Effects of stoichiometric mixture fraction on triple-flame propagation in strained mixing layers

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April 29, 2017

This numerical study addresses effects of strain rate and reactant dilution on propagation of triple flames along mixing layers separating counterflowing streams of fuel and oxidizer. The problem is formulated in the thermo-diffusive approximation with a one-step irreversible reaction with Arrhenius rate employed for the chemistry description, leading to a two-dimensional eigenvalue problem that determines the flame propagation velocity U_f. For values of the strain rate A small compared with the extinction value of the one-dimensional nonpremixed flame A_E the integrations reveal a thin curved front advancing at a velocity of the order of the flame propagation velocity of the stoichiometric planar deflagration S_L. As the strain rate increases, the flame progressively loses its front character to become an edge flame with reduced propagation velocity. This decreasing velocity becomes negative at a critical value of the A/A_E, marking the transition from an advancing to a retreating front, with the latter ceasing to exist as $A \rightarrow A_E$. Our computations reveal that when the stoichiometric mixture fraction Z_S is equal to $1/2$, the case considered in most previous studies, the solution is symmetric and the resulting propagation velocity U_f approaches S_L as $A/A_E \ll 1$. Non-symmetric solutions are found for $Z_S \neq 1/2$, with the flame leading point shifting to the oxidizer side for $Z_S < 1/2$ and to the fuel side for $Z_S > 1/2$. Contrary to expectations, the leading point is found at an off-stoichiometric location and the resulting propagation velocity exceeds S_L for weakly strained configurations. These unexpected features of the strained flame are clarified by investigation of the thin-front solutions emerging in the limit $A \ll A_E$.