A simple biofuel surrogate blend for diesel fuel: heptane/iso-butanol mixtures and their droplet burning characteristics

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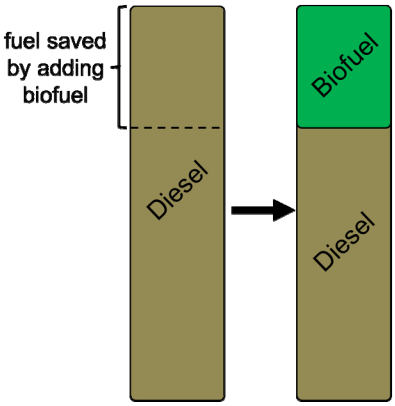
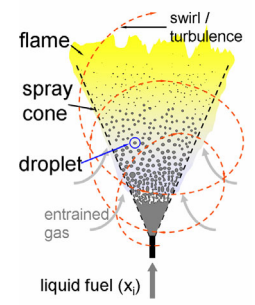
Motivation

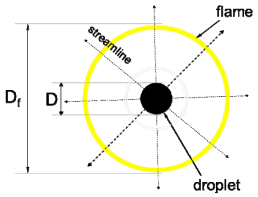
- Petroleum-based fuels (e.g. gasoline, diesel) are in limited supply.
- Biofuels (e.g. ethanol from corn) are produced from biological feedstock and are renewable.
- Blending with biofuels leads to a direct volume reduction of petroleum fuels and mitigates our reliance on them.
- Diesel is a complex fuel comprised of many miscible constituents. Heptane, a prominent component of diesel, has been used as a surrogate in this study.
- Iso-butanol has superior combustion properties compared to ethanol (e.g. 30% higher energy content) and therefore was chosen for this study.
- Combustion characteristics of heptane/iso-butanol blends at various compositions are investigated.



Combustion characteristics from a single droplet

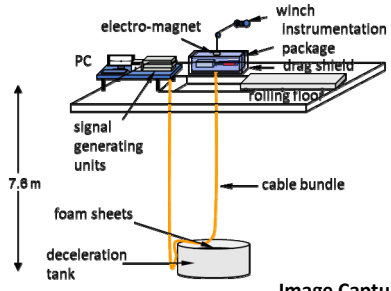
- Sprays are not well controlled environments due to the presence of turbulence and swirl.
- Direct numerical models of spray combustion dynamics do not currently exist and therefore data from a spray configuration would not be useful to modelers.
- Burning a single droplet in a configuration that simplifies heat and mass transfer would allow for precise study of the influence of mixture fraction, our primary variable, on combustion characteristics.
- Removing convection leads to a spherically symmetric droplet flame which facilitates direct numerical modelling and allows for including effects that would otherwise be prohibitive to simulate.





Experimental apparatus and procedures

Drop Tower Facility



Droplet Deployment

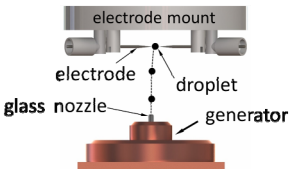


Image Capturing

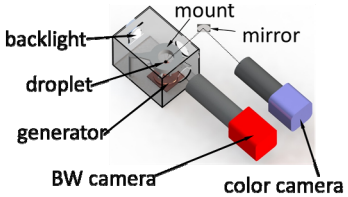
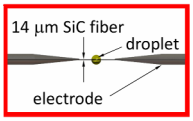


Image Area Captured



Event Sequence

(1) Package Release

-------free fall begins-------

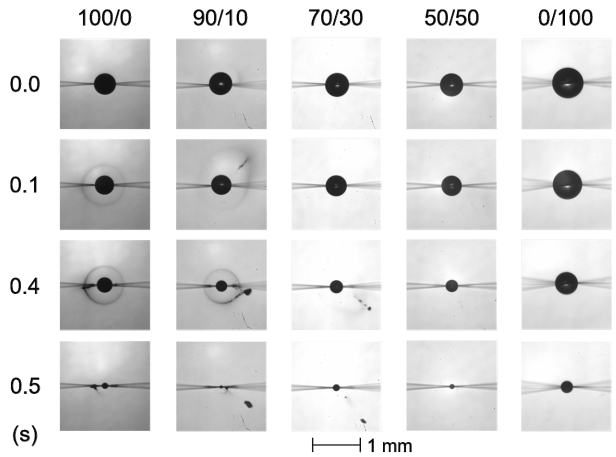
(2) Spark Ignition

(3) Electrode Retraction

(4) Uninfluenced Burning

free fall

Experimental Observations – BW droplet images



Heptane (100/0) results are from Y.C. Liu et al., *Comb. Flame* 159 (2012) 770-783.

