EFFECT OF FAR-FIELD RADIATION ON FREELY-FALLING DROPLET BURNING BEHAVIOR

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Numerous studies have used ground-based, freely falling, isolated droplets to study the combustion behavior of liquid fuels, fuel emulsions, and liquid-solid slurries (Sangiovanni and Labowsky, *Combust. Flame*, 1982; Choi *et al*, *23rd Symp. (Int'l.) on Comb.*, 1990; Lee and Law, *Comb. Sci. Tech.*, 1992). Droplets of mono-disperse size formed repetitively are projected down a duct flow oriented parallel to the gravity vector. Typically, ignition of the individual droplets is achieved by exposure of the droplet stream to post-combustion gases issued from an inverted flat-flame burner and projected downward through the duct. The isolated droplets are subjected to both Stokes drag and body forces, causing a varying gas-drop relative velocity and local buoyancy disturbances of the flame structure surrounding each droplet. A novel method of further reducing both relative convection and buoyancy effects is to incorporate acceleration of the surrounding gases to match that of gravity, resulting in minimal Reynolds number and Grashof number based upon the characteristic length scales of droplet and flame diameter, respectively. A second consideration is that the post flame gas stream may have heat losses that result in centerline temperature gradients of more than 10 K per cm if the duct surfaces are not thermally buffered to reduce heat losses.

Shaw and co-workers have recently studied experimentally the combustion of isolated droplets of n-heptane, n-decane and n-hexadecane in these configurations, with both constant duct cross-section and with duct cross section properly shaped such that the post flame gases have an acceleration on the duct centerline equivalent to that of gravity (Choi, Ph.D. Thesis, 1991; Wang and Shaw, *Rev. Sci. Inst.*, 1991). The purpose of these experiments was to provide direct comparisons of droplet combustion parameters under the more common freely falling configuration with constant duct cross-section and the shaped duct configuration, which should achieve the low Grashof/Reynolds number characteristics similar to those found in typical drop tower experiments that require larger diameter droplets. To address the duct flow heat loss issue, the duct walls in both configurations were heated using electrical resistance heaters and insulation to approximate an isothermal field surrounding the droplet combustion event. Establishing minimal heat loss from the flow is also critical to determining the appropriate duct shape for achieving flow acceleration equivalent to gravity. The experimental measurements appear to support that the low Grashof/Reynolds number result differs from the straight duct result; however, the droplet combustion parameters in the low gravity configuration appear to also differ from those found in actual drop tower experiments (Ross, *Microgravity Combustion*, 2001).

Simulations of droplet combustion were conducted using a one-dimensional, transient, finite-element, reactive flow model that includes a detailed description of chemical kinetics and transport as well as non-luminous radiation from the gas phase (Kazakov *et al.*, *Combust. Flame*, 2003). Initial simulations did not compare favorably with experimental results. The discrepancy was attributed to thermal radiative transfer between the droplet surface and the duct walls. In some system configurations, the ratio of the estimated incident thermal radiation from the far-field as compared to the total energy flux of the unperturbed, simulated system reached 25%. As the model was developed with the assumption of droplet isolation from any solid boundary and included an adaptive numerical grid, explicit inclusion of a thermal radiative boundary in the far field was prohibitively complex. By assuming the bath gas to be optically thin to thermal radiation wavelengths, an effective heat source term was introduced to the droplet surface to mimic the gray-body radiative exchange between the liquid surface and far-field solid boundary. This modification was sufficient to account for the discrepancy in droplet behavior and to bring these experimental results in line with previous experimental work conducted under true microgravity conditions. This provides support for the design concepts involved in the development of similar experimental facilities and suggests an issue of consideration for previous ducted experiments where high wall temperatures were imposed.