Lean Blow-Off of Ammonia-Hydrogen Flames at Gas Turbine Conditions with a Toroidal Jet Stirred Reactor

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Introduction

To reduce carbon emissions produced by modern technology while still meeting energy demands, alternative sources of power generation must be considered.

Pros of ammonia:

- Theoretically, it only has byproducts of nitrogen & water
- More accessible due its popularity in fertilizers
- Easy to store

Cons of ammonia:

- Low flammability
- Highly attractive to water, toxic health hazard
- Combustion distruption leads to NOx or N2O emissions

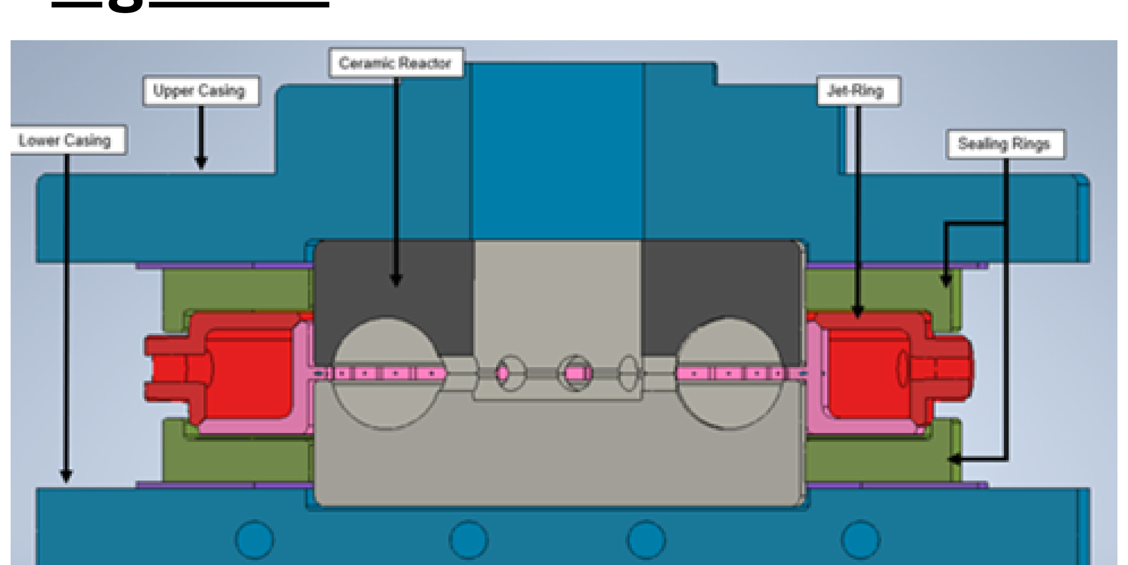
This experiment aims to study the blow-off behavior of ammonia flames, assisted with hydrogen, when placed in conditions similar to a gas turbine.

Toroidal Jet-Stirred Reactor

A toroidal jet-stirred reactor (TJSR) was constructed to simulate jet engine conditions on a smaller scale.

- Two stainless steel casings and sealing rings
- An Inconel 625 jet-ring
- A two-part inner ceramic reactor

