STUDY ON THE INFLUENCE OF ETHANOL ON THE SOOT FORMATION IN PREMIXED ETHYLENE FLAMES

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Aim
- Study on influence of ethanol on soot formation in selected fuel-rich atmospheric pressure laminar premixed ethylene/oxygen/argon flames
- Study on influence of residence time (height above the burner HAB) and equivalence ratio δ and C/O ratio on Particle Size Distribution Functions (PSDFs)
- In-situ probe sampling with suitable gas conditioning and online analysis using a Scanning Mobility Particle Sizer (SMPS)

Investigated ethylene/ethanol flames
- Two series of tests:
  - Ethylene/oxygen/argon flame (C/H₂/O/Ar = 0.139:0.181:0.880) at δ = 2.3 = const
  - Ethylene/oxygen/argon flame (C/H₂/O/Ar = 0.128:0.183:0.689) at C/O = 0.7 = const
- δ = 2.1 and stepwise addition of ethanol: 5% - 30% of total carbon feed
- δ = 2.2 and stepwise addition of ethanol: 5% - 30% of total carbon feed
- Inlet gas temperature of 323 K, atmospheric pressure, cold gas velocity of 8 cm/s (at 273 K and 1 atm)

Experimental setup
- Oil-cooled flat flame model burner (McKenna burner [1]) with bronze plug (Ø 60 mm) and N₂–shroud
- Stabilization plate at HAB = 30 mm
- Fluid supply via Bronkhorst MFCs (ΔP = ± 0.03)
- Direct evaporator for liquid fuel (type aSTEAM from aDROP GmbH)
- Separation of fuel and oxidizer via special mixing chamber
- Conditioning of reagents at 323 K after evaporating the liquid fuel at higher temperature
- Sample probe (Al₂O₃ > 99.5%, 9 mm ID, 10 mm OD) with Ø 0.3 mm orifice
- Dilution ratio ~2.10⁴ (uncertainty ± 24%)
- Type 5 thermocouple (Ø 0.5 mm, ΔT = ± 80 K) for temperature measurement

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References:

Results for ethylene/ethanol flames with constant δ = 2.3
- Flame temperatures are similar independent of ethanol content
- With increasing ethanol content shift of PSDs to smaller diameters (δ₂ ethanol = 50% at HAB = 12 mm; bimodal → unimodal)
- Ethanol-doped flame undergoes a slow down process on soot formation
- Observed effects are consistent with results obtained by others [3, 4]

Conclusions
- Addition of ethanol to the fuel leads to a reduction of the soot formation
- For constant equivalence ratio the PSDFs are bimodal in pure ethylene flames and in flames with an ethanol content of < 50%, even for HAB = 12 mm; for 50% ethanol content the PSDFs become unimodal
- The tendency of the reduction of soot formation due to the addition of ethanol is more distinct at low equivalence ratios
- For constant C/O ratio soot formation is increasing with higher amounts of ethanol in the fuel due to the fact that the equivalence ratio increases
- However, the PSDFs in the flame with 20% ethanol and in the pure ethylene flame are quite similar, what leads to the assumption that mainly the fuel structure influences the soot formation

Results for ethylene/ethanol flames with constant C/O ratio = 0.7
- Flame temperatures are similar independent of ethanol content
- With higher amounts of ethanol and constant C/O ratio δ is increasing and therefore soot formation increases
- However, PSDFs in pure ethylene flame (δ = 2.1) and in flame with 20% ethanol (δ = 2.28) are quite similar
- Effect mainly due to fuel structure? (heteroatom O in ethanol)

Results for ethylene/ethanol flames with δ = 2.2/2.3/2.4
- Reduction of soot volume with increasing ethanol content in the fuel
- Already 5% of ethanol in the fuel have a significant influence on the soot formation
- Tendency of soot reduction induced by ethanol addition increases at lower equivalence ratios

Aim:

Results:

Conclusions:

References: