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Tribological Behavior of Structural Materials in High Temperature Helium Gas-Cooled Reactor Environments

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ABSTRACT:

The next generation high temperature gas-cooled reactor (HTGR) is expected to generate electricity at higher efficiency than the present LWRs and provide by-product process heat for operating chemical plants. Due to the high operation temperature of HTGR (>750^{o}C), alloys 800H and 617 have been selected for the construction of primary circuit of HTGR. It is well-known that impurities in helium gas coolant such as H_2, H_2O, CO_2, CO, and CH_4 in HTGR can induce a variety of corrosion reactions (oxidation, carburization, and decarburization) at structural alloys' surfaces, and will profoundly influence their wear behavior. The proposed research will aim to understand, quantify, and model the elevated-temperature tribological behavior of alloys 800H and 617 in various impurity regimes of helium environment. Integral tests will be performed in prototypic HTGR helium and separate effects tests by varying the H_2O and CH_4 impurity concentrations in helium.

To mitigate wear of components in high temperature helium environment, surface treatments for alloys 800H and 617 will be investigated to: **(i)** mitigate tribological damage in HTGR environments, **(ii)** minimize sensitivity of corrosion to various impurity regimes and provide greater predictability in wear behavior, **(iii)** promote the formation of a mechanically stable oxide layer that would acquire a low-friction glaze nanostructure during the high temperature wear process, and **(iv)** impede carbon diffusion into or out from the alloys (for carburizing and decarburizing environments, respectively). Examples of surface treatments include NiCrAlY and Nitronic^{TM} coatings, and shot peening.

Characterization of the wear track to understand wear mechanisms at play under various test conditions of load, sliding velocity, temperature, and environmental impurity concentration with be performed using a suite of characterization techniques, including scanning electron microscopy (SEM) in conjunction with energy dispersive spectroscopy (EDS), x-ray diffraction (XRD), transmission electron microscopy (TEM), Auger electron spectroscopy (AES), and x-ray photoelectron spectroscopy (XPS). The wear track dimensions will be quantified using atomic force microscope (AFM) and high resolution profilometry coupled with a number of state-of-the-art image analysis techniques. To gain a fundamental understanding of the macro wear processes, we will incorporate recent advances in micro- and nano-tribology by using a combination of nanoindentation and atomic force microscopy (AFM). Models for predicting wear damage will be developed based on experimental data, operating wear mechanisms, and theory and will also include data from more fundamental micro- and nano-tribology studies.