EXPERIMENTAL INVESTIGATION OF THE ACOUSTIC FLAME INTERACTIONS IN A BUNSEN BURNER

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Abstract: *Thermo-acoustic instabilities has long been recognized as a problem in continuous combustion systems. These perturbations occurs as a result of unstable coupling between the heat release fluctuations and acoustic perturbations. The main aim of the present work was carry an experimental investigation of the interactions between combustion, turbulence and acoustic. Laser Diagnostics are a powerful tool for the study of flame behavior and its structures. Here this tool was used to see these acoustic excitation and flame interactions. In the present work OH PLIF measurements were carried out to investigate a flame on a turbulent Bunsen burner excited with acoustic waves. The measurements revealed that the flame was strongly affected by the pressure fluctuations.*

Keywords: *Combustion, Acoustic, PLIF, Active control.*

1 Introduction

Combustion instability, also known as thermo-acoustic instabilities, is one of main problem in aerospace engine combustors. Such instabilities are due to a positive closed loop of the interactions between the acoustic field and the unsteady heat release from combustion. Acoustic waves can lead to fluctuations in heat release of the flame. By turns, can amplify the acoustic waves and so successively. Thermo-acoustic instabilities in combustion chambers can lead to severe degradation of the combustion process, such as unacceptable noise pollution, structural damage due to high pressure pulsations, heat transfer increasing and so on (Kabiraj and Sujith,2012; Kornilov *et al.*,2009; Zikikout,1988).

According to Rayleigh's criterion, the heat release process adds energy to the acoustic waves when pressure and heat release oscillations are in phase. When these oscillations are out of phase, fluctuations in heat release damps the acoustic waves. The system is unstable when the acoustic driving due to the combustion–acoustics interaction exceeds the acoustic damping by inherent dissipative processes (Bellows,2006).

In general, two methods of control of the thermo-acoustic instabilities exist: passive and active control. The passive control modify the resonator system of the combustor. Baffles, resonators, vortex generators and acoustic liners are used to damp the thermo-acoustic interactions. The active control monitors the coupling between the heat release and the acoustic waves and applies a modulation in the fuel flow or in the acoustic field in order to damp the instabilities. In acoustic modulation, an acoustic driver is used to modulate the pressure field inside of the chamber and consequently modify the fuel-air mixing pattern before entering the flame front.(Campos-Delgado *et al.*,2003; Fritsche,2005)

The knowledge and control of the physical phenomena related to thermo-acoustic instability is needed to design and analyze equipments. This knowledge provides data for the validation and improvement of physical and mathematical models of turbulence and combustion in computational fluid dynamics. The application of advanced laser-based diagnostics has provided considerable insight into these interactions and other phenomena important to thermo-acoustic instabilities. (Steinberg *et al.*,2010; Zikikout,1988).

Some authors (Bellows,2006; Kornilov *et al.*,2009) showed that applying a known waveform in the reactants feed line is possible to act in the cause of the process of instabilities. In this way it causes other instabilities changing the pattern of the turbulent flow. The consequence is that the instabilities caused by the flame can be attenuate and to present characteristics necessary for proper operation of the engine.

In the present work, the *OH* Planar Laser Induced Fluorescence (*OH*-PLIF) was used to investigate a premixed flame on a turbulent Bunsen burner excited with acoustic waves. The thermo-acoustic interactions were be produced by active system based on speakers. The main objective is to modify the diffusive pattern of the turbulence through a known acoustic disturbance. Both acoustically excited and non excited flame will be studied to compare the effect of acoustic excitation in the flame front.

2 Experimental Setup

The turbulent premixed flames studied were produced by an axisymmetric Bunsen burner with an inner diameter of 26.5 mm. The fuel (LPG) and air were premixed upstream of the combustor. Acoustic oscillations (sine function) were introduced using a function generator, one audio amplifier (4W, LM380) in house built and one speaker ($3W, 4\Omega$), which were mounted in the fuel line. The speaker input RMS voltage was measured by an oscilloscope and kept at $2.77V$.

OH-PLIF was used to visualize the spatial dynamics of the flame since that the instantaneous flame front were characterized by measuring $OH*$ radical emissions. The OH-PLIF system consists of a dye laser system (Sirah Precision) pumped by the third harmonic of an Nd:YAG laser (Quantel, Brilliant b). The pump laser delivers $233mJ/pulse$ at $355nm$. The dye laser is tunned such that the output wavelength is $283.408nm$. By consequence of a misalignment, the actual wavelength shown in the Sirah control has a small shift in comparison with the actual wavelength. The output laser beam pass through the energy monitor and a collimator objective to produce a laser sheet. The setup is adjusted so that the laser sheet cross the burner nozzle centerline. The induced fluorescence is detected using a intensified CCD camera (ICCD). A schematic of the system with its laser system is provided in Fig. 1.

