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# Fabrication and Performance Analysis of Laminar Burning Velocity of Fuel Air Mixture

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ABSTRACT

This study aims to calculate the rate of laminar combustion of air premix with a hydrogen flame using the Bunsen combustion test technique. The purpose of this combustion study is to measure the laminar velocity of the gas-fuel mixture. Hydrogen is one of the alternative fuels for use in vehicles and can be a promising alternative fuel because of its excellent properties. We made an attempt to obtain a laminar combustion rate, measuring hydrogen with a mixture of air (79.0mol-%H2 and 21.0mol-%O2) in a constant volume Bunsen burner with controlled temperature. The mixture is ignited with an igniter. A shield is used to measure the angle of the cone of fire. After measuring the cone angle, the laminar firing rate is calculated. All experimental data were compared with the calculated combustion rates for a free laminar flame. The measured and calculated combustion rate was used to investigate the effect of flue gas insertion.

**Keywords –** hydrogen-air, Bunsen Burner, cone angle, laminar burning velocity

## I. INTRODUCTION

The laminar burning velocity (also referred to as the flame velocity, the burning velocity, the transformation velocity or, the normal combustion velocity) is defined as the velocity of an infinite flame front normal to itself and relative to the unburnt gas. The gas mixture was made to flow through a tube and out of an orifice. A flame was ignited there and the flame speed was defined as the flow speed in the tube which was just low enough to produce light back.

The fundamental purpose of combustion research is the acquisition of a thorough understanding of the mechanism of ignition, flame propagation, species distribution, pressure and temperature developments and energy release.

The practical results of such knowledge are evidently the control of combustion processes from the point of view of safety, environment friendliness and efficient utilization as a source of energy.

Two Various methods have been used to determine the laminar burning velocity. It is now generally agreed that the spherical constant volume bomb method is one of the most potential, versatile and accurate methods for determining laminar burning velocity. The main difficulties are that reliable burning velocity equations are necessary for its calculation since it cannot be measured directly and this constant volume bomb method requires accurate measurements of the relevant parameters for the determination of burning velocity.

However, the potential of the constant volume bomb method is verified by the reproducibility and the accuracy of the results. A great deal of data exists for the laminar burning velocity for various fuel-air mixtures at low pressures and temperatures, particularly using burner methods. But the same cannot be said for elevated pressures and temperatures, particularly using constant volume bomb methods. In fact, data on laminar burning velocity of gaseous/liquid fuels showing the effects of an inert diluent at elevated pressure and temperature are quite scarce.

## II. EXPERIMENTAL SET UP

### A. Configuration

Configuration The experimental setup used to obtain LBV is shown in the figure 1 with a brief description. There are four subsystems in the experimental setup

(i) mixture preparation systems,
(ii) combustion reaction environment,
(iii) optical and dynamic pressure instrumentation, and
(iv) electrical systems.

The mixture preparation system has the reactant tanks, mixing tanks, liquid fuel injection, capacitance manometers, and vacuum pump. The combustion reaction environment consists of the temperature-controlled combustion spherical chamber. The Bunsen burner has a diameter of 3.5 mm. The gaseous fuel was flow through the tube which has 1.27 cm of diameter to the burner via gas roto meter. The Air was flow through the tube which has 1 cm of diameter to the burner via air roto meter. The Bunsen burner was shown in fig 1.

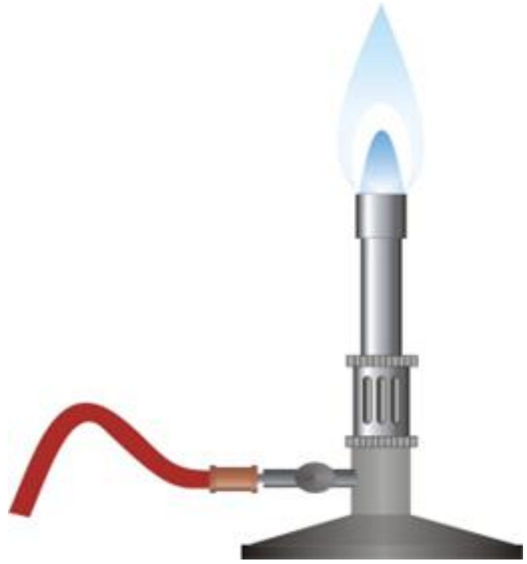


Fig 1 Bunsen burner

### B. Operating procedure:

1. First ensure all the valves of the Rota meters gas cylinder and compressor is closed.
2. Then open regulator valve of the gas cylinder slightly
3. Make ready for ignition with a gas lighter or match stick.
4. Then slowly open the gas rota meter valve and ignite the gas
5. Then open the air rota meter valve slowly by observing the flame.
6. By observing flame through the glass adjust the gas flow and air flow to get a good blue and laminar flame condition
7. Now a cone flame established.
8. Now measure the cone angle with respect to centre line of the cone (flame) by using the angle protector. (First set the angle protector to $90^0$ positions and by holding in the same position brings the protector arm to tangent/ inclined line

of the outer flame and then lock. And remove and see the angle and note down).

