Thermal Hydraulic & Structural Testing and modeling of Compact diffusion-bonded heat exchangers for Supercritical CO_2 Brayton Cycles

PI: Devesh Ranjan, Georgia Institute of Technology

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Collaborators: Mark Anderson (UW-Madison); James Sienicki, Argonne National Laboratory (ANL); Matthew Carlson, Sandia National Laboratories (SNL)

ABSTRACT:
The importance of improved efficiency and reduced capital cost has led to the renewed efforts in studying advanced Brayton cycles for high temperature energy conversion. The use of compact diffusion bonded heat exchangers combined with the small turbomachinery results in a compact footprint which can also be useful is applications such as marine propulsion. Although the diffusion bonded heat exchangers are attractive, there are concerns regarding their thermal and mechanical behavior when subjected to severe transient scenarios which are relevant to the nuclear power plants. The primary focus of this research proposal would be on validating and verifying the structural integrity of continuous channel –type PCHEs such as the Heatric zig/zag or Marbond (otherwise known as Shimtec) continuous micro-channel heat exchanger opposed to fin-type geometries. The proposed research utilizes experimental and numerical framework to provide the technical basis for the development of ASME BPVC Section III, Division 5 Code Case for the proposed diffusion bonded heat exchangers in nuclear systems. Resistance against plastic collapse, creep, and fatigue will have to be validated and guaranteed with respect to the ASME Boiler and Pressure Vessel Code (BPVC). The Plant Dynamics Calculations will be used to provide optimized compact diffusion-bonded heat exchanger designs including length, width, and depth as well as channel configurations and dimensions. It will provide time dependent boundary conditions for flowrate, temperature, and pressure for both fluid streams for operational transients and postulated accidents. Experimental pressurization and thermal stressing of PCHE sections will be used to verify the numerical modeling methods. Crack initiation and propagation through the PCHE designs will also be investigated by studying tensile test samples to understand the limitations of the diffusion bond due to possible imperfections.

Overall Project Objectives:

1) Establish operating conditions (time-dependent boundary conditions for flow rate, temperature and pressure) for PCHEs in the sCO_2 cycle for the various reactor concepts and determined loading conditions through plant dynamic modeling of the power cycle.
2) Utilize finite element analysis (FEA) framework to understand primary, secondary, and peak stresses within the proposed compact heat exchangers when subjected to anticipated transient scenarios in the nuclear power plants.
3) Evaluate the thermal-hydraulic performance of the prototypic diffusion bonded heat exchangers at design conditions relevant to the sCO_2 Brayton cycles.
4) Provide experimental data for thermal and mechanical transient loadings as well as destructive testing needed to validate the finite element analysis data.
5) Analyze the diffusion bonding parameters for Nickel super alloys
6) Training students in the areas of code case, thermal hydraulics &structural analysis in order to develop a pipeline of strong workforce for nuclear industry and national labs.