Time-resolved description of a flame front propagation toward an inclined wall - The effect of local stretch on flame speed

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The turbulent flame-wall interaction, which occurs in any industrial burning equipment, is a process controlled by a competition between thermo-diffusive and aerodynamic processes. The presence of a wall creates a new boundary condition for the flow ahead of the flame front. This flow pattern is likely to affect the flame front irregularities, conditioning ultimately the flow ahead of the flame. This is a cyclic process and therefore as a turbulent flame approaches a wall the flame speed S_u, perpendicular to the flame surface and which defines the burning rate, might vary along the flame surface as result of characteristic flame curvature and local flow induced stretch. As a consequence, and in wall vicinity, burning rate might increase or decrease, leading ultimately a premature extinction. In this context, this paper addresses the study of an artificially deformed flame as it approaches an inclined wall, to create a non-symmetric flame wall interaction.

Is the main objective of this paper to quantify the relation between $S_u = S_u^o - Lk$, finding experimentally Su and k and where L is the Markstein length. The determination of total stretch is given by the summation of flow stretch (k_s) and curvature stretch (k_c) producing $k = k_c + k_s$. Flow induced stretch is determined based on flow velocity along the flame surface and curvature induced stretch is calculated based on instantaneous flame curvature.

The flame consists on a premixture of propane and air with equivalence ratios of 0,86 and 1,52 developing freely inside a cylindrical combustion chamber on the top of it is placed an inclined wall. The experimental characterization was made based on high speed time-resolved PIV measurements using a high speed Kodak CCD camera and a 2W Spectra Physics Ar-Ion Laser.

A typical result, for a lean flame of Φ=0,86, is shown in figure 1 where can be visualized the wall reactants and products. On figure 2 are the PIV results acquired for the instant presented on the previous image where can be found flow reversion near the flame tip and a stagnation point at the wall.

On figure 3 the total stretch factor (k) and the correspondent calculated flame speed (S_u) are correlated for a lean flame (Φ=0,86). It can be seen that there is a strong correlation between the two variables and the qualitative evolution is consistent with results of Law & Sung 2000 for lean flames but for low stretched factors.

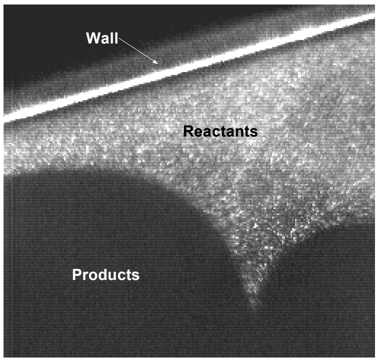

Fig. 1. Instant image from a flame propagation in a lean mixture

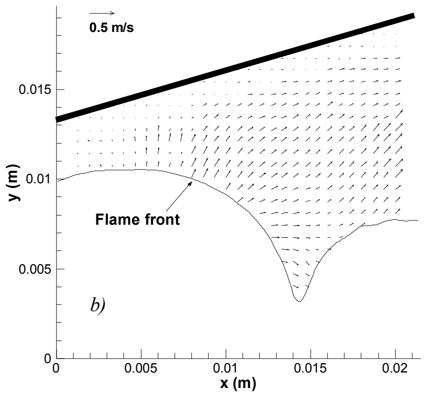

Fig. 2. PIV results for the instant time in figure 1

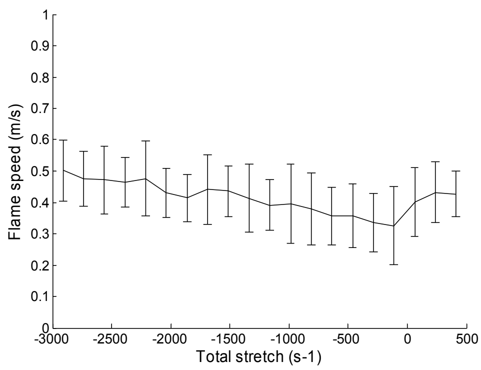

Fig. 3. Flame speed variation variation relative to total flame stretch in lean flames

Bibliography

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