MODELLING OF COAL COMBUSTION IN A COMBUSTOR

MOHD ZULFADLI BIN MOHD YUSOF

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MODELLING OF COAL COMBUSTION IN A COMBUSTOR

MOHD ZULFADLI BIN MOHD YUSOF

This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering (Plant and Maintenance)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this project report entitled “Modelling of Coal Combustion In A Combustor” is the result of my own work except as cited in the references

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Plant & Maintenance).

Signature : .....

Name of Supervisor: .....

Date : .....

DEDICATION

To my beloved parents, Mohd Yusof Bin Abdullah and Kamariah Bt Ibrahim, most supporting supervisor, Dr.Fudhail bin Abdul Munir, not to forget my course mate and my entire friends in UTeM for their encouragement.

ABSTRACT

Coal has many important users worldwide. Usually, coal was burned in order to generate electricity. Today, there is lots of technology related to the coal combustion such as fluidized bed combustion. To develop these technologies, the fully understanding about the coal is needed. The types, rank and properties of the coal are important because it can affect the combustion process. After getting fully understanding about the coal, modelling process can be proceed. Modelling the coal combustion in the combustor is not too easy. There are many parameter that involved in this process. One of that is inlet velocity magnitude. The effect of this parameter must be known to avoid unwanted tragedy such as the explosion of the combustor. In order to analyze the reaction of coal combustion process in a combustor, numerical simulation which is ANSYS is used while to model the combustor, SolidWorks is used. During the coal combustion process in a combustor, the velocity magnitude, temperature and pressure were affected the combustor. This study will discuss detail related to the effect of the inlet velocity to the combustor during the coal combustion process.

ABSTRAK

Arang batu mempunyai banyak kegunaan penting di seluruh dunia. Selalunya, arang batu dibakar bagi menjana tenaga elektrik. Hari ini, terdapat banyak teknologi yang berkaitan dengan pembakaran arang batu seperti pembakaran katil fluidized. Untuk membangunkan teknologi ini, pemahaman sepenuhnya mengenai arang batu amat diperlukan. Jenis, pangkat dan sifat-sifat arang batu adalah penting kerana ia boleh mempengaruhi proses pembakaran. Selepas mendapat kefahaman sepenuhnya mengenai arang batu, proses pemodelan boleh diteruskan. Pemodelan pembakaran arang batu di dalam pembakar tidak terlalu mudah. Terdapat banyak parameter yang terlibat dalam proses ini. Salah satunya ialah halaju masuk. Kesan parameter ini perlu diketahui untuk mengelakkan tragedi yang tidak diingini seperti letupan pembakar. Dalam usaha untuk menganalisis reaksi proses pembakaran arang batu dalam pembakar, simulasi berangka iaitu ANSYS digunakan manakala untuk pemodelan pembakar, SolidWorks digunakan. Semasa proses pembakaran arang batu di pembakar berlaku, halaju magnitud, suhu dan tekanan akan memberi kesan kepada pembakar. Kajian ini akan membincangkan detail berkaitan dengan kesan halaju masuk ke kebuk pembakaran semasa proses pembakaran arang batu.

ACKNOWLEDGEMENT

Bismillahirahmanirahim,

First and foremost I would like to make a special thanks to Allah because giving me the strength for this whole 4 years in engineering course and the opportunity to finish my study in Bachelor of Mechanical Enigneering(Plant and Maintenance) at Universiti Teknikal Malaysia Melaka(UTeM). Next I would like to express my appreciation to my supervisor Dr.Fudhail bin Abdul Munir for giving me a lot of guidance and encourage me to finish my project.

I would like to thank to my lovely parents for their never ending support and give me the chances to continue my study in degree without hesitation. They have helped me so much in not only my education but they also guide me on how to be the better person afterwards. Not to forget for my older sister that has always boost me for never give up in my study and also my life.

