EMISSIONS REDUCTION FROM AN OIL BURNER BY AIR STAGING

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Dedicated to my beloved family

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ABSTRACT

The increasing concern and awareness among the public regarding the quality of environment that currently become more polluted due to combustion activities, particularly in industrial field has instigate the researchers and industrialists to find more comprehensives and enhanced technologies to reduce the so called pollutants emissions such as NO_x, CO, CO_2, SO_x, VOCs and particulate matter (PM). These pollutants gases do not only harmful to the environment but also have appalling implications on human health and to all inhabitants in our ecological system. There are a few well-known methods that can reduce the emissions of those pollutants either by combustion modifications or post combustion treatment that is effective in reducing emissions pollutants but much expensive than the former. For this present project, the method that will be adapted is air staging method. By air staging techniques, some of the combustion air will be directed into the primary combustion zone, while the remaining air is directed into secondary zone. The function of the secondary air is to reduce the peak flame temperatures, which theoretically reduce the emissions of NO_x emissions. The primary concern for this project is to investigate the reduction trend of NO_x emissions. However other emissions such as CO, CO_2 and SO_2, will be accounted too.

ABSTRAK

Peningkatan keprihatinan dan kesedaran daripada masyarakat tentang kualiti persekitaran yang semasa ini telah mengalami pencemaran disebabkan oleh aktiviti-aktiviti pembakaran terutamanya dalam industri telah mengilhamkan para pengkaji dan pengindustri mencari teknologi-teknologi yang lebih kukuh dan berkesan untuk mengurangkan pembebasan bahan pencemar seperti NO_x, CO, CO_2, SO_x, VOCs dan particulate matter (PM). Gas-gas pencemar ini bukan sahaja berbahaya kepada persekitaran tetapi juga mempunyai pelbagai kesan buruk atau implikasi terhadap kesihatan manusia dan pada semua kehidupan dalam ekosistem. Terdapat beberapa kaedah yang telah dikenalpasti yang berhasil mengurangkan pembebasan bahan pencemar sama ada menerusi kaedah modifikasi pembakaran atau kaedah perawatan selepas pembakaran yang lebih tinggi kosnya. Untuk projek ini, kaedah yang digunapakai adalah kaedah pemeringkatan udara. Melalui kaedah pemeringkatan udara, sebahagian daripada udara pembakaran akan diarahkan ke dalam zon pembakaran utama manakala yang udara selebihnya akan diarahkan ke dalam zon sekunder. Fungsi udara sekunder adalah untuk mengurangkan suhu nyalaan puncak di mana secara teorinya akan mengurangkan pembebasan NO_x. Tujuan utama projek ini adalah untuk menyiasat corak pengurangan NO_x. Walaubagaimanapun pembebasan gas-gas yang lain seperti CO, CO_2 dan SO_2 akan diambilkira.

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LIST OF SYMBOLS

ºC	Degree Celsius
K	Kelvin
BS	British Standard
LPM	Liter per minute
LFL	lower flammability limit
UFL	upper flammability limit
BTU	British thermal unit
AFR	Air Fuel Ratio
FAR	Fuel Air Ratio
A	Supply air
C_N	Net caloric value
HHV	Higher heating value
ppm	part per million
$\mu g/m^3$	microgram per cubic meter
CO	Carbon monoxide
CO_2	Carbon dioxide
NO	Nitric oxide
NO_x	Nitrogen oxides
N_2O	Nitrus oxide
NO_2	Nitrogen dioxide
O_2	Oxygen
O_3	Ozone
SO_2	Sulfur dioxide
SO_x	Sulfur oxides

N_2	Nitrogen
VOC	Volatile particulate matter
PM	Particulate matter
ϕ	Equivalence ratio
ρ	Density

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CHAPTER 1

INTRODUCTION

1.1 Importance of Study

Combustion processes have played major roles in human civilization for centuries. Combustion of fossil fuels is the predominant source of energy and will likely to stay that way for many years to come. Demands placed on the combustions system changed rapidly and become more and more stringent, especially on the environmental aspects.

The environmental concern regarding the *reducing quality* of air has been significantly important in these recent years due to the increasing combustion processes and their pollutant emissions. The rapid development of combustion-related-industries that operating involves of boiler and furnace has contributed to the increasing emissions of NO_x and other pollutants. The appalling effects of these processes on the quality of air have attracted the scientist and researchers to find and to create better ways to eliminate or at least, reduce these emissions. As known, the pollutant gases such as oxides of nitrogen (NO_x), oxides of sulfur (SO_x), carbon monoxides (CO) and particle matters that resulted from combustion processes are harmful not only to human but also to the ecological system of the environment.

