Numerical Studies of Paraguayan Chaco Natural Gas Combustion in a Counterflow Diffusion Flame

Hernando A. Maldonado[*,†], Dario A. Alviso[*], Miguel A. Mendieta[*], Juan C. Rolón[*]

[*] Laboratorio de Mecánica y Energía, Facultad de Ingeniería, Universidad Nacional de Asunción
2160 San Lorenzo, Paraguay
[†] hernandomaldonado90@gmail.com

ABSTRACT

Practical combustion systems or industrial applications generally involve turbulent flows and complex geometry. Combustion and fluid dynamics are strongly coupled in those cases and is difficult to show a particular interest in the structure and properties of flames.

In order to acquire a better understanding of combustion fundamental phenomena, it is preferable to study a configuration with flows relatively simple and flames that are easy to control. The counterflow laminar flames meet these criteria: the flow is well known, it can be modelled from a theoretical point of view and experimentally it can be controlled in a relatively easy manner. The simplicity of the geometry allows a detailed study of the flame structure from an experimental and numerical point of view.

Therefore, to carry out both experimental and numerical studies of Paraguayan Chaco natural gas combustion, a counterflow diffusion (non-premixed) flame configuration was chosen.

Experimentally, a diffusion flame is obtained using a counterflow burner, where different operating conditions (equivalence ratio and strain rate) were studied. Moreover, the chemiluminescence of the excited radicals $CH^*(A^2)$ and $C_2^*(d^3)$ are studied experimentally by emission spectroscopic techniques. Furthermore, opposed flames have a slight curvature, which creates in the line of sight of the camera an integrated signal that increases the measured concentration. To solve this problem, an Abel inversion of a 2-D image captured with the ICCD camera lens assembly was performed. Narrow-band interference filters were interposed along the optical path to capture the CH^* and C_2^* emissions, as done in [1].

Numerically, the operating conditions described in the previous paragraph were reproduced, using REGATH package, which takes into account natural gas chemical kinetics, as well as thermodynamics and transport properties of all species. We consider an axisymmetric counterflow configuration.We model our system using similarity approach by searching for similar solutions of gaseous flow equations (mass, momentum, energy and species conservation equations) in the vicinity of the central axis [2]. CH^* and C_2^* production and destruction chemical reactions were added to the natural gas model available in the literature.

Finally, a comparison between experimental and numerical CH^* and C_2^* species axial profiles is performed. Also, the natural gas flame structure is analyzed. Validation of this model is realized for several operating conditions.

REFERENCES

[1] D. Alviso, P. Scouflaire, D. Lacoste, N. Darabiha, J. C. Rolon (2013). Experimental and numerical characterization of the Methyl Decanoate combustion in laminar counterflow spray premixed flames. Proceedings of the ASME 2013 Turbo Expo 2013, June 3-7, 2013, San Antonio, USA.

[2] Darabiha, N., F. Lacas, J. Rolon, and S.Candel (1993). Laminar counterflow spray diffusion flames: A comparison between experimental results and complex chemistry calculations. Combustion and Flame 95 (3), 261-275. (p. 123)