

## Leak-Tightness-Oriented XFEM Simulation of Cryogenic Spill Thermal Shock on Pre-Cracked Concrete Outer Containments in Full-Containment LNG Tanks

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### Abstract

Liquefied natural gas (LNG) is increasingly used worldwide, driving the deployment of full-containment, above-ground LNG storage tanks. In this system, an inner metallic containment is backed by an outer reinforced/prestressed concrete wall that must remain structurally sound and leak-tight under credible accidents. This paper investigates a severe scenario in which a breach in the inner containment produces a cryogenic spill or jet that directly impinges on the inner face of the outer concrete wall. The resulting rapid cooling generates extreme transient thermal gradients and restraint-dominated strains that can reactivate pre-existing surface flaws and accelerate crack growth, potentially compromising containment performance.

A sequential thermo-mechanical-fracture simulation framework is developed in Abaqus. First, a transient heat-transfer model resolves temperature penetration under localized cryogenic exposure. The evolving temperature field is then mapped into a mechanical analysis to compute time-dependent thermal stresses. Finally, crack initiation and propagation from an assumed initial inner-surface crack are simulated using XFEM, enabling discontinuous crack growth without remeshing. Key outcomes include crack depth evolution, crack opening displacement, and identification of stress pathways governing the transition from surface cracking to through-thickness fracture. The proposed workflow supports leak-tightness-oriented performance assessment and provides a basis for evaluating mitigation measures such as insulation strategies, material selection, and reinforcement detailing.