Shock-initiated combustion: New insights into the nature of the shock-focusing phenomenon

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The shock-focusing phenomenon (SFP) refers to the refraction and subsequent convergence of a planar shock wave as it interacts with a heavy spherical bubble. This phenomenon is fundamental to many shock-accelerated inhomogeneous flows and can be construed as a building block to more complicated geometries with applications to Inertial Confinement Fusion (ICF), shock propagation through interstellar media and supersonic combustion. The refraction of the transmitted shock wave results in a focusing near the downstream pole of the bubble, thereby increasing the local thermodynamic conditions (T, p). By introducing a fuel and oxidizer to the bubble gas, the locally elevated temperatures and pressures resulting from the SFP may initiate the combustion of the bubble gases. The ignition delay time will vary for different incident strength shocks, characterized by the Mach number, M. Experimentally measured ignition delay times are then used to provide information about the conditions during the shock-focusing process. This is achieved through the use of a two-step model (thermo-neutral induction period followed by the chemical reaction and heat release stage) developed for an undiluted H_2-O_2 system in conjunction with the shock Hugoniot relations. The experiments are performed at the Wisconsin Shock Tube Laboratory in a 9 m-long, downward-firing vertical shock tube. A stoichiometric mixture of H_2 and O_2 is diluted with Xe to maintain larger acoustic impedance than the quiescent N_2. The heavy bubbles are released into free-fall and accelerated by a planar shock wave of strength M = 1.3, 1.7, 2.0 and 2.8. Simultaneous planar Mie scattering and Chemiluminescence of the OH* intermediate of combustion are used to obtain 2D images of the bubble morphology, combustion regions and measurements of the ignition delay time. Also discussed is a brief description of initial planar laser-induced fluorescence (PLIF) experiments where the A-X (2,0) band is excited by the frequency quadrupled output of a Nd:YAG laser (~20 mJ/pulse at ~266nm) without additional wavelength tuning (e.g. via intra-cavity etalon).