MODELING RADIATIVE HEAT TRANSFER AND SOOT FORMATION IN LAMINAR DIFFUSION FLAMES

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Abstract. Modeling thermal radiation and soot formation are important for accurately simulating diffusion flames, since they are strongly related. For one side thermal radiation will determine the energy lost by the flame and therefore its temperature, while for the other side the soot formation is highly affected by the local flame temperature. Also, depending on the soot concentration, the radiation released by the flame can be dominated by the soot present in the flame or the combustion gases. This complex interrelationship will produce that evaluating accurately the flame temperature and soot volume fraction are nowadays a very challenging tasks. In this work two axisymmetric laminar ethylene/air coflow diffusion flames were simulated, considering a normal (NDF) and an inverse (IDF) configuration. In coflow NDF the fuel is injected by a central tube while the air is injected at the surroundings, whereas in IDF the relative position of the fuel and oxidant are exchanged. Studying numerically laminar flames allows obtaining insights that can be easily extended to turbulent flames via the flamelet concept [1]. This greatly facilitates the task of simulation and also of experimentation. Particular interest presents the IDF, in which the soot forms in different conditions compared to a NDF. This type of flame is usually studied for modeling soot nucleation and growth, and to learn about soot formation in under-ventilated fires [2]. The numerical model used in this work is based on the Steady Laminar Flamelet (SLF) model, while a semi-empirical two-equation acetylene/benzene based soot model [3] was chosen. The radiative transfer is modeled with the Statistical Narrow Band Correlated K (SNBCK) model [4] and solved with a Finite Volume Method (FVM) specially developed for axisymmetrical configurations [5]. Predictions, in the form of temperature and soot volume fraction fields, are in reasonable agreement with the available experimental data. The radiative contribution of gas prevails in the weakly-sooting IDF while soot radiation dominates in the NDF.

Keywords: Thermal radiation, soot formation, normal diffusion flame, inverse diffusion flame, axisymmetric laminar flames.

References

[1] N. Peters. Laminar Diffusion Flamelet Models in Non-Premixed Turbulent Combustion. *Progress in Energy Combustion Science*, vol. 10: 319-339, 1984.
[2] M.A. Mikofski, T.C. Willims, C.R. Shaddix, A.C. Fernandez-Pello and L.G. Blevins. Structure of Laminar Sooting Inverse Diffusion Flames. *Combustion and Flame*, vol. 149: 463-478, 2007.
[3] R.P. Lindstedt. Simplified Soot Nucleation and Surface Growth Steps for Non-Premixed Flames. In: *Soot Formation in Combustion: Mechanism and Models*, H. Bockhorn (ed.), pp. 417-441, Berlin: Springer-Verlag, 1994.
[4] M.F. Modest. *Radiative Heat Transfer*, 2nd edition, pp. 317-323, New York: Academic Press, 2003.
[5] E.H. Chui, G.D. Raithby and P.M.J. Hughes. Prediction of Radiative Transfer in Cylindrical Enclosures with the Finite Volume Method. *Journal of Thermophysics and Heat Transfer*, vol. 6:605-611, 1992.

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