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Oxy-Fuel Combustion of Gas Flames in Tubular Burner

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ABSTRACT: Global warming is the on going rise of the average temperature of the earth's climate system and has been demonstrated by direct temperature measurements and by the measurements of various effects of the warming. The primary cause for the problem is the large amount of flue gases exhausted from many industries that produces large amount of CO₂ that will leads to these kind of environmental problems. This type of combustion yields a luminous yellow sooty flame as a result of incomplete combustion. This produces a relatively longer flame which tends to high radiation losses. It tends to decrease in efficiency and increase in unburnt hydrocarbons. by overcoming these effects we go for oxy-fuel combustion, is the one of the most promising carbon capturing technology nowadays. By these oxy-fuel combustion process Zero emission power generation could be possible

I. INTRODUCTION

Global warming, caused by greenhouse gases has become a worldwide concern in recent years. Many efforts have been made to reduce the dependency of fossil fuels in order to reduce the generation of carbon dioxide (CO₂) gases. Greenhouse gases play an important role in keeping the planet warm enough to inhabit.

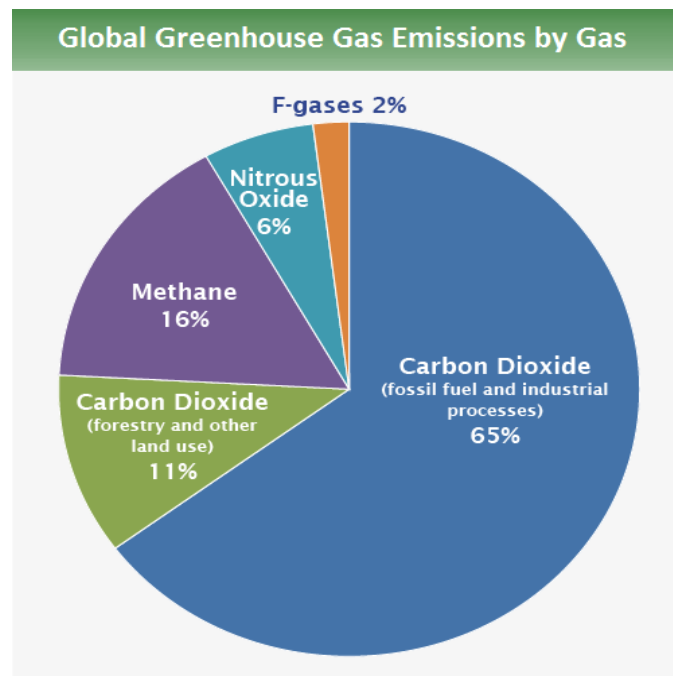


Figure 1.1: Global Greenhouse Gas Emission by Gas

Burning fossil fuels such as natural gas, coal, oil and gasoline raises the level of carbon dioxide in the atmosphere, and the carbon dioxide is a major contributor to the greenhouse effect and global warming. In day today CO₂ exhausted major on IC engines. An internal combustion engine (vehicles) is a heat engine in which the combustion of fuel occurs with an oxidizer (usually air) that releases large amount of CO₂. That which leads to global warming, ozone depletion and so on.

The oxy-fuel combustion process is the one of the most promising technology for carbon capture, in order to reduce hydrocarbon emission and to avoid many environmental problem have to go on with the oxy-fuel combustion process

the scope of this work is to addressing the global warming in order to reduce the CO₂ by the help of oxy-fuel combustion process. Further more there are several types of combustion based up on the different types of applications

II. LITERATURE SURVEY

This paper discussed et al, The impact of the amounts of gaseous fuel added, engine load, and engine speed on the combustion efficiency and exhaust emissions of the gaseous fuels were examined and then compared the impact of engine load on the combustion efficiency of gaseous fuel was more prominent with the addition of a small amount of gaseous fuel. The slightly lower combustion efficiency of CH₄ of the NG-diesel dual fuel engine was due to the emissions of CO accounted as an incomplete combustion product of CH₄ in this research [1].

