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Research Status and Development of Low-nitrogen Burner for Low Calorific Value Gas Fuel

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Abstract. Low calorific value gas fuel is a general term for fuel with calorific value lower than 1500 kcal / m3, mainly derived from low calorific value gas produced in industrial production process, including blast furnace gas, refinery associated gas, gas , pyrolysis gasification of biomass, etc. However, its heat value is low and it is difficult to control stable combustion. It is generally mixed with other fuels with high heat value and is widely used in smelting, chemical industry, power generation and other fields. Therefore, it is of great significance to study the gas burner suitable for low calorific value gas. This paper summarizes the structure, working principle and technology development status of low calorific value gas burner at present, introduces some application examples of low calorific value fuel burner, and discusses the existing problems and future development trend in this respect.

1. Introduction

At present, gas burners are mainly used for common gases such as natural gas, and their research is relatively mature. The research on gas burners for low calorific value gas fuels such as coal bed gas, blast furnace gas, gas, methane, coke oven gas, water gas, biomass gas, etc. is the focus of energy conservation and environmental protection at present and also a hot spot. This kind of gas has low heat generated by combustion and has the following characteristics: (1) it is flammable and explosive. (2)Some of the gas contains CH_4, and CH_4 has a stronger greenhouse effect than CO_2, which will lead to an increase in global warming and affect the global climate.(3)Some of the gas also contains harmful substances like hydrogen sulfide and ammonia.

In the practical application of low calorific value gas burner, there are some problems such as unstable combustion and unable to adjust the load change in time. The main research points of the low heat value gas burner are also relatively focused on the injection mode of the nozzle and the bluff body structure, which can help the gas and air mix and form a recirculation zone, and finally raise the temperature of the burner nozzle to form a stable heat source. In addition, the method of mixing and burning low heat value gas with higher heat value fuel can enhance the overall combustion stability of thermal equipment and improve the combustion efficiency.

2. Research Progress of Low Calorific Value Gas Burner

The low calorific value gas burner studied by Yan B, Li B et al [1] is a partial premixed burner. The main fuel component of the burner is methane, and a small amount of carbon monoxide, carbon dioxide and hydrogen are added in order to make the fuel conform to the biomass gas component in practical application, and finally diluted by nitrogen. The burner is composed of a sleeve-type structure, and the nozzle is a gradually expanding nozzle. In order to test the influence of turbulent combustion, the large eddy model was used to calculate the flow field and mixing process of the whole burner through numerical simulation. For the distribution of hydroxy, the distribution characteristics under different Reynolds numbers and equivalence ratios were measured by PLIF. Finally, it was found that the critical speed of sticking and blowing out of low calorific value gas during combustion was high, but combustion was relatively stable due to the presence of hydrogen. The installation of the divergent nozzle also makes the stability of the flame higher than that of the non - divergent nozzle as shown in fig. 1 and fig. 2.

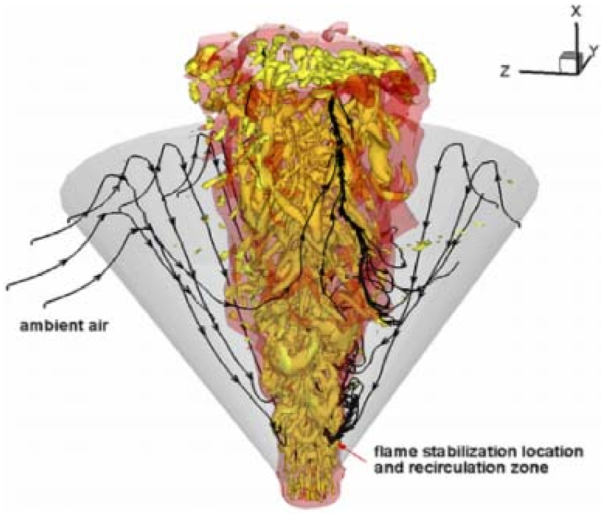

Figure 1. Instantaneous flow streamlines, iso-surface of stoichiometric mixture fraction (pink/grey), and vortex structures visualized Using the second eigen-value of the velocity Gradient tensors (K2).

