U.S. Department of Energy

Fundamental study of key issues related to advanced S-CO_2 Brayton Cycle: prototypic HX development and Cavitation

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Program: [Reactor Concepts: *Advanced Technologies, Development and Demonstration*]

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 supercritical carbon dioxide (s-CO_2) Brayton cycle seeks to combine the primary advantages of the ideal Brayton Cycle (single phase fluid) and the Rankine cycle (small back work ratio), by utilizing CO_2 above its critical pressure. In addition to single phase and small back work ratios, supercritical fluids offer other advantages in terms of heat transfer augmentation and low specific volume. These are realized by substantial decreases sizes of heat exchangers and turbo-machinery as compared to supercritical water or helium Brayton cycles. While this cycle is very attractive due to the high efficiency, high power density and limited reaction with sodium (i.e. making it of interest to the sodium fast Reactor (SFR) and fluoride high temperature reactor (FHR) programs), there are still areas where progress is needed to make this cycle commercially viable. These areas include commercial fabrication of diffusion bonded compact heat exchangers, development of alternate heat exchanger technology for recuperators, and resolution of issues with cavitation and fluid instabilities operating near and in the two-phase region. There is a pressing need to understand the transition of the working fluid-CO_2 near the critical point. It is expected that at some degree of pressure reduction where the pressure and temperature are within the vapor dome, homogenous nucleation will occur resulting in vapor production. In rotating machinery this can take place at the end of the turbine blades and at the entrance of the compressor resulting in cavitation phenomena. This is of serious concern with respect to operation and the materials used in designing such a flow system.

The proposed research (integrated experimental, numerical and analytical work) utilizes the existing facilities at the universities to address the key scientific and operational issues pertinent to the compact heat exchanger systems and turbo-machinery. The specific objectives are:

1. Perform fundamental study of s-CO2 cavitation near the critical point. The goal of this task will be to study the possible effects of cavitation on the turbo-machinery components due to the operation near saturation condition and possible transients resulting from vapor production and collapse in the turbine and compressor.
2. Perform heat transfer and pressure drop measurements in various compact heat exchanger designs for working fluids under different operating conditions. We will perform finite element analysis for the optimized design to understand the thermal stresses under various transient conditions. The overarching goal of this task will be develop road map (designs) for the commercially feasible diffusion bonded/brazed compact heat exchanger or competing optimized alternate heat exchanger technology for recuperators.
3. Evaluation of the alternate bonding technology applied to the optimized heat exchanger manufacturing. In this task, in addition to diffusion bonded parts, high temperature brazed systems will also be studied to determine their effectiveness for operation in s-CO_2 heat exchanger systems.