

Laminar flame modeling is an important element in turbulent combustion research. The accuracy of a turbulent combustion model is highly dependent upon our understanding of laminar flames and their behavior in many situations. How much we understand combustion can only be measured by how well the model describes and predicts combustion phenomena. One of the most commonly used methane combustion models is GRI-Mech 3.0. However, how well the model describes the reacting flow phenomena is still uncertain even after many attempts to validate the model or quantify uncertainties.

In the present study, the behavior of laminar flames under different aerodynamic and thermodynamic conditions is studied numerically in a stagnation-flow configuration. In order to make such a numerical study possible, the spectral element method is reformulated to accommodate the large density variations in methane reacting flows. In addition, a new axisymmetric basis function set for the spectral element method that satisfies the correct behavior near the axis is developed, and efficient integration techniques are developed to accurately model axisymmetric reacting flow within a reasonable amount of computational time. The numerical method is implemented using an object-oriented programming technique, and the resulting computer program is verified with several different verification methods.

The present study then shows variances with the commonly used GRI-Mech 3.0 chemical kinetics model through a direct simulation of laboratory flames that allows direct comparison to experimental data. It is shown that the methane combustion model based on GRI-Mech 3.0 works well for methane-air mixtures near stoichiometry. However, GRI-Mech 3.0 leads to an overprediction of laminar flame speed for lean mixtures and an underprediction for rich mixtures. This result is slightly different from conclusion drawn in previous work, in which experimental data are compared with a one-dimensional numerical solutions. Detailed analysis reveals that flame speed is sensitive to even slight flame front curvature as well as its finite extension in the radial direction. Neither of these can be incorporated in one-dimensional flow modeling.