Evolution of Nonlinear Acoustics during Creep in ASME Grade 91 Steel Welded Joint

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ASME Grade 91 (9Cr-1Mo-MnVNb) has been used for boiler components in ultra-supercritical (USC) thermal power plants at approximately 873 K. The creep life of the welded joints in this steel decreased as a result of Type IV creep damage that forms in the heat-affected zone (HAZ) under long-term use at high temperatures [1]. In this study, we investigated the relationship between microstructural change and the evolutions of two nonlinear acoustic characterizations with electromagnetic acoustic resonance (EMAR) [2] throughout the creep life in the welded joints and the correlation between two nonlinear acoustic characterizations. One was resonant frequency shift [3] and other three-wave mixing [4, 5]. EMAR was a combination of the resonant acoustic technique with a non-contact electromagnetic acoustic transducer (EMAT) [2]. We used a bulk-wave EMAT, which transmits and receives shear wave propagating in thickness direction of a plate specimen. Creep tests of thick welded joints specimens were interrupted at several time steps at 873 K and 90 MPa. Two nonlinear acoustic parameters and ultrasonic attenuation decreased from the start to 20% of creep life. They gradually increased from 50% of creep life to rupture. We interpreted these phenomena in terms of dislocation recovery, recrystallization, and restructuring related to the initiation and growth of creep void, with support from the SEM and TEM observation. This noncontact resonance-EMAT measurement can monitor the evolution of nonlinear acoustics throughout the creep life and has a potential to assess the Type IV creep damage advance and to predict the creep life of high Cr ferritic heat resisting steels.

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References: