Experimental Methods in Thermo-Acoustics

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1. Introduction

The general characterization of laminar/turbulent flows, isothermal or with reaction, can be made using different types of techniques such as: LDV, PIV, Rayleigh, Raman, Thermometry, Microphones/Piezoelectric, Chemiluminescence sensors and gas analysers, for quantification of vectors and scalar entities such as velocity, temperature, species and pressure fields (e.g. Durão et al, 1992, Taylor, 1993).

Moreover, when these flows become regularly unsteady, the above modern techniques can still be applied, but it requires a proper combination between the required technique and another sensor, in general a microphone or a piezosensor.

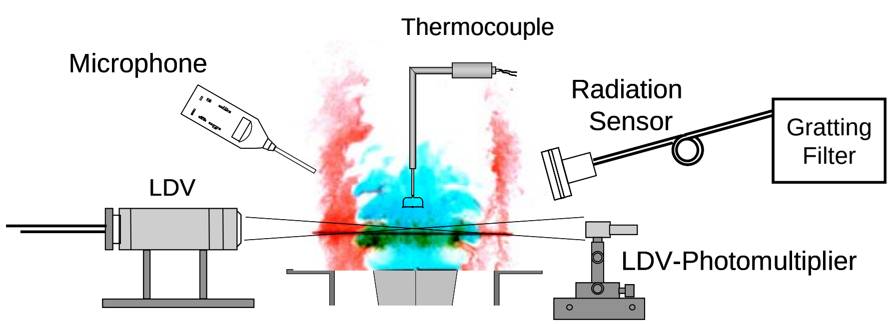

Figure 1.1. Schematic diagram of combination between LDV, Microphones, Fine-wire thermometry and Radiation sensor to characterize an unsteady flame

The main objective is to define or to have a reference time signal to allow the data to be properly processed and correlated with each other. Also, and in particular for the techniques that requires particles in the flow (LDV, Phase Doppler, PIV) these particles must have certain characteristics to reproduce correctly the unsteadiness of the flow, while intrusive sensors like thermocouples disturb the flows and must have a time lag characteristic value lower than the unsteady characteristic time scale. In addition, the post-processing is specific and requires a more carefully approach rather than the traditional Reynolds averaging procedure.

This document is presented in this context and intends to give a basic overview of LDV, Fine-Wire Thermometry, Chemiluminescence and Pressure waves measuring techniques, as schematically shown in Figure 1.1, the usual techniques for a satisfactory characterization of unsteady flows and the necessary requirements for their successful application. Then a case study will be explored where these four techniques are used together.

2. Experimental Techniques

Laser Doppler Velocimetry

Introduction/Fundamentals

LDV stands for laser Doppler Velocimetry and is a non-intrusive technique, based on lasers and the Doppler effect, to measure flow velocity through the movement of particles that should exist in the flow. The basic of the technique requires that a pair of focused laser beams crosses in space to form an optical control volume (at the intersection) where interference fringes are formed. The fringe characteristics are a function of intersection angle, optical wavelength, and whenever a particle passes through this control volume will scatter light that is collected by a photomultiplier. The frequency of the scatter signal is then proportional to the particle velocity.

When two coherent laser beams, with electric fields $\varepsilon 1$ and $\varepsilon 2$ given in Eq. [1], crosses in space, as shown in Figure 2.1, it forms an ellipsoid where the interaction between the two electric fields generates an interference pattern with the light intensity distribution given by Eq [2] (Durst et al, 1981).