Effect of Shot-Peening on Oxidation Behavior of Nuclear Light Water Reactor Fuel Cladding Material to Improve Accident Stability

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One of the largest barriers preventing the widespread proliferation of nuclear technology as a source of renewable energy to combat climate change is public concerns over nuclear reactor safety. Zirconium alloy is commonly used as material for fuel cladding, an important component of nuclear reactors for preventing radioactive material release, for its favorable properties under standard operating conditions. However, when exposed to high-temperature environments, zirconium readily oxidizes and forms cracks in cladding, accelerating the reactor towards breakdown and exposing radioactive material. This report investigates the efficacy of shot-peening, a technique used to strengthen a material's mechanical properties, in enhancing high-temperature oxidation resistance of Zircaloy-4 fuel cladding material. Zircaloy-4 samples were subjected to an oxidation test at 650 °C, yielding mass gain and oxide layer thickness measurements characterizing oxidation behavior. These data, in conjunction with scanning electron microscopy (SEM) imaging, energy-dispersive X-ray spectroscopy analysis, and surface roughness data from Zygo surface profilometry analysis, reveal that shot-peening is an ineffective solution for reducing Zircaloy-4 oxidation, directly contradicting previous literature. These findings indicate that surface roughness is the primary factor governing Zircaloy-4 oxidation behavior. This valuable insight will enable the development of advanced fuel cladding technology with improved accident tolerance and stability, increasing coping time for mitigation of complications if an accident were to occur.

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