In this study, an experimental study has been carried out to investigate the NO_x reduction characteristics of the fuel-lean reburn system in a 15-kw lab scale furnace, The effect to reburn fuel injection location on NO_x reduction rate and CO emission, It is reburn fuel injection height is varied along seven locations in the axial direction. There burn fuel nozzle is of flat type with a spray angle of 95 degree, of which flow rate is controlled using a mass flow controller. To establish LPG diffusion flame, a coaxial burner is fabricated and installed. Energy consumption becomes more efficient than the conventional reburning process when the fuel-lean reburn system is adopted. This high efficiency in NO_x reduction for the fuel-lean reburn system may result from a change in residence time of there burn fuel inside the furnace [2].

This paper evaluates the potential of hydrogen (H₂) and ammonia (NH₃) as carbon-free fuels. The combustion characteristics and NO_x formation in the combustion of H₂ and NH₃ at different air-fuel equivalence ratios and initial H₂ concentrations in the fuel gas thermal-NO_x decreases in H₂-NH₃-air combustion, compared with pure H₂-air combustion. NO_x concentration reaches its maximum at stoichiometric combustion. H₂ as fuel for improving burning performance with moderate burning velocity and NO_x emission enables the utilization of H₂ and NH₃ as promising fuel [3].

The results shows at, The flame in the combustion chamber is narrowed, as the fuel consumption rate is decreased. This is probably due to the low fuel and combustion air mass amounts entering the system. The CO₂, O₂, and CO emissions in the combustion chamber do not show any significant difference between the simulations the mixing of pure methane and combustion air in the combustion chamber. By this means, the flame length in the combustion chamber is shortened, and it is radially expanded. Thus, more uniform flame structures in terms of the temperature values are obtained [5].

In the present work an experimental investigation was conducted to examine the effect of dual fuel combustion on the performance and pollutant emissions of a diesel engine. The engine operation was found to be stable and smoother in dual fuel mode at the engine operating conditions considered in this study- With the introduction of gaseous fuel, specific UHC emissions increased sharply compared to baseline diesel fueling-Specific NO_x emissions for dual fueling was always lower than the diesel fueling conditions [6].

Calculation of stoichiometry amount of air for LPG

Liquefied Petroleum Gas consists of the mixture of 60% propane (C₃H₈) and 40% butane (C₄H₁₀). The stoichiometric amount of air required for the complete combustion of fuel can be calculated on the following two bases:

1. Mass Basis
2. Volume Basis

Mass Basis

Let us consider the mass of air to be 1 kg of air consists of 0.23 Kg of oxygen and 0.77 Kg of Nitrogen. This can be given below.

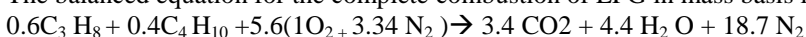
$$1\text{Kg of air} = 0.23 \text{ Kg of O}_2 + 0.77 \text{ Kg of N}_2$$

Therefore,

$$\text{Mass of Air contains } 1 \text{ Kg of O}_2 = 1 \text{ Kg of Air} / 0.23 \text{ of O}_2 = 4.34 \text{ Kg of Air}$$

$$\text{Mass of N}_2 \text{ present in } 4.34 \text{ Kg of air} = 4.34 \cdot 0.77 = 3.34 \text{ Kg of air}$$

The balanced equation for the complete combustion of LPG in mass basis is given by,



Calculation of Mass of reactants

$$\text{Atomic weight of carbon} = 12 \text{ Kg/ mole}$$

$$\text{Atomic weight of Hydrogen} = 1 \text{ Kg/mole}$$

$$\text{Atomic weight of Oxygen} = 16 \text{ Kg/mole}$$

$$\text{Atomic weight of Nitrogen} = 14 \text{ Kg/mole}$$

Mass of fuel = $0.6 [(3 \times 12) + (8 \times 1)] + 0.4 [(4 \times 12) + (10 \times 1)] = 49.6 \text{ Kg}$

Mass of Air = $5.6 [1(2 \times 16) + 3.34(2814)] = 702.91 \text{ Kg}$

Therefore, stoichiometry amount of air required for the complete combustion of 1 Kg of fuel is 14.17 Kg.

