Modelling fire-related problems with Lattice Boltzmann Methods

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Summary: Over the last two decades, the role of CFD in fire protection engineering has continuously been enhanced with the development of large-eddy simulation-based fire simulators. These simulators have to handle the complex coupled physical processes involved in fire problems, namely, condensed-phase pyrolysis, buoyancy-controlled flows, buoyancy-induced turbulence, turbulent combustion, thermal radiation, and soot generation [1]. Their objective is, on the one hand, to help in the design of safer industrial or civil installations and, on the other hand, to improve the knowledge in the physics of fire. A challenge for such numerical tools is to provide high-fidelity predictions with simulation times compatible with "engineering" applications.

Lattice Boltzmann Methods (LBM) are a powerful tool for the simulation of fluid dynamics [2]. Due to its attractive computational cost [3], its capacities for massively parallel computing and the ease to deal with complex geometries using multi-level Cartesian grids, these methods have attracted growing interest both in the academic and industrial spheres in the past decade [4].

The objective of this PhD thesis is to develop a low-Mach Lattice-Boltzmann Large-Eddy Simulation- based fire model. The focus will be put, on the one hand, to the development of the LBM method and, on the other hand, to the development and implementation of the state-of-the-art physical submodels for turbulent combustion, thermal radiation and soot production. The model will be validated by comparison with available experimental data of the literature (see [1] for example), including non-sooting and sooting pool fires and other fire-related configurations.

Profile of the candidate : The candidate will have to possess a strong background in fluid dynamics, computational fluid dynamics and heat transfer. Knowledge in combustion would be appreciated.

Literature:

[1] A. Brown, M. Bruns, M. Gollner, J. Hewson, G. Maragkos, A. Marshall, R. McDermott, B. Merci, T. Rogaume, S. Stoliarov, J. Torero, A. Trouvé, Y. Wang, E. Weckman, Proceedings of the first workshop organized by the iafss working group on measurement and computation of fire phenomena (macfp), Fire Safety J. 101 (2018) 1–7.

[2] S. Chen, G. D. Doolen, Lattice boltzmann method for fluid flows, Annual review of fluid mechanics 30 (1) (1998) 329–364.

[3] P. Boivin, M. Tayyab, S. Zhao, Benchmarking a lattice-boltzmann solver for reactive flows: Is the method worth the effort for combustion?, Physics of Fluids 33 (2021) 017703.

[4] T. Krüger, H. Kusumaatmaja, A. Kuzmin, O. Shardt, G. Silva, E. M. Viggen, The Lattice Boltzmann Method: Principles and Practice, Springer, 2016.

[5] F. Nmira, J.L. Consalvi, Local contributions of resolved and subgrid turbulence-radiation interaction in LES/presumed FDF modelling of large-scale methanol pool fires, International Journal of Heat and Mass Transfer, Volume 190, 2022, 122746

[6] L. Ma, F. Nmira, J.L. Consalvi, Modelling extinction/re-ignition processes in fire plumes under oxygen-diluted conditions using flamelet tabulation approaches, Combustion Theory and Modelling, 2022, 10.1080/13647830.2022.2036373.

[7] F. Nmira, L. Ma, J.L. Consalvi, Influence of gas radiative property models on Large Eddy Simulation of 1 m methanol pool fires, Combustion and Flame, Vol. 221, pp. 352-363, 2020.

[8] F. Nmira, L. Ma, J.L. Consalvi, Assessment of subfilter-scale turbulence radiation interaction in non-luminous pool fires, Proceedings of the Combustion Institute, vol. 38, pp. 4927-4934, 2021

Professional integration after thesis At the end of the thesis the candidate could applied to both academic or industrial research positions.