Radiation Tolerance of Additively Manufactured HT-9 Ferritic/Martensitic Steel

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Ferritic martensitic (FM) steels and reduced activation FM (RAFM) steels are candidate materials for high-dose applications in advanced nuclear reactor power applications due to their low swelling rates. RA/FM steels are known to degrade in these high dose applications due to irradiation hardening, helium embrittlement, and swelling. The use of additive manufacturing, including directed energy deposition (DED) techniques, is a potential pathway for rapid production of complex nuclear components made based on RA/FM materials. However, it is unknown if the commonly identified degradation modes in irradiated RA/FM steels that have been traditionally processed will also be observed in RA/FM steels produced using DED techniques. Here, an FM steel, HT-9, was produced using powder-blown laser DED at Oak Ridge National Laboratory's Manufacturing Demonstration Facility (MDF). Variants in the as-printed and normalized and tempered state were irradiated at the Michigan Ion Beam Laboratory (MIBL) to a total damage dose of 50 displacements per atom (dpa) at 460°C at 600 nm from the surface using 5 MeV Fe^{++} ions in the defocused ion beam mode with a damage rate of 5.8 x 10^{-4} dpa/s. Scanning transmission electron microscopy coupled with energy dispersive X-ray spectroscopy (S/TEM-EDS) spectrum imaging and 2-beam TEM imaging was completed to investigate the radiation-induced/enhanced microstructure features. Results showed instability of pre-existing Nb-rich MX precipitates coupled with the formation of Ni-Si rich clusters that formed both in δ-Ferrite grains and martensitic laths. Precipitate evolution is complemented with dislocation loop formation but limited to no cavity-induced swelling. The quantitative comparison between these initial findings and on conventionally processed HT-9 alloys irradiated to similar conditions will be discussed.

This work was supported by the U.S. Department of Energy, Office of Nuclear Energy under DOE Idaho Operations Office Contract DE-AC07- 051D14517 as part of a Nuclear Science User Facilities experiment.