Volume Basis

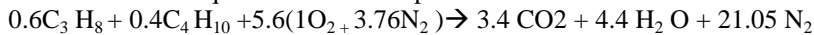
Let us consider the volume of air to be 1 L, 1L of air contains 0.21 L of O_2 and 0.79 L of N_2

1 L of air = 0.21 L of O_2 + 0.79 L of N_2

Volume of air contains 1L of O_2 = 1Kg of Air / 0.23 of O_2

Volume of O_2 present in 4.26 L of air = $4.26 - 1 = 3.26 \text{ L of } N_2$

The Balanced Equation for the complete combustion of LPG in volume basis is given by,



Volume of fuel = $(0.6 \times 1) + (0.4 \times 1) = 1 \text{ L}$

Volume of air = $5.6 (1 + 3.76) = 26.65 \text{ L}$

A/F ratio = volume of air / volume of fuel = $26.65/1 = 26.65 \text{ L of air / L of fuel}$

Therefore Stoichiometry amount of air required for the complete combustion of 1 L of fuel is 26.65 L.

2.1.2 Equivalence Ratio Calculations

The Formula for calculating the equivalence ratio is given by,

$$\phi = [V_{\text{fuel}} / V_{\text{air}}]_{\text{actual}} / [V_{\text{fuel}} / V_{\text{air}}]_{\text{stoichiometry}}$$

Let us consider the Volumetric fuel flow rate as 0.2 lpm. The Stoichiometry amount of air required to get completely combusted the 0.2 lpm of fuel is 5.33 lpm. The equivalence ratio is calculated for premixed, non-premixed combustion.

For Premixed Combustion

For Premixed Combustion for a given flow rate of 0.2 lpm, the premixed air is 5.33lpm. The Equivalence ratio is calculated below:

$$\phi = [0.2/5.33] / [0.2/5.33] = 1.$$

For Non-Premixed Combustion

For Non-Premixed Combustion, for a flow rate of 0.2lpm and primary air, the Equivalence ratio is calculated below:

$$\phi = [0.2/0] / [0.2/5.33] = \infty$$

For Partially Premixed Combustion

In case of partially premixed combustion, the equivalence ratio for 0.2 lpm of fuel and 50% PA ie, 2.665 lpm of air was calculated below:

$$\phi_{\infty} = [0.2/2.665] / [0.2/5.33] = 2.$$

2.1.3 Calculation of Port Velocity

Let us consider $V_{\text{fuel}} = 0.2 \text{ lpm}$ and $V_{\text{air}} = 5.33 \text{ lpm}$. The port velocity can be calculated by using the formula,

$$U_p = [V_{\text{fuel}} + V_{\text{air}}] / A_p$$

$$V_{\text{fuel}} = 0.2 \text{ lpm} = 0.2 * 0.001/60 = 3.33 \times 10^{-6} \text{ m}^3/\text{s}$$

$$V_{\text{air}} = 5.33 \text{ lpm} = 5.33 * 0.001/60 = 8.88 \times 10^{-5} \text{ m}^3/\text{s}$$

Let the diameter of the port, $d = 9.5 \text{ mm}$.

$$A_p = (3.14/4) \times d^2 = (3.14/4) \times [9.5 \times 10^{-3}]^2 = 7.088 \times 10^{-5} \text{ m}^2$$

$$U_p = [(3.33 \times 10^{-6}) + (8.88 \times 10^{-5})] / [7.088 \times 10^{-5}] = 1.2998 \text{ m/s.}$$

III. PROPOSED THEME

The present work focussed on the experimental investigation on the flame behaviour and flame stability by replacing carbon dioxide with nitrogen widely known as oxy fuel combustion. For the various oxygen mole fraction and also to draw out the combustion efficiency of the burner, And to validate the results with the existing literature.

