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Creep and creep-fatigue crack growth mechanisms in Alloy 709

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In this proposed research, an interdisciplinary team from the Mechanical & Aerospace Engineering department of North Carolina State University in USA and the School of Metallurgy and Materials at the University of Birmingham in UK, will study creep and creep fatigue crack growth mechanisms under plane stress and plane strain conditions. While the US partner is being funded through the DOE-NEUP program, the UK partner will be funded through the Research Council UK Energy Program (RCUKEP) and CINR R&D.

The USA team will utilize a novel technique including in-situ heating - loading and Scanning Electron Microscope (SEM) imaging to study the “real-time” crack growth of alloy 709 under plane stress conditions. Crack propagation modes will be studied and compared, primarily at elevated test temperatures between 500 and 750^{0}C, with the potential to increase the test temperature up to 900^{0}C. Both creep and fatigue creep tensile and bending tests together with in-situ SEM observation will be utilized to evaluate crack initiation and growth at elevated temperatures. Some of the important features of defect nucleation and growth within the specimen (under more constrained conditions) will also be addressed by the subsequent fractographic assessments. Thus, we will combine the advantages of in-situ SEM observation to reveal the “real-time” fracture behavior and fractography to assess the failure mechanisms of Alloy 709 under various service conditions. The crack growth images received from the SEM during the entire test will be video recorded for further analysis and evaluation. TEM characterization of samples before, during and after creep and creep-fatigue testing will address local deformation behavior, dislocation analysis and damage evaluation. The research will focus on similarities and differences in the creep and creep-fatigue crack growth mechanisms between the accelerated test conditions at higher temperatures and fast reactor operating conditions at lower temperatures. The outcome of the project is expected to provide a mechanistic basis for a validated flaw evaluation procedure in support of fast reactor licensing activity. Using this validated method, we will develop a Finite Element model to predict the service life of alloy 709 under creep and creep-fatigue conditions.

Parallel to these efforts, the fatigue, dwell-fatigue, creep and creep-fatigue of larger samples under constrained conditions will be studied by our collaborator in UK. Attention will be directed towards establishing micro-mechanisms of fatigue crack growth, crack growth under dwell fatigue loading, creep and creep-fatigue crack growth at temperatures ranging from 500 to 750°C in air and in vacuum on larger samples under ‘plane strain’ conditions. Transitions in crack growth micro-mechanisms must be established across this temperature range as a function of microstructure (ageing in service), waveform (static, dwell, fatigue) and environment if extrapolation from accelerated testing regimes are to be made with confidence. Within the UK collaborating partner the team will have open access to a truly comprehensive suite of mechanical testing facilities (assembled over a generation and with a replacement cost of some £5.0M) and electron-optics facilities for characterization (assembled over the past ten years, with a recent refreshment grant of £2.0M and replacement cost of some £7.0M).