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# Numerical and experimental study on laminar burning velocity of syngas produced from biomass gasification in sub-atmospheric pressures

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ABSTRACT

The laminar burning velocity of syngas mixtures has been studied by various researches. However, most of these studies have been conducted in atmospheric conditions at sea level. In the present study, the effect of sub atmospheric pressure was evaluated on the laminar burning velocity for a mixture of $H_2$, CO and $N_2$ (20:20:60 vol%) in real sub atmospheric condition. The measurements was conducted in an altitude of 2130 m.a.s.l (0.766 atm) and 21 m.a.s.l (0.994 atm) to evaluate the effect of pressure, the temperature and relative humidity were controlled using an air conditioning unit and was maintained in 295 ± 1 K and 62.6 ± 2.7% respectively. The Flames were generated using contoured slot-type nozzle burner, and an ICCD camera was used to capture chemiluminescence emitted by OH*-CH* radicals present in the flame and thus obtain the flame front and determinate the laminar burning velocity using the angle method. The experimental results were compared with numerical calculations, conducted using the detailed mechanisms of Li et al. and the GRI-Mech 3.0. It was found that the laminar burning velocity increases at lower pressure, for an equivalence ratio of 1.1, the laminar burning velocity increases by almost 23% respect to the sea level conditions.



## 1. Introduction

The need to reduce emissions, the increased demand for energy gives and development flexible combustion systems have created the need to search for new energy resources. Within these, the syngas obtained from gasification of coal and biomass, whose reserves are abundant worldwide, is a promising alternative due to reduction in pollutant emissions compared to conventional fuels [1,2]. Depending on gasification technology the syngas produced is mainly composed of $H_2$ and CO and also contains $N_2$, $CO_2$ and small quantities of $CH_4$ and $H_2O$ .The presence of hydrogen in the chemical composition of syngas, improve the combustion characteristics as the laminar burning velocity and extends the flammability limit in lean conditions, which are of especial interest for industrial applications; in comparison to conventional fuels [1,3]. In particular the gasification of biomass can be installed on small scale to produce energy at local scale. However, the chemical composition of syngas produced from biomass gasification, depends of the type of this (Wood, organic wastes, cellulose), the reaction agent (Air, steam,

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oxygen/steam) and gasification process [4,5]. The variation in the syngas composition modifies the combustion behavior and therefore the design of combustion systems is more complex.

In this sense, the laminar burning velocity is one of the most important parameters due to physicochemical information of the mixture that it contains. Besides, it is a referring to study premixed flames phenomena and turbulent premixed combustion. Laminar flame velocity is a property of fuels that depends of the chemical composition of the fuel mixture, the temperature and the pressure [6]. It is defined as the flame propagation velocity of a one-dimensional flat flame that is considered to be steady and unstretched.

By this reason many studies has been conducted for different syngas composition, with the objective of characterize the most representative mixtures, which allow to design flexible combustion systems [5,7–9]. However, almost all of these studies were conducted at atmospheric conditions near of the sea level. Although some researchers have evaluated the pressure effect on the laminar burning velocity for different fuels, these studies are focused especially for higher pressures [4,10–16], whereas very few studies have been conducted at atmospheric pressures lower than 1atm [17,18].

In the specific case of syngas mixtures produced by biomass gasification, the investigations are even more limited, Burbano et al. [19] found that the laminar burning velocity decreases when increasing pressure except for the equivalence ratio corresponding to the highest value of laminar burning velocity, where the behavior is opposite. Although in Ref. [19] various syngas mixtures were studied, they not performed a comparative analysis between laminar burning velocity at 1 atm and sub-atmospheric conditions and the temperature was not controlled.

Taking account that some major cities and the rural regions of Latin America are located at high altitudes with pressures lower than 1 atm; it is necessary to extend the studies of renewable fuels obtained from biomass gasification under sub-atmospheric conditions to improve the knowledge of premixed flames in general and laminar burning velocity in particular flames to improve the design of flexible combustion systems.

## 2. Methodology

The composition of fuel mixture obtained from biomass gasification was determined from the typical compositions presented by other authors in their investigations. In order to simplify the mixture composition, this was defined as 20% $H_2$, 20% CO and 60% $N_2$, which adequately represents the syngas produced from biomass gasification according to the literature [4,5,20].

### 2.1. Experimental methodology

The flames were generated in rectangular burners with contoured slot-type nozzle with size of 7 × 21 mm and 9.4 × 29.8 mm for the measurement of high and low values of the laminar burning velocity, respectively. Rotameters specifically calibrated for each of the component gases were used to prepare the fuel-air mixture. Details about the burners and rotameters are in Ref. [1]. The experiments were conducted at isothermal atmosphere of 295 ± 1 K in two different altitudes 2130 and 21 m.a.s.l with pressures of 0.766 atm and 0.994 atm respectively. Flame front images are obtained using an ICCD camera and a colored filter centered at 430 nm and with a narrow wavelength of 10 nm which allows the passage of the CH* emission and blocks radiation outside this wavelength, the schematic representation of experimental setup can be seen in Fig. 1. Typical images of the flame front with ICCD camera can be seen in Fig. 2.

The laminar burning velocities were determined by the burner stabilized flame technique through the angle method. From the equilibrium in the velocities of the flame front, the laminar burning velocity can be defined as:

$$S_L = U\sin(\theta/2) \tag{1}$$

Where $U$ is the average velocity of the unburned mixture, $S_L$ is the laminar burning velocity and $\theta$ is the angle flame as can be seen in Fig. 3.

Given than, the burner used reduces the effects of curvature and stretch, the angle method and the technique to capture the flame front have been used in previous studies with good results [3,21–23]. To avoid the flashback effect the methodology used in Ref. [1] was implemented. The standard deviation of θ's calculated with this technique, were lower than 1.15, in both burners.

It is important to note that there are some conditions under which it was not possible to measure laminar burner velocity, for example, at sea level, unstable flames were obtained near of the stoichiometric conditions and at high altitude flame fluctuates at very rich conditions.

### 2.2. Numerical methodology

Numerical calculations of laminar burning velocity were obtained using PREMIX code of the CHEMKIN-PRO package. The detailed reaction mechanism of Li et al. [24] and GRI-Mech 3.0 [25] were employed to make the simulations. These mechanisms were chosen by theirs good agreement with the

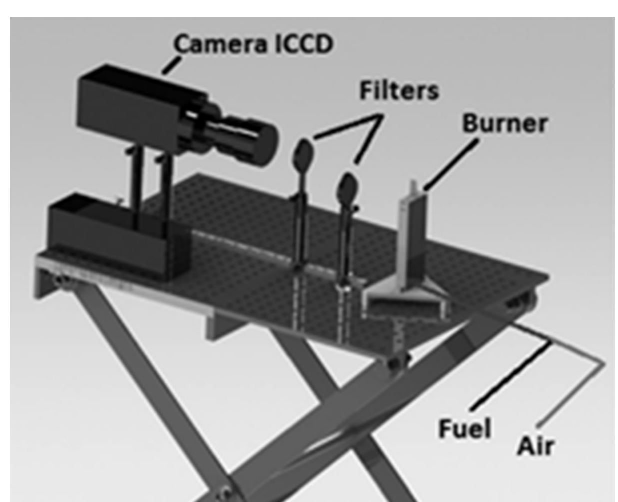


**Fig. 1 – Schematic diagram of the experimental setup.**

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