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Multiscale Study of Creep Ductility Prediction of Additively Manufactured 316H Stainless Steel

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ABSTRACT:

The objective of this project is to achieve a comprehensive mechanistic understanding of creep damage behavior of Additive Manufactured (AM) 316H stainless steel (SS) and to develop a multiscale modeling approach to accurately predict its creep ductility. 316H SS is being considered for advanced reactors which operate at elevated temperatures. The AM 316H SS has demonstrated a good combination of tensile strength and ductility at room temperature. However, it was found to have much lower creep ductility compared to conventionally manufactured samples without aggressive heat treatment such as solution annealing. Additionally, the AM samples exhibit substantial variation in secondary creep rate and creep ductility when printing and post-build processing conditions are altered. Creep ductility is critical for high-temperature applications of austenitic stainless steels, as materials with low creep ductility are more prone to forming cracks and are considered less forgiving. A fundamental understanding of creep rupture of AM 316H is essential but has not yet been fully developed to predict AM 316H creep ductility. This project aims to investigate several critical factors affecting creep ductility, including grain boundary weakening due to cavitation and precipitation, and microstructure heterogeneity, by combining advanced characterization and measurement techniques with multiscale modeling. The expected outcomes of the research include (i) uncovering creep damage mechanisms of AM 316H with constant and stress change creep testing and microstructural characterization, (ii) achieving a fundamental understanding of grain boundary weakening through micro-scale modeling, and (iii) developing an experimentally validated multiscale modeling approach to predict creep ductility. By targeting both a fundamental understanding and a predictive modeling tool, the proposed research will accelerate AM materials qualification advanced nuclear reactors applications.