AIR STAGING COMBUSTION AND EMISSION FROM OIL BURNER

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ABSTRACT

Emissions from combustion of liquid fuel tend to cause an effect to the environment. The formation of pollutant such as NOx, CO, CO2 and SOx were hazardous and affect the green house environment. There are many methods in reducing the composition of the pollutant. As the method of reduction becoming more effective, the cost of such technology increases. In this study, air is used as the medium in reduction of the pollutant due to the ease of handling and availability. Airflow rate at 100 l/min is supply within the range of 600 to 1200 °C. At this range, the temperature window created. Air is injected at distance of 900mm from the flame. Results taken from equivalent ratio, which calculated from fuel and airflow rate. At a fix flow rate of fuel and variation of air create a fuel rich, fuel lean and stoichiometric conditions. Combustion efficiency for the combustor is measured versus the equivalent ratio to determine the effectiveness of the air injected to reduce the pollutants. As the results, the reduction of the pollutant relates with the combustion efficiency is measured and analyzed from air staging process.

ABSTRAK

Hasil pembakaran dari bahan api cecair cenderung di dalam menjejaskan alam sekitar. Kewujudan pelbagai bahan cemar seperti NOx, CO, CO2 dan SOx adalah amat berbahaya kepada rumah hijau. Didalam untuk mengurangkan komposisi bahan cenar tersebut pelbagai cara telah dilakukan. Kaedah dan cara-cara ini juga melibatkan kos didalam menghasilan keputusan pengurangan yang lebih berkesan. Di dalam ujikaji ini, udara digunakan sebagai medium untuk mengurangkan bahan cemar tersebut memandangkan ia mudah didapati dan senang dikendalikan. Kadar alir udara sebanyak 100 l/min dialirkan pada jangkauan suhu antara 600 hingga 1200 °C. Dimana dalam jarak ini tetingkap suhu(*temperature window*) terbentuk. Udara disuntik pada jarak hampir 900 mm dari pembakar. Keputusan diambil dari nilai setara yang didapati dari kadaralir udara dan bahanapi. Pada kadaralir bahanapi yang tetap dan udara yang berubah mengikut kesesuaian membentuk keadaan lebihan udara, stoikiometrik dan lebihan minyak pada pembakaran. Kecekapan pembakaran bagi radas tersebut diukur melawan nisbah setara bagi mengenalpasti kadar keberkesanan suntikan terhadap pengurangan epada bahan cemar. Hasilnya pengurangan terhadap bahan cemar bersama kecekapan pembakaran boleh dikenalpasti dalam pembakaran udara berperingat bagi pembakar berbahanapi cecair.

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LIST OF SYMBOLS

°C	-	Degree Celsius
°F	-	Degree Fahrenheit
K	-	Kelvin
ASME	-	American Society of Mechanical Engineers
BS	-	British Standard
d	-	Diameter
gm	-	Gram
GPH	-	Gallon per Hour
H2	-	Hydrogen
HCN	-	Hydrogen cyanide
hr	-	Hour
ki	-	Kilo Joule
Kmol	-	Kilo mole
kW	-	Kilowatt
LNB	-	Low NOx Burner
m^3	-	Cubic meter
ml	-	Milliliter
mm	-	Millimeter
CO	-	Carbon monoxide
$C0_2$	-	Carbon oxide
N20	-	Nitrous oxide
NO	-	Nitric oxide
$N0_2$	-	Nitrogen dioxide
NO	-	Nitrogen oxides
0_2	-	Oxygen

0_3	-	Ozone
ppm	-	Parts Per Million
SCR	-	Selective Catalytic Reduction
SNCR	-	Selective Non-Catalytic
$S0_2$	-	Sulfuric dioxide
T	-	Temperature
Vol	-	Volume
wt	-	Weight
π	-	pie(3.14)
η	-	efficiency
ρ	-	density
ν	-	volumetric flow rate
m	-	critical flow rate
p	-	pressure

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CHAPTER 1

INTRODUCTION

1.1 Background Studies

In Malaysia, the Air Pollution Index (API) is a system to measure the air pollutants, which could cause potential harm to human health if reach the unsafe levels. The pollutants are ozone (0_3), carbon monoxide (CO), nitrogen dioxide ($N0_2$), sulphur dioxide ($S0_2$) and suspended particulate matter less than 10 microns in size. Table 1.1 shows the acceptance level of pollutant.

To reflect the status of the air quality and its effects on human health, the ranges of index values could then be categorized as in Table 1.2. The key reference point in these air pollution index systems is the index value of 100, which is the "safe" limit.

Table 1.1: Recommended Malaysia Air Quality Guidelines taken from Air Pollutant Index (API) calculation.

