Design and Development of Additively Manufactured Molten Salt to Supercritical CO_2 Heat Exchanger in Concentrating Solar Power Application

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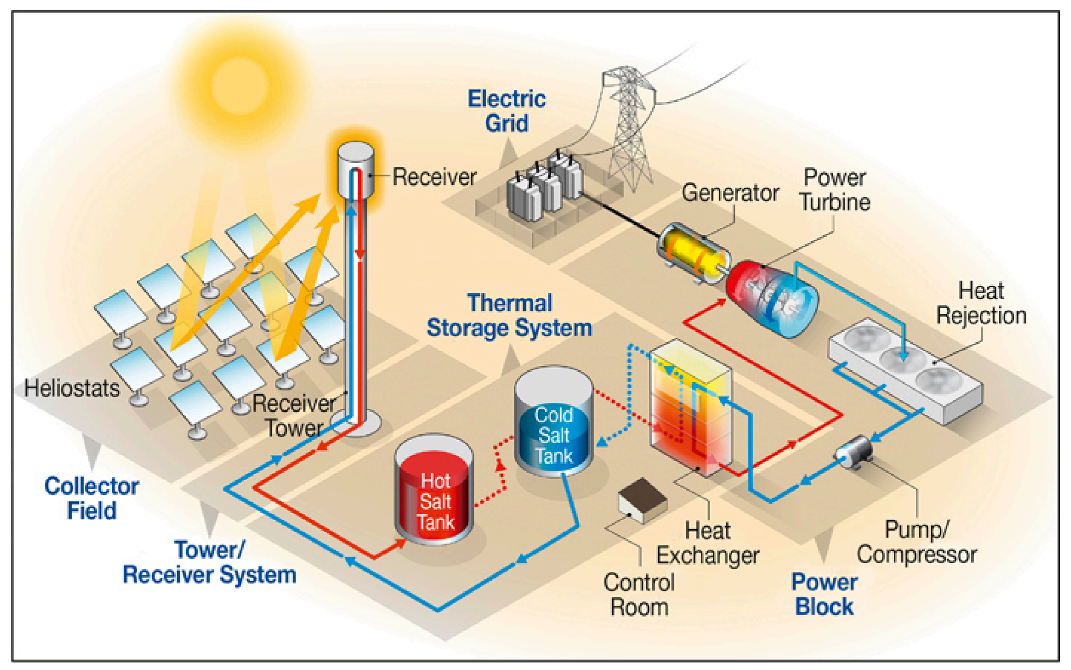
Can additive manufacturing (AM) be used to manufacture a low cost, high efficiency primary heat exchanger (HX) for Concentrating Solar Power (CSP)?

BACKGROUND

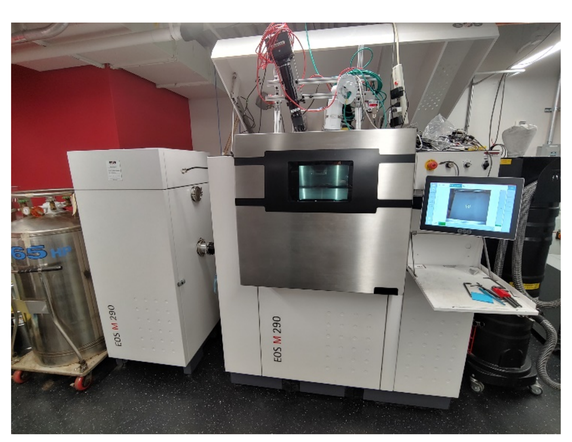
CSP can provide clean, dispatchable power, overcoming the grid integration challenges faced by photovoltaics and wind power. To be cost competitive, CSP must use high efficiency power cycles (i.e., supercritical carbon dioxide (sCO_2)



CSP System Diagram
Credit: A. Hicks, National Renewable Energy Laboratory

Brayton cycle). Currently, the primary HX accounts for 60-70% of cost for this cycle. **Reducing HX cost is critical for increasing CSP adoption.** This requires unconventional designs, materials, and manufacturing techniques to meet demanding operating requirements .

