1B05: THE EFFECT OF CO-FLOW STREAM VELOCITY ON TURBULENT NON-PREMIXED JET FLAME STABILITY.

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Comment by Alexander Y. Klimenko, The University of Queensland, Australia
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The parameter that you use—effectively the same as the Karlovitz number—characterizes small-scale behavior of the flame while it seems that flame blowouts are also highly dependent on large-scale motions. Please comment on this.

Reply by Teresa Leung
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The proposed criterion characterizes only the small-scale behavior. Since flame blowout is dependent on a wide range of scales, this is the reason why such criterion is not a constant for all blowout conditions. The present results support that flame blowout should be related to scales larger than the Kolmogorov scale. The authors propose that such criterion should be a function of a jet similarity parameter (the Craya-Curtet number) that characterizes the amount of mixing momentum between the jet and the co-flowing streams. The large-scale mixing motion, which affects the entrainment of air into the jet and as a result the mixing of oxidant and fuel, is related to the amount of mixing momentum available between the two streams. It appears that there is good correlation between the criterion and the Craya-Curtet number for a variety of conditions, and support the idea that both small-scale turbulence and large-scale mixing are important in determining flame blowout.

Comment by Godfrey Mungal, Stanford University, USA
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I think your results bear similarity to [1]. There it is shown that a coflow velocity of 3 S_L leads to a complete blowout of flames. Also, in [2] the ideas of the edge flame velocity and the stoichiometric velocity, see also [3], are used to describe liftoff and blowout mechanisms.

Finally, [4,5] shows that $\xi L < 1$ is more appropriate for momentum driven flows and provides growth laws for jets in coflow relevant to your work.

References:

[1] L. Muñiz, M.G. Mungal, *Comb. Flame* 111 (1997)16–31.
[2] Donghee Han, M.G. Mungal, *Proc. Combust. Inst.* 28 (1) (2000) 537–543.
[3] D. Han, M.G. Mungal, *Comb. Flame*, 132 (2003) 565–590.
[4] Donghee Han, M.G. Mungal, *Comb. Flame* 124 (2001) 370–386.
[5] L. Muñiz, M.G. Mungal, *Comb. Flame* 126 (2001) 1402–1420.

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The current experiments demonstrate that there exists a maximum co-flow velocity for lifted flames for methane (S_L = 0.38 m/s) at 0.9 m/s, which is ~2.3 S_L. Another similar set of experiments has also been performed on ethylene, which give very similar results and a maximum co-flow velocity was found to be at 2.5 m/s (S_L = 0.70 m/s) corresponding to ~3.6 S_L. Similarly a maximum co-flow velocity of 3 S_L has been reported for methane [1]. Based on the available data, it is possible that the ratio of maximum co-flow velocity over the laminar burning velocity is dependent on fuel type and the chamber size. Furthermore, there has been a wide range of values reported for S_L in the literature and it is difficult to determine an exact value for S_L. In the authors' view, it is still inconclusive whether such ratio is a fixed value and therefore this point was not emphasized in the present work.

The present work deals with the blowout limit in particular, at which a lifted flame can no longer exist. The proposed blowout criterion has to be evaluated at a single point and not over the entire flame surface. The shape of a lifted flame at the instance of blowout (when the blowout limit is reached) loses the typical edge flame characteristic of a stable lifted flame that has been observed and it becomes "disk-like" at the tip of the stoichiometric contour [2]. Therefore, the structure of a lifted flame at its last stabilization point differs dramatically from that of a stable lifted flame as reported by Han and Mungal [3]. They also showed that the axial velocity near the flame surface (which also includes the flame base) can be approximated by a simple equation (Eq. (3) in [3]). Applying such equation to the different blowout conditions of the present study, it was found that is no characteristic axial velocity that can determine when blowout would occur.

The current model assumes the blowout criterion to be a function of the mixing momentum between the jet and co-flowing streams represented by the Craya-Curtet number. It is also possible that it is related to the asymptotic entrainment rate [4]. However such possibility has not been explored by the authors and will be considered in the future work.

References:

[1] L. Muñiz, M.G. Mungal, *Combust. Flame* 111 (1997) 16–31.
[2] C.-Y. Wu, Y.-C. Chao, T.-S. Cheng, Y.-H. Li, K.-Y. Lee, T. Yuan, *Combust. Flame* 145 (2006) 481–494.
[3] D. Han, M.G. Mungal, *Proc. Combust. Inst*. 28 (2000) 537–543.
[4] L. Muñiz, M.G. Mungal, *Combust. Flame* 124 (2001) 370–386.