International Conference on Numerical Combustion
Rome, Italy, October 14-17, 2025
www.icnc2025.com

An Adaptive Mesh Refinement cell size estimation for solving turbulence in unstationary reactive systems

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In the context of explosion events, the flame is observed to encounter obstacles, leading to an enhancement of turbulence activity. This phenomenon is characterised by its highly unsteady nature, attributable to its temporally and spatially localised behaviour. For instance, the position behind obstacles is considered to play a significant role in the flame propagation dynamics. The use of the Adaptive Mesh Refinement method is ideal for easily remeshing regions of interest without incurring significant CPU costs. Recently, a new vortex identification method was proposed, which defines a criterion Ω [1], that identifies turbulence when the rotation rate overcomes the deformation rate. This method has recently been enhanced to improve its identification of turbulence in confined reactive situations [2]. In addition to Liu's sensor, this AMR method fixes a single target cell size in the region of interest. Thus, in practical applications, it can be a priori challenging to ascertain the required refinements to be applied locally.

The objective of this study is to establish a robust AMR methodology for unsteady cases with local varying mesh sizes. In order to achieve this goal, we propose a clearer formulation of the ϵ parameter of Liu's model, which represents a vortex detection threshold. To enhance the formulation, the efficiency function of the Thickened Flame Model is incorporated within the model, and the ϵ parameter is estimated at the cutoff scale Δ. The Adaptive strategy is enhanced by the incorporation of a local metric estimate, which serves to define automatically the AMR level based on flame and flow quantities. This scaling model assigns smaller cell sizes in regions where turbulent activity is more pronounced. This method, based on a Reynolds formulation, allows for the formulation of a novel AMR routine that can efficiently target turbulence in LES. The strategy is initially implemented in a partially premixed swirl burner, with a comparison of pressure fluctuations and mean/rms velocity/temperature profiles. Then the approach is validated by analysing the vortical structures behind obstacles on the H2-air GraVent explosion channel [3]. Using pressure probes at different locations and flame tip velocity measurements, we compare experimental data, a refined static mesh and our improved AMR setup. Additionally, we examine the computational CPU improvement resulting from our adaptive approach. Future work will focus on verifying the robustness of our methodology on industrial safety cases.

References

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