sifar di sepanjang pergerakan ke bahagian atas penggas tersebut.

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a	-	absorption coefficient
C_x	-	constant
c_p	-	specific heat
F	-	body forces
f	-	mixture fraction
g	-	gravity
H	-	total enthalpy
h	-	species enthalpy
J	-	mass flux; diffusion flux
k	-	turbulence kinetic energy
m	-	mass
p	-	pressure
P_r	-	Prandtl number
q	-	heat flux
t	-	time (s)
T	-	temperature (K)
U	-	mean velocity (m/s)

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Globally rising demands of clean energy has made Malaysia's largest power provider TNB to invest in the IGCC (Integrated Gasification Combined Cycle). Studies are carried out to ensure that the first application of IGCC in Malaysia is worth the time and money being spent. Due to the availability of coal in Malaysia that is higher in moistures despites the lower energy content, type of gasifier that is suitable to produce optimum clean power need to be carefully selected. Selection of gasifier from entrained type gasifier, bubling fluidized bed or updraft gasifier are available in the market. Every each of it has the advantages and disadvantages depend on the type of feedstock.

Existing coal power plant does not tackle the climate changes issues that the world is facing. By applying conventional hydroelectricity and small biomass power plant it helps Malaysia in lowering the index of pollution but still it is not sufficient. Therefore, a promising technology IGCC is the reliable solution.

The needs of developed countries to reduce total emission of greenhouse gases between year 2008 and 2012 based on Kyoto Protocol is by at least 5% from the reported level in 1990. 32% power efficiency is achievable for IGCC complete with carbon capture and storage compare to the conventional coal power plant that is 26% according to study conducted by National Energy Technology Laboratory (NETL)

In IGCC system where gasifier is the heart, a process that converts carbonaceous materials such as coal, petroleum, biofuel or biomass into synthesis gas takes place. By subjecting the coal to a high temperature, with controlled amount of oxygen or steam, gasification process is carried out. Major difference between combustion and gasification is the heat released from the chemical reaction. Chemical energy is released as heat in combustion but not in gasification. The temperature within the gasification zone could be too low for reaction to start which minimum of 350°c to gasify coal.

As a result gas mixture synthesis also known as syngas is being produce. In this case the mixture gas itself is a fuel use to generate the gas turbine. Synthesis gas contains carbon monoxide (CO), hydrogen (H_2), and other components such as water (H_2O), methane (CH_4) and carbon dioxide (CO_2).

Computing ability enhancement has made computational fluid dynamic (CFD) as a reliable tools to perform a study for complex flow and multiphase chemical reactions. Information of gasification process could be provided in designing large scale industrial gasifier. Via CFD modeling, troubleshooting problems that normally difficult to be measured in experiment is possible. Implementation of commercial software FLUENT made all the objectives seems achievable.

Studies on fluidized bed gasifier will be carried out by focusing the temperature effect within the gasifier itself. Temperature is the main effect on the hydrodynamic parameters which in the end giving the ultimate end product.

1.2 Research Objective

There are several parameters in gasification process which have different effect to the process. The objective of the study is to focus on the effect of temperature on various other parameters such as carbon conversion, cold gas efficiency as well as tar

and char content for coal by conducting a 2D fluent simulation. However, this study focused more to the fluidized bed gasifier as the pilot scale gasifier operated in TNBR, Bangi is using this type. This pilot scale gasifier is the ultimate model to perform the studies.

The aims of this paper it to study the temperature effect within the gasifier itself to the carbon conversion process. Been taken into consideration that the minimum temperature for a pyrolysis process to start is at minimum temperature of 350°C, study will be starting beyond this temperature. Other specific objectives of this study is to observe the effect for running the gasifier above the maximum average temperature for fluidized bed gasifier that is 1100°c.

1.3 Problem Statement

With numerous of research conducted, efficient production of synthesis gas (a mixture of hydrogen and carbon monoxide) is gaining attention as the worldwide interest in synthetic fuels. Depending on the feedstock and the process this will contribute to the effect of hydrogen to carbon monoxide ratio which is also called as syngas ratio. Study will focus on temperature above (>350°c) by CFD simulation. Comparison will be made with result from past research papers for the temperature effect and syngas ratio produced.