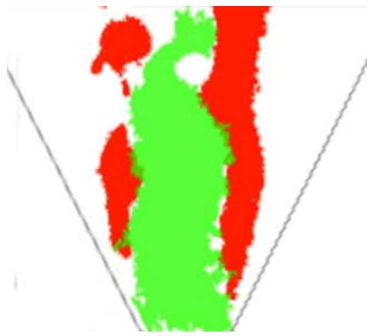

Figure 2. Snap-shots of simultaneous OH radicals and acetone for L2F1V2; dark/red region, OH; light grey/green region, acetone. See Table 2 for flame notations.

Hoffmann, the turbine combined cycle power generation development center of ABB Power Generation Co., Ltd. in Switzerland, and ECHI Go and others [2] from Tokyo institute of technology Institute of Mechanical Engineering and Science in Japan have conducted targeted research on the porous medium burner of blast furnace gas. In this paper, three kinds of materials without pore diameter are used to study the porous medium burner, and the influence of pore diameter, gas velocity and chemical equivalence ratio on the burner outlet temperature and pollutant emission is analysed. The research shows that the lowest lean burn limit equivalent ratio is 0.026 at present. The main variable affecting lean combustion is the inner diameter of porous media. The gas flow rate and equivalence ratio both have an important influence on the temperature distribution of the burner flame and also have a great influence on the flue gas temperature. CO emission is closely related to the velocity of gas flow and the material of porous media. The larger the pore size, the less CO emission. The average NOx emission after using this burner is 0.2 ppm, as shown in fig. 3 and fig. 4.

