

4B02: EFFECTS OF GLOBAL FLAME CURVATURE ON SURFACE DENSITY FUNCTION TRANSPORT IN TURBULENT PREMIXED FLAME KERNELS IN THE THIN REACTION ZONES REGIME.

Nilanjan Chakraborty, University of Liverpool, UK

Markus Klein, Technische Universität Darmstadt, Germany

Comment by Godfrey Mungal, Stanford University, USA

mungal@stanford.edu

Your decomposition of Displacement Speed into three terms leads me to wonder how the decomposition might work for the curved Bunsen flame tip as described in [1,2,3].

References:

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Reply by Nilanjan Chakraborty

n.chakraborty@liverpool.ac.uk

It will be fair to mention that the decomposition of displacement speed into its reaction, normal diffusion and tangential diffusion components has been done by Peters et al. [1]. This paper is duly referred to in our paper and this reference was there on the relevant slide of our presentation. The same procedure has been followed in several subsequent studies [2–11], and the same approach is followed in the present work as well. The decomposition of displacement speed into three components is motivated by the fact that the tangential diffusion component of displacement speed St deterministically accounts for curvature dependence of flame propagation behaviour as St is directly proportional to the negative of curvature (i.e. $St = -2 \cdot D \cdot \text{curvature}$). The mean value of density-weighted combined reaction and normal diffusion component of displacement speed $\rho^*(S_r + S_n)$ remains close to the product of fresh gas density and laminar burning speed ([11,25] in the paper) [3,6,8]. Moreover, $(S_r + S_n)$ for statistically planar unity Lewis number flames in the thin reaction zones regime is weakly correlated with curvature ([10,11,25] in the paper) [3,7,8], but strongly dependent on flame straining ([21,26] in the paper) [3,6,7,8–10]. According to the modelling argument of Peters ([21] in the paper), $(S_r + S_n)$ can be modelled by strained laminar flame solution. However, turbulent flame kernel study shows $(S_r + S_n)$ has significant curvature dependence when the flame has a mean radius even at unity Lewis number ([10,11] in the paper). In this respect it is worth noting that $(S_r + S_n)$ has significant curvature dependence for statistically planar flames with non-unity Lewis number ([8] in the paper), [10]. Thus, our study suggests that curvature dependence of $(S_r + S_n)$ also needs to be taken into account in addition to the contribution of St for a robust modelling approach in the thin reaction zones regime [9–11]. This was shown to be particularly important for the Flame Surface Density (FSD) transport especially in the context of Large Eddy Simulation [9–11].

The same decomposition of displacement speed can be applied to analyse the propagation characteristics of the tip of a Bunsen burner flame or any other flame configuration. The Bunsen burner tip will have high negative curvature thus St at that point will be highly positive. The high positive value of St will act to increase the local displacement speed significantly in comparison to the laminar burning speed. The thickening of flame tip due to focussing of heat gives rise to a positive correlation between $|\text{grad } c|$ and curvature, which will lead to a net negative correlation between the reaction component of displacement speed S_r and curvature. The curvature dependence of normal diffusion component of displacement speed S_n is difficult to predict without examining the statistics of molecular diffusion rate in local flame normal direction. However, for thin reaction zones regime combustion, the normal diffusion rate in the reaction zone (i.e. the heat releasing zone of the flame) can be taken to scale as $-D^*|\text{grad } c|$ [7,9], which suggests that a negative correlation between curvature and S_n might be expected in the thin reaction zones regime. However, at this point the curvature dependence of S_n for Bunsen burner tip based on the above scaling is just an intelligent guess, and needs to be confirmed based on experimental and DNS data.

From the experimental images it is possible to determine the curvature of the tip of Bunsen burner which will provide information about St and $(S_r + S_n)$ will be obtained once St is subtracted from the displacement speed S_d from velocity measurements.

References:

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