Development and Evaluation of Cold Spray Chromium Coatings for Accident-Tolerant Zirconium-alloy Cladding

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In response to the Fukushima-Daiichi accident in 2011, efforts are underway to develop accident tolerant fuel (ATF) fuel cladding that would be significantly more oxidation-resistant than the bare zirconium-alloy. As a near-term solution, protective coatings of oxidation-resistant materials for the outer surface of current zirconium-alloy cladding are being actively developed. The coated cladding designs seek high temperature oxidation resistance to mitigate hydrogen generation and increase coping times for compensatory actions under Design Basis Accident (DBAs) and Beyond Design Basis Accident (BDBAs). While various coating materials for the zirconium-alloy substrates have been explored, chromium has been considered as the most promising with respect to excellent corrosion/oxidation resistant under normal operating conditions and oxidation resistance in high temperature accident scenarios. In this regard the cold spray process, an ambient temperature and pressure and high deposition rate process, is being investigated for manufacturing full-length Cr-coated fuel claddings. This approach is being actively pursued by Westinghouse Electric Company with much of the earlier development performed at the University of Wisconsin. In this presentation we will talk about development of the cold spray process for deposition of Cr coatings on Zr-alloys along with evaluation of the performance under prototypical LWR conditions. A variety of cold spray process parameters were investigated using multiple types of Cr feedstock powders produced by distinctly different route to achieve the desired coating microstructure and properties in a commercially cost-effective manner. The corrosion and oxidation behavior of the Cr coated Zr-alloys in a pressurized water environment and high temperature steam conditions was investigated. Inter-diffusion reaction between the Cr coatings and the zirconium-alloy substrate at elevated temperatures was experimentally investigated and an engineering solution to mitigate the inter-diffusion phenomena has been proposed and experimentally demonstrated. In-situ TEM evaluation of defect evolution during ion irradiation for the cold spray deposited Cr coatings was performed for preliminary investigation into the radiation damage tolerance of the coatings. Finally, mechanical testing for the coated claddings was conducted to evaluation wear resistance, coating adhesion strength, and the failure behavior under potential mechanical disturbance. In-reactor neutron irradiation of the coated cladding is presently in progress.