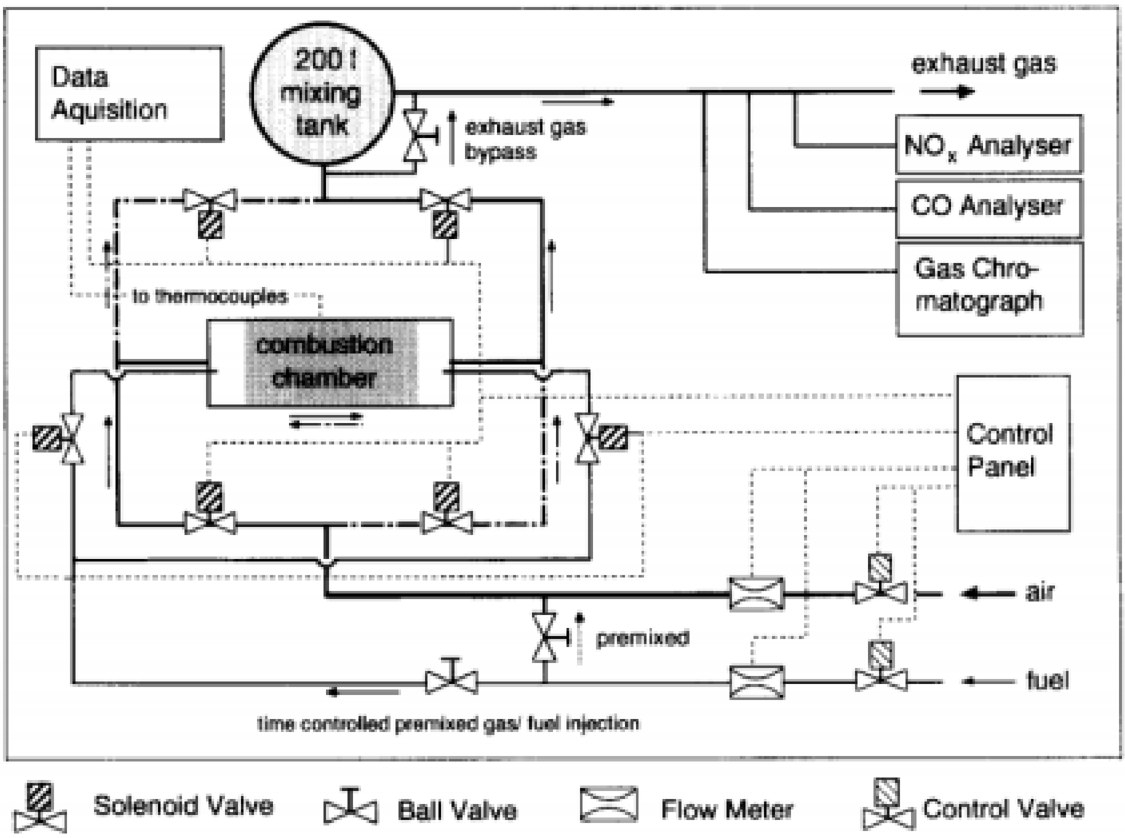

Figure 3. Experimental setup.

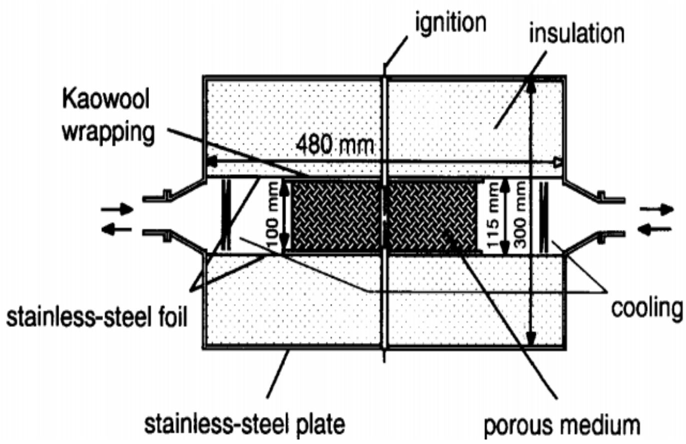

Figure 4. Design of the combustion chamber.

The structure of the low heat value burner studied by P.R. Bhoi and S.A. Channiwala [3] is shown in fig. 5 and fig. 6. The gas and combustion-supporting air enter the combustion chamber through the guide vanes, which has a premixing effect in the mixing chamber and then the flame is ejected through the ignition system. The study found some factors related to NOx emissions, such as excess air coefficient and air-fuel mixture ratio. However, the stable combustion and jet rigidity of the burner have not been analysed. The burner is slightly insufficient in jet rigidity, which will affect the later combustion effect.

