Adaptation of Renewable Fuel to High Temperature Industrial Processes

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Introduction

This project aims to investigate the feasibility of using carbon-free fuel in the high-temperature industrial processes in order to achieve a significant reduction in greenhouse gas (GHG) emissions and meet the COP-21 commitment. Hydrogen is one of the most promising alternative fuels that is the focus of this project. Using hydrogen as the base fuel has a significant reduction in carbon intensity in comparison to fossil fuels.

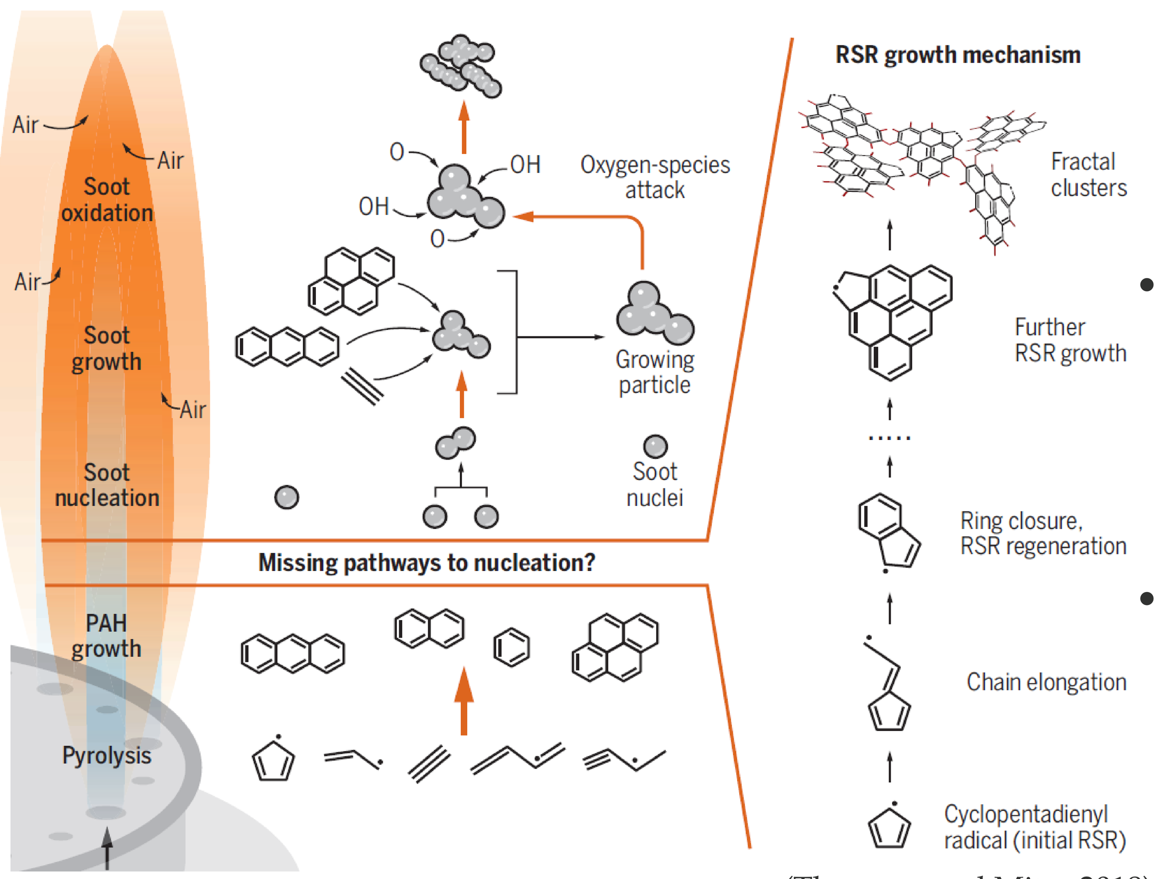
Hydrogen in Industrial Processes

Hydrogen
- Carbon-free
- High flame temperature
- Non-luminous
- Low radiation

Industry
- High-temperature processes
- Rely on fossil fuel
- Rely on thermal radiation

Blending hydrogen with a small amount of highly sooting hydrocarbon dopants to enhance the radiant intensity of the hydrogen flames.

