Project ID: 08536: Additively-Manufactured Molten Salt-to-Supercritical Carbon Dioxide Heat Exchanger

Headline. Metal Additive Manufacturing for Monolithic, Conformal High Pressure and Temperature Heat Exchangers

1. Impact

Demonstrate the efficacy of Ni superalloy additive manufacturing (AM) for high effectiveness (>90%), high power density (>10 MW/m^3), low pressure drop primary heat exchanger (HE) for molten salt to sCO_2 with integral headers.

2. Project Goal

Design a compact primary Ni superalloy HE using laser powder bed fusion (LPBF). Assess the fabrication challenges and dimensional tolerances of AM-built HE. Assess the mechanical properties and microstructure of specimens. Develop a process-based cost model (PBCM) and assess cost-reduction strategies in near-, medium-, and long-term.

3. Methods

Mechanical and thermal-fluid co-design including manufacturing and cost considerations using low-order models and detailed simulations. Quantify porosity and dimensional tolerance to establish process window for LPBF of Haynes 230 and 282. Measure tensile, creep, and fatigue of AM-built and heat-treated samples. Experimentally characterize the performance of a prototype HE.

4. Outcomes

Developed scalable, modular, integrated core-header designs with > 10 MW/m^3 power density, > 90% effectiveness, and < 0.5 bar sCO_2 pressure drop. LPBF yields > 99.9% dense parts over a range of process parameters. LPBF HE units are fully de-powdered; pressure drop reduction demonstrated after internal smoothing. AM-built H230 specimens have tensile and creep comparable to wrought. PBCM helped identify cost-cutting design and process improvements.

5. Conclusion/Risks

Viable path for LPBF AM for SETO high temperature components being demonstrated.

6. Team

UC Davis, Carnegie Mellon University, Univ. Michigan, NREL, Metal Powder Works, HEXCES, Carpenter Powder Products, Special Metals.

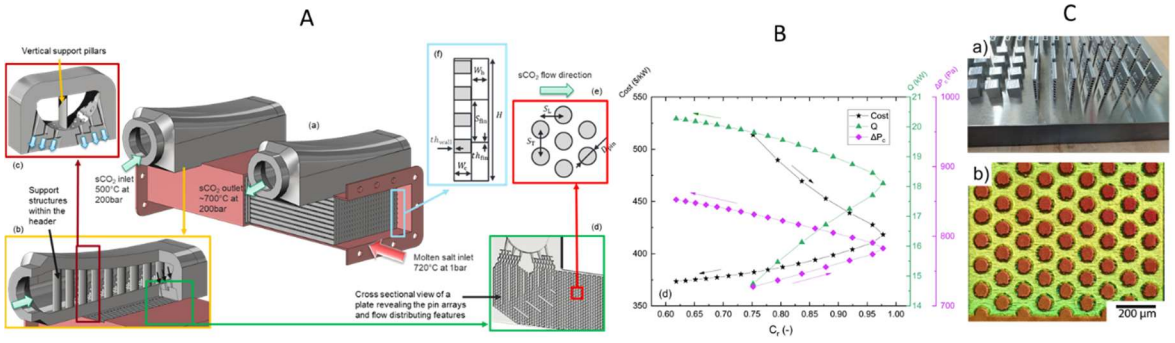

Figure: [A] 1st generation AM HE design showing details of the pin arrays on the sCO_2 side and header details; [B] Sample thermofluidic + cost model results- variation in thermal performance and cost with heat capacity rate ratio; [C] Test coupons for LPBF process window determination (top), unit cell channels and surface height scans of pin arrays to evaluate the conformance to the designed dimensions (bottom).