AS SEEN IN
JULY 2018
E&P

Raising The Bar On Refracture Modeling

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In a market continuing to experience commodity price uncertainty, operators looking to boost field economics turn to refracturing as a cost-effective alternative to drilling new wells. Hundreds of horizontal wells have been refractured in unconventional basins throughout North America to re-establish reservoir connectivity, target previously under- or unstimulated zones and restore production. Despite greater understanding of fracture geometry and innovations in downhole surveillance tools and diversion techniques, refracturing results have remained inconsistent.

Refracturing has long been used effectively in vertical wells. However, the geologic complexities of unconventional formations present unique challenges, starting with candidate selection. Refracture modeling helps manage economic risks by enabling engineers to better determine what is happening downhole and more reliably predict production results before capital is deployed. Modeling enables engineers to consider multiple refracturing scenarios and examine the impact on offset wells when a nearby well is refractured.

Refracture modeling remains problematic, primarily due to reservoir depletion, which results in decreased pore pressure and in situ stress, and lateral coverage challenges. Degradable chemical diverters, mechanical isolation methods and combinations of both have been used to improve coverage and connectivity. Because chemical diverters are bullheaded from the surface, it is difficult to know exactly where they go and how they affect ensuing fluid and proppant. Even with mechanical isolation, the fluid may travel down the annulus between the casing and formation to a previously depleted zone. A clear methodology for numerically simulating refractures would improve the efficacy of refracture modeling.

Numerical simulation methodology

To address depletion and lateral coverage issues, Schlumberger developed an integrated refracturing workflow that models refracture treatments in a numerical simulator to assess performance of previously refractured wells and better predict the performance of future refractured wells. As described in SPE 187236 “Proposed Refracturing Methodology in the Haynesville Shale,” the multidisciplinary workflow combines complex hydraulic fracture models, geomechanical models and multiwell production simulation. In its first implementation, it was used to optimize the refracturing strategy for a multiwell pad in the dry gas window of the Haynesville Shale.

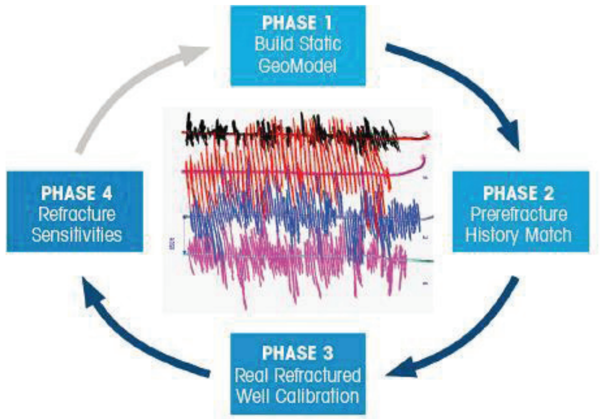

FIGURE 1. The integrated workflow simplifies multiwell pad refracturing simulation and improves accuracy of predictions. (Source: Schlumberger)

At the heart of the workflow, the refracture numerical simulation methodology accounts for historical production depletion using calculated pressure and stress values along the lateral and in the reservoir. The altered stress fields resulting from reservoir depletion are then calculated through the workflow, which combines simulated 3-D reservoir pressure with a geomechanical finite-element model to quantify changes to the magnitude and azimuth of in situ stresses. The altered stress field provides input for modeling the new fracture system created by the refracturing treatment, which is validated by production history-matching data from a previously refractured well.

Divided into four main phases, the workflow is enabled by the Petrel E&P software platform to combine multiple disciplines and facilitate workflow standardization (Figure 1). The platform incorporates the Kinetix Shale reservoir-stimulation- to-production software, integrating geophysics, geology, petrophysics, completion engineering, reservoir engineering and geomechanics to ensure data integrity. The software predicts the structure of the new fractures to enable a production forecast.

