PROCEEDINGS PAPER

MECHANISTIC UNDERSTANDING BASED ON MICROSTRUCTURE CHARACTERIZATION OF 316L STAINLESS STEEL FATIGUE SPECIMENS TESTED IN EU INCEFA-SCALE PROJECT

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Abstract:

Austenitic stainless steels used in light water reactor coolant environments can be susceptible to environmentally assisted fatigue due to non-monotonic loading conditions, primarily associated with load-follow, thermal transients, or intermittent plant shutdowns and start-ups. One of the main goals of a five-year INCEFA-SCALE (INcreasing safety in NPPs by Covering gaps in Environmental Fatigue Assessment - focusing on gaps between laboratory data and component SCALE) project, kicked off in October 2020 and supported by the European Commission HORIZON2020 program, is to develop an improved mechanistic understanding behind the effect of a pressurized water reactor (PWR) primary environment on the fatigue behavior of austenitic stainless steels through coordinated extensive characterization of tested specimens at partner organizations.

Post-mortem characterization of fatigue specimens tested in air and high-temperature PWR water environments with different loading parameters was performed. In this program, the effects of a PWR environment containing hydrogen and cyclic loading parameters on the low cycle fatigue (LCF) behavior of 316L stainless steel were investigated by comprehensive striation spacing evaluation and microscopic characterizations. The exposure to a PWR environment results in a decreased LCF lifetime, an enhanced fatigue crack initiation and an accelerated fatigue crack growth rate of 316L austenitic stainless steel. The interaction of hydrogen and localized deformation contributes to the accelerated fatigue crack growth rate in a PWR environment. The effect of waveform (periodic underload PUL, periodic overload POL and constant amplitude sawtooth CA) was evaluated. PUL and POL reduce the low cycle fatigue lifetime, accelerate the fatigue crack growth rate and advance the cycle where initiation of fatigue crack occurs compared to CA loading. LCF waveform strongly influences the shear band formation, localization of plastic deformation and stress state.

Keywords: environmentally assisted fatigue, stainless steel, pressurized water reactor, hydrogen, electron microscopy

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