Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME/CFDSC/CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

A Practical Framework for Modeling Flow in Uncertain Geometries: Application to Squeeze Cementing

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***Abstract*—Gas leakage in hydrocarbon wells often arises due to shrinkage and the formation of microannuli along the cement-casing and cement-formation interfaces. These microannuli develop from inconsistencies during primary cementing and operational challenges, ultimately compromising well integrity. Squeeze cementing is a widely used remediation technique in which a pressurized cement slurry is injected into these defects to restore zonal isolation. However, its success rate remains relatively low due to significant uncertainties in microannulus geometry, slurry behavior, and evaluation methods.

Our proposed framework builds upon the stochastic leakage model developed by Trudel and Frigaard, which predicts potential leakage pathways based on field data from British Columbia, Canada. We extend this approach by incorporating a physical model to describe the invasion of viscoplastic slurries into these pathways. A Monte Carlo method is employed to simulate the injection of yield-stress slurries into irregular microannuli, providing probabilistic predictions of squeeze cementing outcomes and highlighting the inherent variability in the process.

This study explores various operational scenarios, emphasizing the impact of slurry rheology and other key factors influencing microannulus repair. By integrating probabilistic modeling with a detailed analysis of fluid behavior, we aim to reduce uncertainties, enhance the success rate of squeeze cementing, and propose practical strategies for achieving effective zonal isolation and mitigating gas migration in hydrocarbon wells.

***Keywords-component*—Monte Carlo; Squeeze cementing; multiphase flow;**