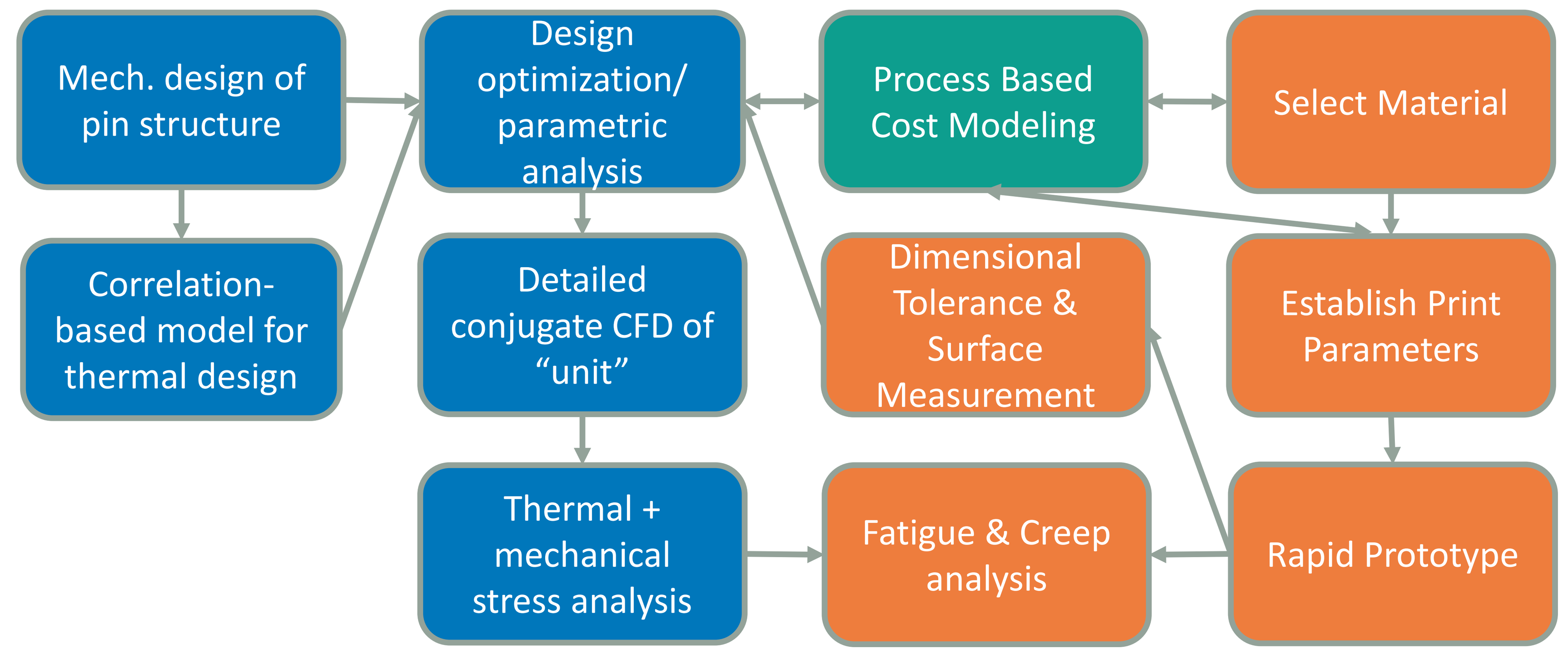
- **> 50% thermal efficiency**
- **> 700 °C temperature, 200 bar pressure**
- **Highly corrosive environment**



AM via Laser powder bed fusion (LPBF) builds parts layer-by-layer with resolutions of a few hundred micrometers. **AM (LPBF) offers several advantages for HX design:**

- **Use of difficult to machine materials**
- **Complex, compact, flexible geometrical design**
- **Elimination of welded joints**

