Design and Testing of a Prototype Particle/sCO$_2$ Heat Exchanger at Gen3 Operating Conditions

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SolarPACES 2022
Power Cycles
Friday, September 30, 2022
Introduction

• Particle CSP is being developed to enable high efficiency sCO₂ power cycles

• The particle/sCO₂ heat exchanger is a critical enabling technology for these systems

• Moving packed-bed heat exchangers are a promising option

• Solex, VPE, and Sandia have been collaboratively developing advanced moving packed-bed heat exchangers
Prior 20 kW$_t$ Stainless Steel Prototype Testing

Prototype heat exchanger designed and built as part of G3P3 program
Prototype performance measured using integrated particle and sCO$_2$ flow loops
Data was used to verify heat exchanger thermal model in Sierra/Aria
Design Requirements:

- Design temperature: 800 °C
- Design pressure: 25 MPa
- Nickel alloy construction (IN617)
- Overall HTC: >450 W/m²-K
- <3 mm particle channel width
- sCO₂ microchannel enhancement
- Pressure Drop: <30 kPa
- Reduction in material per surface area
20 kW<sub>t</sub> Nickel Heat Exchanger Modeled Performance

- Model performance is based on stochastic analysis considering uncertainty in input parameters (conductivity, near-wall resistance, flow uniformity, sCO<sub>2</sub> HTC)
- Expected overall heat transfer coefficient is **603 W/m<sup>2</sup>-K** based on input parameters verified against 20 kW data or **526 W/m<sup>2</sup>-K** based on 90% confidence level
Heat Exchanger Test Facility Upgrades
Revised Particle and sCO₂ Flow Loop Geometric Design
sCO₂ Flow Loop Assembly and Commissioning

- System has been operated up to temperatures of 500 °C using electric heat addition at 200 g/s and 17 MPa
- Recuperator and cooling heat exchangers appear to be over designed and within pressure drop allocations
- Pump performance map matches vendor data corrected for sCO₂ properties
- Electric heater is controllable and doesn’t show any evidence of local hot spots
Particle Flow Loop Assembly and Commissioning

- Particle system has been assembled with third-party prototype heat exchanger installed
- Skip hoist has been installed and integrated with LabVIEW control system and demonstrated up to 300 °C at 200 g/s
- Revised weigh hopper design has been installed and used as feed hopper for skip hoist
- Final item to be modified is the particle heater upgrade to achieve temperatures up to 800 °C
Skip Hoist System Integration

Design Requirements:
- Maximum flow rate: 300 g/s
- Operating temperature: >600 °C
- Particle inventory: 22 kg
- Cycle time: < 75 s
- Lift height: 14 ft (vertical)
- Agnostic to particle type
- Incorporate horizontal conveyance
- Low particle abrasion
60 kWt Particle Electric Heater

- Electric heater design uses cartridge heater elements to create a shell-and-tube geometry
- Heater element count based on heat flux limitation for particle heat transfer coefficient
Summary

Revised particle and sCO$_2$ flow loop assembly and commissioning has been completed up to temperature of 500 °C and operating pressures of 17 MPa.

Particle-to-sCO$_2$ heat exchanger with Gen3 operating conditions is nearing manufacturing completion.

Testing of the particle-to-sCO2 heat exchanger at Gen3 operating conditions should be completed in the last quarter of 2022.
Acknowledgements

Sandia would like to acknowledge the contributions of industry partners VPE and Solex
This work was funded in part or whole by the U.S. Department of Energy Solar Energy Technologies Office under Award Numbers 34211, 34152, and 37371.

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Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy’s National Nuclear Security Administration under contract DE-NA0003525.