Hydrogen Realities:
Hydrogen Basics, Challenges, Opportunities

Jacqueline O'Connor, Ph.D.
Associate Professor of Mechanical Engineering
Director, Center for Gas Turbine Research, Education, and Outreach
Pennsylvania State University
https://sites.psu.edu/gtreo/


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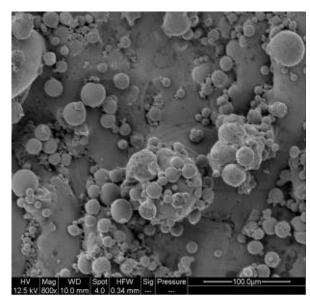
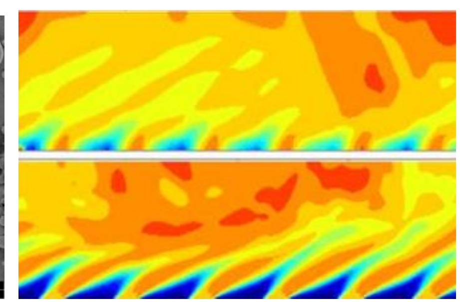

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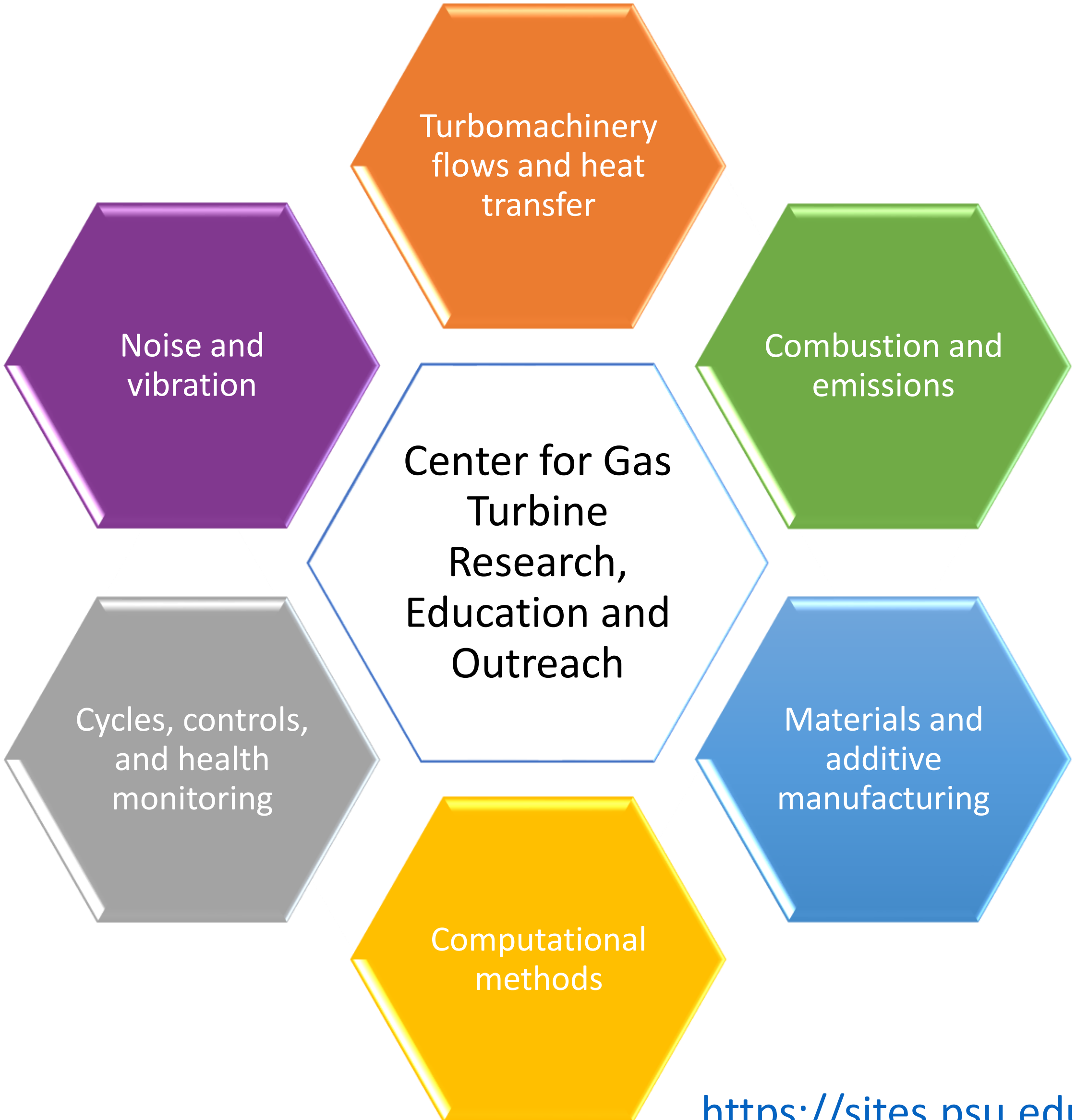
GTREO research addresses every part of the engine and industry, educating the future gas turbine workforce