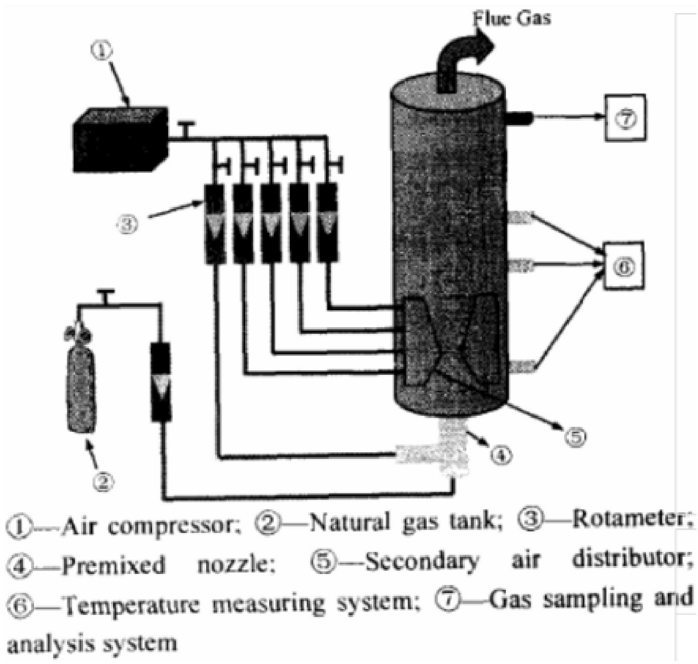

Figure 5. Schematic of the experiment setup

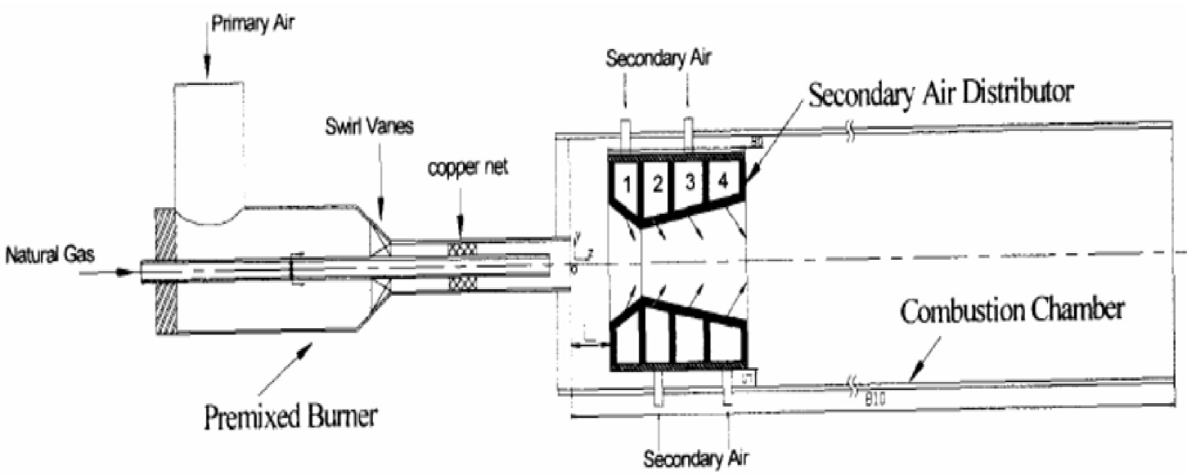

Figure 6. Schematic of combustion system

Nishumra et al [4] studied the low heat value regenerative burner and improved it to reduce NOx emissions by separating fuel from air, as shown in fig. 7 and fig. 8. The new burner delays the mixing of fuel and air and effectively reduces the generation of NOx. At a furnace temperature of 1000℃ and an oxygen excess of 11 %, NOx emission is less than 50p pm, which is far lower than that of the traditional regenerative burner.