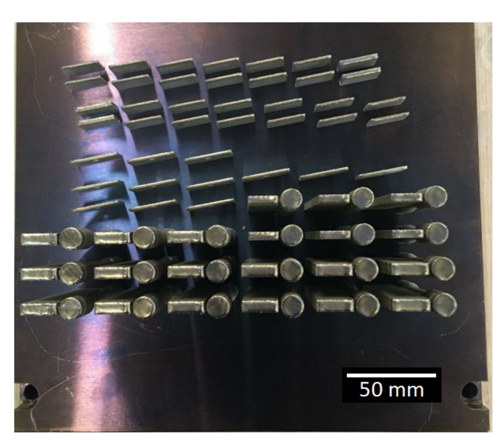
INTEGRATED DESIGN PROCESS

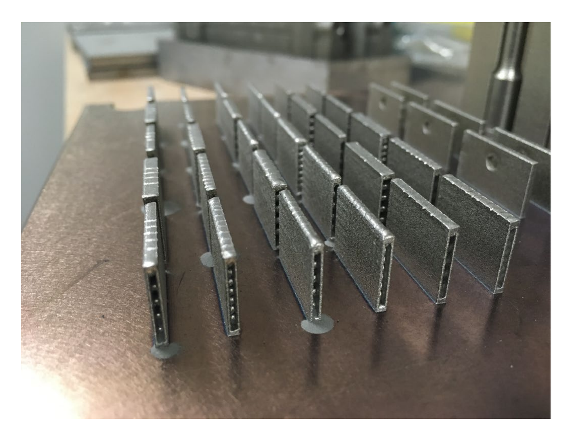


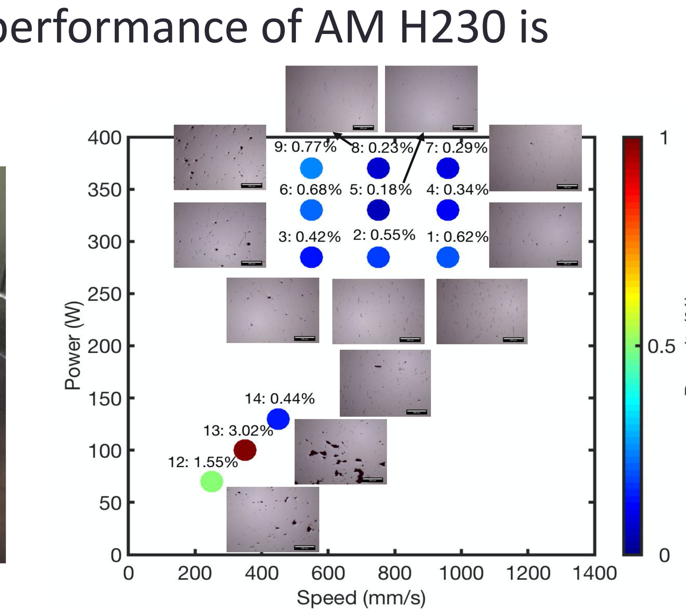
AM PROCESS DEVELOPMENT & PROTOTYPE

Haynes 230 (H230), which has long been used in high temperature applications, is a good candidate for the primary CSP HX. Since H230 is not widely used in AM, successful printing required:

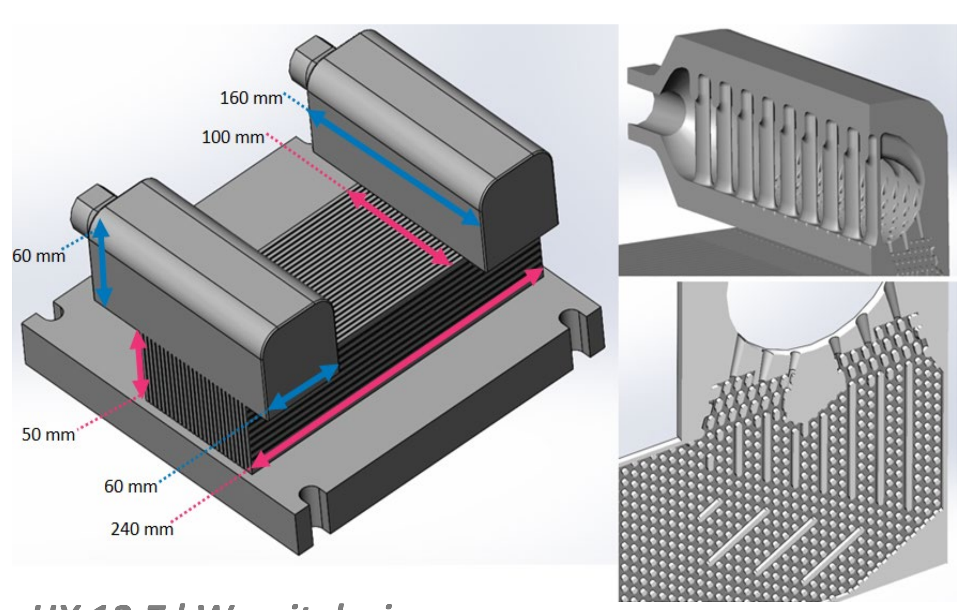
- Calibrating machine parameters to produce fully dense components
- Adjusting design to achieve dimensional tolerance of fine features
- Demonstrating the mechanical and corrosion performance of AM H230 is comparable to wrought H230



