Response of Premixed Laminar Flames to Equivalence Ratio and Pressure Oscillations using Detailed Chemistry (TARDIS)

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We address two important questions: (1) how does the laminar flame speed respond to simultaneous oscillations in equivalence ratio oscillations and pressure oscillations. (2) How can we characterize multiple flame length and time scales? The method of investigation features a new direct numerical implicit method, TARDIS (Transient Advection Reaction Diffusion Implicit Simulations) [1-3]. TARDIS couples the compressible flow to the comprehensive chemistry and detailed multicomponent transport properties, and as such it resolves all the time and spatial scales in the stiff thermochemical system – an important step towards 'realistic' combustion simulations. Comprehensive chemical schemes for H2/air [4] and for CH4/air [5] are used to model the chemistry.

Transient premixed hydrogen/air flames contracting through inhomogeneous fuel distributions and subjected to stretch and pressure oscillations are investigated numerically using TARDIS. The impact of increasing positive and negative stretch is investigated through the use of planar, cylindrical and spherical geometries, in H2/air flames [1] and CH4/air flames [2]. The flame relaxation number $n_R = \tau_R/\tau_L$ (τ_R is the time that the flame takes to return to the mean equilibrium conditions after initial disturbance; τ_L is a flame time scale) decreases by 10% in negatively stretched contracting H2/air flames, in contrast to the two positively stretched expanding H2/air and CH4/air flames where n_R decreased by 40%. n_R appears to much more sensitive to variations in positive/negative curvature than to the thermo-chemistry of different flame types. n_R may thus be a useful indicator of the strength of flame-curvature coupling.

A question of great importance in combustion theory is how to characterise the flame length and time scales –there is no universally accepted theory as yet. One of the most important concepts in combustion theory is flame stretch, $Z = (dA(t)/dt)/A(t)$, which is the relative rate of change of an element of surface area $A(t)$ on the flame surface. Stretch quantifies the effect of local heat release of a propagating flame on variations in the surface area along the flame front and the associated local flame curvature; as such stretch is sensitive to the local strain and to the flame geometry, which is turn affect physical quantities like the flame speed Sn. For axi-symmetric and spherically symmetric flames stretch scales like, $Z(r) = 1/r_u$ where r_u is the flame radius. We explore the thermochemical structure of stretched laminar flames through simulations of eight premixed flames at atmospheric pressure and at stoichiometric mixture levels: expanding and contracting H2/air and CH4/air flames in axi-symmetric and spherical geometries. The aim is to explore consistent methods of characterising the flame thickness and the associated time scales.

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