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EVALUATION OF THE LAMINAR BURNING VELOCITY OF A SYNGAS MIXTURE IN OXY-COMBUSTION

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Abstract. The objective of this work is to perform an evaluation of the laminar burning velocity of several equivalence ratios of syngas mixtures in oxy-combustion and to compare them with the computational combustion simulations using known models. The method used for the experiment is the heat flux method. The setup of the experiment counts on mass flow meters to produce the fuel/oxidant mixture, thermostatic baths for regulating the burner temperature, thermocouples type T and datalogger for obtaining the measurements of the burner temperature, which allow the approximation of an adiabatic flame, essential for the execution of the method. The work is in its initial state of development, so it has no conclusions at the moment.

Keywords: syngas, laminar burning velocity, oxy-fuel combustion

1. INTRODUCTION

With the growing need for energy in the world and concern for the environmental preservation of the planet, the necessity for new sources of energy that cause less harm to the environment has increased. With this purpose, many technologies have been developed to provide a safer, more efficient and environmental friendly energy production. The IGCC (Integrated Gasification Combined Cycle) is one of the technologies that was developed and presents advantage such as the capacity of working with several types of fuel, solids and liquids, generating a gaseous fuel called synthesis gas (syngas) that is used in a gas turbine for power generation. This combined cycle can achieve high efficiencies and low emissions and, when used in conjunction with carbon capture storage (CCS), can achieve zero CO_2 emissions.

Syngas or synthesis gas are consisting mainly of CO and H_2, but may also contain CH_4, CO_2, N_2 and H_2O. It has many utilities and has been focus of several studies over the years such as those carried out in (Varghese *et al*., 2018; Zhang *et al*., 2016; Wang Z. *et al*., 2015; Han *et al*., 2015; Wang J. *et al.*, 2012), among others. However, a very small portion of those studies deals with syngas in oxy-combustion, which is a method that uses pure oxygen instead of air as the oxidant in the chemical reaction. This method adapts very well to the IGCC because the CO_2 released in the exhaust gas can work as a diluent for the oxidant.

In order to enhance the application of fuels in large scale, its characterization is very important to understand the combustion behavior. Thus, this investigation can be performed by measuring the laminar burning velocity, which can be done by the use of the heat flux method developed by (De Goey *et al*., 1993) and later studied by (Bosschaart and De Goey, 2003), in a manner similar to that performed by (Nonaka and Pereira, 2016).

2. METHODOLOGY

The current work aims at the measurement of laminar burning velocity of syngas mixtures in oxy-combustion and the comparison of them with simulations using known flame simulation mechanisms. For this purpose, the heat flux method, developed and improved by (de Goey et al., 1993; Bosschaart and de Goey, 2003), which uses a burner generating a flat flame that approaches an adiabatic flame, is used. Acquired through T-type thermocouples mounted in a brass circular plate, with uniformly perforated holes and 30 mm of diameter.

The burner has two temperature regulated water jackets, one cold, which keeps the temperature of the unburned mixture at 25°C and a hot one that keeps the edges of the perforated plate at 90°C, thus, preventing the flame from exchanging heat in the radial direction, as can be seen in Fig. 1. Both the water jackets are controlled by thermal baths that maintains the desired temperature. The thermocouples located on the brass plate are connected to a datalogger that

provides the data acquisition to a computer where they are treated and evaluated. Four mass flow controllers control the mixture of fuel and oxidant. The experimental setup is shown in Fig. 2.
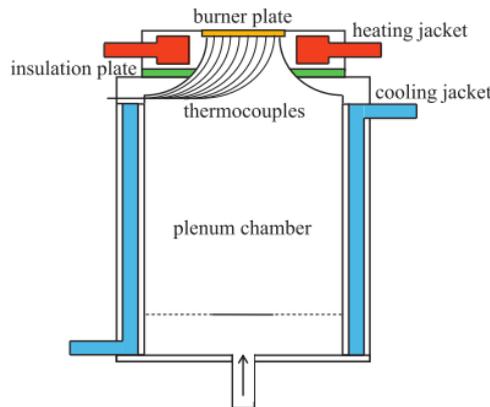

Figure 1. Heat flux burner elements (Nonaka and Pereira, 2016)

In order to stabilize a flat flame on the burner brass plate, the net heat transfer rate needs to be zero. In other words, the heat transfer from the flame front to the plate and, the heat transfer from the plate to the unburned mixture have to be zero. It is possible since keeping the plate edge temperature constant, there is no heat transfer in the radial direction, and the unburned mixture absorbs the heat transferred. The heat energy is carried by the flow of the mixture into the flame again, thus, the exit velocity of the mixture is the adiabatic flame velocity.
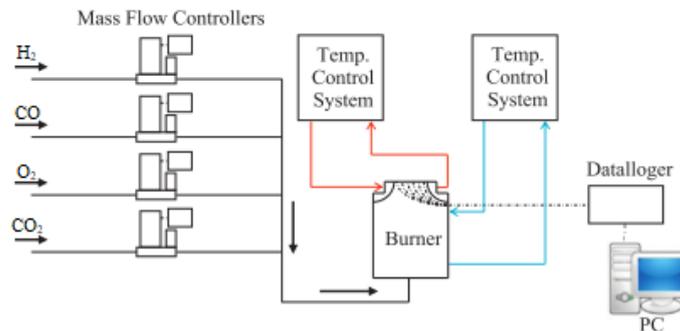

Figure 2. Experimental setup (Nonaka and Pereira, 2016)

Experimentally it is more difficult to obtain the condition of an adiabatic flame, because, there is only one combination of the mixture components flow rates that provides such condition. Therefore, the plate temperature measurements are performed under different conditions: 1. Sub-adiabatic, where the flow rate of the mixture is below that required for adiabatic, 2. Super-adiabatic, where the flow rate of the mixture is above that required for adiabatic. Using the least squares method, shown in Eq. 1, a gas velocity versus the C coefficient graph is plotted and through the interpolation process, it is possible to obtain the theoretical value of flow, which results in a perfectly adiabatic flame, where C is equal to zero.

$$Tp(r) = Tc + Cr^2 \qquad (1)$$

Where Tp (r) is the temperature in position r, Tc is the temperature in the center of the plate and C is a parabolic coefficient.