Iso-butanol (0/100) results are from Y.C. Liu et al., *Comb. Flame* 169 (2016) 216-228.

Experimental Observations – Color droplet images

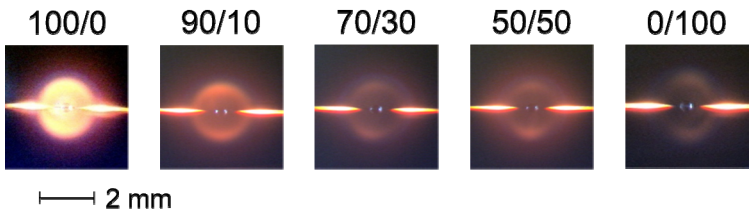


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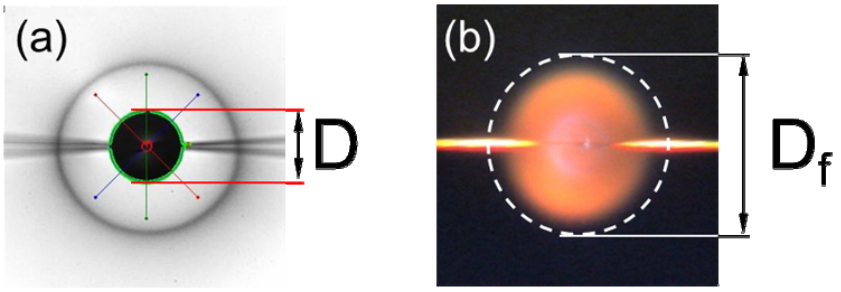
Image Analysis

(a) Image processing using a MATLAB program to extract droplet dimensions from consecutive images

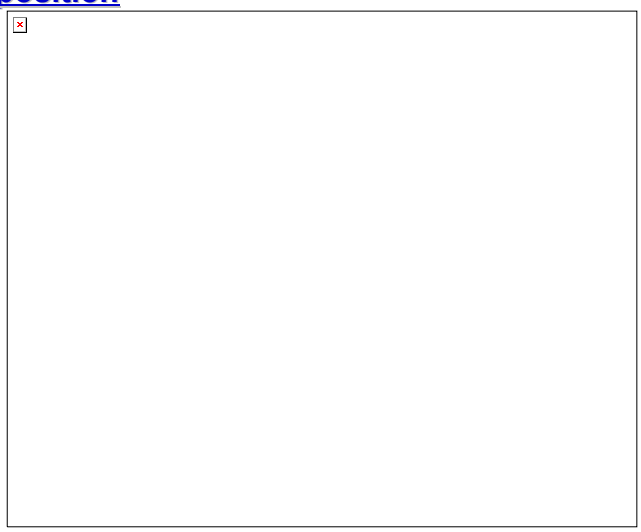
(b) Flame measurement by manual placement of a virtual ellipse around the outer luminous zone

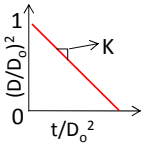


Dembia et al., *Image Anal. Stereol.*, 31 (2012) 137-148

Heptane, iso-butanol and their mixture: Droplet diameter evolution

Variation of droplet burning rate with composition





Evolution of flame standoff ratio (D_f/D)

Summary

- The burning rates of heptane/iso-butanol mixture droplets varied nonlinearly with composition.
- Spherical droplet flames were produced by minimizing convective influences on burning.
- Sooting propensities varied with mixture fraction and reduced as heptane was diluted with iso-butanol.
- The evolution of droplet diameters was nearly linear throughout burning though the flame standoff ratio was not constant, thus indicating that burning was not quasi-steady.
- The relative position of the flame to the droplet generally decreased by diluting heptane with iso-butanol.
- A heptane/iso-butanol mixture is a good model surrogate system for a transportation fuel/biofuel blend.

Thermal Sciences Laboratory

Thank you for your attention.