Perforating Assemblies and Procedures Designed to Maximize Dynamic Underbalance to Achieve Optimum Well Productivity

The Halliburton SurgePro™ perforating-design software program can be used for a large variety of dynamic wellbore calculations. The sub models contained in the program are physics-driven and rely on measurable or estimated actual input parameters – no curve fitting or back-of-the-envelope calculations are needed.

Benefits

As a result, the SurgePro program is ideal for predicting

- Wellbore, perforation and gun pressurizations
- Wave propagation – fluid injection/production
- Perforation behavior – perforation damage
- Completion integrity – burst/collapse and packer differential

Applications

- Assess the natural surge potential of conventional gun systems
- Evaluate the effectiveness of underbalance perforating and back-surging techniques
- BHA customization to generate the desired DUB
  - Number of vents, chambers length, partial loading
- Evaluate tools that are use to mediate DUB
  - Charge selection, Pressure Isolation Device (PID), propellants
- Monitoring the effects of operational procedures on the perforating process
  - Applied pressures, opening/shutting of a valve, pumping, etc.

Accuracy – Physics-based Solution with Documented Validation

The SurgePro program is based on a proprietary analysis developed from

- API Section IV perforation flow laboratory studies
- Time-marching finite-difference modeling
- High-speed pressure measurements
- Empirical field data

Mass, momentum and energy are conserved for each time step. The solution is derived by using energy-release equations for the gun, simultaneous coupled finite-difference solutions of the Navier-Stokes equations for wellbore, perforation and fracture flow, and solid rock mechanics for perforation breakdown.

Capability to Model a Wide Range of Wellbore Conditions

To fully represent dynamic wellbore behavior, the SurgePro program takes a wide variety of factors into account

- Thermodynamic mixing and multiple compressible fluid types/phases
- Various energy sources, including perforating gun ignition and residual energy deposition (gun, well and perforation tunnel)
- Valves, pumping and orifices
- Multiple diameter effects in the well, including:
  - Surface pressurization, pumping and fluids flow-back
  - Flow into and breakdown of perforation tunnels
  - Subsequent transient return flow from perforations
Dynamic underbalance is created with the application of a special fast-opening surge vent assembly. Note the gauge reading hydrostatic pressure in the wellbore, prior to the perforating event, following a minimum surge pressure, across the perforated interval of ± 4,000 psi at 110 milliseconds.

Identical sandstone targets (below) were perforated with the same 39-gram shaped charge at the same reservoir pressure and effective stress condition. The image on the left is perforated in a balanced condition and the one on the right is perforated ideally with 3,000 psi underbalance pressure. The difference in productivity or core flow efficiency in this case is approximately 82% by not completely cleaning up the perforation tunnel with proper underbalance pressure or differential surge flow. In cases where conventional underbalanced perforating is not applicable, it may be possible to apply the SurgePro service to create a localized dynamic underbalance pressure to overcome the perforation damage or skin factor associated with balanced or overbalanced perforating techniques, while still maintaining well control.

Halliburton's SurgePro software dynamic prediction overlay with high-speed recorded pressure response during perforating. There is clear validation of a dynamic underbalance occurring and validation of the SurgePro accuracy in stimulating dynamic vents.

This minimum surge pressure across the formation results in a dynamic underbalance 8,000 psi that can potentially improve well productivity. The high-speed gauge readings are in good agreement with the theoretical prediction from the physics-based model. Hundreds of high-speed pressure records have been collected under varying well conditions to validate the generated modeling results.

SurgePro software inhole depiction of pressure transient propagation within the wellbore

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