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Role of Vaporization Time Scale on the Spray Detonations Characteristics in Jet Fuels

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Understanding the properties of detonations in liquid sprays is complicated by the highly nonlinear interactions between various intricate multiscale physical processes and intrinsic instabilities present in a spray detonation, which ultimately control its structure and propagation limits [1]. One such key physical process is droplet break-up due to atomization and evaporation, which controls the fuel mass loading of the flow. The details of this process, and in particular its associated timescales, sensitively control the detonation cell cycle and its macroscopic properties. Here, we probe the sensitivity of the spray detonation properties to the characteristic timescale of the droplet break-up. Multidimensional Eulerian-Lagrangian simulations are carried out in n-dodecane sprays under atmospheric conditions in adiabatic slip-wall and isothermal no-slip-wall channels. The simulations include complete molecular transport, state-of-the-art chemical kinetics for jet fuels, and spray submodels for droplet drag, atomization, and evaporation [2, 3]. The results demonstrate that the average spray detonation velocity remains insensitive to the break-up timescale as long as the droplets completely vaporize within the detonation. However, significant macroscopic changes in the detonation structure are observed by varying the characteristic break-up time. In particular, the results reveal a critical timescale, below which the average size of the detonation cell remains virtually constant, irrespective of the actual droplet break-up time and the details of the atomization and evaporation submodels. The implications of these findings for the development of predictive spray models for liquid-fuel detonations are discussed in detail.

References

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