EFFECT OF DIMETHYL ETHER MIXING ON SOOT SIZE DISTRIBUTION IN PREMIXED ETHYLENE FLAME

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Background

- **Soot**: Carbonaceous particles resulting from incomplete combustion of hydrocarbon fuels
  - Incomplete Combustion: Efficiency
  - Deposition: Burner Lifetime / Performance
  - Health: Carcinogenic and Mutagenic
  - Climate: Global Warming & Regional precipitation
  - Visibility: Haze

- **Dimethyl Ether (DME)**
  - High oxygen content & absence of C-C bonds
  - Smokeless combustion, low formation and high oxidation rates of particulates.
  - High cetane number:
    - Low auto-ignition temperature, almost instantaneous vaporization.
    - Low boiling point: quick evaporation
  - Low energy density
  - High requirements on sealing materials

Methodology

- **Experimental techniques**
  - Flame configuration:
    - Burner-stabilized stagnation flame with the equivalence ratio (Φ) of 2.0
  - Temperature measurement:
    - Rapid insertion technique with a type-R thermocouple
  - Soot size distribution measurement:
    - Probe sampling and Scanning Mobility Particle Sizer (SMPS)
  - Soot characterization:
    - Thermo-gravimetric Analyzer (TGA), Elemental Analyzer (EA)

- **Numerical simulations**
  - CHEMKIN PRO
    - Module: Premixed Laminar Burner-Stabilized Stagnation Flame
    - Reaction kinetic model: KAUST-Aramco PAH Mech 2 Ver1.0

Results: Soot Size Distribution

- Normalized particle size distribution functions (PSDFs)
  - DME mixing ratio: 0%
  - DME mixing ratio: 10%
  - DME mixing ratio: 20%
  - DME mixing ratio: 30%

- The bimodal distribution appears at:
  - Hₚ = 0.8 cm (0% DME)
  - Hₚ = 0.9 cm (10% DME)
  - Hₚ = 1.0 cm (20% DME)
  - Hₚ = 1.2 cm (30% DME)

- Notable delay in soot formation due to DME addition

Results: Soot Oxidation Behavior

- Thermo-gravimetric analysis of soot samples at incremental DME mixing ratios.
- Temperatures corresponding to 5% (a), 95% (b) conversion ratios, respectively.
- Lower temperature represents better oxidizability.

- Elemental analysis of soot samples at incremental DME mixing ratios.
  - Higher O/C and H/C mass ratios represent better oxidizability.

Results: Mole fractions of Major Species

- Calculated mole fractions of several crucial species in soot formation and oxidation

- DME mixing ratio
  - CH₄
  - SOOT formation
  - CH₄
  - SOOT oxidation

- The addition of DME inhibits soot formation and facilitates soot oxidation.

Conclusion

- The addition of DME reduces soot emission in two ways:
  - The addition of DME inhibits soot nucleation and size growth, then the production of soot particles decreases;
  - The addition of DME promotes soot oxidation process by increasing the concentration of OH radicals and improving the oxidizability of the soot particles, then more particles are oxidized.
- Both of them are responsible for the reduction of soot emission at the presence of DME.