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

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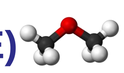
Background

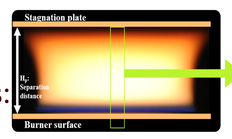
❑ **Soot**: carbonaceous particles resulting from incomplete combustion of hydrocarbon fuels

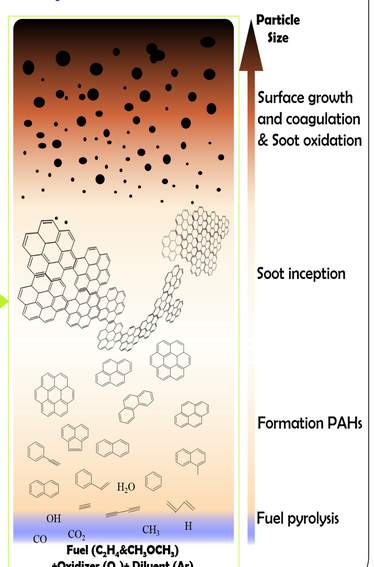
- Incomplete Combustion: Efficiency
- Deposition : Burner Lifetime / Performance
- Health: Carcinogenic and Mutagenic
- Climate: Global Warming & Regional precipitation
- Visibility: Haze

❑ **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

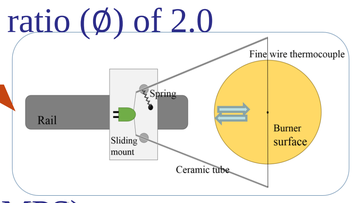




Methodology

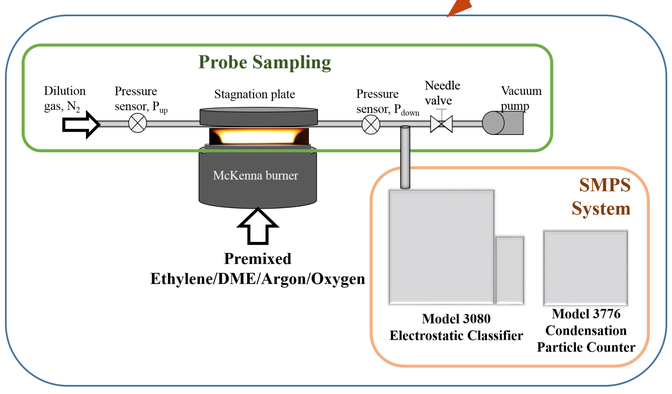
❑ **Experimental techniques**

- ❖ Flame configuration:
  Burner-stabilized stagnation flame with the equivalence ratio (Ø) 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)



Detailed experimental conditions for ethylene/DME flames at Ø = 2.0

Flame series	Cold gas velocity (cm/s)	DME mixing ratio (%)
A	6	0
		10
		20
		30
B	8	0
		10
		20
		30



