NZG

Case Study: Quantitative & Probabilistic Risk Assessment of Well Integrity Loss in the Casing-Cement-Formation System for Reducing Methane Leaks

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Introduction

The potential for integrity loss and methane leaks through either new or legacy wells is a major risk for subsurface projects. Sustained containment of fluids and gases ensures compliance with regulations, prevents fines and prevents remediation costs. The authors will introduce an evidence-based methodology developed in collaboration with TotalEnergies, Shell, and Equinor. This methodology predicts and reduces the risk of leakages through the casing-cement-formation system. Using numerical and statistical methods, the probability of integrity loss is predicted and its key drivers are identified. This enables improvements to the well design, materials and operational loads for reducing the well's risk profile. The benefits of the approach will be illustrated through a case-study for a gas production well.

Methodology

NZG's methodology is based on two pillars: Simulations and Statistics. Simulations capture the thermo-hydro-mechanical and chemical behaviour of well sections, including casings, cement sheaths, and the surrounding formation. The simulations incorporate fully coupled thermo-poro-elasto-plasticity and account for the complex chemical reaction occurring during cement hydration. The simulations are conducted with DRISCO (Figure 1.a) a semi-analytic well integrity simulator developed in collaboration with TotalEnergies, Shell, and Equinor. The simulations span the entire lifecycle of the well (Figure 1.b), encompassing in-situ conditions, drilling, formation integrity testing, casing and cement placement, wait on cement, casing shoe tests, gas production cycles, reservoir depletion, workovers, injection/production cycles, reservoir depletion, plugging and abandonment. Throughout these stages, NZG monitors various well integrity failure mechanisms (the "failure metrics"), including fracturing, debonding, and leakage rates (Figure 1.c).

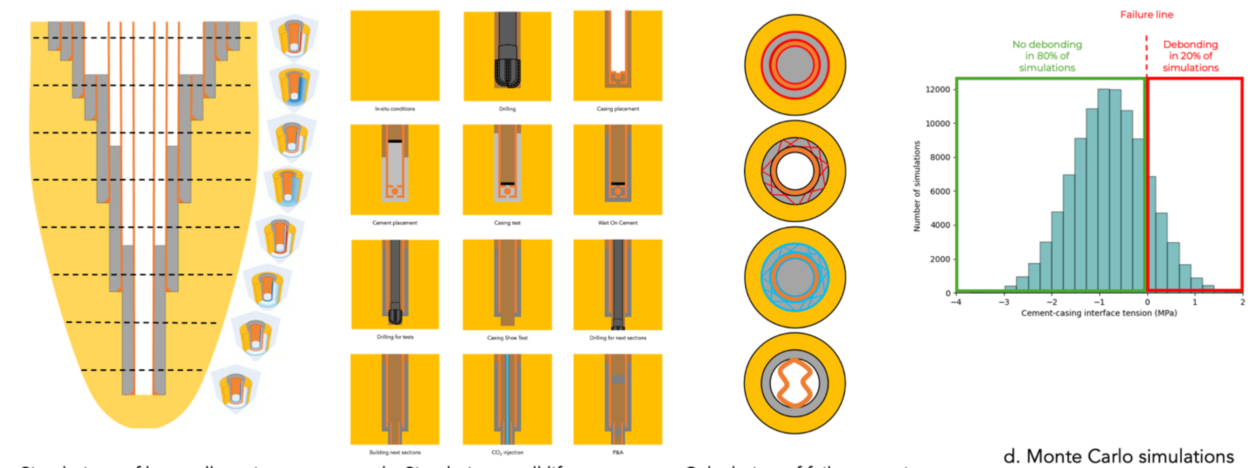
Statistics and in particular, the Monte Carlo method, enable the calculation failure probabilities. The Monte Carlo method consists in performing simulations for a multitude of possible well scenarios (Figure 1.d). A simulation is performed for each scenario, and for each simulation, the different failure metrics are computed. The probability of integrity loss corresponds to the ratio of scenarios indicating failure over the total number of scenarios.

Case-Study

NZG will present a case-study on a gas production well. For this study, 10,000 Monte Carlo simulations are performed, and probabilities of failure are computed (See Figure 5 for a summary of the results). Further, NZG will demonstrate how the probability of failure can be brought to virtually 0% by identifying the key drivers of failure, reducing uncertainty, optimizing cement compositions, well designs, well construction procedures and pressure & temperature envelopes.

	In-situ	Drilling	Cement Placement	Wait On Cement	Formation tests	Gas production
Formation shear failure	<0.01%	<0.01%	<0.01%	<0.01%	<0.01%	<0.01%
Formation tensile failure	<0.01%	<0.01%	<0.01%	<0.01%	<0.01%	20%
Cement shear failure	-	-	-	-	<0.01%	<0.01%
Casing-cement debonding	-	-	-	-	42%	54%
Formatio-cement debonding	-	-	-	-	<0.01%	<0.01%

Table 1: *Summary of probabilities of integrity loss for the gas production well under study.*



a. Simulations of key well sections b. Simulations well life stages c. Calculation of failure metrics d. Monte Carlo simulations and probabilities of failure

Figure 1: *Illustration of the simulation and statistics methodology.*