Phase II: Microstructure considerations in creep and creep-fatigue interaction of additively-manufactured 316H stainless steel: mechanisms and modeling

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Program: Fiscal Year 2025 Phase II Continuation

ABSTRACT:

Phase I confirms the initial microstructure of additively-manufactured (AM) 316H stainless steel (SS) serves as the root cause responsible for its shorter creep and creep fatigue (CF) life as compared to wrought 316H SS. Building upon the success in Phase I, we propose to deep the mechanistic understanding of the CF interaction dominated by the characteristic microstructures created by laser direct energy deposition (DED) AM, and develop the microstructure-based creep model and CF interaction model for life assessment. In parallel, we will expand the existing creep and CF dataset by evaluating steel chemistry effects to support EPRI's ASME code effort and specification development.

Our approach is to (1) use the interrupted creep and CF experiments and advanced characterization tools to reveal the microstructure-dominated mechanisms for the time-dependent deformation and damage accumulation, (2) develop the microstructure-based creep model for DED AM 316H SS, (3) incorporate the microstructure creep-based model into the CF interaction model that was developed in Phase I, (4) generate longer-term creep-rupture data (lower stress) and CF data (longer hold time) for model validation, (5) systematically study the effects of alloy chemistry on creep using combinatorial alloy synthesis. A robust understanding of the processing-structure-property relationship and accurate prediction model are both necessary for reliable AM qualification. The assessment of steel chemistry sensitivity is needed for nuclear AM material guideline. We believe the proposed plan will not only contribute to the mechanistic understandings, but also support the code and regulatory approval.