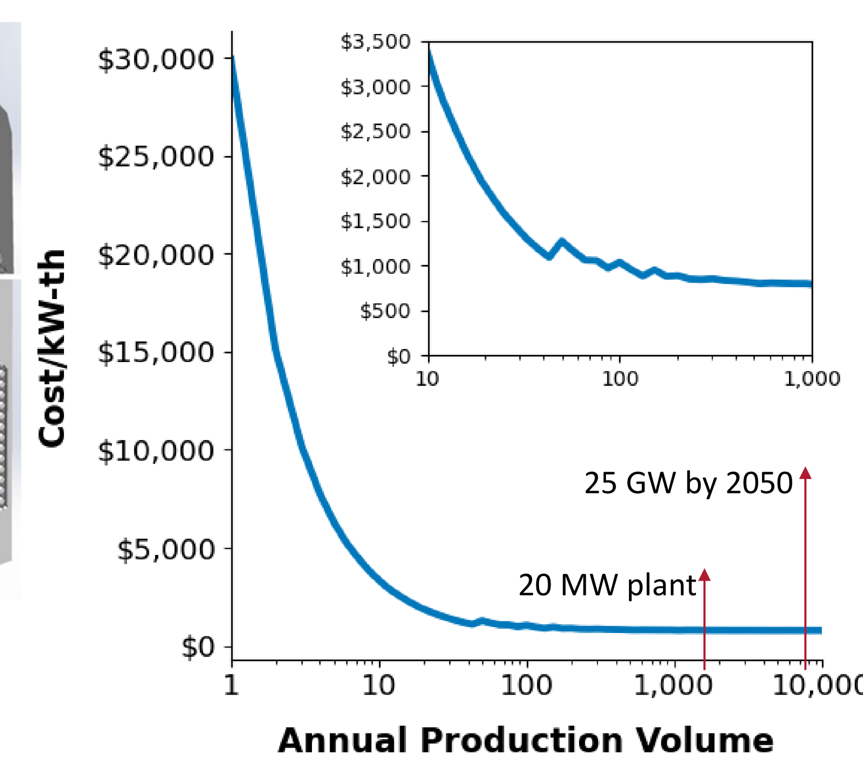




INITIAL MODULAR HX DESIGN & COST

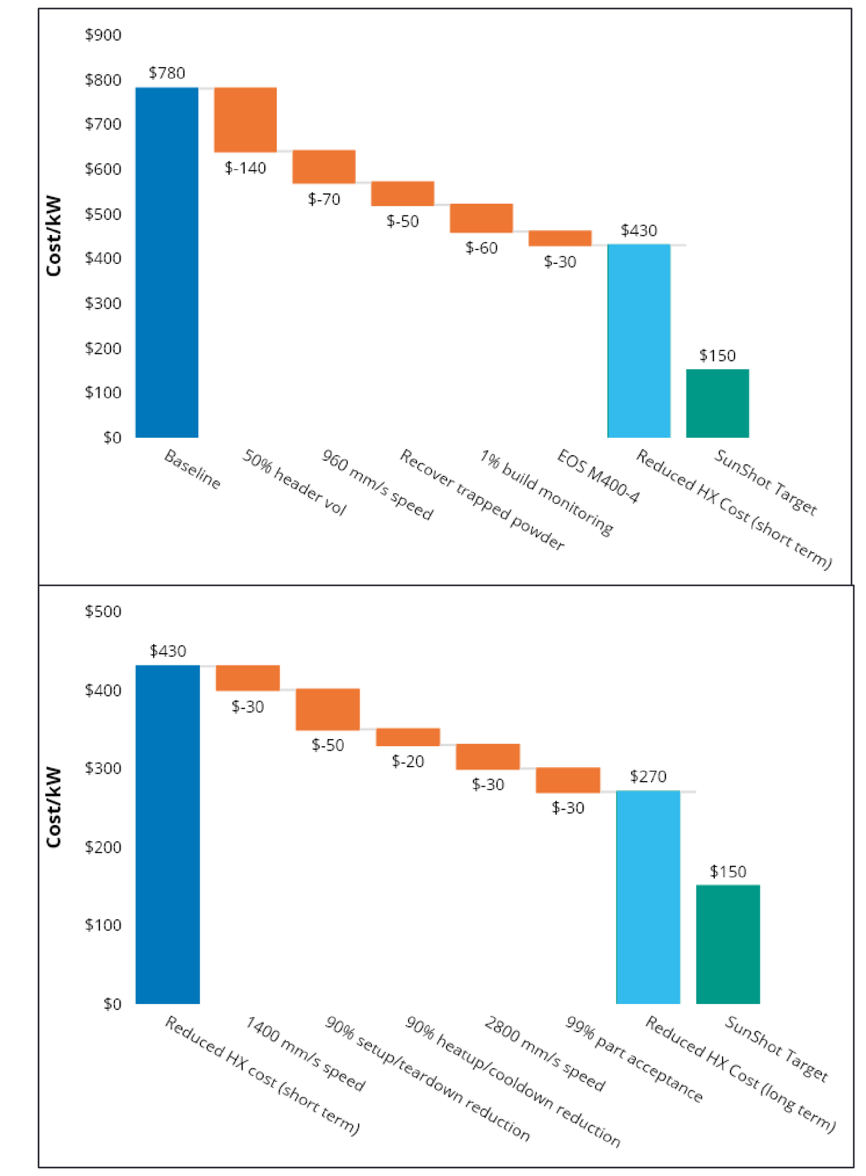


HX 12.7 kW unit design
Credit: V. Narayanan & E. Rasouli, University of California Davis

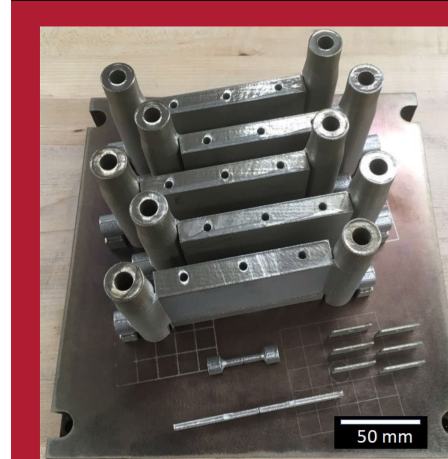


COST REDUCTION PATHWAYS

Process Based Cost Modeling (PBCM) evaluates production-scale costs to manufacture parts. The initial HX design cost was high so cost reduction pathways were modeled to determine if AM cost reduction would be possible. **Design and manufacturing process optimization could reduce HX cost from \$780/kW to \$430/kW. Innovations in AM machines could further reduce HX cost from \$430/kW to \$270/kW.** Recently, a new machine was announced by SLM that will enable many of these cost reductions to be realized.



CONCLUSIONS



- **Established parameters to print fully dense H230 using AM**
- **Demonstrated good high temperature mechanical performance and corrosion resistance in printed H230**
- **Successfully printed prototype HX**
- **Showed design and process optimization with near term AM technology upgrades can lower AM HX cost.**

Future Work

- Switch to more creep resistant Haynes 282 for design flexibility
- Optimize cost – performance tradeoff

ACKNOWLEDGEMENTS

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