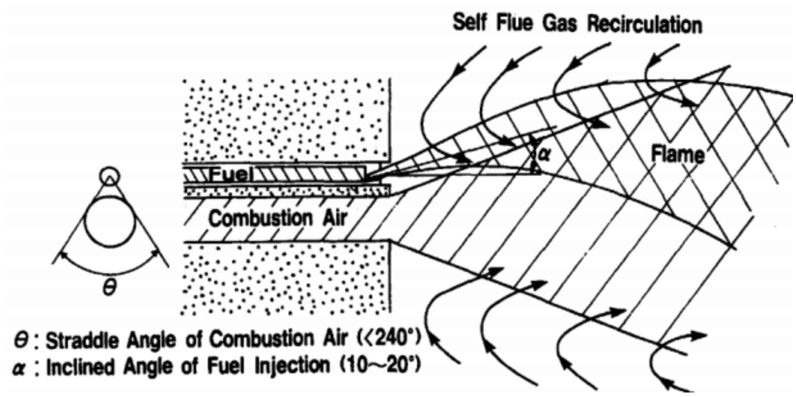

Figure 7. Principle of combustion of KOBELCO low-NOx regenerative burner

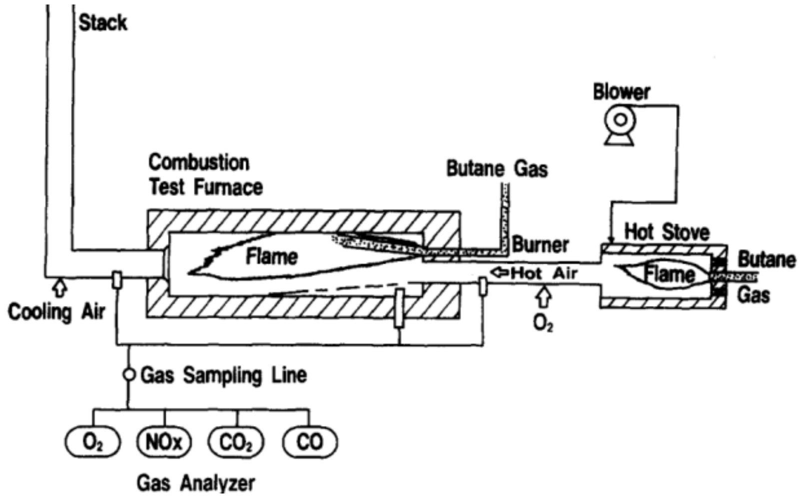

Figure 8. Schematic of combustion test facility.