3. EXPECTED RESULTS

As this work is not finished, there is not a complete set of results yet. However, it is expected that the experimental results will be pertinent to those found in the computational simulations obtained using the software Cantera, from the

kinetic mechanism GRI-Mech 3.0. The results cover a range of equivalence ratios ranging from 0.4 – 4, for a series of mixtures, which are organized according to the notations shown in Eq. 2 and Eq. 3.

$$ZH2 = \left({XH2}/{XCO + XH2} \right) \tag{2}$$

$$Z = \left({XCO2}/{XCO2 + XO2} \right) \tag{3}$$

Equation 2 is the proportion of H_2 in the mixture of H_2 with CO, varying from 0.1 - 0.3, and Eq. 3, the proportion of CO_2 in the mixture of CO_2 and O_2, ranging from 0.6 - 0.8. Thus, the behavior of the laminar burning velocity with the variation of the equivalence ratio and its components in the mixture can be evaluated.

Figure 3 shows the results obtained in the computational simulations. Figure 3 a, b and c are related to the different values of ZH2.
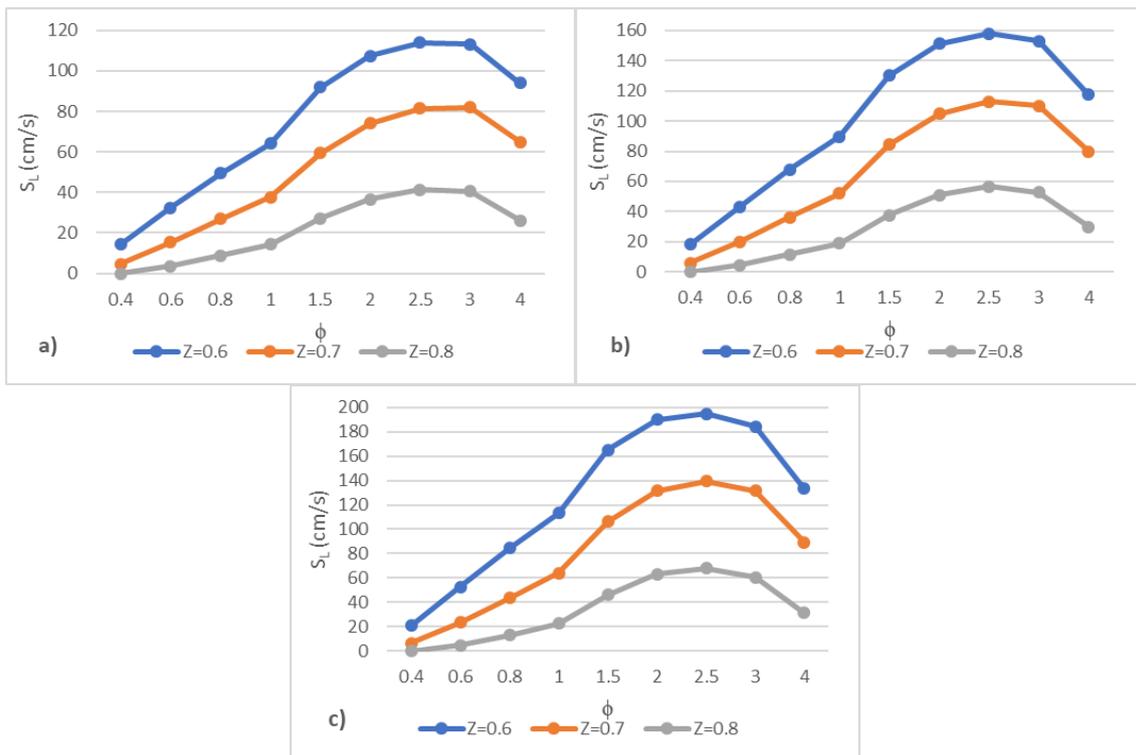

Figure 3. Laminar burning velocity of CO-H_2-CO_2-O_2 mixtures. (a) ZH2=0.1, (b) ZH2=0.2, (c) ZH2=0.3.

From the simulation results presented in Fig. 3, it was observed that the laminar burning velocity of this kind of mixture is high, reaching values of almost 200 cm/s. Therefore, due to the limitations of the heat flux method, which can measure flame velocity values between 10 and 50 cm/s, this work will be limited to experimentally reproducing the graphic points in this range.

4. CONCLUSION

The present work is in the initial stages of execution, hence, no conclusion is available at the moment. However, it is expected that the results can characterize the combustion of syngas in oxy-combustion by the measurement of laminar flame velocity in the various equivalence ratios. Furthermore, the assessment of a computational combustion model that better represents the combustion behavior will be investigated in this work.

5. REFERENCES

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