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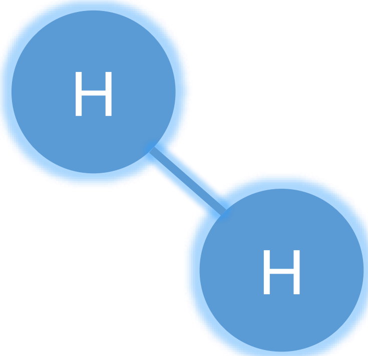
Overview of presentation

- Hydrogen: “a sneaky little molecule”
- Hydrogen combustion basics
- Hydrogen challenges and opportunities

Hydrogen is the lightest element on Earth, but packs a big punch as a fuel, particularly for ground-based applications

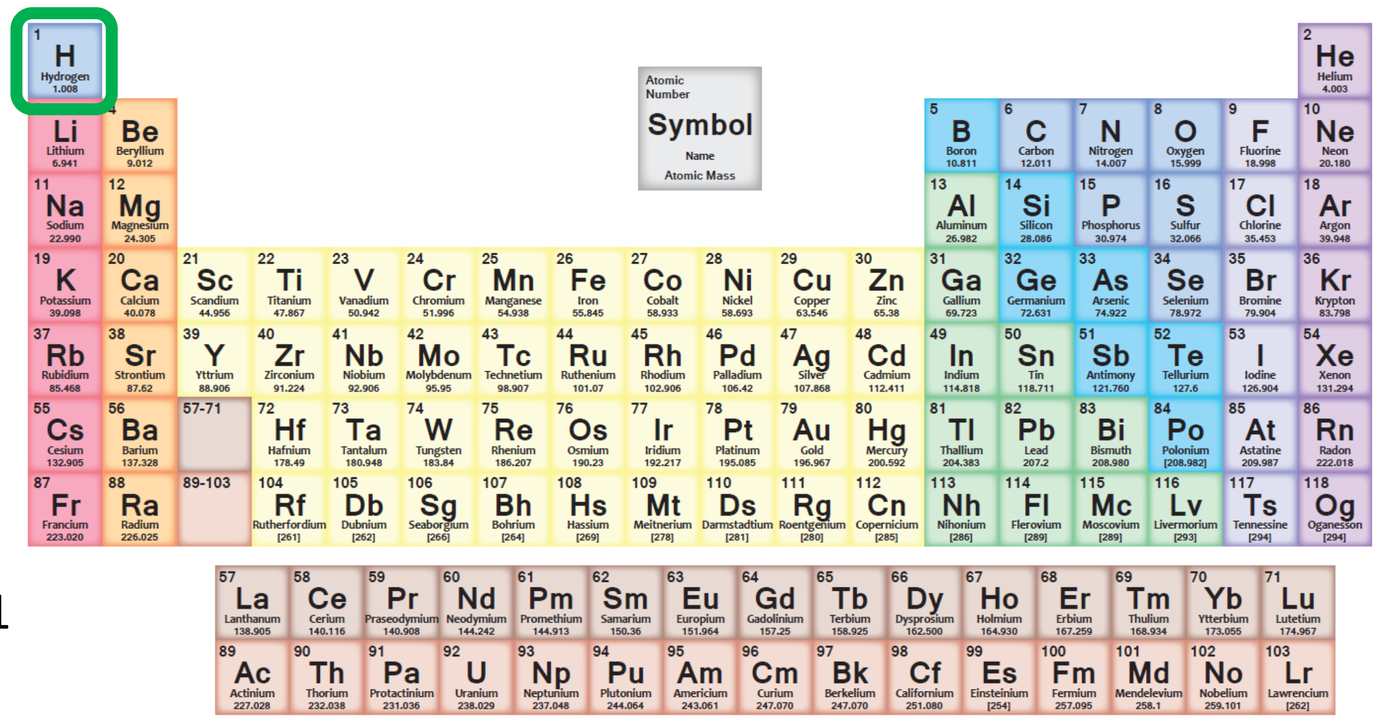


Key chemical properties:

- Mass-specific energy density: 120 MJ/kg
- Volume-specific energy density: 0.01005 MJ/L at STP
- Flammability limits: 4-74% in air at STP

Key physical properties:

- MW = 2.061 g/mol
- MP = −259.16 °C
- BP = −252.879 °C
- Density at STP = 0.08988 g/L
- Diffusivity in air at STP = 0.756 cm^2/s
  - (compare to 0.21 for CH_4)



https://sciencenotes.org/printable-periodic-table/