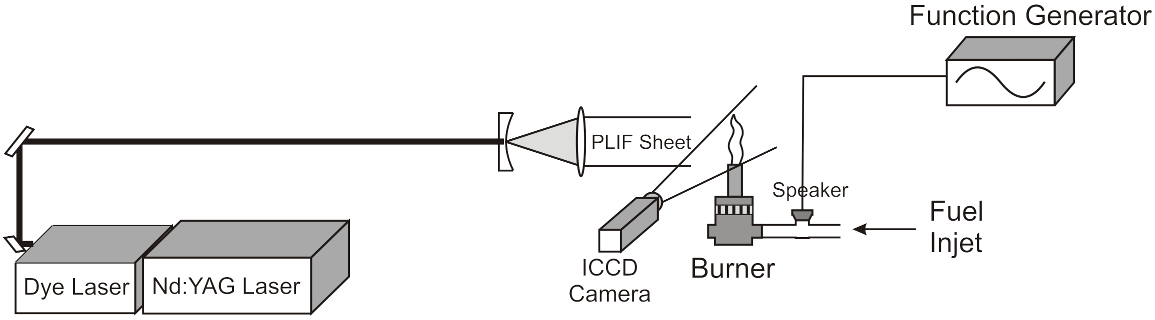
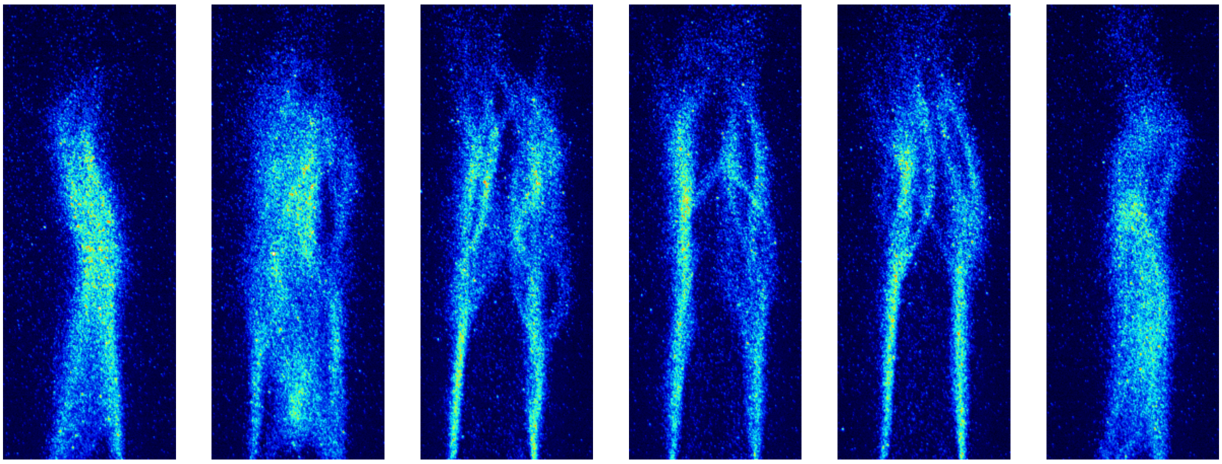


Figure 1: Schematic of Bunsen burner

Experiments were conducted by exposing the flame to acoustics at a selected range of frequencies. The frequencies used are: $580, 960, 990, 1200$ e $2460Hz$. 50 flame images were recorded for each frequency, these images were then post-processed to correct the background e take the average values.

3 Results and Discussion



not excited $580Hz$ $960Hz$ $990Hz$ $1200Hz$ $2460Hz$

Figure 2: Averaged images obtained by OH PLIF from flame excited acoustically

For each selected excitation frequency a total of 50 pictures were took. From these, a sequence of 6 best consecutive pictures were selected and processed by LAVision DaVis data acquisition software. The averaged images of the frame front obtained by OH-PLIF for different frequencies are shown in Fig. 2. It is possible to see from these pictures that the flame behavior change with the frequency of the excitation. Without excitation, the flames presents a spread character. The injection of acoustic excitation in the fuel feed line up a given value (from $580Hz$ to $1200Hz$), the flame tends to present a well-defined behavior.

However, beyond a give frequency these behavior is not more visualized and the flame presents a spread pattern however with less dispersion than non excited case. It is possible to see such behavior when the frequency is about $2640Hz$. The explanation for these flame pattern changes arise from the modification of the hydrodynamic instability process once that the turbulence is related directly with that. The turbulent flame is a consequence of flame front and turbulent vortexes interactions. The acoustic excitation induces other hydrodynamic instability modes and by consequence other vortexes in order to change the pattern of turbulent flow. Changing this pattern, the flame front changes. In such way, it is possible to act actively in combustion process and therefore eliminate or reduce combustion instabilities.

4 Conclusions

The measurements revealed that the flame was strongly affected by the acoustic perturbations. The acoustic oscillations cause fluctuations in the heat release of the flame, causing changes in the flame pattern.

The OH PLIF techniques showed that is a powerful tool to visualise reaction flow. The effect of the acoustic excitation and changes in the flame pattern can be visualised using this technique.

In the active control, an acoustic driver is used to modulate the pressure field inside of the chamber. Modulate mixing air/fuel into the combustion chamber demands a larger amount of energy than the modulation in the fuel line, this is due to the larger volume. Therefore the system used in this work can be used for active control of the combustion process therefore eliminate or reduce combustion instabilities.

Acknowledgments

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