

THREAT AGENT DEFEAT MODELING AND TESTING

Measurements Of Dimp And Ethanol Evaporation Rates For Validation Of High-temperature Phenomenological Models

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The goal of this work is to improve the understanding of chemical warfare agent (CWA) simulant evaporation during the interaction of aerosols with high temperature gas-phase products of combustion. This can be challenging because of the need to isolate and measure the time history of in-situ aerosols across a size range of microns to millimeters for temperatures up to ~2400 K. Over this range, evaporation times can vary from milliseconds to seconds. Another difficulty is in capturing and holding aerosols over such a large size range during exposure to high temperature gases. Hence, this work explores the use of a piezo-driven nozzle to inject individual droplets into uniform flames of known thermodynamic conditions and product concentrations to emulate sudden exposure to combustion conditions. Different high-resolution imaging methods, including various illumination and detection schemes, are investigated with an aim to maximize measurement resolution. In addition, the droplet injection and imaging time scales are designed to maximize the measured variation in aerosol size, and hence the corresponding precision of the measured evaporation rate. Measurements of ethanol and DIMP are employed to evaluate the impact of the liquid properties on evaporation rates and for comparison with droplet evaporation models. Data are acquired for temperatures in the range of ~850–1100 K in heated nitrogen and ~950 K to 2400 K in flame products with varying concentrations of residual oxygen and droplet burning characteristics. Lower temperatures are characterized by slower evaporation rates associated with conductive/convective heating, whereas a step change to higher evaporation rates occurs at temperatures associated with the onset of droplet combustion. For ethanol, the onset of droplet combustion was observed between 1000–1200 K, while for DIMP it was observed between 1200–1500 K. This was the case for aerosols exposed to both fuel lean combustion products with significant amounts of residual oxygen, as well as in fuel rich conditions where the oxygen is minimal in the product gases. This indicates the presence of oxidizer chemical species that are produced during droplet evaporation that can help to sustain droplet combustion over a wide range of conditions. In the case of DIMP, impurities associated with the initial composition, from in-situ water condensation/surface diffusion, and/or chemical decomposition led to micro-explosions that altered the size of the aerosols. Hence, two sources of DIMP with varying levels of initial impurities were tested, along with varying residence times and water concentrations in the product gases to evaluate the relative effects on the likelihood of micro-explosions and allow measurements over a wider range of aerosol sizes. The evaporation rate data are interpreted in the context of a diameter-squared law and compared with existing numerical models. The methods developed in this work extend the range of data needed for understanding the physical processes that impact aerosol evaporation rates under realistic combustion conditions. Future work will investigate the impact of elevated pressures to further improve the accuracy of numerical predictions.

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