

## Stress cracking mechanism in duplex stainless steel applied in ultra-deep scenarios

Yong Hua

**Abstract** Duplex stainless steel (DSS) is extensively used in harsh environments where high strength and corrosion resistance are essential. However, failures have been observed in DSS used in ultra-deep downhole and subsea conditions, highlighting concerns about stress corrosion cracking (SCC). For internal surface corrosion, the high temperatures and elevated CO<sub>2</sub>/H<sub>2</sub>S pressures in these environments accelerate anodic dissolution reactions, degrading the passive film and initiating pitting. The presence of H<sub>2</sub>S leads to the formation of FeS<sub>2</sub> and FeS in the corrosion product layer, which causes preferential ferrite dissolution or at the phase boundaries. This preferential corrosion of the ferrite phase promotes pitting under sulfur-rich products, increasing stress concentrations at the pits and facilitating crack propagation by reducing the energy required to initiate cracks.

In subsea environments, cathodic electrochemical protection can generate large amounts of hydrogen through water reduction reactions on duplex stainless steel (DSS), resulting in hydrogen charging. Consequently, under mechanical load and additional hydrogen-induced stress, DSS, particularly coarse-grained variants, may experience significant fracture when loaded close to its yield strength. The development of hydrogen-induced strain, especially localised strain within the microstructure, is strongly linked to hydrogen-induced degradation in DSS. High hydrogen concentrations generate internal stresses and promote the formation of brittle hydrogen-rich phases, which markedly reduce ductility and fracture toughness, thus facilitating crack initiation and propagation. Additionally, elevated hydrogen levels can weaken phase boundaries, which act as rapid diffusion pathways, further compromising atomic bonding and increasing susceptibility to cracking. Hydrogen-enhanced decohesion (HEDE) is a key factor in the fracture of DSS under mechanical loads near yield strength and high hydrogen flux.

These findings enhance our understanding of DSS degradation mechanisms in ultra-deep environments and inform engineering strategies to address stress corrosion cracking (SCC) and hydrogen-induced stress cracking (HISC).