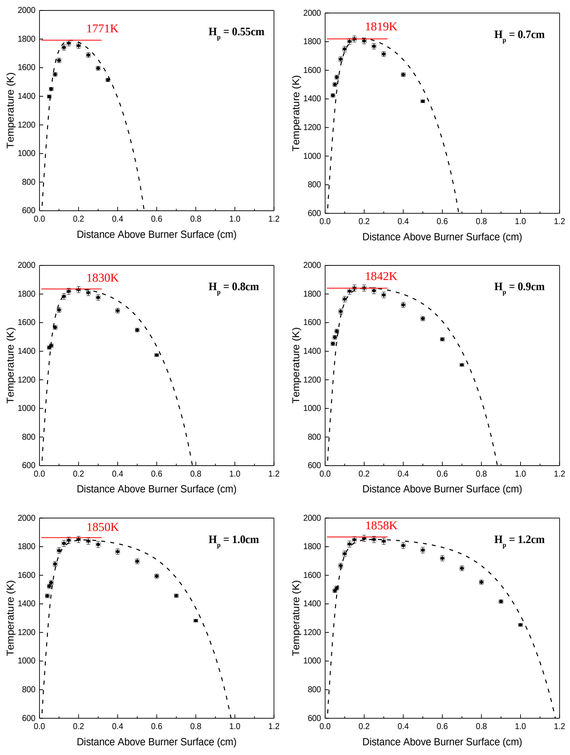
❑ **Numerical simulations**

CHEMKIN PRO

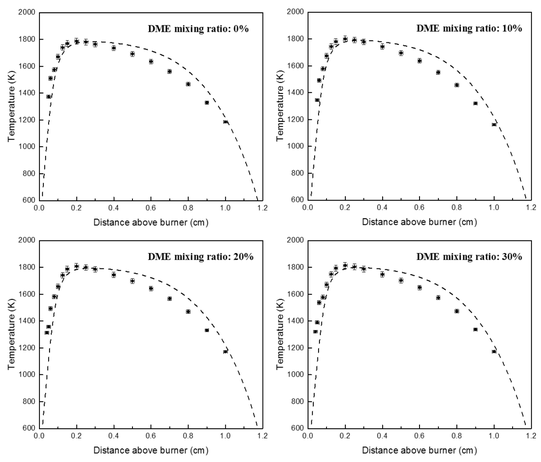
- Module: Premixed Laminar Burner-Stabilized Stagnation Flame
- Reaction kinetic model: KAUST-Aramco PAH Mech 2 Ver1.0

Results: Flame Temperature Profile

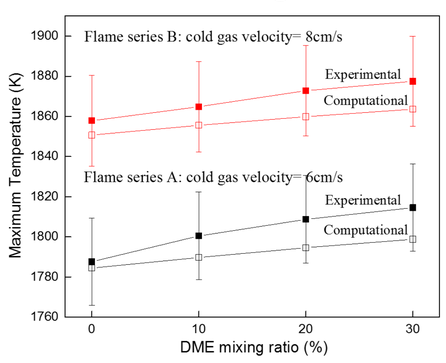
Comparison of experimental (radiation corrected, point) and simulated (dash line) flame temperatures at elevated separation distances



Comparison of experimental (radiation corrected, point) and simulated (dash line) temperature profiles at H_p = 1.2cm



Peak flame temperature as a function of DME mixing ratio

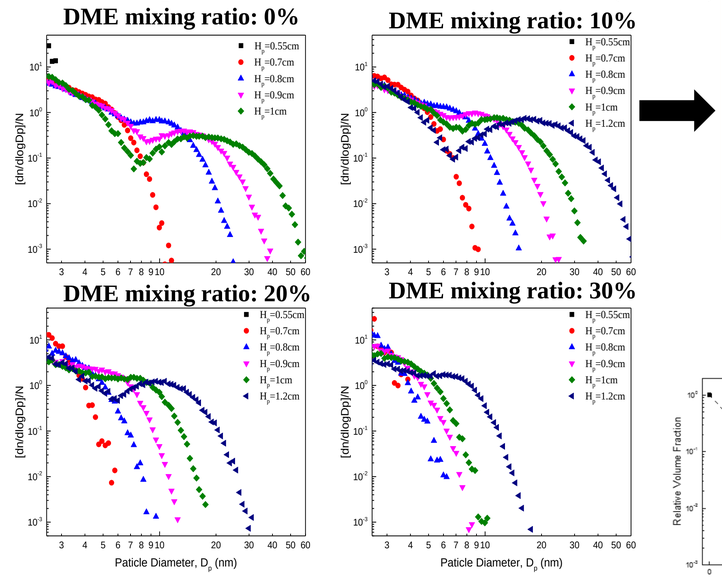


❑ Good agreement between experiment and model prediction.
❑ Maximum flame temperatures increase as separation distances increase.

Peak flame temperatures are lifted as a consequence of DME addition.