POLLUTANT	AVERAGING TIME	MALAYSIA GUIDELINES	
		(ppm)	(ug/m^3)
OZONE	8 HOUR	0.06	120
CARBON# MONOXIDE	8 HOUR	9	10
NITROGEN DIOXIDE	24 HOUR	0.04	320
SULFER DIOXIDE	24 HOUR	0.04	105
PM10	24 HOUR		150

#mg/m^3

Table 1.2: Categorized of Air Pollution Index(API)

API	DESCRIPTOR
0-50	good
51-100	moderate
101-200	unhealthy
201-300	very unhealthy
>300	hazardous

All these pollutant contribute to the performance of the air quality. The effects on air pollutants are:

1. Effects on Materials.
2. Effect on Vegetation
3. Effect on Health

However there are many methods to reduce the effect on pollutants. Air staging combustion is one of many methods introduce to reduce NOx, SOx and CO emission. The staged air burner is utilized for either gas or liquid fuel firing. This type of burner normally has three air registers to control the flow rate and distribution of combustion air through the burner and only one fuel injection nozzle. The three air registers are the primary, secondary and tertiary. Figure 1.1 shows the diagram of the basic staging condition. Each flow rate of air and fuel must be correctly adjusted to successfully minimize the exhaust production. NOx control is now the driving force behind the development of new burners. The formation of NOx is not only depend on the peak flame temperature but also contribute by the fuel composition. Nox formation is attributed to three type of mechamism such as:

- thermal NOx.
- fuel bound NOx and
- prompt NOx.

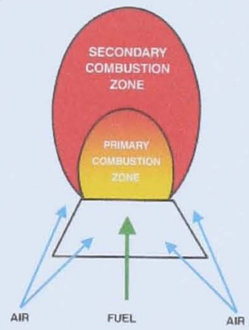

Figure 1.1: Basic Air Staging

1.2 Objectives Of Project

1. To study the emission characteristic such as CO, SOx and NOx in burning combustion system.
2. To study the effect of combustion efficiency on the process of air staging using diesel burner combustion system.

1.3 Scope of the studies

1. Combustion experiment using small-scale diesel burner.
2. Determination the effect of air staging on the diesel combustion and the emission of CO, NOx and SOx.
3. Study the combustion efficiency of the combustor.

CHAPTER II

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Introduction

Air consists of 21% oxygen and 78% nitrogen by volume. With the existing of fuel and heat, -combustion may happen. Most fuel is mixture of chemical compound called hydrocarbon. The emission create from industrial basically emit gasses with contain unburned hydrocarbon (UHC), Nitrogen oxide (NOx). As a result of the Clean Air Act, most of the monitoring of emissions, concentration and effects of air pollution has been directed towards the criteria pollutants. Much on the work on air pollution in the last few decades has centered on criteria pollutants. The pollutant from the industry may not be stopped but to reduce.

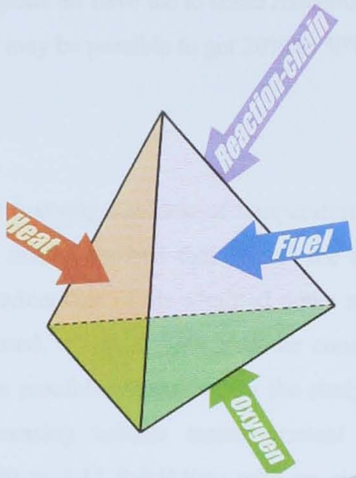

Figure 2.1: Fire Tetrahedral

2.2 Literature Review

Laboratory experiments carried out to examine the influence of air staging on the co-combustion and emission characteristic. With no air staging, the temperature reaching maximum at the flame and decreases proportionally with the height. With air staging, the temperature drop steeply to secondary air injection level then constantly decreases. By increasingly the degree of air staging has only slight effect on carbon combustion efficiency. Increasing the degree of air staging has only a slight effect on carbon combustion efficiency. With increasing proportion of secondary air, NO is more likely to be reduced. K Suksankraisorn *et al* (2003).

NOx emissions decrease substantially as the amount of flue gas mixed with the fuel increases. NOx emission increase with increasing combustion air inlet temperature. Jay Karan & Tony Fennell (Apr 2004).

Over fire or under-grade air have led to some reduction in NOx. Through better air staging and coverage, it may be possible to get 20% to 30% reduction. Gregory Difer (Aug 2000).

NOx emissions are a strong function of temperature in the flame zone and the operation conditions. The results showed that for all the coals and blends tested, air staging by increasing the percentage of air admitted down stream from the coal nozzle, the NOx emissions decreased. Even at both extreme conditions (i.e. without any air staging and with maximum possible air staging) in the study, a guner4al trend of lower NOx emissions with increasing volatile matter content was observed. The NOx emissions ranged from 0.79 to 1.15 lb/MMBtu with no air staging, and 0.54 to 0.74 lb/MMBtu with maximum air staging for the low swirl burner configuration. The NOx emissions ranged from 1.1 to 1.25 lb/MMBtu with no air staging and 0.6 to 0.84 lb/MMBtu with maximum air swirl tested for the high swirl burner configuration. S Pisupati, (2003).

