



「カーボンニュートラル工業炉の実現に向けた高温環境下におけるアンモニア乱流燃焼特性の解明」

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関連キーワード「CO2フリープロセス開拓分野」

Background and Objective

Benefits and drawbacks of using ammonia in industrial furnaces:

Pros

- Carbon-free combustion
- High hydrogen density
- Easily liquefied & stored

Cons

- Weak flame stability
- Weak radiation transfer[1]
- High fuel-NOx emission

Ammonia is a carbon free fuel and hydrogen energy carrier for decarbonization of industrial sectors.

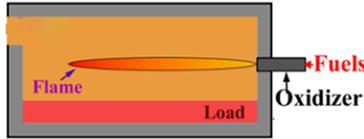


Fig. 1 Schematic of the industrial furnace [2].

The overall objective of this work is to understand the fundamental combustion characteristics of ammonia-based flames for industrial furnaces.

[1] Xia et al., Fuel 396 (2025) 135274.
[2] C. E. Baukal, CRC Press, 2000.

The present work aims to understand the turbulent flame extinction behavior of ammonia-based flames.

Methodology

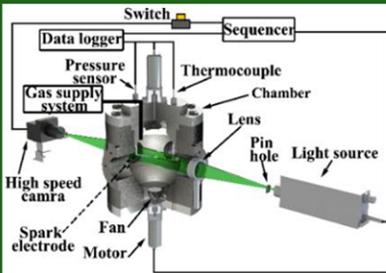


Fig. 2 Turbulent combustion facility.

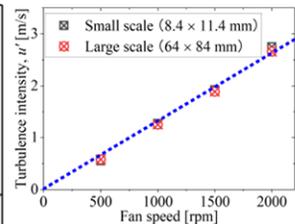


Fig. 3 Turbulence intensity as fan speed (by PIV) [3].

[3] Xia et al., Proceedings of the Combustion Institute 40 (2024) 105511.

Experimental method: Spherical turbulent combustion chamber (Constant volume)

Turbulence intensity, u' : 0 – 6 m/s

Detection method: Schlieren photography and pressure sensor

Mixture: $\text{NH}_3\text{-H}_2\text{-O}_2\text{-N}_2$

O₂ concentration, β_{O_2} : 0.12

H₂ mole fraction in fuel mixture, X_{H_2} : 0.4, 0.45, 0.5

Results

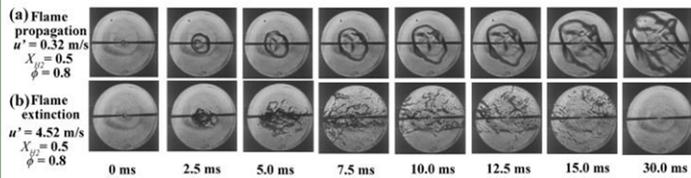


Fig. 4 Turbulent flame propagation and extinction process [4]

[4] Xia et al., International Journal of Hydrogen Energy 223 (2026) 154130

□ Turbulent flame propagation limits define the maximum turbulence intensity beyond which a flame cannot be sustained.

□ Figure 4 shows turbulent flame propagation and extinction processes. During propagation, the flame front advances with a pressure rise, whereas during extinction, turbulent eddies induce flame extinction without pressure increase.

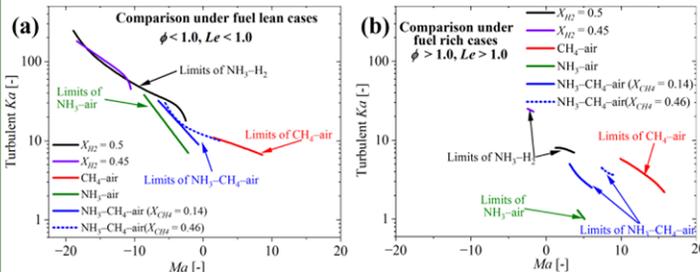


Fig. 5 Comparison of turbulent stability behavior between $\text{NH}_3\text{-H}_2\text{-O}_2\text{-N}_2$, $\text{CH}_4\text{-air}$, $\text{NH}_3\text{-air}$, and $\text{NH}_3\text{-CH}_4\text{-air}$ premixtures [4]

□ Figure 5 compares the flame stability characteristics of $\text{NH}_3\text{-H}_2$, CH_4 , NH_3 , and $\text{NH}_3\text{-CH}_4$ mixtures. The results indicate that the addition of hydrogen substantially enhances the stability of ammonia flames.

Output and Contributions

◇ This work provides significant insights into the utilization of ammonia-hydrogen fuels in energy systems and supports the advancement of numerical models for their turbulent combustion.

◇ The results of this work can significantly contribute to the decarbonization of industrial furnaces and support the realization of a carbon-neutral society.

◇ Further work will be conducted to investigate radiation and NO_x emissions of ammonia-based flames.