3.1 Experimental Work

3.1.1 Experimental setup

In the oxy-fuel combustion of gaseous fuel that held in the tubular burner shows in the figure 5. LPG contained in a steel cylinder which is used as a fuel for the process, which consists of 60% of butane and 40% propane by volume and diluted over a range of equivalence ratios. The burner is of tubular concentric flow type which is used to carry out the experiment. It consist of several feed pipe each has its own diameter respectively .The outer concentric tube consists of diametrically opposite tangential inlets for the entry of swirl air at the last case. The first case is held is the primary air case detailed that when air which comes out from the compressor directly into the burner on the opposite port there should be fuel just into the burner .At that case the flame should be low intensive pre-mixed flame and that would occur. The second case is the oxy case carried out by the help of the oxygen and carbon dioxide cylinders. At each fuel and air passage, there exists a pressure gauge to regulate the pressure of flow. Compressed air is supplied continuously by means of the air compressor. When the fuel and air get reached the burner mouth, it gets ignited and starts combustion. The fuel from LPG cylinder and the air from compressor is allowed to flow into the burner system through the pressure gauges and rotometers individually. The pressure inside an LPG cylinder is dependent upon the temperature of the cylinder .The higher the temperature, The higher the pressure of the LPG contained in the cylinders LPG, propane and butane exist in both liquid and vapour phase.

IV. EXPERIMENTAL RESULTS



Figure 10 Experimental setup

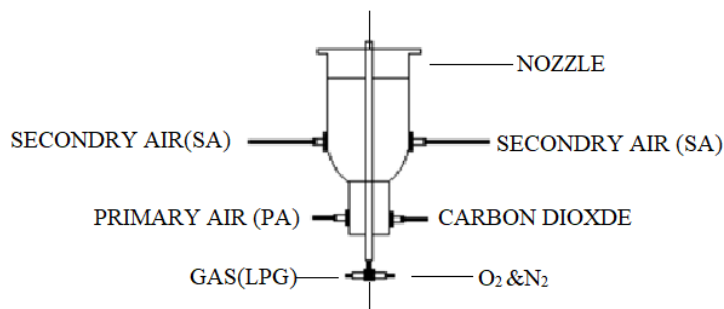


Figure11 Schematic diagram of a coaxial burner assembly

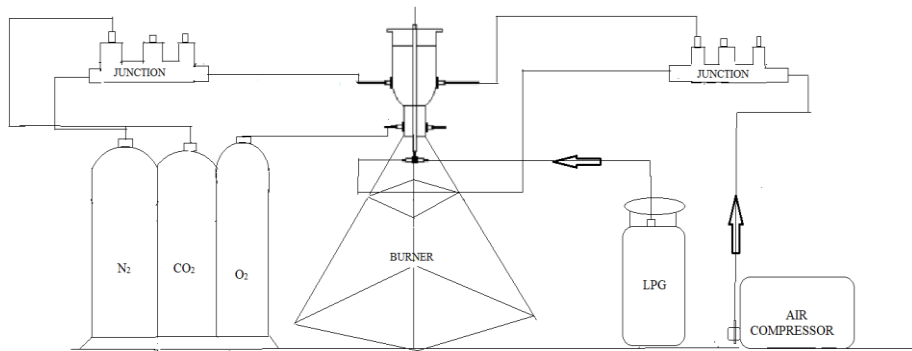
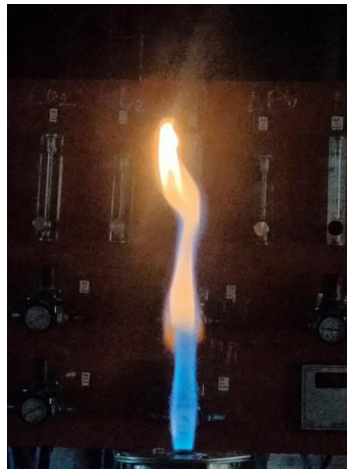