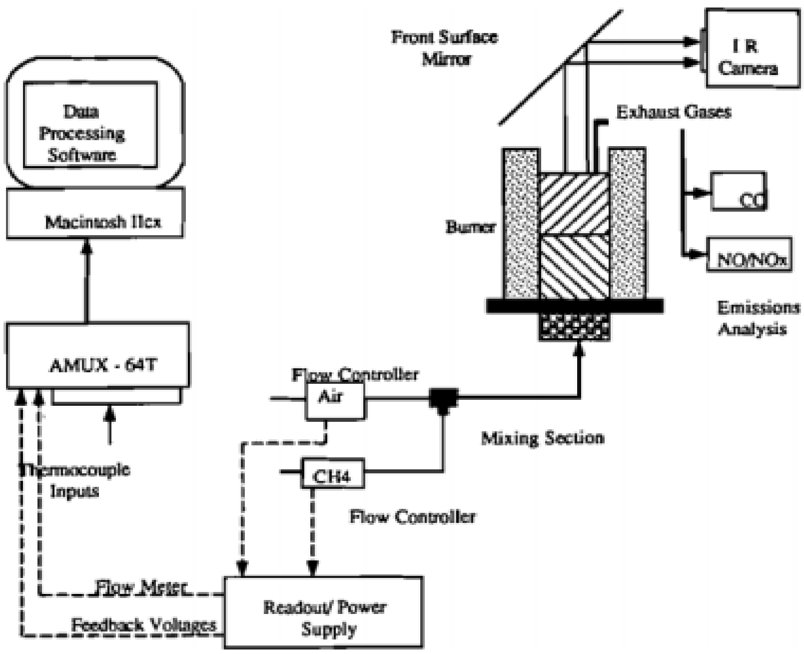

Figure 9. Experimental setup

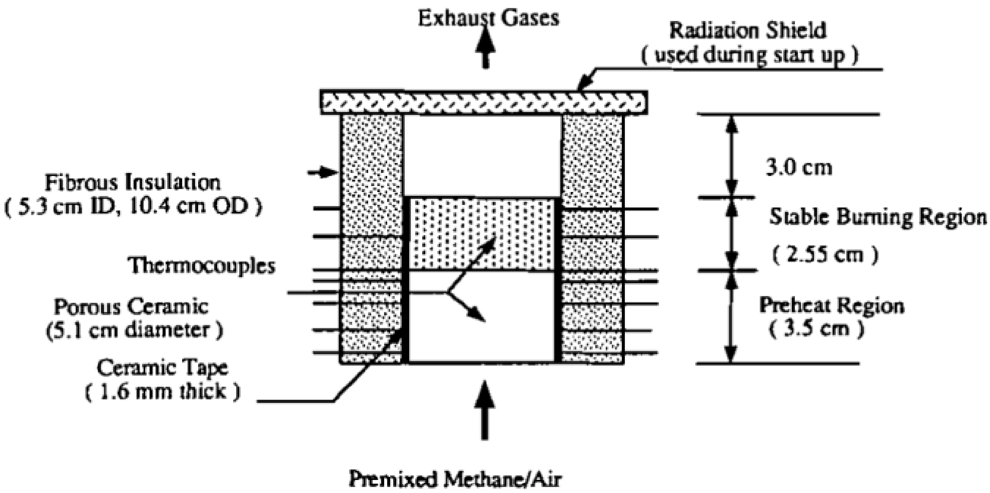

Figure 10. Design of the combustion chamber.

Khan na et al [5] studied the pollutant emission characteristics of the porous medium burner as shown in fig. 9 and fig. 10. The results show that the NOx emission of this burner is very low in most cases, all lower than 36 ppm, but the CO emission is always high.

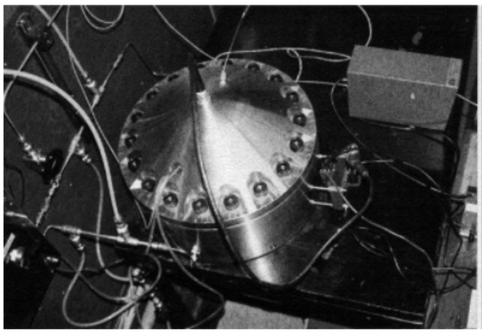

Figure 11. Photograph of the spherical combustion bomb.

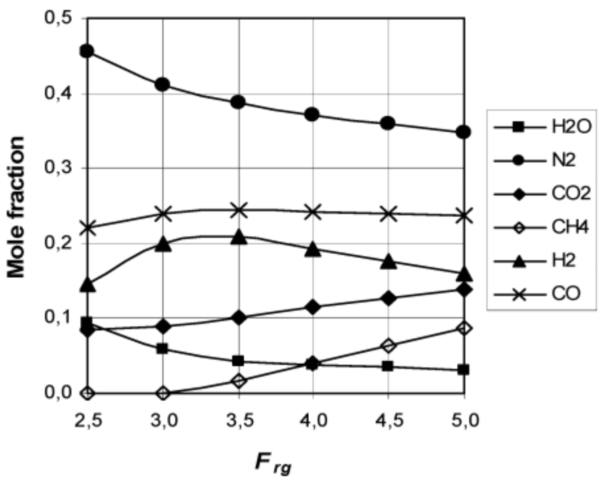

Figure 12. Producer gas composition versus the biomass/air relative ratio (F_{rg}).

Juan j. Hernandez et al [6] studied the laminar flame velocity of gaseous fuel by numerical simulation and experimental study, as shown in fig. 11 and fig. 12. By using Chemkin software and GRI - MECH, as well as pressure-time recorder and instantaneous flame image, the laminar flow velocity of other conventional gas fuel flames was compared. The results show that the flame is not stable in the actual process, and there is a certain difference between the simulation results and the high temperature and high pressure ones. Because of the inherent instability of the H_2 - containing fuel flame, it is too difficult to measure the flame's measurement speed by experiment, and it tends to use the results obtained by numerical simulation. The velocity of laminar flame of fuel containing H_2 gas increases with the increase of temperature and decreases with the increase of pressure. At the same time, if the dye contains moisture, it will weaken the laminar flame speed. The laminar flame speed is higher than methane and smaller than isooctane. Finally, sensitivity analysis shows that when the molar ratio is different, the chemical equations leading to the chemical reaction are different, and the reactants affecting the laminar flame speed are also different. When $\varphi<1$, oh+co =h+CO_2 will increase the laminar speed, and the reaction equation of h + O_2 = o + oh is very important.

