

Chemical and Physical Surface Controls for Gas Hydrate Adhesion

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Gas hydrates are ice-like solids, where molecular cages of water surround light hydrocarbon species at high pressure and low temperature. In conventional energy pipelines, exposure to cool seawater temperatures may lead to the rapid growth of hydrate particles and blockage of the pipeline. In the past decade, a new hydrate management strategy has emerged, where the injection of anti-agglomerant (AA) chemicals can prevent the formation of large hydrate aggregates or wall deposits. In limited case studies, AAs have been successfully deployed to generate a flowable hydrate-in-oil slurry without the formation of a blockage. In this paper, we present a comprehensive review of hydrate-wall adhesion forces, based on over ten years of experimental research using a micromechanical force (MMF) apparatus. The basic physics of hydrate adhesion is based on a capillary liquid bridge between the hydrate particle surface and pipeline wall. By injecting both ionic and nonionic surfactants, the interfacial tension of the bridge may be sufficiently weakened as to eliminate the functional deposition force. More recent investigations have focused on physical alteration to the pipeline surface roughness, which has been shown to control adhesion force. Together, the data support the use of a revised physical model to predict hydrate adhesive force in a four-phase adhesive system; we present a theoretical model for this force based on the free energy of the capillary bridge.