Broaching Analysis

By Mo Amer

Several clients have been asking Wild Well for an engineered assessment of broaching. Wild Well, a well control technology leader, has confirmed the application of a fracture modeling concept and technology to this well control issue, which can involve significant risks, particularly for shallow formations. Wild Well has provided this service to investigate the development, rate, and magnitude of broaching.

Introduction

As the industry-leading provider, Wild Well has been involved in preventing, intervening, and responding to well control incidents. The most catastrophic event during a drilling or workover operation is a blowout or an uncontrolled flow of formation fluids from the wellbore. Wild Well has focused its efforts to provide technology solutions that help to mitigate well control risks during the life cycle of any given well. Among those well control risks is the broaching risk. Broaching results from a venting of fluids to the surface or to the seabed through channels external to the casing.

Broaching has always been a concern to many operators while drilling, especially in shallow formations. The concern has been more focused lately on broaching during deepwater drilling operations. In the US, the Bureau of Safety and Environmental Enforcement has adopted a Well Containment Screening Tool to assess new wells' adequacy for capping and containment should a total loss of well control takes place. The geological integrity and broaching possibilities of drilled and cased formations is one of the assessment criteria to gain required permits to drill.

The goal of Wild Well's broaching analysis is to determine what geologic conditions might lead to broaching (fracturing to surface) from an underground blowout where the blowout from a deeper influx zone has broken down and is fracturing at a shallower casing seat or a shallower weaker zone. This objective is typically accomplished by building a relevant geologic model for fracture simulations and determining the "injection" rate into the zone being fractured due to outflow from the blowout zone.

The broaching simulation is an iterative process requiring several iterations to achieve an optimum solution. The iterations cover injection rate, different pore pressures, fluid loss layering, etc., to determine what geologic conditions may lead to "broaching."

The Simulator

A fully 3D finite element simulator provides a number of technology improvement over conventional geologic models. It can simulate the actual behavior of a reservoir influx, starting with influx from the reservoir, initiation of fracture, fracture geometry, fracture width, and propagation profile to the surface.

Modeling Approach

Building a Relevant Geologic Model

A relevant geologic model is the core of the broaching analysis. It is understood that several uncertainties are associated with geologic parameters of a given wellbore, especially during exploration. A practical alternative to overcome such volatility is to provide a sensitivity analysis that covers a range of values for each of the critical model parameters. The critical parameters for the model includes:

In Situ Stress/Pore Pressure

A typical pore pressure and fracture gradient are used to provide an estimate for the in situ stresses.

