Improved Accident Tolerance of Austenitic Steel Cladding through Colossal Supersaturation with Interstitial Solutes

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Program: Advanced Fuels

ABSTRACT

We propose a *program-supporting* research project that addresses the area of *fuel-cycle R&D*, and in particular the topic of advanced fuels. Our goal is to significantly improve nuclear fuel claddings with regard to their performance, safety, service life, and accident tolerance. The alloys that are presently used for nuclear fuel claddings suffer from degradation by corrosion and during high-temperature excursion. In a loss-of-cooling accident, this behavior may be disastrous. In addition, the alloys currently used are prone to fretting failure, which imposes a high risk of failure during the operation of nuclear power stations. To address these important problems, we propose a three-year research program to improve claddings by applying a new concept of surface engineering: “Case hardening” (generating a hard near-surface region) by *colossal supersaturation* with interstitial solutes. We intend to demonstrate that this method can be adapted for post-processing fabricated claddings to significantly enhance their mechanical properties (hardness, wear resistance, and fatigue life), their corrosion resistance, their resistance to stress–corrosion cracking (hydrogen-induced embrittlement), and – potentially – their radiation resistance (against electron-, neutron-, or ion-radiation damage). Surface engineering by colossal supersaturation, particularly surface engineering of stainless steels by low-temperature carburization, has been subject to intense research at CWRU (Case Western Reserve University) for more than a decade. In addition to well-established alloy performance benefits, this method is applied as a highly conformal post-process step to components in their final shape – without changing their dimensions – and at low cost. Therefore, we believe that we can make a very important contribution to developing better, safer, longer-lasting, and more accident-tolerant fuel claddings.

To accomplish this goal, a team has been formed with investigators from CWRU, UA (University of Akron), and LANL (Los Alamos National Laboratory). Researchers at CWRU will develop low-temperature carburization and nitridation gas-phase processing schemes for fuel cladding alloys and optimize the microscopic structure and composition of the alloy surface for improved performance, safety, service life, and accident tolerance. All three partners will then perform comparative tests on surface-engineered alloys and non-treated reference specimens to demonstrate performance improvements that have been accomplished. Researchers at CWRU will test the mechanical behavior, partners at UA will investigate the corrosion resistance, resistance to stress–corrosion cracking, and resistance against high-temperature steam exposure, and researchers at LANL will perform experiments to investigate potential improvements of radiation resistance. Considering previous work, improvements in mechanical properties and corrosion resistance are almost certain. Improvements in resistance against high-temperature steam and radiation seem possible / likely – based on how the treatment impacts the microscopic structure of alloys – and may provide further technological advantages over conventional cladding materials.