Interactions of Protective Internal Corrosion Scales with Hydrate Particles in CO_2 Environments

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The development of new long subsea tiebacks will make possible the connection of new energy discoveries with offshore and onshore LNG facilities. The safe and reliable transportation of fluids through subsea networks is a key challenge for the flow assurance community, with hydrate agglomeration and wall deposition representing one of the biggest risks for production. Further, in the Australian context of large gas reservoirs with moderate to high CO_2 content, the use of low-cost carbon steel pipelines is an economic imperative; internal corrosion in aqueous CO_2 environments can threaten pipeline integrity, requiring a flow assurance solution that considers both hydrate risk management alongside an internal corrosion strategy. This work focuses on the cross-interactions between clathrate hydrates and protective iron carbonate scales. Iron carbonate layers of different morphologies and degrees of protection were formed on API X65 carbon steel in a glass reactor cell using a standard three-electrode configuration. The protectiveness of the surface films was determined in-situ using electrochemical techniques, which included open-circuit potential (OCP), linear polarization (LP) and electrochemical impedance spectroscopy (EIS) measurements. As expected, the microscopic surface film acted as a mass-transfer barrier, which reduced the corrosion rate of the carbon steel sample to various degrees depending on the pH of the electrolyte. After testing, the structure and composition of the films were characterized using surface analysis techniques, including scanning electron microscopy (SEM) coupled with energy dispersive X-Ray spectroscopy (EDS).The influence of the surface film on hydrate adhesion was subsequently investigated using a micromechanical force (MMF) apparatus, which measures the adhesion force between a cyclopentane hydrate particle and a selected solid substrate surface. The combination of methods enabled an analysis of how corrosion scale formation affects hydrate deposition tendency. Results suggest that presence of $FeCO_3$ layers may increase the risk of hydrate particle deposition at the pipeline wall; such cross-disciplinary work will be of key importance as offshore production moves towards a risk management, rather than hydrate prevention philosophy.