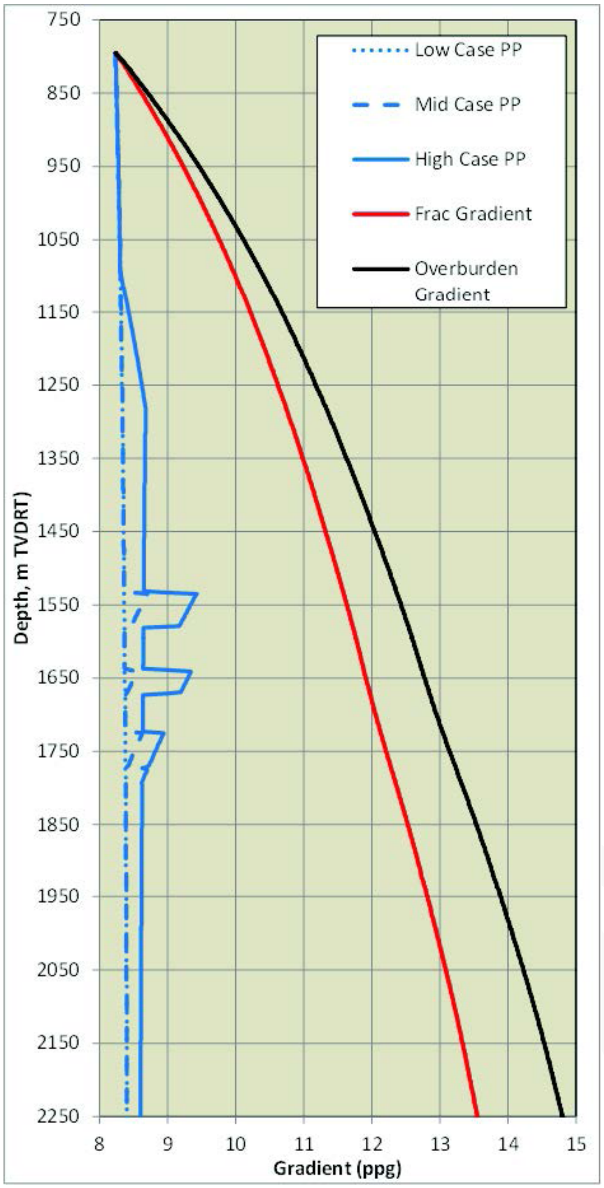

Figure 1 – In Situ Stress/Pore Pressure

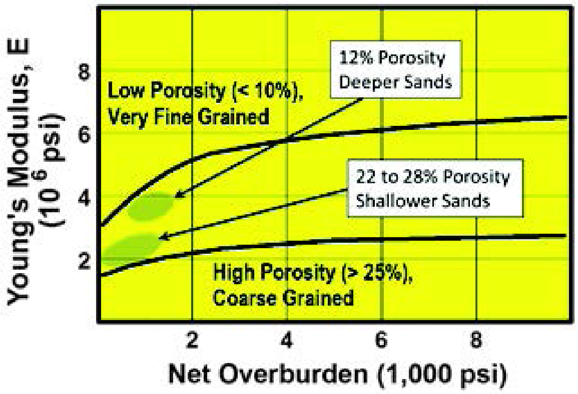

Figure 2 - Modulus

Modulus

Young's modulus provides other formation properties of significance for hydraulic fracture geometry. This property controls the relation between the pressure inside the fracture and fracture width – higher modulus goes to narrower fracture widths. Modulus for shale layers can vary widely depending on the clay percentage, the presence of calcite in the shale, etc.

This is illustrated in Figure 2. It is difficult to choose a 'most important' variable for fracturing, but modulus must certainly be considered when making such a choice. Modulus is the only fracturing variable that is subject to direct measurement based on core samples.

Fracture Toughness

Fracture toughness controls the pressure near the fracture tip required to propagate the fracture.

Formation Porosity/Permeability

A range of estimate can be used for the porosity and permeability of formations. A typical sensitivity analysis covers the range of possible values of permeability for formations.

Drainage Area

The simulations use the reservoir's target zones drainage area, with closed outer boundaries. The size of the drainage area affects the direction of fracture propagation.

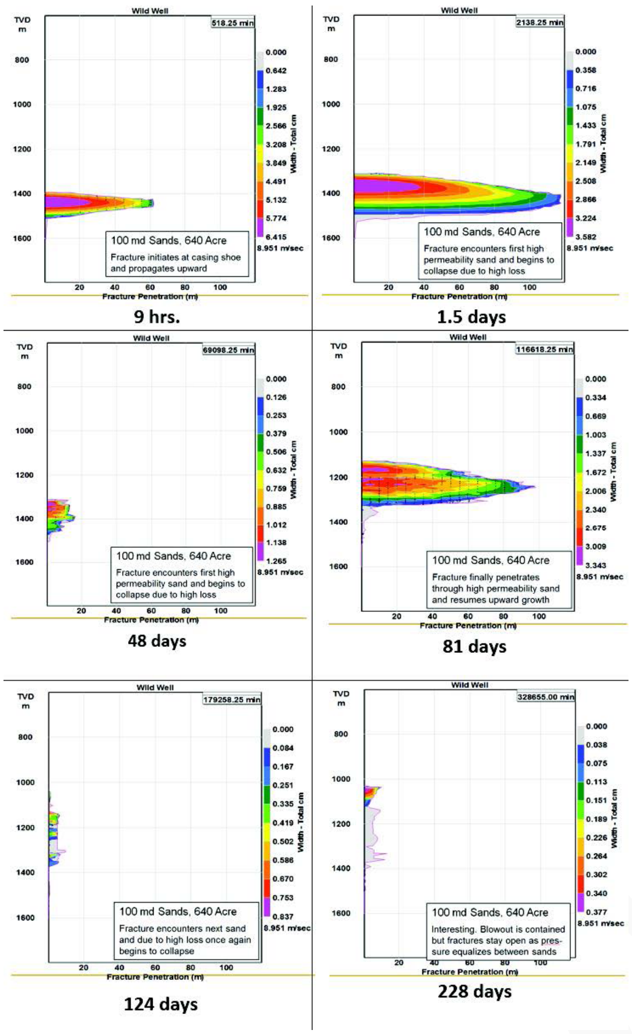

Figure 3 - Fracture Propagation for a modeled case

Vertical or Lateral Propagation of Fracture?
The simulations model the two phenomena expected to dominate the vertical propagation of the fractures:

Fluid Loss – Depending on the formation(s) permeability and the rheology of the reservoir influx; the rate of fluid loss to shallower (permeable) formations is evaluated. Based on the simulations outcome, the fracture propagation direction and time is modeled.

Reservoir Pressure Induced Stress – As the reservoir influx exits into the permeable shallower formation, an induced stress takes place as a result of the increase of the reservoir pressure in that shallow layer. This induced stress will, in turn, increase the fracture pressure for that layer.

Vertical Propagation of the Fractures – A question may be: "Why is it necessary for a sand reservoir to be charged up to the increased fracture pressure of the sand before broaching propagates upward to the adjacent shale?" The explanation here is that reaching fracture pressure may initiate small fractures in the shale. However, these fractures cannot propagate vertically until significant fractures have developed in the adjacent sand to provide the flow path and rate for vertical propagation into and through the shale.

Conclusions

Well control incidents can be mitigated by development of a risk management program that identifies, analyzes, and mitigates well control risks associated with different activities throughout the life of a well. The success of a risk management program requires a commitment of continuous implementation. Wild Well provides several services that address and mitigate several well control risks during the planning phase of a well design. Well control simulation augmented now by broaching analysis provides a useful tool for helping to manage these risks. Wild Well is introducing a new technology to address simulation and prediction of broaching, which regulators have often asked operators to conduct. The above graphics are just a quick preview of what Wild Well can provide. If there is further interest, we will be glad to arrange our engineers to visit and present technology application and benefits to your drilling and intervention operations.