Hydrogen is a reasonable replacement fuel by some metrics, but others cause some challenges in combustion technologies

	H_2	CH_4	Gasoline	Diesel
Mass-specific energy density (MJ/kg)	120	55	44	46
Volume-specific energy density (MJ/L at STP)	0.01005	0.0364	32	34
Mass diffusivity in air (cm^2/s)	0.756	0.21	n/a	n/a
Adiabatic flame temperature (°C)	2254	1963	2138	2102
Flame speed (cm/s at STP)	300	40	~35	~35

Adiabatic flame temperature is the maximum temperature of a combustion reaction, indicative of potential thermal loads

Combustion reaction: Fuel + Air → Products (+ Heat)

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Combustion reaction: Fuel + Air → Products T_{ad}

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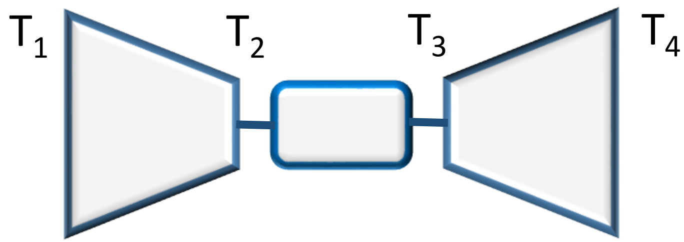
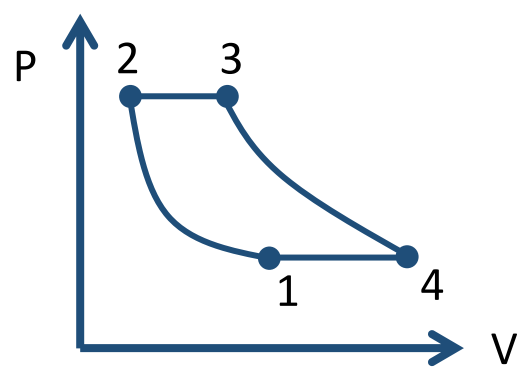
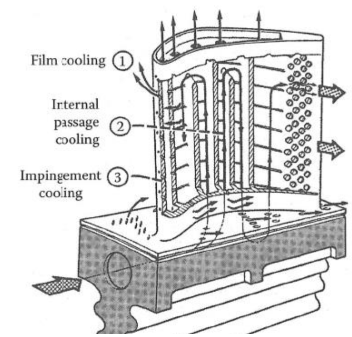
Opportunities



