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Electrochemical Corrosion and Mechanical Properties of Structural Materials for Oil and Gas Applications in Simulated Deep-Sea Well Environments

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Abstract : Structural materials used in today's oil and gas exploration and drilling of both onshore and offshore oil and gas wells must possess superior tensile properties, excellent resistance to corrosive degradation that includes general, localized (pitting and crevice) and environment assisted cracking such as stress corrosion cracking and hydrogen embrittlement. The High Pressure and High Temperature (HPHT) wells are typically operated at temperature and pressure that can exceed 300-3500F and 10,000psi (69MPa) respectively which necessitates the use of exotic materials in these exotic sources of natural resources. This research investigation is focussed on the evaluation of tensile properties and corrosion behavior of AISI 4140 High-Strength Low Alloy Steel (HSLA) possessing tempered martensitic microstructure and Duplex 2205 Stainless Steel (DSS) having austenitic and ferritic phase. The selection of this two alloys are primarily based on economic considerations as 4140 HSLA is cheaper when compared to DSS 2205. Due to the harsh aggressive chemical species encountered in deep oil and gas wells like chloride ions (Cl-), carbon dioxide (CO2), hydrogen sulphide (H2S) along with other mineral organic acids, DSS 2205, having a dual-phase microstructure can mitigate the degradation resulting from the presence of both chloride ions (Cl-) and hydrogen simultaneously. Tensile properties evaluation indicates a ductile failure of DSS 2205 whereas 4140 HSLA exhibit quasi-cleavage fracture due to the phenomenon of 'tempered martensitic embrittlement'. From the potentiodynamic polarization testing, it is observed that DSS 2205 has higher corrosion resistance than 4140 HSLA; the former exhibits passivity signifying resistance to localized corrosion while the latter exhibits active dissolution in all the environmental parameters space that was tested. From the Scanning Electron Microscopy (SEM) evaluation, it is understood that stable pits appear in DSS 2205 only when the temperature exceeds the critical pitting temperature (CPT). SEM observation of the corroded 4140 HSLA specimen tested in aqueous 3.5 wt.% NaCl solution reveals intergranular cracking which appears due to the adsorption and diffusion of hydrogen during polarization, thus, causing hydrogen-induced cracking/hydrogen embrittlement. General corrosion testing of DSS 2205 in acidic brine (pH~3.0) solution at ambient temperature using coupons indicate no weight loss even after three months whereas the corrosion rate of AISI 4140 HSLA is significantly higher after one month of testing.

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