Last but not least, thank you to my fellow classmate and housemate for the unlimited time spending with me through all this 4 years' time. We have gone through a lot of pain, delight and hardness together especially to complete assignment and discussion. Thanks a lot with all your help and ideas that you have given me and motivation to finish my studies in UTeM.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBEREVATIONS

CFB Circulating Fluidized Bed Combustion

RFG Recycled Flue Gas

CHAPTER 1

INTRODUCTION

1.1 Background

Coal have many important uses worldwide. Today, coal were used in the industry such as in steel production, cement manufacturing, electricity generation and as a liquid fuel. Usually, coal will go through to the combustion process to allow us get benefits from it. So, modeling the coal combustion are needs before start the combustion process. In order to modeling the coal combustion, there are a few aspect that must be consider. For example, Fig.1 illustrate some aspects of a complex pulverized-coal flame at the industrial or utility coal boiler.

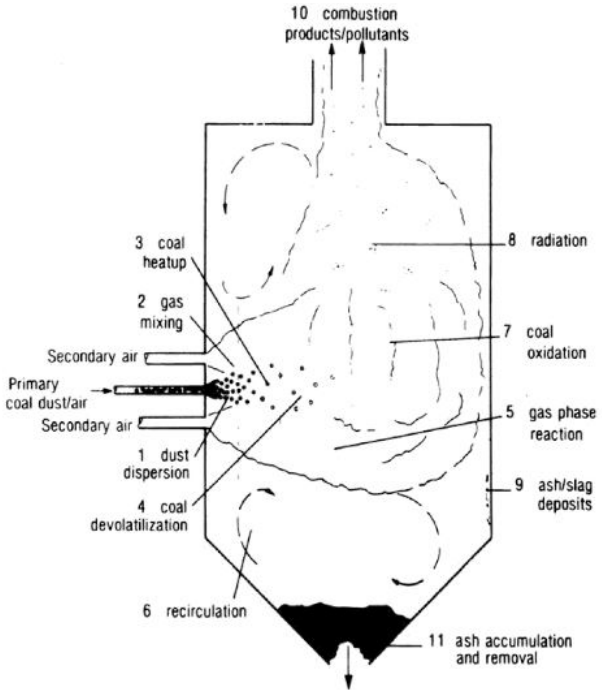

Figure 1.1: Aspect of pulverized-coal flames[1]

The main point of this study to establish a workable three dimensional (3D) model the coal combustion using the commercial software that is ANSYS with Fluent capability. In modelling the coal combustion, there are a few properties must be consider to get the best data for modelling the coal combustion. The typical properties need to be included are as follows [1]:

Independent variables

Physical coordinates(x, y, z)

Time(t)

Dependent variables

Composition of gas species	Pressure
Temperature of the gas	Mean turbulent kinetic energy
Velocity of the gas	Turbulent energy of dissipation

Input data for inlet

Velocity of the gas	Turbulent intensity of the gas
Composition of the gas	Mass flow rate of the gas
Temperature of the gas	Pressure

Reactor Parameter

Inlet location	Wall material
Dimension	Wall thickness

The results of the combustion process will be identified and discussed which is :

1. contours of temperature
2. contours of velocity magnitude
3. contours of pressure

ANSYS Fluent software contains the broad physical modelling capabilities needed to model flow, turbulence, heat transfer, and reactions[2]. By using this

simulation software, the flow inside the combustor will be established of which represents the combustion occurs inside the combustor. By changing parameters such as the inlet and outlet size, the flow is also affected[4]. Figure 1.2 shows the example of the flow that can be generated using ANSYS-Fluent.

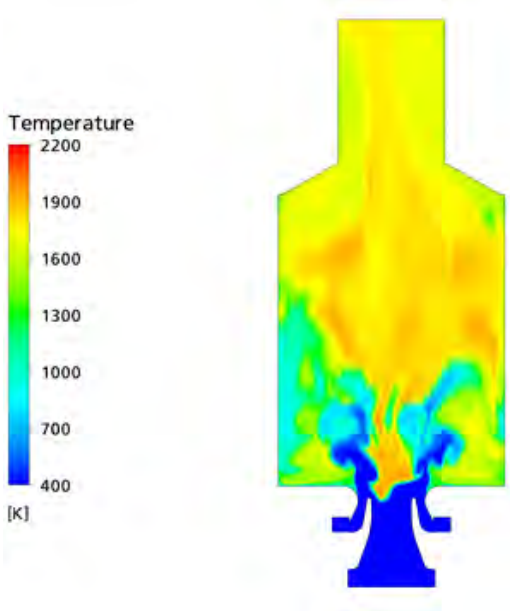

Figure 1.2 Simulation ANSYS-Fluent Flow[4]

1.2 Problem Statement

Modelling coal combustion generally difficult. There many parameters involved in the process of establishing a numerical model of coal combustion. Each parameter will affected by the process of the coal combustion. It is important to identify the effect of these parameter on the coal combustion to improve combustion efficiency and enhance safety.

