

# DNS of inhomogeneous reactants premixed combustion

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The search for clean and efficient combustors is motivated by the increasingly stringent emissions regulations. New gas turbine engines are designed to operate under lean conditions with inhomogeneous reactants to ensure cleanliness and stability of the combustion. This ushers in a new mode of combustion, called the inhomogeneous reactants premixed combustion.

The present study investigates the effects of inhomogeneous reactants on premixed combustion, specifically on the interactions of an initially planar flame with a field of inhomogeneous reactants. Unsteady and unstrained laminar methane-air flames are studied in one- and two-dimensional simulations to investigate the effects of normally and tangentially (to the flame surface) stratified reactants. A three-dimensional DNS of turbulent inhomogeneous reactants premixed combustion is performed to extend the investigation into turbulent flames. The methane-air combustion is represented by a complex chemical reaction mechanism with 18 species and 68 steps.

The flame surface density (FSD) and displacement speed  $S_d$  have been used as the framework to analyse the inhomogeneous reactants premixed flame. The flames are characterised by an isosurface of reaction progress variable. The unsteady flames are compared to the steady laminar unstrained reference case. An equivalence ratio dip is observed in all simulations and it can serve as a marker for the premixed flame. The dip is attributed to the preferential diffusion of carbon and hydrogen-containing species.

Hysteresis of  $S_d$  is observed in the unsteady and unstrained laminar flames that propagate into normally stratified reactants. Stoichiometric flames propagating into lean mixture have a larger  $S_d$  than lean flames propagating into stoichiometric mixtures. The cross-dissipation term contribution to  $S_d$  is small ( $\approx 10\%$ ) but its contribution to the hysteresis of  $S_d$  is not ( $\approx 50\%$ ). Differential propagation of the flame surface is observed in the laminar flame that propagates into tangentially stratified reactants. Stretch on the flame surface is induced by the differential propagation, which in turn increases the flame surface area.

In the DNS, inhomogeneous reactants were observed to have interacted with the turbulent premixed flame in the preheat zone. Results from DNS show similar FSD and  $S_d$  statistics as previous thin reaction zones regime DNS of turbulent premixed flames. Effects of inhomogeneous reactants as observed in the laminar flame simulations are not prevalent in the turbulent flames.