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Critical Scales, Fundamental Structures and... of Turbulent Flames

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14. ABSTRACT
This research addressed a number of fundamental aspects of turbulent combustion. Regime diagrams were identified for both premixed and non-premixed turbulent flames. Characteristics of turbulent flames in the different regimes were investigated. To complement low-speed regimes, types of high-speed turbulent combustion were determined. Interactions of detonations with turbulent fields were clarified. The limits in which detonation thicknesses were small and large in comparison with the range of turbulence scales were both analyzed. It was shown that in both limits interactions of detonations with non-uniform fluid density fields had greater effects than interactions with non-uniform fluid velocity fields. High-speed turbulent-combustion dynamics thereby was shown to behave very differently than low-speed turbulent-combustion dynamics. In addition,. fuel-spray interactions in mixing layers were studied. By exhibiting fuel-dependent non-monotonic variations of mixture fraction in the two-phase flow fields, traditional approaches to sub-grid-scale modeling of turbulent spray combustion were shown to be in need of revision. Useful directions for future research in the area were identified. In addition to these advances, chemistry of hydrogen combustion was improved.

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1. A. L. Sánchez, E. Fernández-Tarrazo, P. Biovin, A. Liñán and F. A. Williams, "Ignition Time of Hydrogen-Air Diffusion Flames," Comptes Rendus Mecanique 340, 882-893 (2012).
2. P. Boivin, A.L. Sánchez and F. A. Williams, "Four-Step and Three-Step Systematically Reduced Chemistry for Wide-Range H_2-Air Combustion Problems," Combustion and Flame 160, 76-82 (2013).
3. J. Arrieta-Sanagustín, A. L. Sánchez, A. Linán and F. A. Williams, "Coupling-Function Formulation for Monodisperse Spray Diffusion Flames with Infinitely Fast Chemistry," Fuel Processing Technology 107, 81-92 (2013).
4. E. Fernández-Tarrazo, A. L. Sánchez and F. A. Williams, "Hydrogen-Air Mixing-Layer Ignition at Temperatures Below Crossover," Combustion and Flame 160, 1981-1989 (2013).
5. D. Martínez-Ruiz, J. Urzay, A. L. Sánchez, A. Lináñ and F. A. Williams, "Dynamics of Thermal Ignition of Spray Flames in Mixing Layers," Journal of Fluid Mechanics 734, 387-423 (2013).
6. A. L. Sánchez, E. Fernández-Tarrazo and F. A. Williams, "The Chemistry Involved in the Third Explosion Limit of H_2-O_2 Mixtures," Combustion and Flame 161, 111-117 (2014).
7. A. L. Sánchez and F. A. Williams, "Recent Adcances in the Understanding of Flammability Characteristics of Hydrogen," Progress in Energy and Combustion Science 41, 1-55 (2014).
8. C. Huete, A. L. Sánchez and F. A. Williams, "Theory of Interactions of Thin Strong Detonations with Turbulent Gases," Physics of Fluids 25, 076105 (2013).
9. C. Huete, A. L. Sánchez and F. A. Williams, "Linear Theory for the Interaction of Small-Scale Turbulence with Overdriven Detonations," Physics of Fluids 26, 116101 (2014).
10. C. Huete, J. Urzay, A. L. Sánchez and F. A. Williams, "Theory of Weak-Shock Interactions with Transonic Mixing Layers," AIAA Journal, submitted (2015).
11. J. Furukawa, Y. Yoshida and F. A. Williams, "Structures of Methane-Air and Propane-Air Turbulent Premixed Bunsen Flames," Combustion and Flame, submitted, (2015).

Thise interested are encouraged to consult these publications.

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Abstract

This research addressed a number of fundamental aspects of turbulent combustion. Regime diagrams were identified for both premixed and non-premixed turbulent flames. Characteristics of turbulent flames in the different regimes were investigated. To complement low-speed regimes, types of high-speed turbulent combustion were determined. Interactions of detonations with turbulent fields were clarified. The limits in which detonation thicknesses were small and large in comparison with the range of turbulence scales were both analyzed. It was shown that in both limits interactions of detonations with non-uniform fluid density fields had greater effects than interactions with non-uniform fluid velocity fields. High-speed turbulent-combustion dynamics thereby was shown to behave very differently than low-speed turbulent-combustion dynamics. In addition,. fuel-spray interactions in mixing layers were studied. By exhibiting fuel-dependent non-monotonic variations of mixture fraction in the two-phase flow fields, traditional approaches to sub-grid-scale modeling of turbulent spray combustion were shown to be in need of revision. Useful directions for future research in the area were identified. In addition to these advances, chemistry of hydrogen combustion was improved. A wide range of hydrogen combustion problems was identified and solved. Especially noteworthy was the clarification of the third explosion limit for hydrogen. While previously diffusion of HO_2 was believed to be of greatest importance for the third limit, it was shown that, instead diffusion of H_2O_2 was of greatest importance for this limit. The research finally resulted in a thorough

understanding of hydrogen combustion, with the chemical kinetics now well defined. A complete summary of these results was prepared.

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