1.3 OBJECTIVES

Objectives of this project are:

1. To establish a workable model of coal combustion using commercial software.

2. To identify the effect important parameter of the inlet velocity during the coal combustion process.

1.4 Project Scope

The scopes of this project are:

1. To create a workable three dimensional (3D) numerical model of coal combustion.
2. To perform simulation using ANSYS-Fluent software.
3. To investigate the effect of velocity inlet on the coal combustion.

1.5 General Methodology

The actions that need to be carried out to achieve the objectives in this project are listed below.

1. **Literature review**

   Journals, articles, or any materials regarding the project will be reviewed.

2. **Set up parameter**

   After literature review, the research take part on by set up the simulation geometry and parameter. These parameter act as manipulation in this research.

3. **Simulation by using (ANSYS-Fluent)**

   This part is where the result of the data is been collected. By running this simulation, each parameter is been set up into this software.

4. **Analysis**

Analysis will be do for each parameter in order to identify the effect of the parameter to the model.

5. **Report writing**

A report on this study will be written at the end of the project.

The methodology of this study is summarized in the flow chart as shown in Figure 1.3

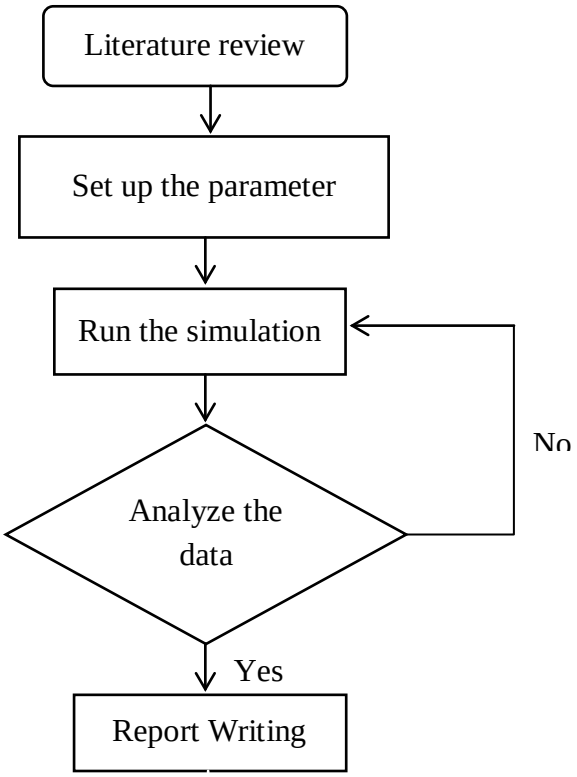

Figure 1.3: Flow chart of the methodology

CHAPTER 2

LITERATURE REVIEW

2.1 Basic Processes of Coal Combustion

Coal is one of the non renewable sources. It also know as an organic fuel. Today, the problem that industry face is to predict the behaviour of the organic and inorganic constituents of coal during combustion [36–42]. When the coal was heated, pyrolyzed occur to the organic matter that consist in the coal, then change as volatile. The factors such as pressure, temperature, biomass composition and heating rate can affect the pyrolysis conversion efficiency[5]. The combination of mineral matter and carbon is remaining solid, which is known as “char”. The coal combustion of is mainly the combustion of carbon as well as the volatile matter. Based on the principal combustion process of coal, there are three basic stage involves which is :

i. Volatile matter will release from the heating of coal
ii. The burning of the release volatile matter
iii. The burning of the remaining char

Usually, by using non-designed coal in a blast furnace or in a pulverized coal boiler, it may cause the combustion problems. Moreover, the problem of burner damage must be considered, which occurs because of the ignition mechanisms involved in high-volatile low-rank coal. Therefore, to avoid burner damage, the ignition behavior as a function of coal rank should be investigated as fundamental data in order to take advantage of the new operating procedure of the burner[17].