In general, the clean air consists of few gases such as Nitrogen (N_2), Oxygen (O_2), Argon and Carbon Dioxide (CO_2) and other gases in relatively smaller

volume. Unfortunately, due to the existence of pollutants, the clean air is no longer viable. The common pollutant gases and particle matters are shown in Table [1.1]. The increase in content of these pollutant gases and particles is the reason the demand on the minimum allowable emissions from combustion processes become more stringent worldwide.

Air pollutions can be classified into two categories, primary and secondary. The primary air pollutions were due to the emissions directly to air and the secondary air pollution was results of reaction occur naturally in atmosphere. The sources of air pollutions come mainly from motorized vehicles, power generation stations and industrial combustion of solid and gases.

Table 1.1: Common pollutants gases and particles [Wanyudi, 2004]

Source	Pollutants	Sub-Pollutants
Non Organic Gases	NO, SO, CO	NO, NO_2, SO_2, SO_3, CO_2
Organic Gases (VOC)	Hydrocarbon, Aldehydes, Ketones	Methane, Benzene, Octane, Butane, Acetone
Particle Matter	Solid Particles	Dust, Smoke, Carbon

In order to reduce the emissions of NO_x and other pollutants, there are two techniques that can be applied. They are combustion modification control and post-treatment combustion control techniques. The combustion modification technique prevents the forming of NO_x during combustion process by altering the design and operations of the combustor. The post-treatment technique removes NO_x from the exhaust gas after it has already being formed in the combustion chamber.

In this study, the first technique has been studied and applied by introducing the staged combustion process. This process involves of re-directing the air for combustion process into primary and secondary zones in certain ratios. This technique is one of the techniques that have been proved to be effective in reducing

the emissions of NO_x, SO_x, CO and UHc. This technique has a promising potential in order to unravel the industrial burner problems and at the same time increase its efficiency.

1.2 Problem Statement

The stringent rules and law regarding the emissions of NO_x into environment is a factor in bringing the development of various design of the combustion process, which apply numerous techniques and method of reducing the emissions of NO_x. As discussed briefly, the methods are combustion modification control and post-treatment combustion control. The modification control reduces the formation of NO_x by changing the peak flame temperature, equivalence ratio and the air-fuel mixture. Meanwhile, the post-treatment control removes the NO_x from exhaust gas and do not require the modification of combustion method. However, the post-treatment technique require additional component to the burner which definitely increase the size and extra cost to build and maintain that components. The method of modification control is seen to be more effective to prevent the emissions of NO_x and other pollutants especially to small and compact-size burner because this method only necessitate small modification to the design and operations of the combustion process without additional gigantic components.

1.3 Objectives

The primary objective of this project is to study ***air-staging*** method as a controlling technique in combustion applications. The main concern is on reducing the emissions especially oxide of nitrogen (NO_x) which is highly predominant gas from an oil burner combustion process. The idea is to supply a secondary air into a combustion chamber to complete the combustion process. The study includes the experimental investigation on the effect of applying various secondary airflow rates

and also the various position of injected supply of secondary air on finding the reducing emissions trend.

1.4 Scopes of project

The scopes of this project include of:

i. Literature study regarding air pollution due to combustion processes
ii. Literature study of emissions characteristic and controlling techniques
iii. Literature study on air staging method as a controlling technique for combustion applications
iv. Experimental parameters study and theory
v. Installation of experimental rig and set-up
vi. Test secondary air flow rate with various injection locations
vii. Emissions and temperature measurement at various locations

1.5 Limitation of the study

i. Locations of injection of secondary air supply are at 100 mm interval axially
ii. Temperature measurement locations are at 100 mm interval axially
iii. Liquid fuel is *a commercial diesel* and supplied by Shell petrol station.

1.6 Thesis Contents

This thesis consists of five chapters arranged as below:

Chapter 2 includes of literature study and review regarding the effects of pollutants on environment, the detailed combustion process, formation mechanisms of NO_x and other pollutants, study on reduction methods generally and air-staging method particularly. Chapter 3 comprises detailed discussion regarding the experimental rig set-up and its procedures. The discussions of the experimental results in chapter 4 consist of the discussion of the effect of applying the secondary air on the relative combustion temperatures and emissions of NO_x, SO_x, CO and CO_2 with comparison to non-staging combustion process. Meanwhile, all the conclusions concerning the study and future improvements are adapted in chapter 5.