Figure 12 schematic diagram of Experimental setup

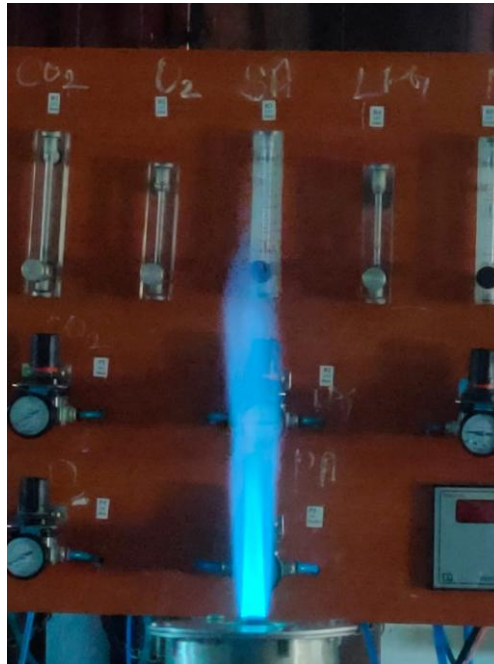
4.1.4 Flame images at air case

In this experiment the first case held under the air case means the fuel and the air with the corresponding lpm value



4.1.5 Flame images at Oxy case

In the second premise is the oxy case mean if the nitrogen is replaced by CO₂. The what will be the behaviour of flame under various concentration. The fuel flow meter reading initially set upto 0.5lpm and the premixing takes place means at the certain percentage like 10%,20%,upto 100% the what would the behaviour and intensity and type of flame that will occur for that condition and that is all under the oxy case.



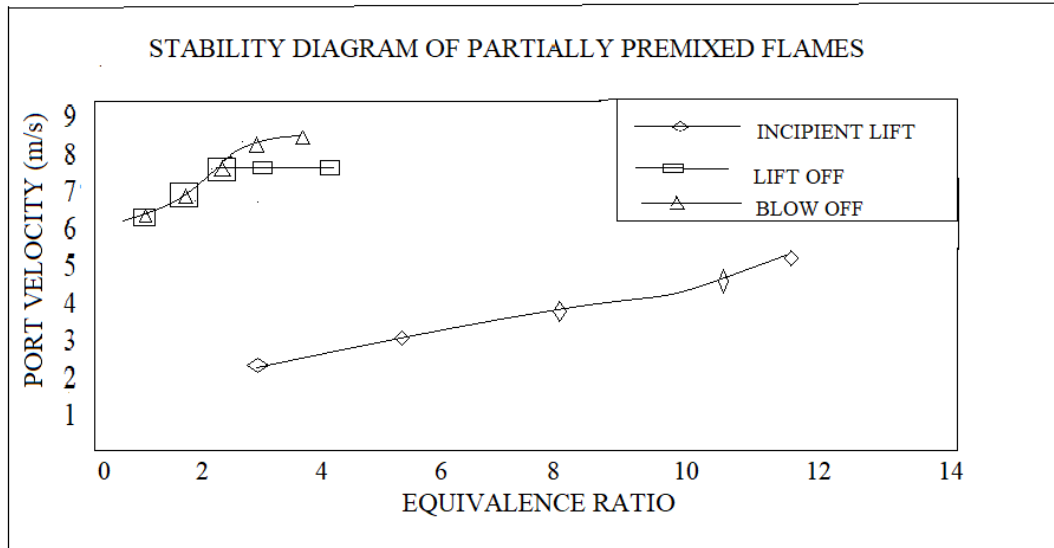
4.1.6 Flame images at swirl air

The experiment was held under different before, the third case is determined as if the air is supplied in the form of swirl then what would be the behaviour of flame.



Figure 8 Flame image for swirl air case

Stability digram for partially premixed flames



VI. CONCLUSION AND FUTURE SCOPE

The scope of these project is to investigate the effect of oxy-fuel combustion on the flame stability in energy efficient LPG burner. The oxygen concentration varied for different flow rates of fuel and the port velocity was calculated for different equivalence ratios.it was found that the port velocity increases with the decrease in equivalence ratio. Also the stability diagram was drawn and the flame stabilization characteristics were found out. The analysis for different flow conditions was carried out by Fluent.

6.2 Future Scope

In Present studies the oxy fuel combustion process is not economically considerable because the separation of oxygen from air is highly intensive and more expensive. However, due to the tremendously increasing world energy demand, fossil fuels would continue in use for decades which necessitates the integration of carbon capture technologies (CCT).The current status and technology is oxygen transportation reactors (OTR),if the oxygen that can be easily separated from the air with economically then these system can be applied for any power plant with respective modification. For which we can reduce the global warming.

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