ON THE STABILITY OF A LAMINAR METHANE/AIR DIFFUSION FLAME UNDER MAGNETIC FIELD INFLUENCE

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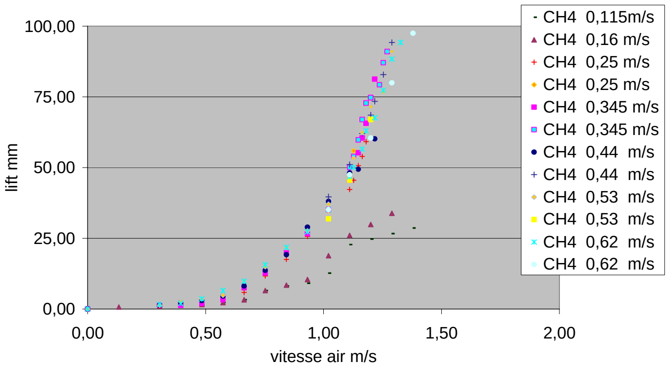
Nowadays, combustion process control is of considerable interest at both scientific and economical levels as it is related with the problem of energy efficiency and ecological improvement. Among numerous methods of combustion control, application of a magnetic field is one of the most promising. In the few researches carried out on magnetic assisted combustion, three interaction mechanisms have been identified. (1) The Lorenz force acting on charged particle, (2) the direct effect of magnetic field on chemical reactions and (3) the indirect effect of magnetic gradient on oxygen. Influence of the Lorentz force issuing from moving charged particles in a magnetic field on combustion has been investigated by Borovskoi et al. [1]. They have shown an increase of the combustion rate only in the specific configuration of combustion of solid propellant in rocket motors. Inducing a Lorentz force opposed to the flow of ionized gaseous products decelerated the flow leading to an increase of the static pressure from which depends directly the combustion rate. However, the amount of ionized species and their velocity are too small in laminar diffusion flames to take into account the influence of the Lorentz force. Y.Mizutani et al. [2] studied the direct effect of a uniform magnetic field up to 5T on chemical kinetics for a premixed laminar flame of propane/air. If high speed chemical reactions seem not to be affected, nitrogen oxide formation shows a slight difference under magnetic influence. The indirect effects are generated by the interaction between non uniform magnetic fields and the combustion derived non homogeneous oxygen concentration and temperature. Oxygen is strongly paramagnetic with a positive magnetic susceptibility χ whereas other chemical species present in a flame are mostly diamagnetic (with χ <0). In a non uniform magnetic field, the force exerted on a para or a dia-magnetic gas is given by $F = \frac{1}{2}\frac{\chi}{\mu_0}\nabla B^2$ where B is the magnetic induction (T), χ the gas magnetic susceptibility and μ_0 the vacuum permittivity ($4\pi\ 10^{-7}$H/m). Apart from attraction of oxygen towards stronger magnetic fields, the magnetic force is also able to generate magnetobuoyancy associated to the non uniform temperature distribution in the considered volume as the magnetic susceptibility of oxygen is varying with temperature following Curie's law. In [Gillon'2000] the effect of positive and negative vertical intense magnetic gradients on a laminar butane jet flame is described. Strong influence on the flame shape was observed attributed to an additional volumetric force of magnetic origin, leading to a flame behavior similar to that obtained at high gravity (in negative magnetic gradient) or at low gravity (in positive magnetic gradient).

In this paper we investigate the influence of local magnetic field gradients on laminar diffusion flame liftoff. Liftoff is an instability of the flame which quits the burner rim to set its position above the burner occurring when the jet speed exceeds some critical value.

The methane/air diffusion flame is formed on a co-flow, coaxial tube burner; methane is fed into the inner tube of 4mm diameter and air into the outer annulus section of 10 mm diameter. The magnetic field around the flame is produced in the horizontal direction by a pair of permanent magnets facing each other just in front of the burner rim. Magnetic field decreases from the burner, the magnetic force acts in the negative z-direction decelerating the flow of paramagnetic species.

The flame liftoff height, distance between the burner rim and the flame base, is measured from video recording of the flame system at fixed Methane flow rate, air flow rate being varied step by step with and without magnet.

Measured liftoff height data are presented on the Fig.1 without magnetic field and on Fig. 2 in the presence of the magnet.



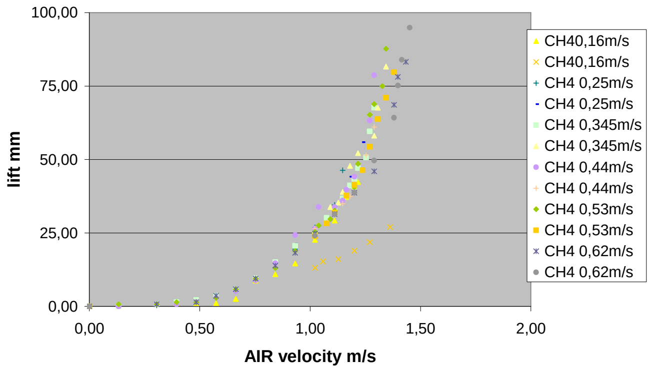


Fig. 1. Flame lift versus air flow rate without magnetic action

Fig. 2. Flame lift versus air flow rate under magnetic action

Curves obtained show two different behaviors: one at low value of methane flow rate and the second one above a critical methane flow rate. As evidenced by flow visualization of the methane flow and numerical modeling of the gas flow, the 1st regime at low methane flow rate is due to a vortex on the axis of symmetry related to the difference in methane and air velocities. This vortex seems not to be influenced by the magnetic field.

The second regime observed above 0.15l/min shows that the flame lift is related to the air velocity and does not depend on the methane velocity in the laminar conditions.

The magnetic field effect is deduced from a comparison of Figure 1 and Figure 2. The magnetic field appears to influence the position of the lift height. For a same set of conditions, the lift is less under magnetic action than without

This effect is related to the orientation of the field gradient and the direction of the magnetic force versus the flame.

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