A FLAMELET BASED MODEL FOR AUTO-IGNITION IN TURBULENT CONDITIONS: VALIDATION USING DNS

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In this study, a turbulent combustion model for large eddy simulation (LES) is analyzed and validated through comparison with a massively parallel direct numerical simulation (DNS). The turbulent flame that is simulated tends to stabilize due to auto-ignition. In the context of turbulence, however, true asymptotic auto-ignition behavior is rarely observed. Rather, turbulent mixing tends to influence the ignition timescale and the evolution of combustion products.

Flamelet based models for LES that attempt to describe turbulence and auto-ignition interactions often make use of unsteady non-premixed flamelets. In statistically steady problems such as jet flames, this leads to modeling complexity. Either the time scale from a single unsteady flamelet must be correlated with the distance from the jet, or a time-like variable must be used to parameterize a large, computationally expensive set of unsteady non-premixed solutions. Here, these modeling issues are addressed by appropriately combining information from the pure steady non-premixed regime and from the pure auto-ignition regime. Separating these regimes eliminates the need to interpret the unsteady time scale, and dramatically reduces the cost of chemistry storage.

In the LES, auto-ignition solutions are combined with steady non-premixed flamelet solutions using a method proposed by Knudsen and Pitsch (*Comb. Flame* 2009). This method determines the local combustion regime by explicitly considering which transport processes balance the chemical source term. The combustion regime is then used to map the appropriate chemistry solutions into the flow field. This method has the ability to quantitatively relate the importance of auto-ignition and mixing. Once applied in an LES simulation, the model's ability to predict flame structure and evolution is analyzed.

The case that is considered is a lifted C_2H_4 jet flame with a Reynolds number of Re=10,000. This flame is not an experimental case, but is rather the subject of a massively parallel compressible DNS study by Yoo *et al.* (*Proc. Comb. Inst.* 2010). The DNS employs high order numerics, a 1.29 billion cell mesh, and a 22 species mechanism describing C_2H_4 combustion. Schematics of both the DNS and LES are shown in Fig. 1. Results of the DNS demonstrated that, at the high temperature of the air coflow, auto-ignition is the primary flame stabilization mechanism. Additionally, however, results showed that turbulent mixing could locally inhibit the auto-ignition process, and that this inhibition led to an oscillating flame stabilization point.

After LES of the C_2H_4 jet flame is performed, the importance of each combustion regime is analyzed. In particular, the use of progress variable source terms from the different regimes is considered, and relevant statistics from the LES are compared with those of the DNS. The lift off height observed in the LES is in reasonable agreement with the lift off height predicted by the DNS.

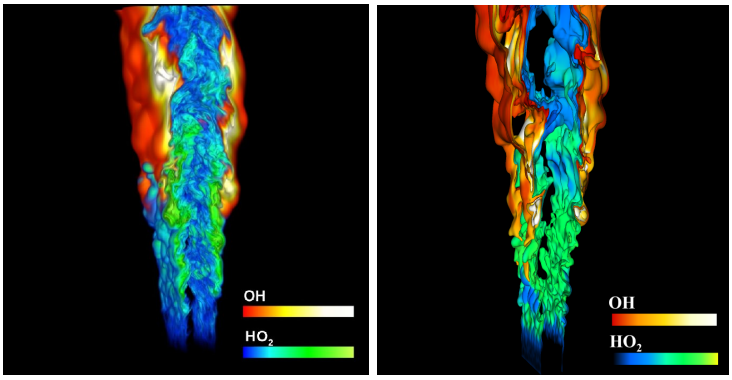

Figure 1: OH and HO_2 radicals in the DNS (Left), and in the LES (Right).