Soot



(Thomson and Mitra 2018)

- Contributes to the luminosity and hence the radiant intensity of a flame
- Formed from carbon which is lacking in hydrogen fuels
- All the soot yield from small portion of hydrocarbon are oxidized in the hydrogen flame before it is emitted.

Bio-oil

- Oxygenated fuel with a high sooting propensity
- Derived from biomass refining, which mainly converts lignin, cellulose, and hemicellulose from renewable resources into fuel.
- Complex properties are highly depending on the type of feedstock and manufacturing method.

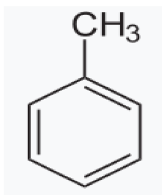
Potential Bio-oils

- Higher C/H, C/O ratio
- Lower water content
- Abundant lignin and aromatics
- Availability

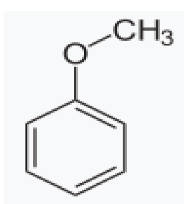
Feedstock	Major components %			Chemical compounds Area %		C/H	C/O	Water wt.%
	Cellulose	Hemicellulose	Lignin	Acetic Acid	Phenolics			
Red gum	42	21	22	8.6-9.6	16-21	9.2	2.6	7.7
Mallee eucalypt	14-22	14-40	24.7	5.73	Eucalyptol 27	5.9	0.9	20.8
Algae	8.5	17.2	13.8	Indole 16	3.1	8.3	2.1	26.6

Surrogates

Toluene(C_7H_8)

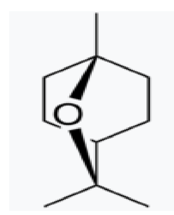


Aromatic structure with different functional group

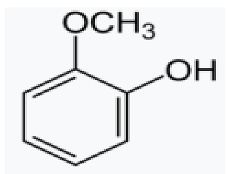


Anisole(C_7H_8O)

Cineole ($C_{10}H_{18}O$)

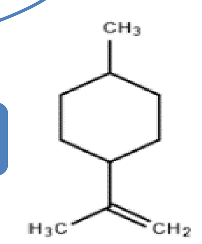


Complexity of bio-oil compounds requires surrogates for analysis.



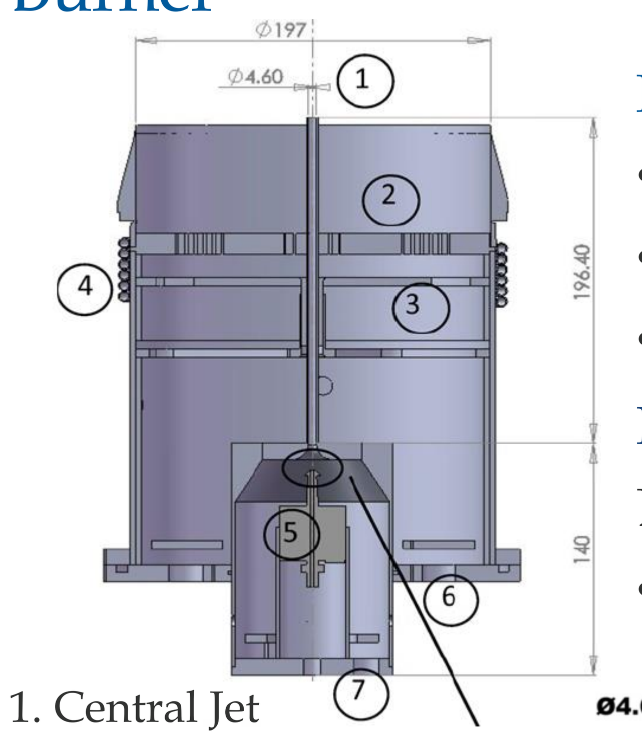
Guaiacol($C_7H_8O_2$)

Limonene ($C_{10}H_{16}$)

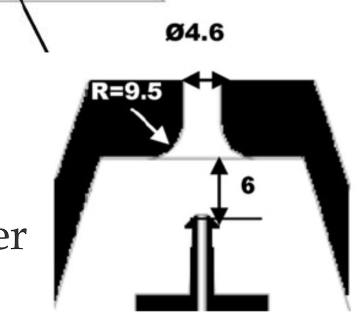


Methodology

Burner



1. Central Jet
2. Co-flow
3. Honeycomb
4. Cooling Coil
5. Ultrasonic Nebuliser
6. Co-flow Inlet
7. Carrier Gas Inlet



(Evans et al. 2020)

