Corrosion in Supercritical Carbon Dioxide: Materials, Environmental Purity, Surface Treatments, and Flow Issues

PI: Kumar Sridharan – University of Wisconsin, Madison

Collaborators: None

Program: GEN IV

ABSTRACT

The supercritical CO_2 Brayton cycle is gaining importance for power conversion in the Generation IV fast reactor system because of its high conversion efficiencies. When used in conjunction with a sodium fast reactor, the supercritical CO2 cycle offers additional safety advantages by eliminating potential sodium-water interactions that may occur in a steam cycle. In power conversion systems for Generation IV fast reactors, supercritical CO_2 temperatures could be in the range of 30°C to 650°C, depending on the specific component in the system. Materials corrosion primarily at high temperatures will be an important issue. Therefore, the corrosion performance limits for materials at various temperatures must be established. The proposed research will have four objectives centered on addressing corrosion issues in a high-temperature supercritical CO_2 environment:

Task 1: Evaluation of corrosion performance of candidate alloys in high-purity supercritical CO2: The following alloys will be tested: Ferritic-martensitic Steels NF616 and HCM12A, austenitic alloys Incoloy 800H and 347 stainless steel, and two advanced concept alloys, AFA (alumina forming austenitic) steel and MA754. Supercritical CO2 testing will be performed at 450°C, 550°C, and 650°C at a pressure of 20 MPa, in a test facility that is already in place at the proposing university. High purity CO2 (99.9998%) will be used for these tests.

Task 2: Investigation of the effects of CO, H_2O, and O2 impurities in supercritical CO2 on corrosion: Impurities that will inevitably present in the CO2 will play a critical role in dictating the extent of corrosion and corrosion mechanisms. These effects must be understood to identify the level of CO2 chemistry control needed to maintain sufficient levels of purity to manage corrosion. The individual effects of important impurities CO, H_2O, and O_2 will be investigated by adding them separately to high purity CO_2.

Task 3: Evaluation of surface treatments on the corrosion performance of alloys in supercritical CO_2: Surface treatments can be very beneficial in improving corrosion resistance. Shot peening and yttrium and aluminum surface treatments will be investigated. Shot peening refines the surface grain sizes and promotes protective Cr-oxide layer formation. Both yttrium and aluminum form highly stable oxide layers (Y_2O_3 and Al_2O_3), which can get incorporated in the growing Fe-oxide layer to form an impervious complex oxide to enhance corrosion resistance.

Task 4: Study of flow-assisted corrosion of select alloys in supercritical CO_2 under a selected set of test conditions: To study the effects of flow-assisted corrosion, tests will be conducted in a supercritical CO_2 flow loop. An existing facility used for supercritical water flow studies at the proposing university will be modified for use in this task. The system is capable of flow velocities up to 10 m/s and can operate at temperatures and pressures of up to 650°C and 20 MPa, respectively.

All above tasks will be performed in conjunction with detailed materials characterization and analysis using scanning electron microscopy/energy dispersive spectroscopy (SEM-EDS), x-ray diffraction (XRD), Auger electron spectroscopy (AES) techniques, and weight change measurements. Inlet and outlet gas compositions will be monitored using gas chromatography-mass spectrometry (GCMS).