TECHNOLOGY ASSESSMENT FOR

ADVANCED FRACTURING TECHOLOGY FOR TIGHT GAS: AN EAST TEXAS FIELD DEMONSTRATION

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Introduction

Improvements to fracturing technologies and practices offer the best chance of improving the performance and economics of gas wells in marginal gas plays. Water-fracs consisting of proppant pumped with un-gelled fluid is the type of stimulation used in many low permeability reservoirs in East Texas and throughout the United States. The use of low viscosity Newtonian fluids allows the creation of long narrow fractures in the reservoir, without the excessive height growth that is often seen with cross-linked fluids. Unfortunately, these low viscosity fluids have poor proppant transport properties. High injection rates can partially offset the impact of low fluid viscosities.

This DOE co-funded project conducted at the University of Texas at Austin and Anadarko Petroleum Corporation has successfully improved the performance and reduced the cost of fracture treatments by improving proppant placement and by verifying our findings in the field by acquiring and analyzing fracture treatment data from the Bossier play in East Texas.

Significant results were achieved in four primary areas. Conclusions in each area are summarized below.

Current Status of Technology

Analysis of Existing Field Data

The Bossier play was selected as the site for our work. It is located on the western flank of the East Texas Basin, an interior salt province. Although gas has been produced from the Bossier interval from the 1970's, the current play began in 1996 and gained major attention with Anadarko's aggressive 1998 drilling program. Bossier wells generally produce dry gas with little or no water production from sands embedded in the Bossier, an Upper Jurassic marine shale. Productive sands are found at depths ranging from 12,000 to 15,000 feet. The upper three sands, Taylor, Shelly, and Moore, are generally of lower reservoir quality than the Bonner. They have reported porosities in the 6 to 15% range and permeabilities in the .001 to 1 md range.

Each operator uses a different procedure for completing a Bossier well. These procedures have been developed by a trial and error method, as adequate methods do not exist to simulate the process. Anadarko has gone through an evolution of fracture stimulation treatments.

In Type I fractures, the wells were stimulated with conventional cross-linked gel and sand treatments. On an average, these wells produced 12,000 cubic feet of gas per day for each net foot of pay during the first six months on line. The traditional-style fracturing jobs cost about $250,000.

Type II treatments involved fracturing the formation by pumping water with no sand. Initially the wells produced at higher levels than those fractured by conventional fracturing methods using gels, but dropped to the same level of production after a month. These frac jobs cost only $75,000 each, thereby improving the well economics significantly.

Type III treatments involved adding proppant into the water fracs. A 20/40-mesh sand was used as the proppant for the water fracs. This led to an increase in production rates. These treatments cost about $120,000 each.

Type IV treatments are waterfracs with 40/70 sand. About 200,000 pounds of 40/70-mesh sand are being pumping as water fracs, alternating water and sand in stages. The Type IV treatments cost about $150,000 each. There has been a tremendous increase in the production rates. The long-term production is stabilizing at about 18,000 cubic feet of gas per day for each net foot of pay.

Currently Anadarko is pumping “hybrid” fracture treatments. These treatments consist of slickwater followed by a crosslinked gel pad and a crosslinked gel with 20/40 proppant.

Analysis of well test data and log data collected on several wells indicate moderate created fracture lengths (600 - 800ft) with propped lengths that are significantly (2 to 3 times) shorter, and effective fracture lengths that are even shorter (3 to 5 times) even when large amounts of proppant are placed in the formation. Our analysis conducted on different types of fracture treatments suggests that this occurs because of improper proppant placement in the fracture. Proppant settling as well as the narrow width of the fractures created with low viscosity fluids may lead to width restrictions that can result in proppant bridging along the fracture length. In addition, the use of large quantities of polymer gel can result in significant reductions in proppant-pack conductivity or excessive height growth.

Much of the rest of our work was focused on developing, data, methods and software tools for systematically designing frac treatments that achieve longer “effective” fracture lengths.

Summary of Fracture Diagnostic Work

Six wells in the Dowdy Ranch field were chosen as data wells. The data collected on these wells included a complete set of logs including dipole sonic logs, downhole temperature and pressure data during frac jobs on six frac jobs. In addition pressure buildups were run on 2 wells. Tracer logs with multiple isotopes were run on 2 wells. The fracture treatments included breakdown and mini-frac stages. Production logs were also run on 5 of the wells.

The formation was found to be a lot more heterogeneous than seen in the logs. In these wells we were able to successfully run BHP/ BHT gauges above the perfs and recover them with slickline. Since pressures and temperatures were measured with bottomhole gauges we have a great deal of confidence in the measurements.

The APC Anderson # 2 well was drilled into the York and the Bonner formations. The data set collected on the Anderson # 2 well represents the most comprehensive data set ever collected for a commercial gas well and provides an invaluable data set for analysis. A full suite of logs was run across the zones of interest. The entire interval was cored and a complete set of core analysis is available across the sands. Stress profiles derived from dipole sonic logs across the pay zone and in the shales below were calibrated with stress tests conducted. Downhole pressure and temperature data were collected during the two frac jobs conducted. Both the frac jobs were microseismically monitored with geophones. A stress test was conducted in the York sand followed by a mini-frac, a small acid stage and a hybrid-frac. A composite bridge plug was set over the York. The Bonner sand was then perforated and a mini-frac conducted. Following a small acid stage the main hybrid-frac was conducted in the Bonner. This treatment was also monitored with microseismic tools. The composite bridge plug was drilled out and both the York and the Bonner were flowed back.

