Tube Geometry Optimization for Concentrating Solar Power Heat Exchangers

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Abstract (in 12 Pt Arial Font)

Solid-particle based concentrating solar power (CSP) systems require efficient heat exchangers capable of transferring heat from the falling ceramic particles at temperatures at >700oC to air/supercritical CO2 that drives the Brayton cycle. Since the heat exchange process is gravity-driven, there exist several challenges related to the nature of granular material, particle-to-wall contact, bulk flowability, and heat transfer performance. Our work focuses on the design and characterization of efficient heat exchangers for CSP by minimizing stagnant and void areas and optimizing particle flow around the heat exchanger tubes. Specifically, we used additively-manufactured coupons representing four tube geometries and a range of pitch distances to investigate the particle-to-wall interaction, bulk flow of the granular material as well as the residence time of the particles around the tubes – all of which contribute to overall heat transfer performance. We utilized Eulerian-Eulerian inhomogeneous multiphase flow modeling approach and particle image velocimetry (PIV) using a high-speed camera to experimentally analyze the velocity fields in the packed bed and correlate with the heat exchanger performance, both numerically and experimentally. Our results demonstrate an optimal pitch distance around 6 mm for circular tubes – achieving an average near-wall velocity around 7 mm/s. The analysis of different geometries showed similar near-wall velocities but highlighted the advantage of an airfoil tube geometry which eliminated stagnant zones (present in circular tubes) and minimized void areas (present in circular, square and hexagonal tubes). This work demonstrates the potential to increase heat transfer coefficients by optimizing particle-tube interaction and achieving higher particle refresh rate, which could improve the performance of shell-and-tube heat exchangers for CSP and other applications.

Biography of Presenter (in 12 Pt Ariel Font)

Julio Jair Izquierdo is currently a PhD candidate in mechanical engineering and is a member of the Pyro-Electric Research Lab (PERL). His research focuses on the modeling and testing a variety of 3D printed geometries for the improvement of high temperature heat exchangers in solar power plants. As a graduate student, he was selected by the committee of mechanical engineering professors as the first awardee of the Ed Toutant fellowship in 2022. He currently works as a manufacturing engineer for an aerospace company where he fabricates carbon-nan-tube-based sensors for the US air force. In his free time, he enjoys SCUBA diving and photography.