2.2 Coal Volatile and Devolatilization Combustion

From heating process of the coal, volatile matter will release and it include in devolatilization stage. At this stage, the present of moisture in the coal evolves as the temperature of the coal rises. So, in characterizing ignition and flame stabilization, this stage is very important[6,7]. The gases and heavy tarry substances are release as the temperature increases. Depending on the coal types and heating conditions, the content of these matters can vary from a few percent up to 70-80 percent of the total weight of the coal. Size, temperature condition and the types of coal will result the time taken of devolatilization to complete. It usually takes a few minutes to complete the process. Tar, hydrocarbon gases and others products are produced during the this process. These products are flammable. It will react with oxygen around the coal particle and produced the bright diffusion flames. The reactions that occur in the volatile and devolatilization combustion process are so complex and it beyond the scope of this thesis.

.

2.3 Types of Coal

As geological processes apply pressure to peat over time, it is transformed successively into different types of coal[8]. There are three major types of coal which is:

1) Lignite

Figure 2.1: Lignite coal[8]

Figure 2.1 show the example of lignite coal. It also known as brown coal. This soft brown coal consist high amount of water which is 70 percent. It has around 60-70 percent of carbon.

2) Bituminous

Figure 2.2: Bituminous coal[8]

Figure 2.2 show the example of bituminous coal. This coal form when the pressure applied to the lignite. When the pressure applied on it, more water that content in the coal will be expelled. So, the amount of pure carbon will be increase. It contains between 69% and 86% carbon by weight. The amount of pure carbon will affect the heat content in the coal.

3)Anthracite

Figure 2.3: Anthracite coal[8]

When the great pressure applied on the bituminous, it form the highest grade coal that call anthracite as shown in the figure 2.3. It is hard rock with a jet-black colour. Water content in this form of coal are lowest than other form of coal. As the result, it has high heat content. It contains between 86% and 98% carbon by weight and it burns slowly, with a pale blue flame & very little smoke.

2.4 Coal Component

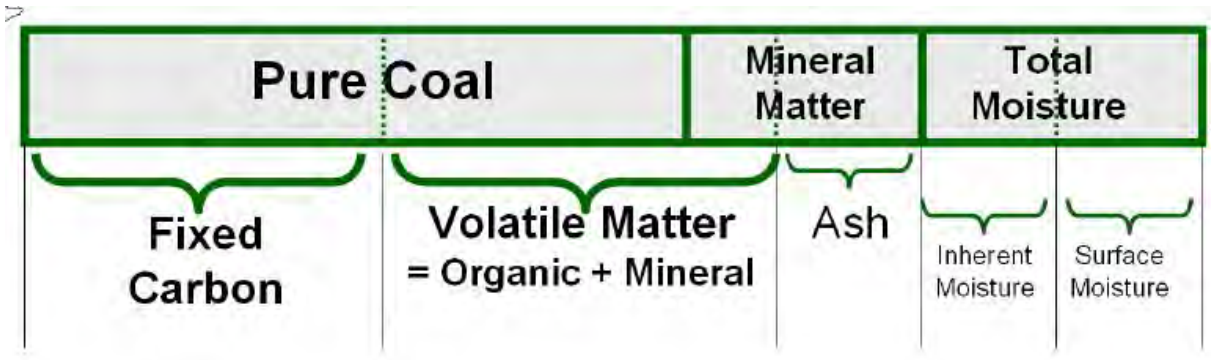

Figure 2.4: Component of coal [8]

Figure 2.4 shows the component that consist inside the coal. From the figure, one of the component is the fixed carbon which is a component which is the quantity of carbon after the volatile matter being removed. the fixed carbon main function ia to estimate the quantity of coke that being yielded from a set of coal sample. Although, the fixed carbon is different from the ultimate carbon content since a few carbon contain will be diminished in hydrocarbon with volatiles.

Another component that consist in coal is volatile matter. It release at high temperature when appearance of air. This component can be determine under rigidly controlled standards. Volatile matter consists of a combination short and long chain of hydrocarbons, aromatic hydrocarbons and a few of sulfur.