Figure 1: Sliced TJSR 3D model



Experiment

Figure 2: Fume Hood

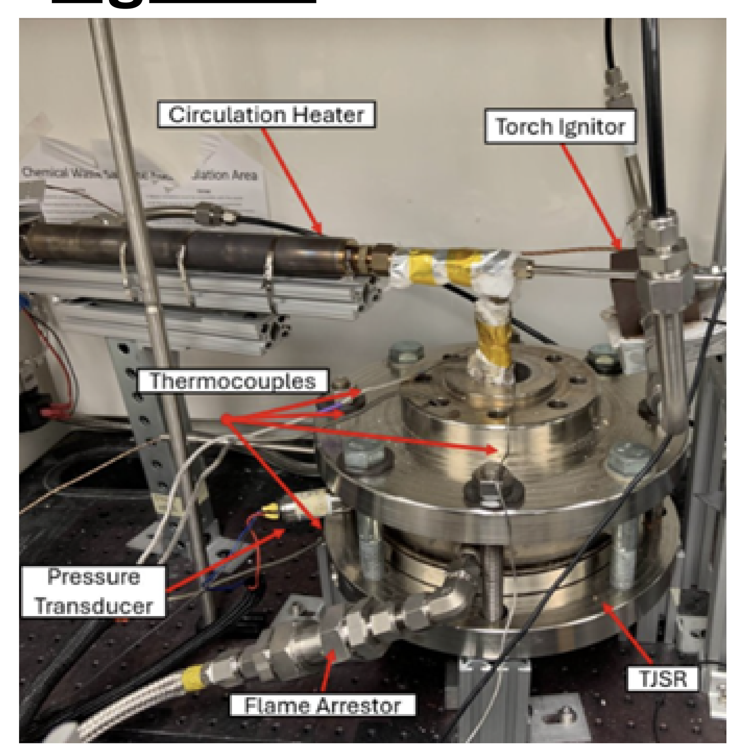


Figure 3: Operating Table

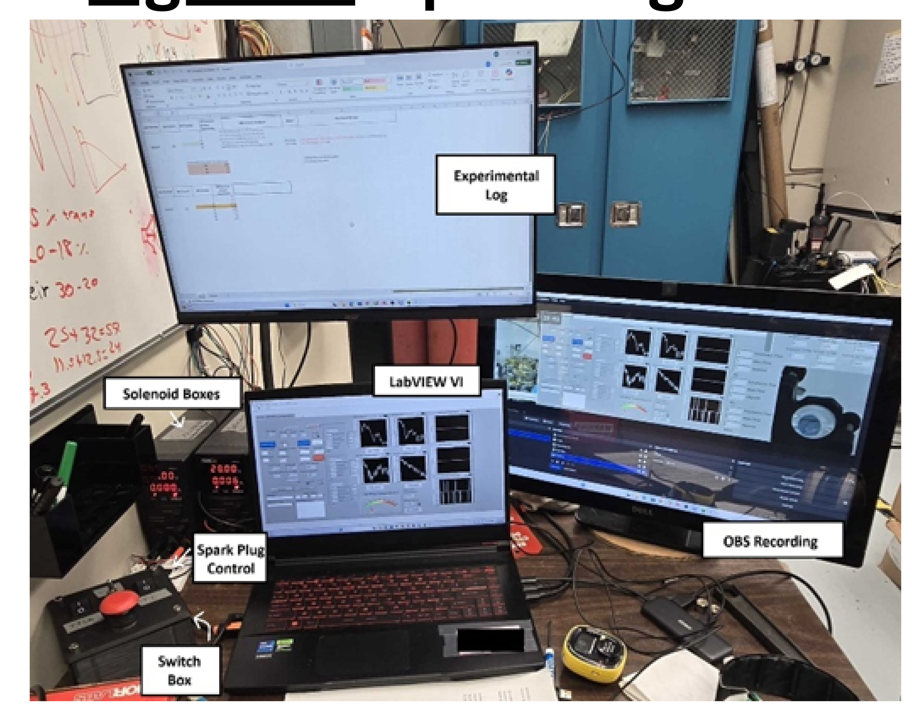
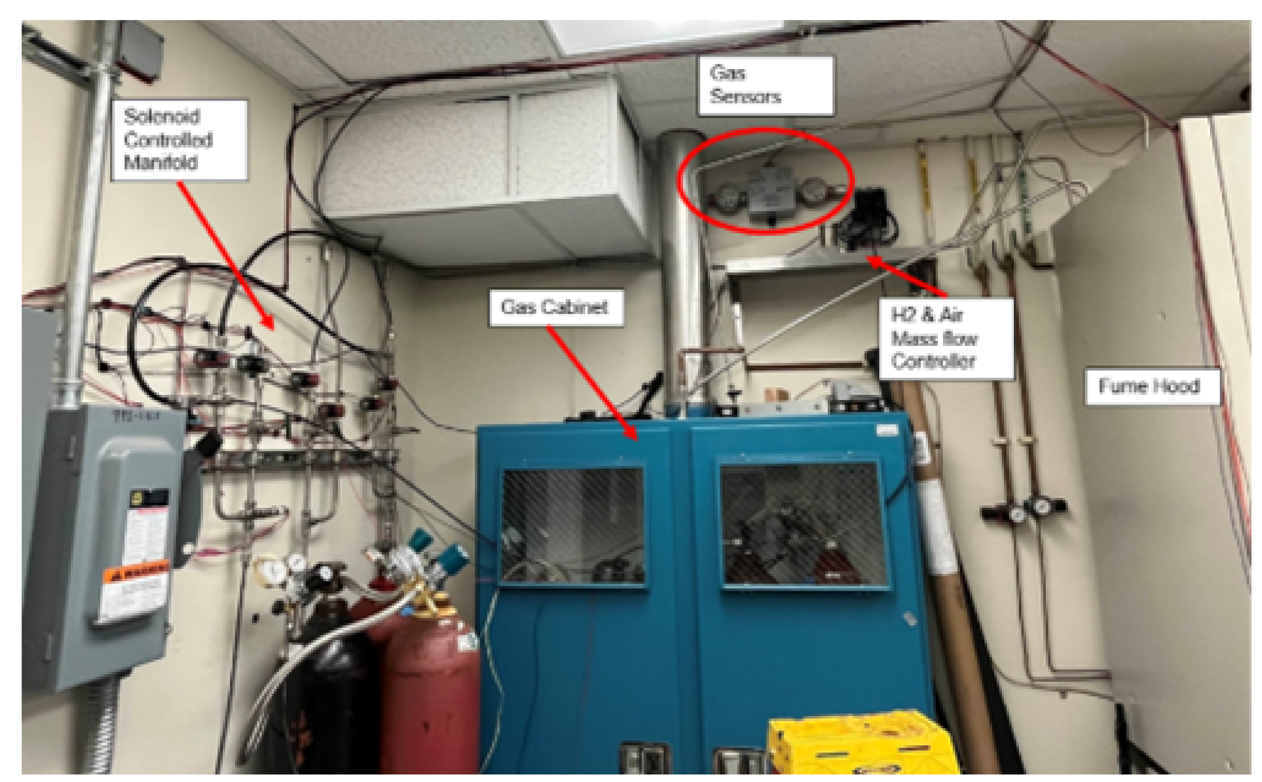


