ME – PhD Thesis Defense

Hybrid Model for Micro Channel Heat Exchangers used in a sCO$_2$ Brayton Cycle

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Meeting link: Click here to join the meeting **(Microsoft Teams)**

ABSTRACT

Supercritical carbon dioxide (sCO$_2$) Brayton cycle power plants are being extensively explored as viable alternatives to conventional steam Rankine power plants. Higher temperatures at the turbine exit in a sCO$_2$ cycle provide better opportunities for heat recuperation, resulting in significant improvement in cycle efficiencies. Studies have shown that Micro Channel Heat Exchangers (MCHEs) or commonly referred to as printed circuit heat exchangers (PCHEs) are suitable candidates for a recuperator and gas cooler used in sCO$_2$ power blocks. Both CFD and 1-d models based on unit-cell approaches have been proposed in the literature for modeling and performance analysis of MCHEs. To estimate the heat exchanger size or to arrive and at an optimum channel configuration, CFD models are found to be computationally expensive, and time-consuming, especially when full-scale MCHEs are to be modelled. On the other hand, unit-cell-based 1-d models are inadequate for correctly estimating the stack size. The thesis addresses this gap by proposing a hybrid model. The hybrid model utilizes the concept of Thermal Resistance Network (TRN) combined with a unit cell-based CFD model to investigate the thermo-hydraulic performance of the complete MCHE stack. CFD-based unit-cell models are developed for straight and non-straight channels to obtain correlations for Nusselt number and pressure drop. A stack optimization strategy based on the rate of heat loss from the external surfaces of the MCHE core is proposed to arrive at the optimum stack volume of MCHE. In addition, a comprehensive model for the inlet and exit manifolds utilizing the concept of flow resistances is developed to attain optimum pressure drop across the entry and exit manifolds. The manifold optimization algorithm facilitates uniform flow distribution across all channels in the MCHE core. The efficacy of the hybrid model is presented for a recuperator and a gas cooler-based MCHE used in an MW scale sCO$_2$ Bryton power block. The TRN model coupled with the CFD model and stack optimization routine is used to arrive at the optimum stack volume for the straight channel-based recuperator with a 5˚C pinch temperature differential. The improvement over the straight channel is demonstrated by using innovative configurations such as sinusoidal and zigzag flow paths. Variations in channel pressure drop obtained from the optimized stack and channel dimensions are used in the manifold model as constraining variables to obtain uniform pressure drop across all channels in the stack. Subsequently, the hybrid model is extended to model the gas cooler performance with water as the secondary heat transfer fluid. The effect of Reynolds numbers (both sCO$_2$ and water) on stack size and performance is demonstrated for a temperature pinch of 3˚C at the cold inlet. Unlike the recuperator where the mass flow rates across the hot and cold sides are identical, the water flow rate and the corresponding Reynolds number in the case of a gas cooler are dictated by the sCO$_2$ side of the gas cooler. The procedure is extended to double and quadruple banking configurations to investigate the impact of plate arrangements on the gas cooler performance and stack volume. Finally, multi-objective optimization studies are performed to arrive at an optimized banking configuration for the gas cooler.

ABOUT THE SPEAKER

Vivek Pandey is a Direct Ph.D. student enrolled in the Department of Mechanical Engineering, IISc Bangalore. His research interests include applied heat transfer, thermal system design, novel power cycles, and mechanisms for heat transfer enhancement.