A NUMERICAL METHOD FOR THE SOLUTION OF CONFINED CO-FLOWING JET DIFFUSION FLAMES

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***Abstract*— The aim of this work is the development of a method to obtain the shear layer, which appears in confined co-flowing jet diffusion flames. A convenient formulation, based on the mixture fraction for fluid flow and on flamelet models for the chemistry, using the RANS (Reynolds Averaged Navier-Stokes) and the LES (Large Eddy Simulation) approaches, is chosen. Numerical tests, for the governing equations discretized using the second order finite difference explicit scheme, were carried out for Sandia Flame D to compare the results with data in the literature. Results of the shear layer development comproves the ability of the developed LES method solving diffusion flames.**

***Keywords*— Diffusion flames, co-flowing jet, methane, finite difference, low Mach-number.**

I. INTRODUCTION

The field of combustion requires studies in thermodynamics, chemical kinetics, fluid mechanics, heat and mass transfer, turbulence, among others areas (Kuo, 2005). The combustion not only generates heat, which can be converted into power, but also produces pollutants such as oxides of nitrogen, soot, and unburnt hydrocarbons. In addition, unavoidable emissions of CO_2 are believed to contribute to the global warming. These emissions will be reduced by improving the efficiency of the combustion process, thereby increasing fuel economy (Peters, 2000).

In gaseous turbulent combustion, the mixing processes can be divided into premixed, nonpremixed, or partially premixed. In this paper we work with nonpremixed combustion, where the fuel and the oxidizer enter separately the combustion chamber.

For many turbulent diffusion flames, the so-called flamelet concept can be used. The flamelet model describes a turbulent flame as a laminar flame in a turbulent flow field. There is general agreement that the flamelet concept is applicable in the zone of large Damköhler numbers with turbulent scales larger than the flame thickness (Warnatz *et al.*, 2001).

The low Mach-number method is employed because usually the combustion occurs in this flow regime. For example, most of the accidental fire problems such as forest fires, fires in road tunnels and fires in buildings, arise at low Mach-numbers, where the local flow velocities are well below the local speed of sound. In addition, combustion within industrial burners normally occurs at low Mach-numbers. For these applications an approach that takes into account the compressibility is necessary (Howard and Toporov, 2007). When the Mach-number goes to zero the pressure gradient contribution in the nondimensional momentum equations becomes singular. Therefore, a numerical method used to integrate the original set of equations tends to fail when applied to very low Mach-numbers in combustion (Klein, 2001).

The combustion involves a large range of time and length scales that are originated from the heat release due to chemical reactions, which induce to strong convective, diffusive and radiative heat transfer. The complexity of the Navier-Stokes equations turns the Direct Numerical Simulation (DNS) of turbulence difficult for most flows of interest, because the number of degrees of freedom grows faster than $O(Re^{11/4})$ [$O(Re^{9/4})$ in space and $O(Re^{1/2})$ in time], where Re denotes the turbulent Reynolds number (Garnier *et al.*, 2009). For the simulation of turbulent combustion the Reynolds Averaged Navier-Stokes (RANS) and the Large Eddy Simulation (LES) turn alternatives.

In this context, the present work is based on the mixture fraction for fluid flow and on flamelet models for the chemistry. We show some inedit numerical results of the shear layer development for a confined co-flowing jet of methane obtained using a finite difference scheme for the discretization of the governing equations. The dynamic pressure gradients come from a Poisson's equation scaled by the Mach-number. The model is validated through comparison with experimental data.

II. MODEL FORMULATION

A convenient formulation for nonpremixed flames, based on the mixture fraction for fluid flow (Bilger,