NUCLEAR ENERGY UNIVERSITY PROGRAMS

Materials, Turbomachinery and Heat Exchangers for Supercritical CO_2 Systems

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Abstract

The objective of this project is to produce the necessary data to evaluate the performance of the supercritical carbon dioxide cycle. The activities include a study of materials compatibility of various alloys at high temperatures, the heat transfer and pressure drop in compact heat exchanger units, and turbomachinery issues, primarily leakage rates through dynamic seals. This experimental work will serve as a test bed for model development and design calculations, and will help define further tests necessary to develop high-efficiency power conversion cycles for use on a variety of reactor designs, including the sodium fast reactor (SFR) and very high-temperature gas reactor (VHTR).

The research will be broken into three separate tasks. The first task deals with the analysis of materials related to the high-temperature S-CO_2 Brayton cycle. The most taxing materials issues with regard to the cycle are associated with the high temperatures in the reactor side heat exchanger and in the high-temperature turbine. The system could experience pressures as high as 20MPa and temperatures as high as 650°C. The second task deals with optimization of the heat exchangers required by the S-CO_2 cycle; the S-CO_2 flow passages in these heat exchangers are required whether the cycle is coupled with a VHTR or an SFR. At least three heat exchangers will be required: the pre-cooler before compression, the recuperator, and the heat exchanger that interfaces with the reactor coolant. Each of these heat exchangers is unique and must be optimized separately. The most challenging heat exchanger is likely the pre-cooler, as there is only about a 40°C temperature change but it operates close to the CO_2 critical point, therefore inducing substantial changes in properties. The proposed research will focus on this most challenging component. The third task examines seal leakage through various dynamic seal designs under the conditions expected in the S-CO_2 cycle, including supercritical, choked, and two-phase flow conditions.