9. Repeat the same procedure by changing the gas and air flow rate.
10. After the experiment is over, please close without forget the gas rota meter valve and Gas cylinder regulator valve firmly. And also close the air flow rate valve.

**C. Equations**

1) Effective area of a burner,

$$A_e = \frac{\pi d^2}{4} m^2$$

Where d = Diameter of burner: ǿ 3.5 mm hole

$$= \frac{3.14x3.5^2}{4}$$

$A_e = 9.6162 \times 10^6 m^2$

2) Total mass flow rate to the burner, $Q_{total} = Q_{air} + Q_{gas} = m^3 / s$

Volume of air supplied in LPM

3) Mass flow rate of air, $Q_{air}$ = -----------------------------------------

= $m^3$ /s

60 x1000

Volume of gas supplied in LPM

4) Mass flow rate of LPG, $Q_{LPG}$ = ------------------------------------------ = $m^3$ /s

60 x1000

$Q_{total}$

Flow velocity, $V_u$ = ------------ = m /s

$A_e$

Laminar burning velocities for hydrogen-air-mixtures are computed for various mixture pressures, temperatures and compositions. Comparison between experimentally observed pressure and thermodynamically computed pressure along with equilibrium temperature (Te), initial moles i.e., number of moles of reactants and final moles i.e., number of moles of products In general, the difference between experimentally observed and computationally obtained values of equilibrium pressure for hydrogen-air mixtures for all cases. It is seen that the difference between the two is always comparatively more on the richer side of the stoichiometric value.

In fact, the high energy species in the elevated flame temperature and in the post flame regions may not be equilibrated with respect to internal partitioning of energy between their own internal vibrational, rotational and electronic energy levels.

Excess energy in the electronic energy levels may be lost as electromagnetic radiation, which is responsible, at least in part, for the characteristic luminosity of flame. These factors cause the peak pressure rise to some extent low during experimentation, which has not been taken into account in case of computationally calculated pressure.

**D. Cone angle measurement**

Cone angle measurement from the angle of the flame cone, and the speed of the incoming premixed fuel and oxidant mixture, it is possible to make an estimation of burning velocity, since the burning velocity can be considered the vector normal to the surface of the flame front once the flame has been stabilized.

However, this method retains the problem of identifying the exact location of the flame front, which will introduce errors into measurements, since α will need to be the angle of the cone produced by the cold flame front. It is also another source of error that the angle of the flame will vary along the flame front as a result of varying burning velocity again due to curvature and variations in temperature, so the burning velocity measured will depend on the region of the flame chosen. Particle image velocimetry, in this technique, the fuel/oxidant mixture is seeded with inert particles, which can be tracked through a succession of photographs to establish the flow field. Since the technique measures the speed of the particle, the particle must be chosen to ensure that the gas velocity and particle velocity are able to be considered equal, by having a suitably large drag/inertia ratio.

The simplest and oldest method for measuring the combustion rate of a cylinder burner is to divide the volume flow rate of the premixed fuel and oxidizer mixture by the approximate surface area of the flame, using the principle. Although simple, there are some notable problems with such methods von Rallis and Garforth (1980). Perhaps the most important problem here is that by using the flame front area, the Burning rate obtained will necessarily be the average Burning rate across the entire surface of the flame. Heat transfer to the edge of the burner will reduce the flame temperature from the adiabatic blade temperature, causing a decrease in the Burning rate, while at the end part the temperature may increase due to heating from all sides. k

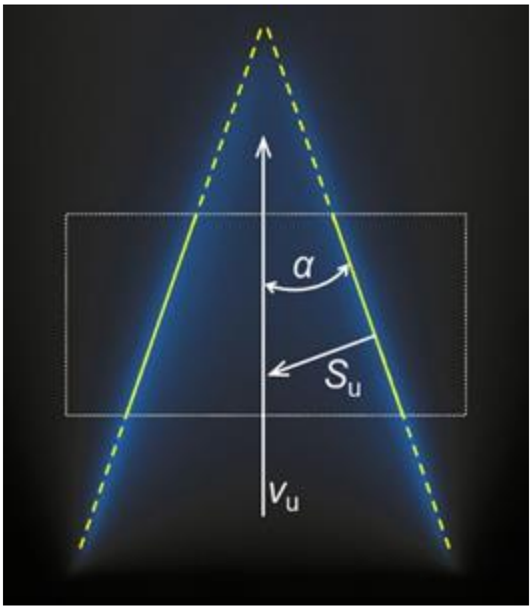



Fig 2 Measure of cone angle


Fig 3 Premixed flame

| S.NO | HYDROGEN FLOW RATE IN (LPM) | AIR FLOW RATE IN (LPM) | CONE ANGLE IN (DEGREE) |
|---|---|---|---|
| 1 | 0.5 | 5 | 11 |
| 2 | 1 | 10 | 10 |
| 3 | 1.5 | 15 | 10 |
| 4 | 2 | 20 | 9 |
| 5 | 2.5 | 25 | 8 |
| 6 | 3 | 30 | 8 |

