Hydraulic Yield Strength Measurements of CO2 Gas Hydrate

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Gas hydrate plugs and deposits pose a challenge to flow assurance in oil and gas flowlines operating in cold environments. In the event that a plug forms, rapid remediation is highly desirable to mitigate production downtime, as well as prevent excessive annealing/densification of the plug. One of the most commonly used hydrate plug remediation techniques, one-sided depressurization, can result in a potentially hazardous scenario where the differential pressure across the plug may result in its detachment from the pipe wall and subsequent acceleration down the flowline. These plug projectiles have resulted in equipment damage, personnel injuries, and fatalities. It is important to understand how plug properties and remediation speed may impact the safety of operations.

Hydrate plug remediation and risk assessment require quantitative information on the mechanical properties of the hydrate. Previous work has focused on examining how the hydrate/solid interface is impacted by system properties, aiming to establish estimates of a maximum allowable differential pressure across the plug based on the interface's shear strength. This work seeks to understand how the properties of the hydrate plug itself (annealing), as well as the rate of applied stress to the interface impact the ultimate shear strength of the system. A high-pressure hydraulic technique is used to apply stress to CO_2 gas hydrate plugs formed in-situ in pipe samples. The resulting shear strength data from the experiments is examined and compared across different levels of hydrate annealing (via water conversion percentage), as well as the rate of applied stress (via hydraulic fluid pumping rate). Two different mechanical failure mechanisms were observed for these plugs: internal cohesive failure (cracking and the establishment of a channel through the plug without detachment from the wall) and adhesive failure (detachment of the plug from the wall and subsequent ejection from the pipe). These failure mechanisms were correlated with the rate of applied stress. Higher levels of annealing were observed to correspond with a greater likelihood of encountering adhesive failure. Lastly, the overall yield strength of plugs in a cohesive failure mechanism was observed to be lower than those that underwent an adhesive failure mechanism.