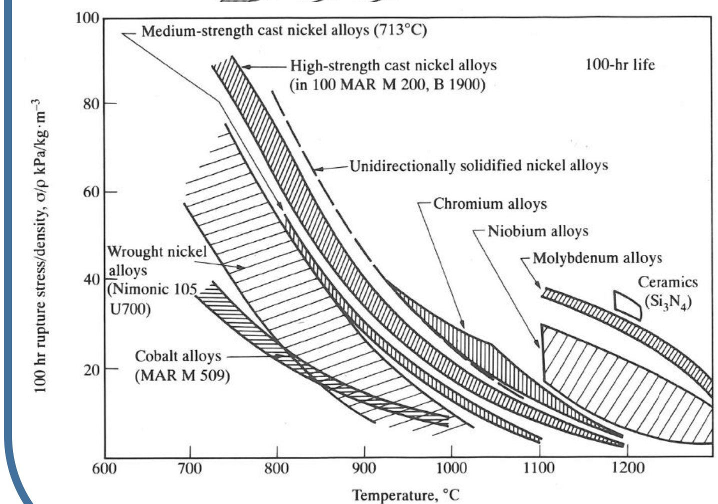


$$\eta_{th,\max} = 1 - \frac{T_1}{T_3} = 1 - \frac{T_1}{T_{ad}}$$

Challenges

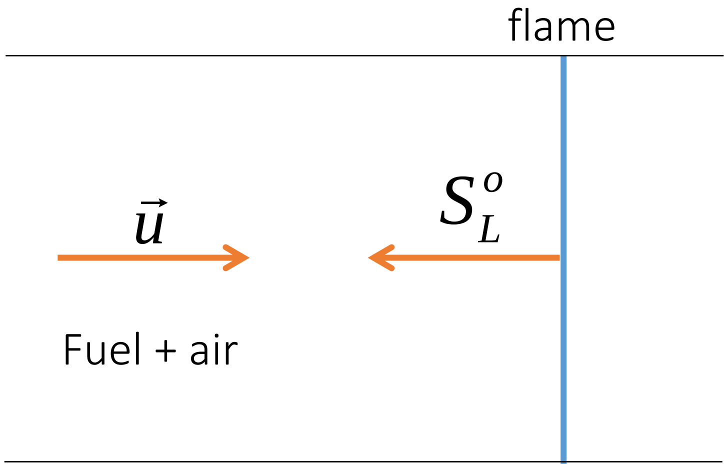


Han, Dutta, Ekkad, “Gas Turbine Cooling”



Hill & Peterson, Mechanics & Thermodynamics of Propulsion

Flame stabilization in premixed combustion systems is driven by the flame speed of the mixture



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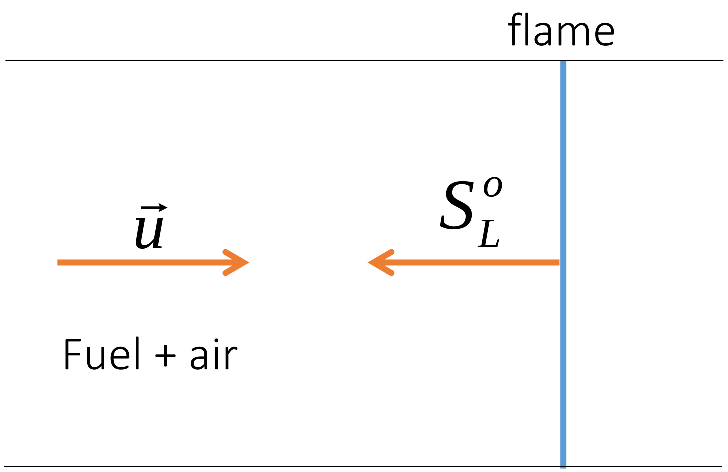

