Novel Fabrication Route for Oxide Dispersion Strengthened (ODS) Steel Cladding Tubes using Cold Spray Technology

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ABSTRACT

Oxide dispersion strengthened (ODS) steels are being actively considered as candidate materials for fuel claddings in advanced nuclear reactor concepts due to their high temperature creep strength and irradiation damage resistance. The microstructure of ODS steels consists of fine grains with a high number density and uniform dispersion of yttrium/titanium-oxide nanoparticles in the ferritic steel matrix. The current manufacturing approach for ODS steel claddings involves powder consolidation followed by multiple extrusion and annealing steps. This conventional manufacturing route is time consuming and not conducive to large scale manufacturing and can also lead to anisotropy in the microstructure and properties. We report here the results of our research on investigating the cold spray process as an alternative manufacturing route for the rapid, cost-effective manufacturing of the ODS steel cladding tubes. In the cold spray process, powders of the depositing material (ODS powders in the present case) are propelled at supersonic velocities onto the surface of a substrate by a pre-heated, pressurized gas stream to form a coating or a deposit on the surface of a substrate. The particle temperature is low and the deposition occurs in solid state, which is ideally suited for the manufacturing of ODS components as any melting will lead to the upward stratification of the oxide nanoparticles. ODS steel cladding tubes up to 200 mm in length have been manufactured at the University of Wisconsin-Madison (UW) using a 14YWT gas atomized powder. The powders were sprayed onto a rotating aluminum alloy mandrel and the deposit was surface polished. The Al mandrel was subsequently removed through chemical dissolution and the free-standing tube was annealed to facilitate precipitation of the nanoparticles and to enhance cladding ductility. TEM examination showed that the impact of the particles leads to the complete dissolution of yttrium and titanium, facilitating the precipitation of the fine distribution of their oxide nanoparticles during annealing. Detailed analysis of microstructural pathways and the results of an on-going investigation of the irradiation damage resistance of the cold spray manufactured ODS fuel cladding tubes bench-marked against ODS steel manufactured by conventional methods will be presented.