Analysis on Literature Review

1) With air staging the flame become reduction zone while the freeboard becomes the oxidizing zone.
2) Increasing proportion of secondary air, NO is more likely to be reduced.
3) Primary flame experience fuel-rich to eliminate NOx formation.
4) NOx emission increase with increasing of combustion air inlet temperature.
5) Air staging helps in NOx reduction more.

The major objective of this study is to examine the NOx, CO, SOx behavior of diesel fuel. The diesel fuel is considered, because it is deemed as one of the cheapest and easy to get in market. A counter-flow configuration is employed, because it facilitates a detailed investigation of the relative importance of various reaction zones in the NOx formation and destruction processes. For example, because the spatial region between the two reaction zones is generally devoid of O_2 and O species, it may represent a destruction zone for NO. The role of this region in the overall production or destruction of NO has not been examined in previous studies. Moreover, the effects of stoichiometry can be more easily separated in this geometry.

2.3 Effect of Emission

2.3.1 Ozone

From figure 2.2 begin with the formation of NO during combustion.

$$N_2 + O_2 \rightarrow 2NO$$

The nitric oxide thus emitted can oxidize to NO_2.

$$2NO + O_2 \rightarrow 2NO_2$$

If sunlight is available, NO_2 can photolysis and the freed atomic oxygen can then help to form ozone.

Ozone can then convert NO back to NO_2

$$O_3 + NO \rightarrow NO_2 + O_3$$

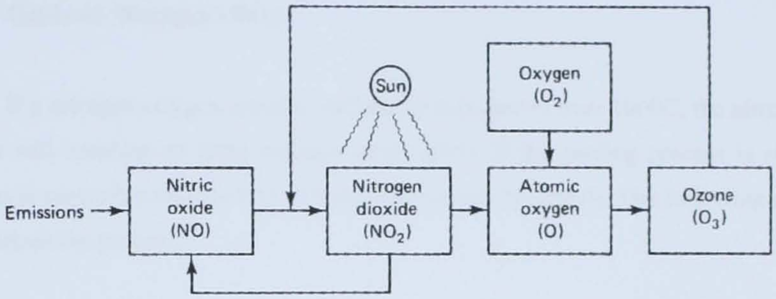

Figure 2.2: Simplified atmospheric nitrogen photolytic cycle.

2.3.2 Acid Rain

Acid rain is form of precipitation containing a heavy concentration of sulfuric acid (H_2SO_4) and nitric acids (NH_3). Rain falling with the pH of less than 5.6 is considered acidic.

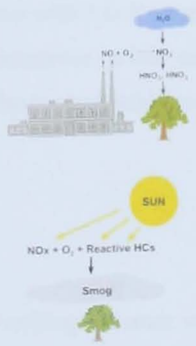

Figure 2.3: The creation of acid rain and smog

2.4 Emitted Gas

2.4.1 Oxide of Nitrogen (NO_x)

If a nitrogen-oxygen mixture such as air is heated to over 1000C, the nitrogen and oxygen will combine to form nitrogen oxide (NO). If the cooling process is slow, the reaction is reversible and the NO will decompose into N_2 and 0_2. The following equation summarizes the process:

$$N_2 + 0_2 \rightarrow 2NO$$

However, if the cooling takes place rapidly, as is the case for most internal combustion engines, then the nitrogen oxide does not have a chance to decompose and will go off as NO. It should be noted that the reaction that forms NO does not directly involve the fuel used in the combustion process but only the nitrogen and oxygen that are the major constituents of air. Nitrogen oxide is a colorless gas that is toxic in sufficiently high concentrations, but its toxicity is generally considered to be minor (about 20%) compared to nitrogen dioxide ($N0_2$). Nitrogen dioxide is a reddish-brown gas that contributes the brownish color to the familiar smog in cities. NO2 may affect the respiratory system. At concentrations of 20 to 50 ppm, there is a strong odor, one's eyes begin to become irritated, and damage to lungs, liver, and heart has been observed. At 150 ppm, serious lung problems occur with 3 to 8-hour exposures. Many feel that chronic lung damage will occur with concentrations as low as 5 ppm if a person is exposed all day. There are alerts in cities when the concentration reaches 4 ppm.

2.4.2 Carbon Monoxide (CO)

The carbon monoxide (CO) exiting a burner will initially increase slowly as the excess air rate decreases. The increase will accelerate as excess air levels continue to decline to near-zero. Typical control points range between 150 and 200 ppm CO. This

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