TURBULENT COMBUSTION MODELING: NEW APPROACHES FOR HIGHLY REFINED SIMULATIONS

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ABSTRACT

Turbulent combustion is a multi-scale problem, where flow turbulence and strongly non-linear chemistry interact. In numerical simulation of turbulent flames, the challenge is twofold: hydrocarbon chemistry involves numerous species and elementary reactions, which cannot all be considered in numerical solutions of real combustors, and, the strongly non-linear character of chemistry is coupled with the sub-grid scale fluctuations of species and temperature, which are not always resolved by the grid. This lack of resolution results from the very thin heat release profiles through reaction zones of flames. Typically, under atmospheric pressure, flame thickness is of the order of a tenth of a millimetre with intermediate radical species evolving over even thinner layers inside reaction zones. If the signal of intermediate radical species cannot be fully captured, a resolution of a tenth of a millimeter can, however, now be afforded in the simulation of small size combustion chambers, using billions of tetrahedrons and massively parallel computing [1]. Along these lines, new approaches are under development to downsize the complexity of chemistry in order to make it compatible with such highly refined simulations of turbulence. Recent works in this direction involve the full projection of species mass fractions into a reduced composition space [2], associated to the development of fast in-situ solution for fully detailed combustion chemistry.

Comparing space-filtered quantities, obtained from Large Eddy Simulation (LES) with experimental measurements is another important issue. LES provides space-filtered quantities to compare with measurements, which usually have been obtained using a different filtering operation; hence, numerical and experimental results can be examined side-by-side in a statistical sense only. Instantaneous, space-filtered and statistically time-averaged signals feature different characteristic length-scales, which can be combined in dimensionless ratios. It is shown that actual Direct Numerical Simulation can be used to perform statistical studies of LES filtered reactive scalar-fields only if it accommodates a sufficiently large range of length-scales; an estimation of the minimum Reynolds number allowing for such DNS studies is given. From these developments, a reliability mesh criterion emerges for scalar LES and scaling for scalar sub-grid scale energy is discussed [3].

REFERENCES

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