Effects of ambient pressure on ignition and flame characteristics in diesel spray combustion

This work reports on numerical investigation of effects of ambient pressure (P_{am}) on spray combustion under engine-like conditions. Three cases with different P_{am} of 42, 85 and 170 bar at a fixed ambient temperature of 1000K are considered. Zero-dimensional calculations are first performed for autoignition of stagnant adiabatic homogenous mixtures to evaluate performance of the selected diesel surrogate fuel models and to identify the P_{am} effects on the most reactive mixture. An Eulerian-based transported probability density function model is then chosen for the three-dimensional computational fluid dynamics study. The results show the predicted ignition delay times and flame lift-off lengths are in reasonably good agreement with experiment, with the relative difference below 28%. The current work reveals that low-temperature reactions occur across a wide range of mixture fraction but a noticeable rise of temperature (>100K above ambient temperature) is detected first on the fuel-lean side of the stoichiometric line in all three cases. The high-temperature ignition occurs first on the fuel-rich side in the 42 and 85 bar cases, where the igniting mixture appears to be more fuel-rich in the latter case. As P_{am} is further increased to 170 bar, the igniting mixture becomes more fuel-lean and the high-temperature ignition occurs first on the fuel-lean side. The ignition behavior is found to depend on both physical and chemical processes. At 170 bar, the reaction rate increases and the associated transition from low- to high-temperature ignition is relatively fast, as compared to the transport of warmer products from the lean zone into the fuel-rich mixture. Also, within the fuel-lean region, the local temperature is low due to liquid fuel vaporization and the condition is not appropriate for ignition. These collectively cause the high-temperature ignition to occur on the fuel-lean side. Analyses on the quasi-steady spray flame structures reveal that, apart from poorer air entrainment due to reduced lift-off length, the higher rich-zone temperature and lower scalar dissipation rate also lead to a higher peak soot volume fraction at higher P_{am}. 

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