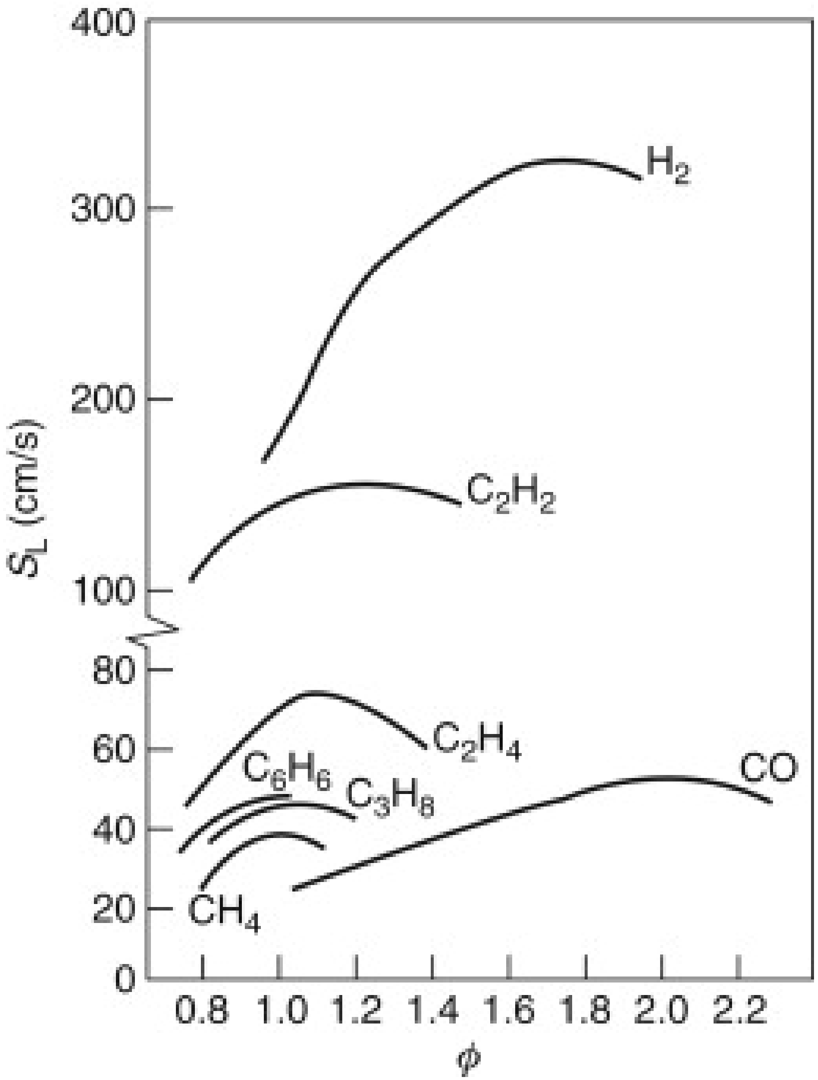

Glassman, I., Yetter, R. A., & Glumac, N. G. (2014). *Combustion*. Academic press.