Figure 4: Plumbing, Electric Manifold, Gas Cabinet



Three main assemblies: fume hood, outside the fume hood, and the operating table. Circulation heater (Figure 2) is used to preheat the reactor to avoid cold starts.

Pre-mixed ammonia-hydrogen fuel and air are injected into the TJSR via the jet-ring where a torch ignitor starts the combustion (Figure 2).

Experimental runs are controlled and monitored at the operating table (Figure 3). Equivalence ratio of air is lowered through a LabVIEW set-up until flames sputter and are purged.

The target ammonia-hydrogen ratio and ending equivalence ratio (lean blow-off) is stored after every experimental run (Figure 2).

Ceramic Reactors

Figure 5: Alumina casts

Figure 6: Sample testing

Previous issue with fracturing reactors during experimental runs.

Pros of using alumina for reactors:

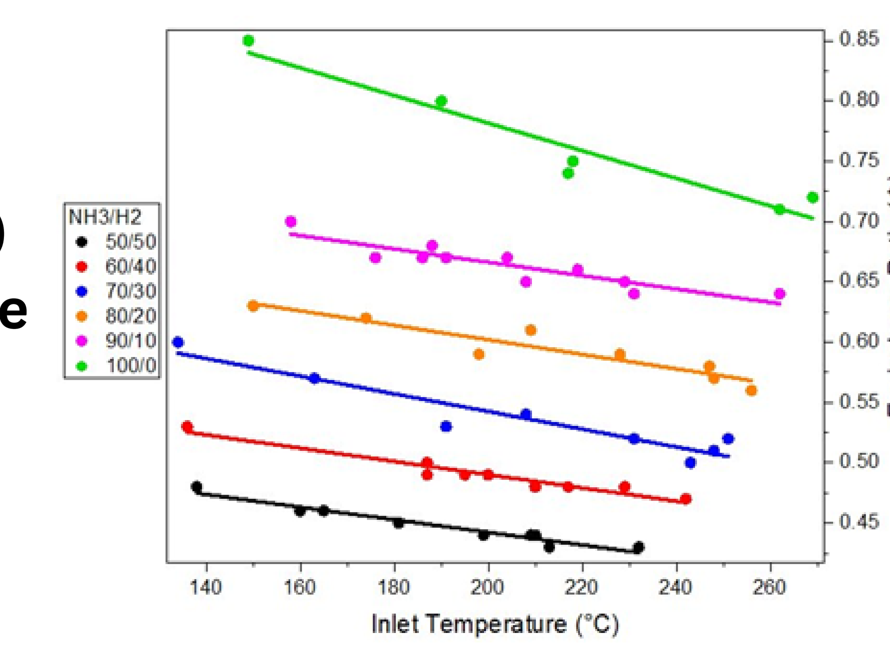
- Strong temperature resistance
- High hardness
- Cost effectiveness
- Low lead time (made in lab)

Further surface finish testing (Figure 6) showed that casts with 20% wt water slurry had less resulting bubbles.

Discussion

Results showed a decreasing trendline for lean blow-off on all ammonia-hydrogen fractions as jet-ring (inlet) temperature raised (Figure 7). Runs with a higher fraction of ammonia displayed higher ending equivalence ratios.

Figure 7: Inlet Temp vs Φ



Engines looking to incorporate ammonia must take heat loss into consideration to prevent premature blow-off of flames.

Next Steps

Future research aims to study production rates of NOx or N2O in ammonia flame exhaust using specialized lasers.

Further testing with alumina reactors to obtain consistent surface finish quality.

References