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Vetting Scaling Laws in Turbulent Reacting Flows: The Case of Damköhler's Second Postulation

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Abstract: Damköhler's second postulation has been the foundation of the development of scaling laws for turbulent premixed flames that led to the establishment of regime diagrams and has been used as the principal argument for explaining experimental and computed observables. Damköhler's arguments are challenged based on direct numerical simulations of vortex-flame interactions and fully turbulent premixed flames under high Karlovitz number conditions. Specifically, the simulations could not prove that sub-flame thickness Kolmogorov eddies can enter the flame due to the high dissipation rate. Local analyses of both configurations showed that frequently used correlations based on the laminar flame structure could not be used to explain, among others, the reported thickening of turbulent flames under extreme turbulence levels. Additionally, laminar flame scales derived using detailed simulations resulted in a wide range of Karlovitz number values of the boundary separating the so-called thin reaction zone and broken reaction zone regimes and are not in agreement with established values in the literature, which have been derived from relatively simple theoretical arguments. Finally, the present results could not support even the existence of the thin reaction zone and broken reaction zone regimes, which have been hypothesized by Borghi and Peters and adopted in numerous computational and experimental studies.

Biographical Sketch: Fokion N. Egolfopoulos is a William E. Leonhard Professor of Engineering in the Department of Aerospace and Mechanical Engineering at the University of Southern California. He obtained his Diploma Degree in 1981 from the National Technical University of Athens, and his PhD in 1990 from the University of California at Davis after spending the last two years of his doctoral research at Princeton University. He is a recipient of the Silver Medal of the Combustion Institute at the Twenty-Second International Combustion Symposium, a Fellow of the Combustion Institute, a Fellow of the American Society of Mechanical Engineers (ASME), and an Associate Fellow of the American Institute of Aeronautics and Astronautics (AIAA). He has authored and co-authored one hundred and fifty-six (156) archival journal publications, eleven (11) editorial comments, three (3) book chapters, one hundred and sixty-two (162) conference proceedings and reports, and has given one hundred and seventy-two (172) invited and contributed scholarly addresses. Since 2009 he has been the Editor in Chief of Combustion and Flame, after serving as an Associate Editor of the journal from 2003 until 2008.

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