Validation and Application of a Next-Generation Event Event Simulator for Perforated Completions.
Presentation Overview

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Introduction

- Cased hole well completions are widely used for onshore and offshore wells.

- Casing, cement and formation must be perforated to create the critical link between production tubing and hydrocarbon reserves.

- Modern perforating operations are typically carried out using explosive shaped charges that create high-velocity jets to generate perforation tunnels.

- Perforating job design considerations
  - Perforation tunnel clean-up (Productive perforations)
  - Risk mitigation for gunshock damage (Safe Operations)
Introduction

Perforating Job-Design: Tunnel Cleanup
- Hydrodynamic process that ensues for tens of seconds after the tunnels are generated.
- Customizing the post-detonation hydrodynamics to generate a transient pressure underbalance that flushes debris and crushed-rock damage layers

Perforating Job-Design: Gun Shock Damage
- Perforating events drive very large impulse forces on the downhole components, resulting in permanent damage to production tubing, isolation packers, and electronic monitoring equipment, as well as HSE risk.
- Mitigating the risk of gunshock damage is critical to ensuring a successful and safe perforating operation.

“A physics-based, robust dynamic modeling software is critical to dynamic flow modeling and risk mitigation for Optimized Perforation Design”
Introduction: Legacy Modeling Platform

- Scientific platform capable of simulating short-time (0.5-tens of seconds) dynamic events, widely used over the last 20+ years.

- Applications include:
  - Dynamics of perforating events
  - Propellants
  - Underbalance mechanisms
  - Tunnel Clean-up
  - Shock modeling
  - Risk Mitigation
Next-Gen Dynamic Event Software

Integration of new physics and numerical algorithms
- New wellbore flow model developed and implemented
- Shock-capturing Riemann-based hydrodynamic solvers incorporated
- Improved fluid thermodynamic closure

A new graphical user interface with a modern look and feel
- Updated input forms and software controls
- Simplified user input
- Automated report generation
Benchmarking and Validation: Classical Drop Bar

- Metal bar with transient gauges is dropped into a 1,500-ft vertical wellbore. The wellbore is filled with water between 1,000 to 1,500ft.
- Legacy software does not preserve the physical wave speeds and therefore transmits information at non-physical (i.e., numerically induced) speeds.
- Accurate prediction of impact time by next-gen software
Benchmarking and Validation: Transient Gun Drop

- Operator interested in a scenario where a perforating gun is dropped after detonation (at t = 0) to the bottom of the wellbore full of fluid, impacting a sub-surface valve.

- Dynamics of this example are dominated by fluid interactions with the solid structure of the gun.

- The next-generation simulator predicts a landing approximately 10 seconds after detonation, followed by few minor impact bounces.

- The legacy software experiences a numerical instability that drives a spurious oscillation of the gun bounce that grows indefinitely.
Benchmarking and Validation: Deepwater, HPHT

- Deepwater, HPHT well with a formation pressure as high as 28,000 psi. Tight rock formation, TCP conveyed.

- Computational efficiency: Next-Gen simulator uses a larger time step, more efficient computational time.

- Instantaneous, small-time scale dynamic behavior is misrepresented by the legacy software due to spurious non-physical oscillations.
Benchmarking and Validation: Flow Optimization

- Middle East well completion, competent sandstone with a porosity of 20% and a permeability > 500mD.

- Deviated well with the perforating job run by wireline conveyance and additional blank chambers included in the bottom hole assembly to optimize cleanup.

- The underbalance magnitude from gauge data is ~2,700 psi compared to 2,500 psi (from next-gen software) and 2,200 psi (from legacy software).

- Subsequent recovery phase (critical to cleanup) indicates that the profile from the next-gen software is in excellent agreement with the gauge data.
Tubing-conveyed perforating job in a low-permeability carbonate formation.

Better prediction of peak pressure (~9,500 psi) with next-gen software is observed in comparison to the legacy software.

Reflective pressure signatures from the rathole are precisely captured with the next-generation software.
North Sea Application

Client’s objective was to evaluate a matrix of gun systems and make a selection based on performance, clean-up, risk evaluation etc.

Amount of underbalance, clean-up, skin reduction and any shock loading on completion equipment was investigated.
Job Design and Optimization: Example

- Physical insight provided by the software on dynamic events
- Pre-job planning
- Post-job analysis
Conclusions

• Results clearly demonstrate that the next-generation dynamic event simulator represents a more accurate, numerically stable, and computationally efficient software platform than the legacy code.

• The new advanced computational tool presented here is a critical component in the ongoing development of a digital perforating workflow, which is based on technology-centric solutions for optimizing perforated completions.

• These solutions are centered on the following aspects that are critical to achieving operational efficiencies and delivering expected productivity:
  - Thorough assessment of the formation and the wellbore architecture
  - Understand and mitigate the risk associated with highly energetic, perforating events
  - Efficient communication between wellbore and reservoir
  - Integrate with completion design strategies (including hydraulic fracturing and stimulation)
  - Fully automated, integrated and scalable job design workflows
Digital Perforating Workflow

- Comprehensive data analysis
- Physics-based models
- Analytics tools
- Data management
- Automation

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QUESTIONS?
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