Measurement

First stage:

- Flame temperature: thermocouple
- Radiant intensity: heat flux sensor
- Soot volume fraction: laser extinction

Next stage:

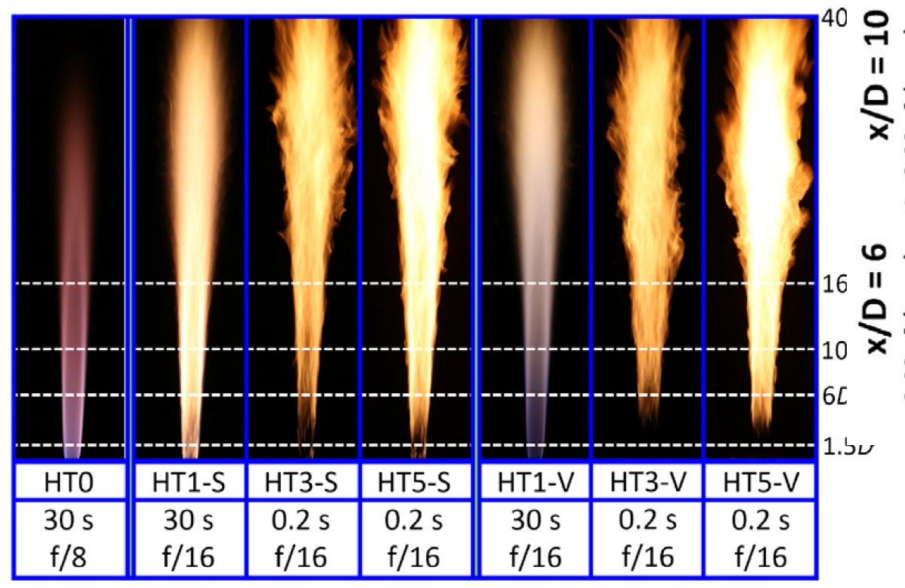
Laser-based experimental techniques

- Flame temperature: two-line atomic fluorescence (TLAF)
- Soot volume fraction: laser induced incandescence (LII)
- Detection of species (OH & PAH): planar laser-induced fluorescence (PLIF)

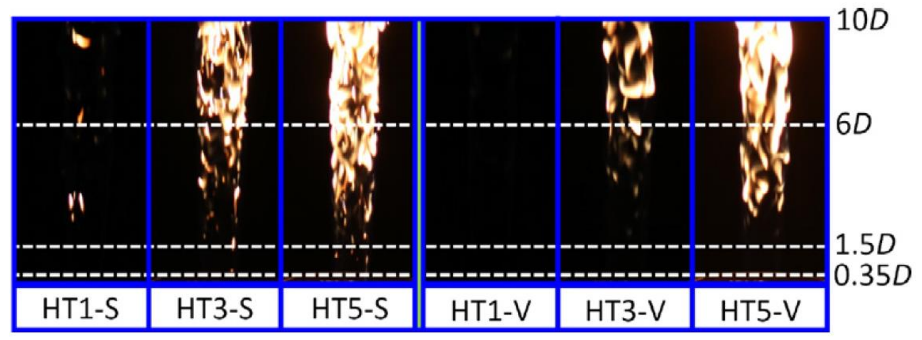
Literature

(Evans et al. 2020)

