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MAGNETIC FIELD EFFECTS ON THE COMBUSTION PROCESSES IN DIFFUSION FLAMES

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ABSTRACT

An experimental study is being undertaken to study the effects of non-uniform magnetic field on laminar hydrocarbon diffusion flames. Recent studies have shown that inhomogeneous magnetic field causes a significant effect in advancing gas flows and in chemical reactions rate. Thus, one of the specific aims of this study is to identify flame configurations which for given fuel-air ratio reduce soot formation in the presence of appropriate magnetic field gradients. Such findings could significantly effect the performance of both mobile and stationary combustion systems.

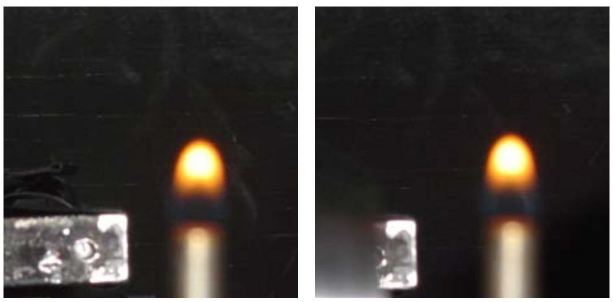
The effects of electric fields influence on flames are well known [1] and their mechanisms have been investigated extensively. However, the study of the influence of magnetic fields on flames is limited. Matter can be broadly classified as ferro-magnetic, diamagnetic or paramagnetic in nature. Ferromagnetic substances exhibit parallel alignment of moments resulting in large net magnetization even in the absence of an external magnetic field. Diamagnetic substances when exposed to an external magnetic field develop negative magnetization and hence are repelled by the field, where as paramagnetic substances when subjected to an external magnetic field by virtue of the alignment of the random orbital spins act as magnetic material and as such are attracted by the magnetic field. Here, emphasis is on the paramagnetic aspect of gases especially oxygen as it is both paramagnetic and is crucial for complete combustion. In 1847, Faraday applied a magnetic field to a flame on a wax taper and observed its tendency to form an equatorial disc [2]. Also, it has been noticed that magnetic fields can influence the behavior of gas flows and can also quench or promote combustion [3-8] depending upon the specific experimental conditions. Flow of gases such as carbon dioxide, nitrogen and argon were observed to be blocked or disturbed when they traveled in the direction of a magnetic field of increasing strength, while a mixture of oxygen and aqueous aerosol has been found to be attracted towards a stronger field and behave as a magnetic fluid [3]. It has also been noticed that inhomogeneous fields promote combustion in diffusion flames when the fuel gas flowed in the direction of decreasing field strength [1, 7]. However, no effect was observed when the field was uniform, be it gas flow or chemical reaction [4, 9]. Also, the effect was not appreciable on pre-mixed flames [9]. A diffusion flame is most suited for this study as the combustion takes place at the interface where the fuel and oxidizer mix in appropriate proportions and by applying a suitable magnetic field, the rate of combustion is expected to be altered. An experimental set-up has been designed, which allows the study of the effects of magnetic field gradients on the flame structure of hydrocarbon – air laminar diffusion flames.

The experimental system consists of a diffusion type propane - air flame centered on a stainless steel burner tube (1/4 inch in diameter). Regulated fuel (using a digital flow meter) is supplied to the burner. Provisions are also in place to change the flame configuration to a pre-mixed or counter flow type. An electromagnet has been set-up by using a permanent magnet (with a cast Iron Core), suitable magnetic wire windings and a DC power supply. The current through the coil and the magnetic field intensity is measured by using a multimeter and a Gauss meter with a transverse probe respectively, to accurately monitor the field intensity during the experimental runs. The current through the coil and hence the intensity of the magnetic field can be varied. The magnetic field intensity is 2.77 KG at the center of the air gap of 3cm at the maximum current through the coil. The flame is subjected to various field intensities and the flame characteristics are captured by using a digital camera for further analysis. A Platinum versus Platinum-10% Rhodium (S type) thermocouple with a bead diameter of 0.2mm is used to measure the temperature at various axial locations with the help of a vertical translation mechanism. Also, there is provision for collecting particles from this system. The particles produced in the flame are collected through a thermophoretic sampling system and are deposited on a 200-mesh copper grid coated with carbon film that is stable under electron beam conditions.

The effects of magnetic field on the flame characteristics for a propane-room air diffusion flame subjected to a magnetic field are presented. A change in the structure of the flame is observed when it is subjected to a vertically decreasing magnetic field. Analysis is underway to obtain correlations of flame heights as functions of magnetic field gradients and air flow velocities.

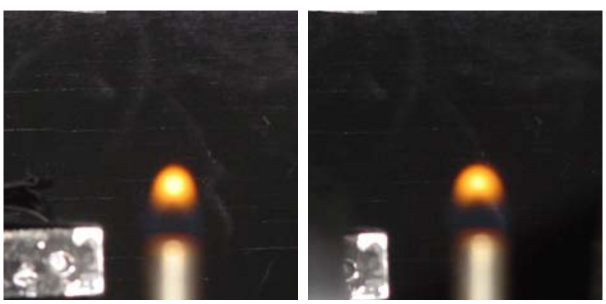
Propane-Air Diffusion Flame

Velocity = 1.32cm/sec



No Field B=2.77 kG
Decreasing magnetic field

Velocity=1.16cm/sec



No Field B=2.77 kG
Decreasing magnetic field

It is well known that para-magnetic substances are attracted by a magnetic field while diamagnetic substances are repelled. Therefore, the differential action of the magnetic field on two different gases causes the observed behavior. When a fuel gas flows in the direction of a decreasing field it is accelerated since it is diamagnetic in nature where as oxygen being paramagnetic is decelerated. Hence, the combustion at the interface is enhanced. Observations of the structure of the propane-air diffusion flame indicate that greater entrainment of air at the base of the flame causes cooling and results in the onset of the detachment of the flame.

The magnetic field effects are to be studied for various flame configurations and modes and compared with published results [1, 3, 5 and 9]. Correlation of flame heights with magnetic field gradients will be sought and developed. A further aim is to include the effects of the magnetic field on the synthesis of materials.

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