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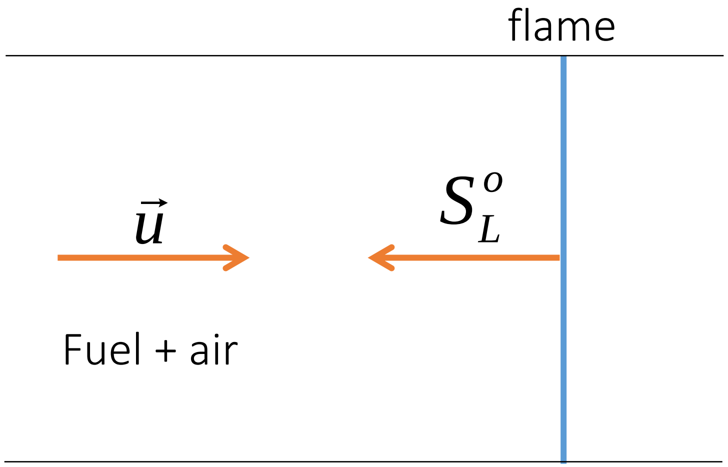
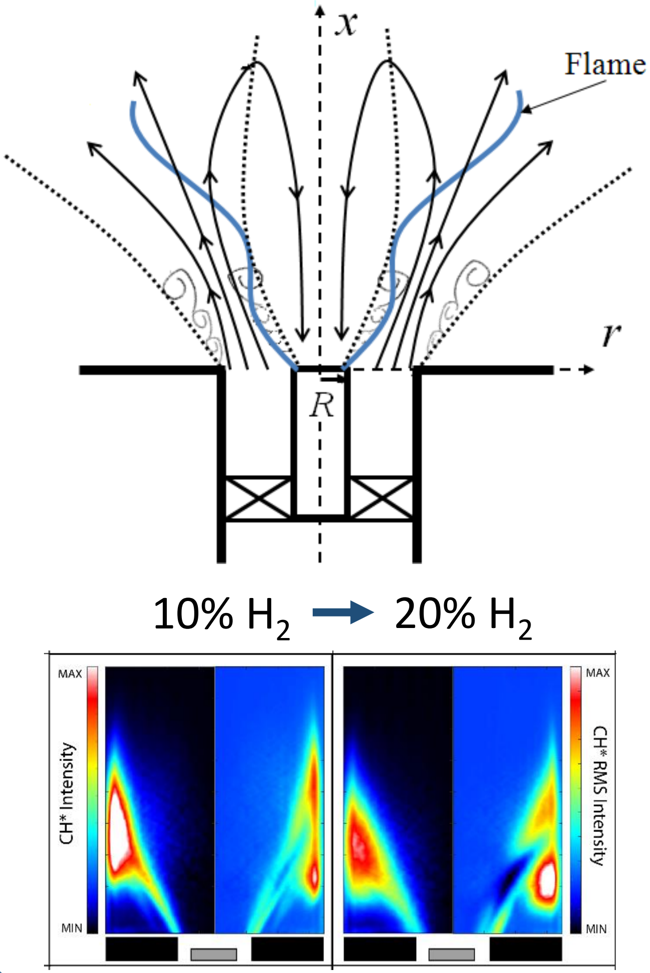


