Research Overview and Highlights

An Overview of the Research Activity

Craig R. Bradshaw, Ph.D.

craig.bradshaw@okstate.edu
http://cibs.okstate.edu
405-744-5246
http://hvac.okstate.edu
Twitter: @BradshawProf
My Vision and Mission

Develop the next generation of thermal energy systems and their components to facilitate maximum energy efficiency across multiple industrial sectors.

To execute this, I want to support research and industrial stakeholders by delivering the next generation of employees, models, and datasets to disseminate knowledge and maximize impact.
Novel Peristaltic Compressor

Potential to Eliminate/reduce major losses by eliminating valves and internal volume ratios plus reducing leakage.

Current Project Deliverables:
1. A validated thermodynamic model
2. Re-configurable prototype compressor
3. Recommendations for applications in HVAC&R

Fig: Re-configurable prototype compressor

Funded by: ASHRAE Innovative Research Grant, Rexel Inc.
Rotating Spool Compressor

**Video: How the Spool Compressor Works**

Developed a comprehensive, first-principles, model that includes sub-models for all major components such as valves and seals. [12]

**Fig:** Model informed design drastically improved spool compressor efficiency.

Novel Comp. - Linear Compressor

A free-piston compressor with potential to be constructed at miniature-scale [13, 16]

**Fig:** Model results showing unique ability for capacity control efficiently, compared against a reciprocating compressor [14]

**Funding:** Torad Engineering LLC, and Cooling Technologies Research Center at Purdue
Compressors of the Future

- CFC's
- HCFC's
- HFC's
- Near-zero GWP Refrigerants

Compressor Technology vs. Capacity | For A/C and HP Applications
---|---
Fractional | 50+ tons
Reciprocating | 3+ tons
Rotary | 20+ tons
Scroll | 40 tons
Screw | 400 tons
Screw | 350 tons
Centrifugal | 4000+ tons

Comparison of Modeling Platforms

Results suggested that open-source PDSim [6] is a good platform for general compressor development [1]

Fig: Reciprocating compressor Control Volume (top) and pressure-volume curve from 4 different modeling platforms

What compressor technology is applied to what application in the future with near-zero GWP refrigerants?
Reduced-order model of positive-displacement compressors

Approach is to leverage machine learning techniques to develop a new model, as close to black-box as possible, that satisfies the other requirements.
Loss Analysis of Spool Compressor

Instrument compressor with high-speed pressure sensor to sample at kHz speed

Using known compressor volume, actual compression process is compared against ideal processes to explore potential optimizations [11]

Fig (left): Instrumented, 40 ton, compressor
Fig (top): A pressure-volume diagram experimentally obtained highlighting losses

Funding: Torad Engineering LLC
Hot-gas bypass load stand development

Two available load stand environments that are commissioned and comply with ASHRAE 23.1 testing standards

- Light-commercial load stand, 10-80 tons of refrigeration [5, 10]
- Fractional, less than 1 ton of refrigeration

Light-commercial stand includes novel features such as independent oil management, economization, and a high-capacity range

Fig: A compressor being tested on the light-commercial load stand at OSU

Funding: Mechanical and Aerospace Engineering, OSU; and Johnson Controls Intl.
Optimize system performance by characterizing cross-fin conduction in fin-tube heat exchangers.

**Figs:** Thermal circuits included in model and example validation data highlighting importance of cross fin conduction.

Developed and validated a discretized heat exchanger model to capture this effect [2,9]

**Funding:** Oklahoma Center for the Advancement of Science and Technology (OCAST), and Johnson Controls Intl.
Heat Exchangers – Model Dev. and Validation

Cross-fin conduction model reduced in order by replacing thermal circuit with air-side area re-assignment [7,8]

Fig: Multiple-circuit coil with one active circuit illustrating model reduction from left to right

Fig: Models are validated using novel experimental infrastructure to support coil testing [4]

Funding: Oklahoma Center for the Advancement of Science and Technology (OCAST) and ASHRAE (RP-1785)
Development of infrastructure to collect charge model data for fin-tube heat exchangers for system optimization [3]

Figs: Differential weighting scheme developed with custom-hardware (left) and the custom-made heat exchanger module, RHXCT (top)

Funding: ASHRAE (RP-1785)
Spool expander development for medium-grade waste heat in ORCs

Low-grade waste-heat recovery options for power plant heat rejection reduction [15]

**Fig:** Greenhouse heating for winter crop production (bottom)

**Fig:** Open-water algae bio-reactor (top)

**Funding:** Torad Engineering LLC, and Hoosier Energy Cooperative
The Center for Integrated Building Systems (CIBS)

CIBS Vision

A holistically built environment that is integrated from component to grid, maximizing energy utilization, occupant comfort and equipment performance.

CIBS Mission

Provide tangible outcomes and manpower to support the integration of components, systems, and buildings through an exploration of the fundamental mechanisms of interaction from component to building scales.

Fig: Research Thrusts (top) and planning meeting attendees (bottom)

Funding: National Science Foundation, I/UCRC Program
References