Table 1 Experimental reading for hydrogen and air mass flow rate.

| S.NO | FLOW VELOCITY (m/s) | BURNING VELOCITY (m/s) |
|---|---|---|
| 1 | 9.53 | 1.81 |
| 2 | 19.05 | 2.3 |
| 3 | 28.5 | 3.2 |
| 4 | 38.1 | 3.6 |
| 5 | 48.1 | 4.1 |
| 6 | 57.74 | 4.3 |

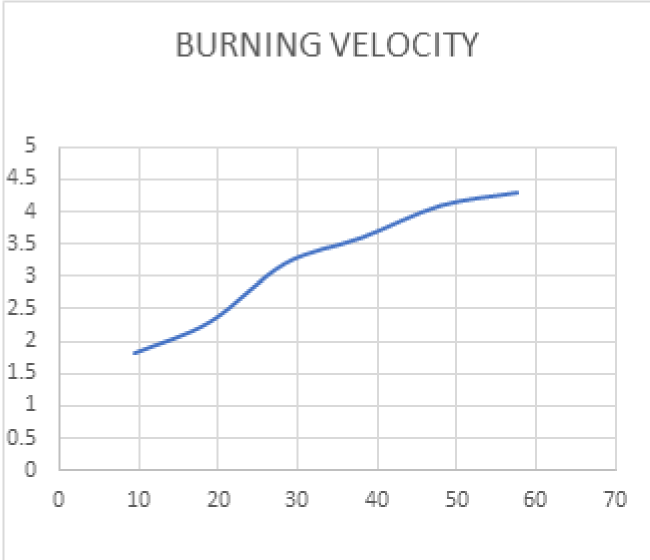
Table 2 Flow velocity and burning velocity.

## III. RESULT AND DISCUSSION

In the previous chapters experimental setup, experimental procedure, equations and computer program methodology employed to obtain the laminar burning velocity and other relevant parameters are described. One of the attractive features of this constant spherical volume combustion method of measuring burning velocity is that as the combustion proceeds from the centre of the bomb to radially outwards, the unburnt gas mixture is compressed, thereby raising its pressure and temperature. In the previous chapters experimental setup, experimental procedure, equations and computer program methodology employed to obtain the laminar burning velocity and other relevant parameters are described. One of the attractive features of this constant spherical volume combustion method of measuring burning velocity is that as the combustion proceeds from the centre of the bomb to radially outwards, the unburnt gas mixture is compressed, thereby raising its pressure and temperature.

For example, ammonia has potential as a store of hydrogen which with some enrichment can be burned in combustion engines however, further investigations for engine relevant conditions would be beneficial to research. With advances in chemical kinetic modelling, it is increasingly important that studies of burning velocity are carried out in conjunction with kineticists, to obtain a more complete picture of laminar combustion. This would also ensure that the appropriate data for mechanism validation is being obtained. Of particular interest is the disagreement between the mechanisms and the experimental correlations at elevated conditions when the fraction of diluent was increased in both the biogas and hydrous ethanol mixtures.

An important direction for the combustion community as a whole is to improve burning velocity measurements at elevated temperature and pressure. For this reason, more collaboration is needed between workers using the constant volume combustion vessel method to determine the cause of discrepancies in measurements of burning velocity and Markstein lengths, and to understand better the effect of vessel size and analysis procedures upon the determined results.




Graph 1 Flow velocity vs Burning velocity

Speeds achieved with Bunsen burners are well above specifications. This could be due to air entering the sides of the flame, which cools down to the temperature of the flame and affects its burning rate. The group also experienced turbulence problems with this configuration. Bunsen burner data is quite accurate. The highest burn rates occurred when the equivalence ratio is approximately equal to 1, where the fuel-air mixture equals stoichiometric conditions. Therefore, complete combustion takes place, which in turn maximizes the flame temperature. Flame temperature and burning rate are directly related, so the flame must have its maximum possible burning rate at $\Phi$=1. The experimental configuration of this project had several flaws that are the main sources of error in the data. For the Bunsen burner device, the most significant improvement would be to add a second tube to the device.

Much of the existing laminar combustion rate data is reported at low temperatures and pressures, and there is a need for data at elevated conditions relevant to engine combustion. The main objective of this project is to measure laminar burning rates with a variety of flame sizes. Speeds achieved with Bunsen burners are well above specifications. This could be due to air entering the sides of the flame, which cools down to the temperature of the flame and affects its burning rate. The group also had turbulence problems with this setup. Bunsen burner data is quite accurate. The highest burn rates occurred when the equivalence ratio is approximately equal to 1, where the fuel-air mixture equals stoichiometric conditions. Therefore, complete combustion takes place, which in turn maximizes the flame temperature.

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