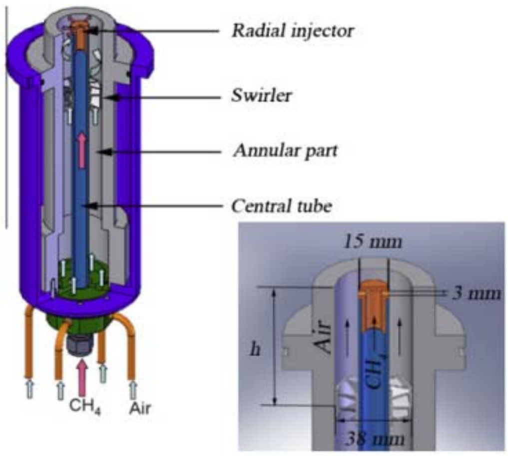

Figure 13. Coaxial swirl burner.

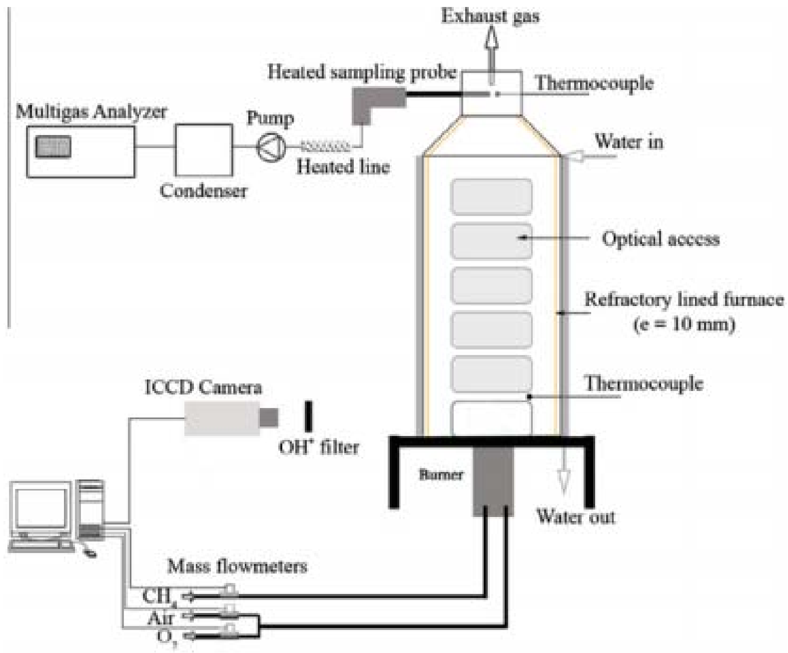

Figure 14. Producer gas composition versus the biomass/air relative ratio (F_{rg})

Nazim Merlo et al [7] studied the stability and smoke emission characteristics of methane combustion flame under oxygen-enriched combustion conditions, as shown in fig. 13 and fig. 14. The results show that oxygen-enriched combustion can improve combustion efficiency and enhance flame stability. The higher the oxygen concentration, the shorter the jet length of the flame, the smaller the fluctuation range, and the flame becomes more stable. With the increase of oxygen concentration, CO_2 emissions decreased exponentially. The distance between the root of the flame and the burner outlet also decreases with the increase of oxygen concentration.

3. Conclusion

At present, the research on the low calorific value gas burner is relatively focused on the stable combustion of the burner, and in order to ensure the stable and safe operation of the burner, low calorific value gas and high calorific value fuel are commonly used for mixed combustion. The research on how to use low calorific value gas burner alone has become a hot spot at present. At present, the research on gas combustion mainly focuses on the emission characteristics of pollutants and the theory of flame combustion. Most of the gas studied are combustible gases with higher calorific value, such as CH_4 and H_2, while the research on low calorific value gas or gas fuel with lower combustible content is less. There are two kinds of gas burners, direct current and swirl, and each has its own characteristics. The once-through burner has strong jet rigidity but poor flame stability, and the mixing effect of gas and air is not good. The flame stability of the swirl burner is strong, but the jet rigidity is poor due to the existence of swirl vanes, and the effect at the later stage of combustion is not very good.

Acknowledgments

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