1.4 Scope of Research

This research deals mainly with coal gasification in detail. There are several process parameters which have a direct effect on the gasification process and among them temperature is the most significant one. In this paper, the production of H2, CO2, CO, CH4, and other hydrocarbons in fluidized bed gasification with the

variation of temperature is reviewed in detail. Temperature limitation 350°c to 1100°c as mentioned in previous paper done by Leila et al. (2012) is taken into consideration. As it mainly influences the gaseous products and their characteristic behavior, this paper will also takes into account the effect of temperature on various other hydrodynamic parameters and carbon conversion.

It is proven by previous research that CFD simulation is an economical and effective tool to study coal gasification. Study is applying method of Eulerian-Eulerian due to concentrations of coal particles which are dense in the fluidized bed and therefore tracing each particle with the Lagrangian method is not realistic. Both gas and solid phase (secondary phase) are solved by using Eulerian method. A process known as "fluidization" which the gas mixture of gas phase is passed up through this bed and converts this granular material from a static solid-like state to a dynamic fluid-like state is needed for both homogeneous (gas-gas) reaction and heterogeneous (gas-solid) reactions to simulate this study.

1.5 Theoretical Framework

Figure on the next page is showing the framework of this study. The critical step is the development of mathematical and computational 2-D model for the fluidized bed gasifier.

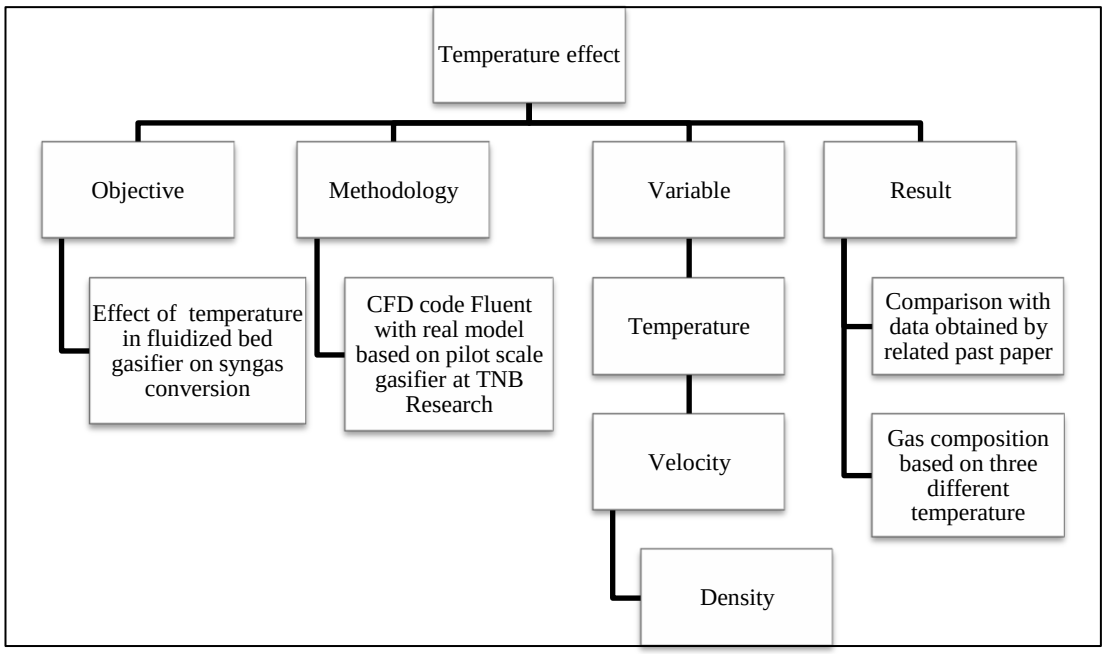

Figure 1.1: Theoretical of Framework

1.6 Organization of Thesis

Chapter 1: Introduction

This chapter describes the research background of this. The objective of the project also been stated in this chapter.

Chapter 2: Literature Review

In this chapter, the item that will be discussed is the related works and literature review that will supported this study.

Chapter 3: Methodology

The most significant chapter that is chapter 3 detailing on the research methodology identifying variables and equations involved in the modeling and

simulation part. Furthermore, data collections method and the accuracy of the result are been listed out in that chapter.

Chapter 4: Result and Discussion

In chapter 4 results from simulation done are listed out and discussion is carried out for the results obtained

Chapter 5: Conclusion and Recommendation

In the last chapter it is dedicated for conclusion of the study and recommendations on future improvements to have the optimized temperature needed for this study. This proposal will have the reference list post and also the appendices.

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