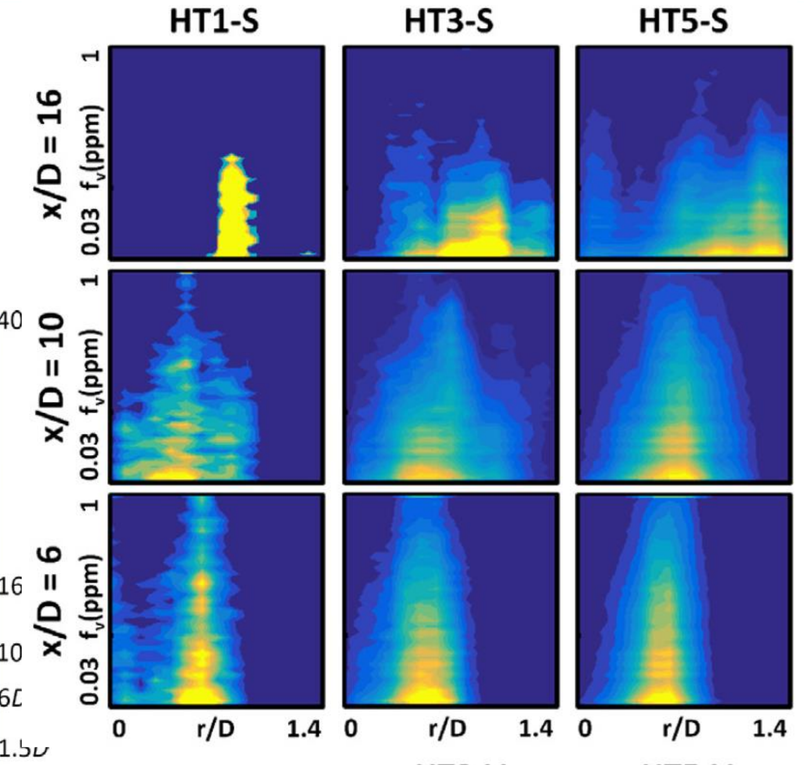
- S: Spray; V: Prevapourised;
- 1,3,5: Toluene 1%, 3%, 5% mol_{H2}

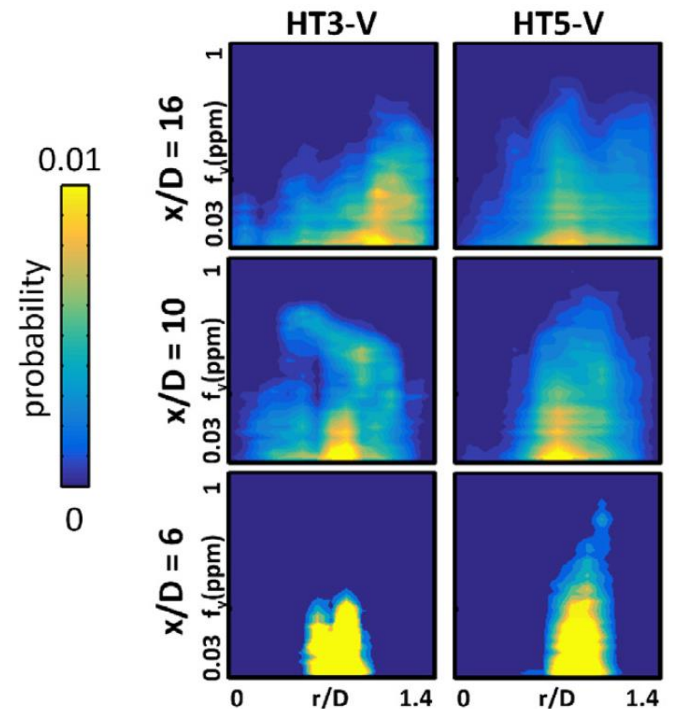


Photographs of hydrogen and toluene-doped hydrogen flames with long exposures (exposure times and f numbers provided below case-name).



Photographs of hydrogen and toluene-doped hydrogen flames with short (1 ms) exposures.





Soot volume fraction PDFs (f_v in log-scale) at different heights in the doped flames taken. No soot was measured in the HT1-V case.

Conclusion

(Evans et al. 2020)

- Soot volume fraction increases non-linearly with the addition of toluene dopant as a proportion of total H_2 fuel.
- Spray flames are found to produce substantially more polycyclic aromatic hydrocarbons, with significantly more soot near the nozzle exit plane, than the prevapourised flames.
- Increasing the dopant concentration from 1 to 3% of the hydrogen has a marked effect on soot loading in the flame. Further increasing the dopant concentration to 5% has far smaller effect on soot produced in the flame.

References

- Thomson, M and Mitra, T 2018, 'A radical approach to soot formation', *Science*, Vol. 361, No. 6406, pp. 978-979.
- Evans, M, Proud, D, Medwell, P, Pitsch, H and Dally,B 2020, 'Highly radiating hydrogen flames: Effect of toluene concentration and phase. ', *Proceedings of the Combustion Institute.*

Zoom: https://adelaide.zoom.us/j/5242016749?pwd=TVZUK0JrMmxRV094ZFJ2TUFnNlUydz09; Meeting ID: 524 201 6749; Passcode: 524097