Influence of hydrogen charging on fatigue life of additive manufactured austenitic stainless steel AISI 304 and martensitic stainless steel AISI420

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In the framework of the green transition, hydrogen is emerging as a key alternative energy carrier for applications such as heating, chemical manufacturing, and refining. Its adoption, however, raises material-related challenges due to hydrogen embrittlement (HE), caused by the diffusion of atomic hydrogen into metallic lattices. While HE mechanisms are relatively well-established in conventionally manufactured steels, the advent of additive manufacturing (AM) introduces distinct microstructural features—such as residual stresses, anisotropy, and porosity—that may alter susceptibility to hydrogen-assisted damage.

This study examines hydrogen embrittlement in both conventionally produced and additively manufactured (laser powder bed fusion) austenitic stainless steels AISI 304 and martensitic stainless steel AISI 420. Specimens were hydrogen pre-charged using a cathodic method at a current density of 20 mA/cm^2, followed by tensile, Charpy impact toughness, and Brinell hardness tests. Fatigue performance was assessed under varying stress amplitudes, and fracture surfaces were analyzed via Scanning Electron Microscopy (SEM) to characterize crack initiation and propagation mechanisms.

Results show that AM steels possess enhanced strength and hardness compared to conventional steels, yet their fatigue life is significantly reduced after hydrogen charging. Hydrogen exposure decreases elongation and ultimate tensile strength, while impact toughness remains largely unaffected. SEM analyses confirmed hydrogen-assisted crack propagation features.

These findings highlight the dual effect of additive manufacturing: while it improves baseline mechanical performance, it also amplifies the sensitivity of stainless steels to hydrogen embrittlement. This emphasizes the need for tailored processing and mitigation strategies for AM components in hydrogen applications.