ASME Code Application of the Compact Heat Exchanger for High Temperature Nuclear Service

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Program: Advanced Reactor Components

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ABSTRACT:

The primary objectives of the proposed project are to characterize the high temperature materials properties of diffusion welded laminated structures and to develop the ASME Code methodologies for preventing failure of printed channel and hybrid compact heat exchangers (PCHE and H^2X) under sustained and cyclic pressure and thermal loading of high temperature nuclear service. The H^2X and PCHE are compact heat exchangers (CHXs) which meet the requirements of space and weight savings, high thermal effectiveness, low pressure drop and high design pressure capability. These attributes improve cost and efficiency of advanced reactors and thereby advances DOE's goal of carbon-free energy production. Currently, CHXs are covered by design rules in the ASME Code, Section VIII, Division 1, which is limited to the maximum temperature of 427°C, hence cannot be applied to the intermediate and secondary heat exchangers in Sodium Fast Reactors (SFRs) and High Temperature Gas-Cooled Reactors (HTGRs) with maximum outlet temperatures 550°C and 950°C, respectively. No detailed design strategies for the CHXs in the temperature range 550-950°C have been published. This project will perform burst and isothermal cyclic pressure experiments on diffusion bonded CHX specimens of SS316L and Alloy 617 to investigate the influence of sharp channel corners and thermal stresses on the failure modes. A set of isothermal tension, creep, fatigue and creep-fatigue tests on diffusion welded SS316L and Alloy 617 coupons will be performed to determine the elevated temperature material properties. The project will implement the recently developed elastic-perfectly plastic (EPP) analysis methodologies in accordance with the ASME Code, Section III, Division 5 for the primary load, strain limit, and creep-fatigue damage evaluation of CHXs. Full inelastic analysis will be performed to provide insight of the failure responses observed in the PCHE and H^2X experiments. The primary outcomes of the project are EPP analysis based design methodologies for failure assessment of CHXs in SFRs and HTGRs, background document for incorporating the EPP based structural design methodologies as an ASME Code case in Section III, Division 5, a set experimental data of diffusion welded SS 316H and Alloy 617 materials and CHX cores, and finally model parameters to perform full inelastic analysis for diffusion welded structures.

The project tasks will be accomplished through integrated efforts of two PhD and one undergraduate students, two university investigators and two leading ASME Code and high temperature design experts. The PhD students will perform the analysis and experiment tasks under the supervision of the university investigators and through consultation with the leading industry experts. Through performing the research tasks and interacting with industry experts, graduate and undergraduate students will be trained for the future work force of the nuclear power industry.