The orientation of the fractures is in the east/west direction. Unusual events are noted when fracturing the Bonner with the frac propagating up into the shale in an unexpected manner. Results from the tracer log do not appear to be entirely consistent with the microseismic data. This, however, is not uncommon as the tracer logs only reflect the fracture geometry very close to the wellbore. The following observations can be made based on a detailed analysis of the data:

- The bottomhole treating pressures were found to be higher than expected based on the measured stress profiles.
- The high treating pressures encountered did not result in excessive fracture height growth.
- The fractures were shorter and better contained than might be expected based on the measured bottomhole pressures.
- Propped frac lengths of 250 feet were obtained from pressure buildup and production response data.
- These propped lengths for hybrid fracs are longer than the propped frac lengths obtained with Type I to IV fracs described earlier which typically show effective frac lengths of 100-150 feet.
- Microseismic data indicate created fracture lengths of 400 to 500 feet (as discussed later). Fracture models predict frac lengths of 1000 to 1200 feet (assuming a single fracture).
- Propped or effective fracture lengths derived from pressure buildup analysis and history matching production data were significantly shorter than designed frac lengths (or those predicted from frac models).
- The net pressure plots showed clear evidence of proppant bridging even at low proppant concentrations indicating that only limited fracture widths were being achieved, especially in the Bonner.
- Production logs were better diagnostic tools than spectral gamma-ray logs.
- The frac slurry heats up only 1 to 1.5 F per 1000 feet during the frac job. This implies that one must ensure that the fluid is crosslinked at the surface at surface temperature plus 10 F.
- The fluid also heats up slower than expected after the treatment. This implies that additional breaker may need to be added.

Proppant Transport and Placement in Hydraulic Fractures

As seen in the well data presented earlier, effective fracture lengths obtained in fracs pumped with slick water are much shorter than created frac lengths. Proppant transport clearly is a central issue in all these wells. To address this issue a fully three-dimensional hydraulic fracture simulator (UTFRAC-3D) was modified to include the effects of proppant transport. The proppant transport equations were solved on an adaptive finite element mesh. The settling of the proppant was modeled taking into account the following important effects:

- Retardation of the proppant flow and settling due of fracture walls,
- Change in settling velocities and rheology due to changes in proppant concentration,
- Turbulence effects due to high fluid velocities, and
- Inertial effects associated with large relative velocities between the proppant and the fluid.

Clearly, when settling is accounted for, shorter propped lengths are obtained. Using high viscosity fluids increases the distance to which proppant can be placed However, increasing the viscosity beyond an optimal viscosity can result in shorter propped fracture lengths due to wider fractures and more vertical growth of the fracture. It is clearly shown that there is an optimum rheology that achieves the maximum propped fracture length. This optimum depends very much on the stress conditions, the injection rates and the proppant concentration and size.

Narrower fractures will significantly retard settling since the proppant particle diameters are comparable to the width of the fracture. As a consequence proppant transport both along the fracture and in the vertical direction is retarded. This effect can result in some very significant changes in the placement of the proppant. It is, therefore, imperative that proppant transport models be coupled with an accurate 3-d rock mechanics model (as done in UTFRAC-3D) that provides a good estimate of the fracture width under a given set of injection conditions.

Experiments were conducted to study the effects of fracture walls, fluid rheology and high flow rates on proppant settling and retardation. The experimental data allowed us to develop correlations for proppant settling that can be used in conjunction with theoretical models to better describe the complex physics of proppant settling and convection in fractures. These correlations have been implemented in UTFRAC-3D.

The accurate model for proppant transport developed and implemented in UTFRAC-3D is an important step in being able to design fracture treatments for better proppant placement under a given set of reservoir conditions. The model has been used to improve fracture treatment designs in the Carthage field.

Water Blocking

Initial testing on Bossier core and some infill wells indicated that some of the depleted low permeability intervals might require a drawdown higher than the available reservoir pressure to initiate flow after coming into contact with water. As a result, these low permeability intervals may not currently be contributing to production. This is particularly evident in re-fraced and infill wells where the reservoir pressure is depleted. An extensive experimental and modeling program has been completed on studying the removal of water blocks during gas flowback. It is shown that in cases where the reservoir pressure is smaller than or comparable to the capillary pressure in the rock, gas well productivity can be significantly reduced for long periods of time (months). In such situations, the use of surfactants and solvents is recommended to prevent the formation of a waterblock.

Conclusions

Incorporation of proppant transport and settling in an accurate 3-d rock mechanics model has been accomplished. Utilization of this model and the work behind its development was applied with success to the Cotton Valley Sands of Carthage Field in Panola County.

Use and application of this model by industry will improve frac designs, optimize use of materials and equipment and reduce cost while assuring a higher level of success in the fracture stimulation of productive horizons.

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