Metis 1kW Microturbine System

Metis Design
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Metis 1kW Microturbine System Team

- Turbomachinery development
- Microturbine integration
- Power electronics

Metis 1kW Microturbine System

- Recuperator development
- Combustor integration

- Low emissions combustion
Technology - Compressor

State-of-the-art Small Scale Compressors

- At GENSETS scale low Reynolds number and adverse pressure gradients result in efficiencies below 70%
- ~50% impeller / 50% diffuser pressure rise
- ~80% impeller pressure rise comes from loss free centrifugal acceleration
- Diffusers are very lossy (loss $\propto V^3$)

Rotating Vaneless Diffuser

- Rotating diffuser relative velocity & streamtube length can be halved
- Diffuser loss can be reduced by ~80%
- Tested at 2x GENSETS pressure ratio at 6x scale for DARPA
Technology - Combustor

- The low-swirl burner evolved from laboratory tool to an ultra-clean combustion technology
  - Developed for basic studies of flame/turbulence interactions
    - Principle of operation invested through experiments and analyses
    - Adapted by researchers world wide for fundamental studies
  - Scientific underpinnings facilitate adaptation to 5kW to 200 MW systems
    - Simple and scalable design
    - Supports stable ultra-low NOₓ lean premixed flames
    - Fuel-flexible
    - High turndown
  - Enabling technology for next-generation advanced combustion systems
    - Combined heat and power
    - High efficiency combined cycle systems
Technology - Recuperator

Brayton capabilities / experience

- 30 years of gas turbine recuperator experience: Design, test, and field results.
- Pilot manufacturing of purpose-built recuperators for gas turbines and microturbines.
- Manufacturing processes for austenitic alloys, super (Ni) alloys, oxide dispersed solidification alloys, FeCrAlY’s and ceramics.
- Laboratory test facilities, employing accelerated life test methods developed for military gas turbine recuperators.
- Materials characterization facilities and procedures for special high-temp alloys.
  - Creep testing: pressures to 50 MPa, and 1000C
  - Fatigue testing at high temperatures
  - Friction factor and heat transfer characterization of novel compact surfaces.
- Full recuperator gas stand testing

Low cost for GENSETS

- Patented design with outstanding compactness and durability.
- Efficient use of high temp alloys
- Manufacturing process amenable to high volume production methods, with modest capitalization.

Brayton Energy LLC
Technical Progress – Compressor

- Compressor design completed and on track for >80% efficiency
- Compressor and test stand hardware fabrication completed
- Instrumentation and data acquisition system procured and tested
- Power electronics designed, fabricated and tested
Technical Progress – Combustor

Emissions test results show plenty of margin to target for both CO and NO\textsubscript{x}. No anomalies expected at engine operating conditions. Pressure drop also within criteria.

- Pressure drop was measured to be 0.26% (target is 3%)
Technical Progress – Recuperator

- Core design and drawings complete
  - HP header fin subjected to hoop load from manifold internal pressure
  - Candidate alloys based on lifing rqmt. and oxidation resistance (IN625, 20-25+Nb, FeCrAl)
- Heat exchanger unit cells complete
  - Hydrostatically tested to 100 psig
- Stock hardware procurement in progress
- Core build to be completed 3\textsuperscript{rd} week, December
- Performance testing to begin 2\textsuperscript{nd} week, January
Lessons Learned

• Compressor
  - On track to demonstrate compressor efficiency of >80%
  - 2ndry flow, leakage and seals are key design challenges

• Combustor
  - Emissions test results show plenty of margin to target for both CO and Nox
  - Combustor pressure drop lower than conventional microturbines <1% vs. ~3%

• Recuperator
  - Brayton's unit cell recuperator with integrated combustor can be adapted for GENSETS scale with reduced number of cells (5)
  - A recuperator cost of $280-340 is estimated (generally 30-40% of a microturbine cost)
Next Steps

• Compressor test section assembly and testing
  ➢ Updated compressor design and fabrication
• Complete fabrication of recuperator core build and begin performance testing
  ➢ Update design of recuperator core #2 as necessary
  ➢ Complete fabrication and performance testing of recuperator core #2
• Combustor / recuperator integration and testing
• Turbine and hot section design and fabrication
• Microturbine testing