Applications in the Haynesville

The integrated refracturing workflow was applied for the first time in 2016 in the overpressured Haynesville Shale, the only dry gas play that has shown repeatable economic viability for refracturing. The overpressured nature of the play along with fracture conductivity loss and proppant damage resulting in underperformance and steep production declines make Haynesville wells ideal for refracturing to reconnect damaged fracture networks with the wellbore while attempting to stimulate new rock.

For this project, a seismic-to-simulation single-well workflow was expanded to an entire pad where four target wells and two offsets could be modeled simultaneously. First, the engineers assessed the original pore pressure and stress, building a static geomodel using petrophysical and mechanical information from a pilot hole, and treating pressures history-matched to microseismic data for an offset well. The microseismic data were used to calibrate the static model used in the simulation study.

Modeling a refracture treatment

The second phase involved fracture modeling and production history-matching the four study wells. Reservoir depletion from two offset wells also was modeled to assess its impact on the study wells. The simulated 3-D reservoir pressure and geomechanical finite-element model were coupled to model how depletion changed the magnitude and orientation of the in situ stresses (Figure 2).

The model was then validated by history-matching the post-refracturing production of a real refractured well. To account for reservoir production, depletion and corresponding stress changes before the refracture treatment, the prerefracturing production history for the refractured well and three offset wells were matched.

Finally, the validated model was applied to the original study pad using a workflow, developed around the newly calculated stress values, that assumes

- Fractures during the refracture treatment start propagating at the lowest-stress clusters first; and
- The entire wellbore can be uniformly treated.

The study modeled several sensitivities, including the ideal number of wells to refracture, treatment sequence, treatment volumes and time to refracture. Measurements from other studies show that it is challenging to obtain full wellbore treatment with chemical diverters; therefore, additional sensitivities were generated to understand the production effect of not achieving full wellbore coverage.

Conclusion

The refracturing methodology, which also is applicable to mechanical-chemical hybrid type refractures, provides a comprehensive guideline for modeling multiple refractured wells on a pad, evaluating previously refractured wells, enhancing understanding of how reservoir depletion affects fracture orientation, and optimizing a refracturing treatment design. The workflow found that the longer the well produces, the greater the magnitude and extent of depletion in the fracture area will be, resulting in a greater reduction of in situ stress and pressure.

Because the fractures are not symmetrical, their depletion effect increases the heterogeneity of the stress profile along the wellbore, significantly increasing the challenge for refracturing. Refracturing geometries may be constrained in these depleted areas, following the path of lowest stress caused by the reduction in pressure. The study also provided a calibration of expectations for refracturing the pad and optimizing the refracture designs before deploying capital. E&P

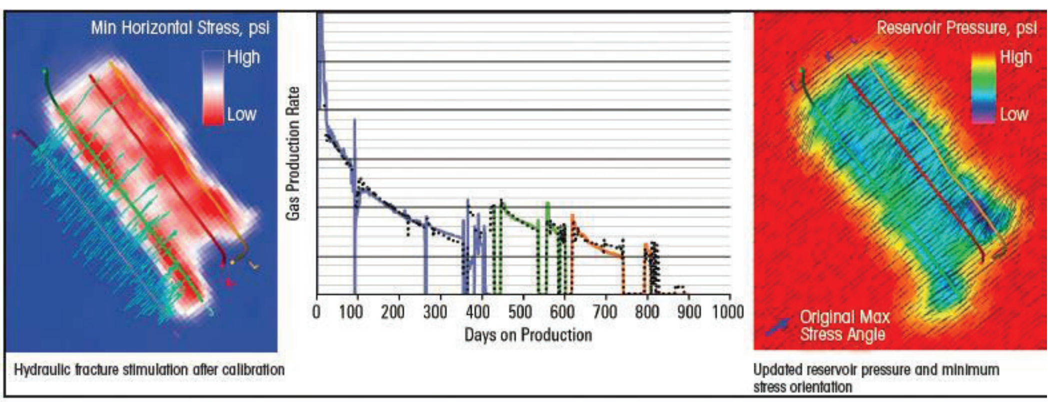

FIGURE 2. The second phase of the modeling process focused on assessing how depletion changed the in situ stress magnitude and orientation. (Source: Schlumberger)

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