Challenges



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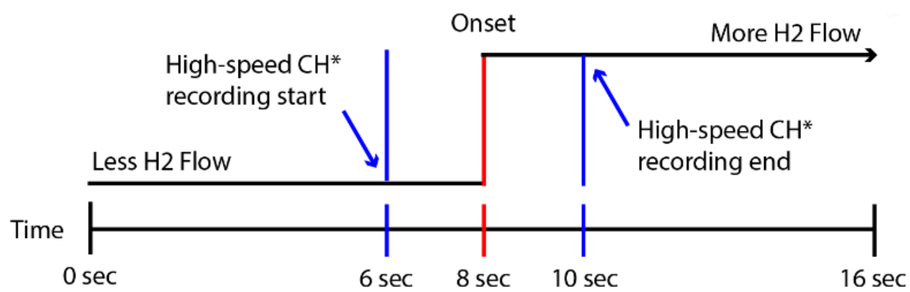
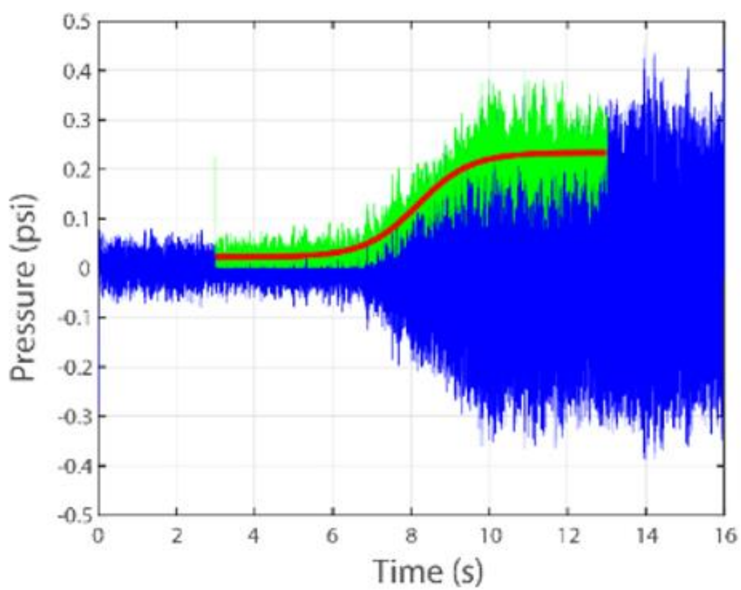
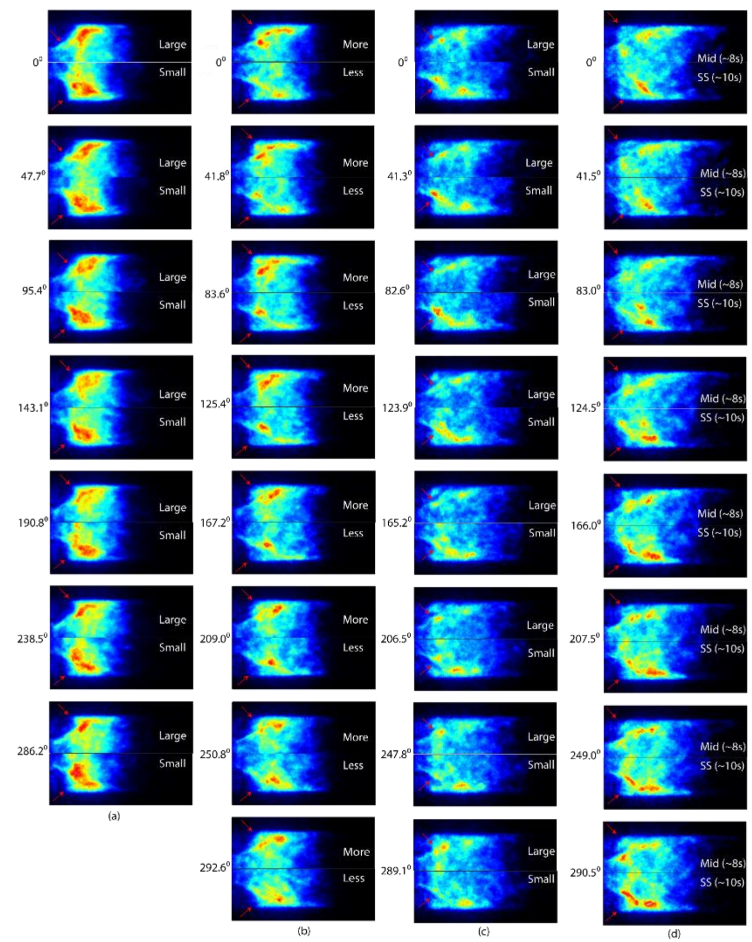
Hydrogen fuel may significantly change the operability of engines, including challenges like flame holding and instability







Strollo, J., Peluso, S., & O'Connor, J. (2020). "Effect of hydrogen on steady-state and transient combustion instability characteristics." *Journal of Engineering for Gas Turbines and Power*. **In press**

Acknowledgements

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Questions?

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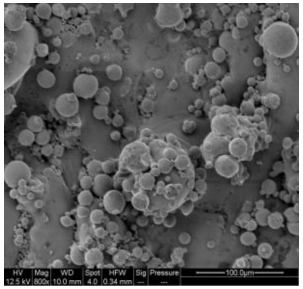
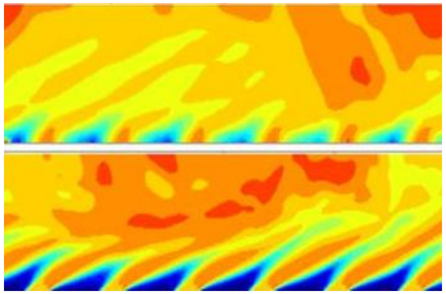

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