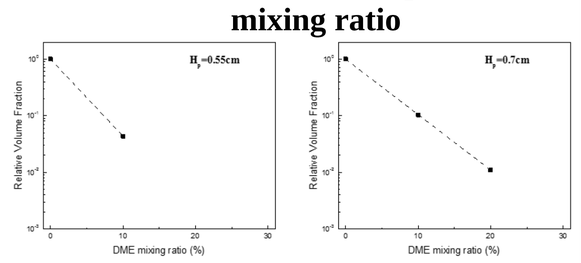
Results: Soot Size Distribution

Normalized particle size distribution functions (PSDFs)

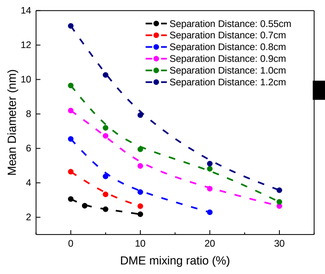


❑ The bimodal distribution appears at:
H_p = 0.8cm (0% DME);
H_p = 0.9cm (10% DME)
H_p = 1.0cm (20% DME)
H_p = 1.2cm (30% DME)
❑ **Notable delay in soot formation due to DME addition**

Relative soot volume upon DME mixing ratio



Measured mean particle diameter upon DME mixing ratio



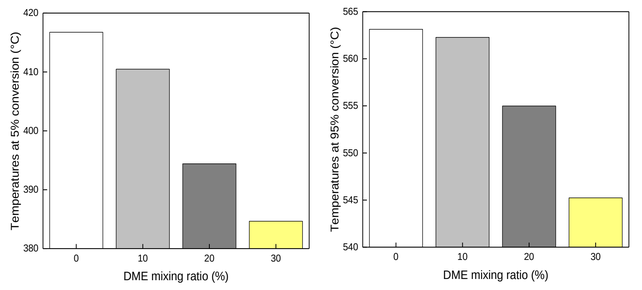
The growth of soot size slows down due to DME addition

Reduced soot volume fraction due to DME addition

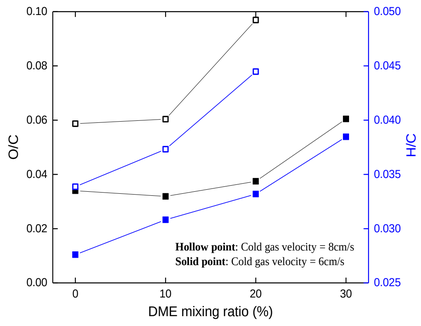
The addition of DME inhibits soot formation.

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.



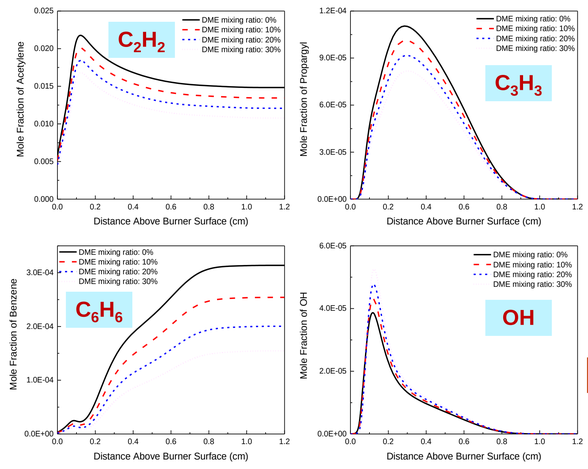
Elemental analysis of soot samples at incremental DME mixing ratios.
Higher O/C and H/C mass ratios represent better oxidizability.



The addition of DME facilitates soot oxidation.

Results: Mole fractions of Major Species

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



DME mixing ratio ↑
❑ C_2H_2 ↓
❑ C_3H_3 ↓ — **Soot formation** ↓
❑ C_6H_6 ↓
❑ OH ↑ ⟶ **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.