H_2 and H_2/CO flames speed correlations in isotropic turbulence

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1 Abstract

In unconfined geometries, laminar flame acceleration depends on flame stretching and curvature. Expansion ratio affect burning velocity and flame structure through Darrieus-Landau instabilities but do not contribute directly to flame acceleration as much as in confined geometries. Spherical premixed flames intrinsically develop instabilities as the curvature decrease because planar flames are unconditionally unstable. In an initial quiescent flow those mechanisms generate wrinkling of the flame front leading to self turbulization of the flame, increasing significantly flame surface and reaction rate. Addition of initial flow unsteadiness enhance the process and lead to higher velocity than within an initial quiescent flow.

To prevent accidental scenarios involving H_2/CO turbulent mixtures in nuclear power plant we need to propose correlation tool able to predict flame acceleration intensity and pressure wave generation. From flow unsteadiness we are able to determine velocity fluctuations ($u^{'}$) and scale of turbulent whirls (integral length scale: L_T), from chemistry we obtain flames properties as laminar flame speed (S_L^0), flame thickness (δ) and diffusive properties (Lewis number: Le). The question is: Can we anticipate flame acceleration from those input? Figure 1, left, represent a Borghi diagram used to describe flame structure due to turbulent deformation. Depending on flame structure, as well as sensitivity to thermodiffusion (via Lewis number), adimensioned turbulent flame speed as a function of radius and turbulent properties seem to collapse on a linear regression [1–3] similar to Eq. 1.

$$\frac{S_T}{S_L^0} = a\left(\frac{r}{L_T}\right)^b\left(\frac{u^{'}}{S_L^0}\right)^c Le^d \tag{1}$$

Based on cumulative experiments ($\sim$ 760 tests) performed in our facility, we propose an update on correlation coefficient (a, b, c, d) for H_2 and H_2/CO flame acceleration at different equivalents ratios, N_2 dilution and temperature in isotropic and homogeneous turbulence ($u^{'}$ = 0.1 to 3.27 m/s) generated inside a spherical bomb [4]. Data sample is biased as most of the tests are performed with lean mixtures, representative of mixture present in nuclear reactor in case of incident. Premixed expending spherical flames propagate in a constant volume and S_T do not reach asymptotic value in our 0.093m^3 bomb. In Eq. 1, r is the radius of the flame to consider increased of S_T. By comparing coefficients for H_2 mixtures and H_2/CO mixtures we can establish if there is an universal correlation between adimensioned turbulent velocity and radius with turbulent properties as the trend suggest on Fig. 1 right.

In a second time, we will reduce the number of variables to a strict minimum via neuronal network techniques in order to simplify Eq. 1 or determine a new set of variable capable of predicting turbulent flame speed knowing only the state of initial turbulence and mixture composition. Comparison with correlations formula and available data in literature will conclude on their validity depending on fuel used and turbulent intensity.

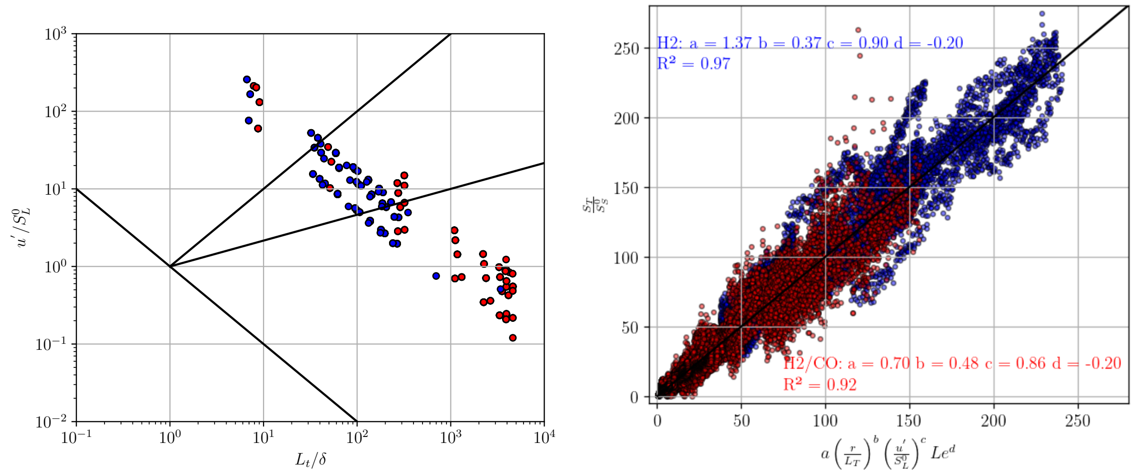

Figure 1: Borghi diagram (left) and correlation between adimensioned turbulent velocity and radius with turbulent properties (right). Red: H2/CO, Blue: H2.

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