Recent progress in testing and qualification of PM-HIP nuclear structural alloys

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The objective of this talk is to describe the state of the research on the testing and qualification of alloys produced by powder metallurgy with hot isostatic pressing (PM-HIP) for nuclear components. PM-HIP processing has attracted interest from the nuclear industry because this method enables complex components to be produced with microstructural uniformity and near-net shape, which simplifies inspection and reduces the need for machining and welding. However, PM-HIP materials must exhibit comparable or better thermal and irradiation stability as conventionally fabricated (i.e. cast, forged) materials. The team is currently in the middle of a multi-year project to evaluate these direct comparisons between PM-HIP and cast/forged material performance in high temperature, high stress, and high irradiation environments. This talk will provide an overview of results to date, and future directions to culminate in qualification of PM-HIP materials for nuclear applications.

We will primarily focus on the comparative performance of PM-HIP to cast/forged nuclear structural alloys 316L stainless steel, Ni-base alloys 625 and 690, and low-alloy steel SA508. First, grain-scale deformation mechanics are studied by synchrotron x-ray diffraction with *in situ* room temperature tensile testing of the 316L and 625. The PM-HIP versions of both alloys exhibit more homogeneous grain-level stress distributions than the wrought versions of the alloys. Electron backscatter diffraction (EBSD) suggests that lower ellipticities of PM-HIP grains promotes a more homogeneous stress distribution. This understanding is extended to develop structure-property relationships after 100-10,000 hour thermal aging and ion irradiation. PM-HIP 625 and 690 appear to withstand thermal aging better than the wrought versions of these alloys, especially at aging temperatures of 800°C. Both PM-HIP and wrought 625 exhibit comparable dislocation loop morphologies following Ni self-ion irradiation at 450°C to doses of 100 and 200 displacements per atom (dpa). However, more irradiation-induced voids are observed in PM-HIP 625 than in wrought 625. This talk will conclude with the status of an ongoing PM-HIP neutron irradiation campaign.