ProTechnics Expert's Corner

INTERVIEWS AND DISCUSSIONS WITH INDUSTRY EXPERTS ON CURRENT STIMULATION TOPICS

COMPLETION DIAGNOSTICS AND NUMERICAL SIMULATORS PROVIDE COMMON SENSE SOLUTIONS FOR STIMULATION OPTIMIZATION

Interview with Dr. Bob Barree

ProTechnics had the great pleasure of interviewing Dr. Bob Barree concerning completion diagnostic technologies and how he values their importance to his work as a consultant.
Bob presented his SPE paper #77442 "A Practical Guide to Hydraulic Fracture Diagnostic Technologies" to the Fall 2003, West Side SPE Study Group in Houston. His presentation was one of the most salient and common sense approaches on how fracture simulation numerical models and completion diagnostics technologies compliment each other to optimize a completion program.

Q: ProTechnics
As with many subjects of debate, different definitions and understandings prevail. For this interview and our audience, would you please give us your definition of "Completion Diagnostics"

A: Dr. Barree
"Completion Diagnostics" is a broad term that covers all measurements that can be made to help define the performance of a stimulation or completion operation.
In the SPE paper (#77442) A Practical Guide to Hydraulic Fracture Diagnostic Technologies, we talked about three general classes of diagnostics: Near-well direct measurements, far-field direct measurements, and indirect measurements.
Near-well direct diagnostics include tracer surveys, temperature logs, production logs, and other tools that indicate how the frac is connected to the wellbore, which perforations took fluid or proppant, and what the near-well distribution of proppant is behind pipe, as well as where production is coming from after the frac.

Far-field "direct" measurements include microseismic, tilt, and surface inclinometer mapping to give a measure of the extent of fracture growth.

Indirect measurements include treating pressure analysis, pre-frac injection/falloff analysis, numerical fracture geometry modeling, pressure transient testing, and post-frac production analysis. All these techniques provide information about the performance of the frac treatment and its resulting impact on production, but do not provide direct measurements of the physical dimensions or placement of the frac.

To adequately "diagnose" a stimulation treatment these tools must be used in combination to understand what a frac actually accomplished compared to its design goals. Only by determining if the frac did what it was intended and performed according to the design can stimulation procedures be optimized.

Q: ProTechnics
As the principle of Barree and Associates, you work with many different operators with varying engineering challenges and project economics. How do you assess the value to your client of applying completion diagnostic technologies when building a completion strategy?

A: Dr. Barree
Without the application of completion diagnostics anyone who designs and performs fracture treatments is shooting in the dark. Unfortunately it seems that a lot of common practices grow out of perceptions and expectations more than out of real data. In most areas I work in, pre-frac injection tests are almost a requirement on every job. These tests provide information on closure stress, extension pressure, leakoff mechanisms, height containment, pore pressure, and reservoir deliverability. Without these data it is virtually impossible to optimize a fracture design or arrive at a realistic expectation of post-job well performance.

Similarly, tracer surveys, production logs, and other direct measurements are necessary to evaluate multi-zone fracs and jobs where height containment is questionable. In many cases perforation breakdown efficiency (or lack thereof) can overwhelm rock property and stress variations and control which zones are actually stimulated. This leads to the need for an integrated application of diagnostic tools. One measurement or type of tool cannot provide all the information needed to diagnose a treatment. Tools must be selected and used to answer specific questions pertinent to each case.

Q: ProTechnics
As the architect of GOHFER 3D fracture simulator, you have great insights and recognition as to the power and utility of these numerical simulators, as well as to their limitations. Would you share some of these insights and limitations with us?

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Core Lab RESERVOIR OPTIMIZATION

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A: Dr. Barree

Again, this topic was discussed in the paper, but should be reiterated here. In numerical modeling, as in most fields, the concept of "garbage in – garbage out" is alive and well. Numerical simulators do a great job of integrating complex physical processes but they cannot tell us more than what we know already and input to the model. If the stress field, rock properties, pore pressure distribution, permeability and porosity distribution we input to the model are wrong, the results will be wrong, even if all the physics are correct and the numerical solution is stable. Similarly, if we tell the model that open perforations exist in a particular place, and they really are not open or do not break-down, the model will be wrong. I don't know how to make a simulator (even a GOHFER) crawl down the hole to see which perforations are open. Pre-frac step-rate or step-down tests can tell you how many holes are open, but not which ones or where they are located. As a result, all simulators or models are constrained by the quality of input data.

It is also easy to demonstrate that treating pressure history matches are highly non-unique, if not properly constrained by additional data. One way to demonstrate this is to look at the theoretical equation for fracture length versus treating pressure in a perfectly contained PKN fracture geometry. The relationship between fracture length and pressure is to the 0.2 or 0.25 power, which is a pretty weak coupling. A very large difference in fracture length may be difficult or impossible to discern based on treating pressures. Things are even worse when the treating pressure we observe is actually in the wellbore (or at surface) and not inside the fracture. Changing perforation and wellbore friction can overwhelm the fracture response. Also, most fracs are not perfectly contained. Any small change in height, leakoff rate, secondary fissure opening, or other factors that affect system compliance or leakoff can change the treating pressure response.

The bottom line is that simulators are valuable tools that allow evaluation of designs based on an assumed set of input conditions. Properly used they should allow engineers to arrive at a cost-effective design and should even allow optimization of job size and pumping parameters. To be able to "close the loop" and use the simulator to match or predict fracture response (including post-frac production and not just geometry and treating pressure) the model must be calibrated and constrained by outside data provided by treatment diagnostics.

Q: ProTechnics

Fracture simulation models; such as GOHFER and others, are in simple terms just numerical models based on some array of input data. What value do you place on calibrating the model through direct measurement of parameters from completion diagnostic technologies?

A: Dr. Barree

Calibration of a numerical simulator is required for the model to represent reality. Calibration can take many forms. In some cases it can mean changing input data, sometimes outside the bounds of actual measurements, to force-fit the model to the observations. In this case the model will probably never be useful as a predictive tool.

In contrast, useful calibration involves using directly measured data on pore pressure and closure stress to develop a consistent geologic and mechanical model for in-situ stress that can be used in a predictive mode. This is the approach we consistently apply with GOHFER, and the results have been consistently positive. With good digital log data and pressure falloff tests a model for in-situ stress can be formulated for a specific reservoir or part of a field. Frequently the insights developed from this exercise impact other areas outside completion and stimulation, such as drilling mud-weight, setting points for intermediate casing, identification of depleted sands, borehole stability, and additional reserve identification.

Even with a calibrated stress and rock-property model, direct measurements of fracture connection to the wellbore are necessary. Sometimes tracer logs will indicate problems with perforating or break-down strategy. Sometimes diagnostics help to confirm the theoretical stress model, or show that some input assumptions are incorrect. The direct diagnostic measurements are the only "ground truth" we have to base model calibration on.

Q: ProTechnics

Specifically; in your opinion, what are the primary reasons to employ completion diagnostics during the completion process?

A: Dr. Barree

Indirect diagnostics like pre-frac pressure falloff analysis are required to measure closure stress, pore pressure, and leakoff. Step-down tests are necessary to determine the number of holes open and the degree of other entry problems frequently lumped together as "tortuosity". In some cases tracing the pre-frac injection provides critical information about fracture height containment and fracture entry points that cannot be determined any other way. Fracture simulation, treating pressure analysis, and post-job pressure history matching help constrain the model and give a possible picture of fracture geometry. This picture cannot be confirmed as a unique result without additional diagnostics to confirm fracture height (as with tracers or down-hole inclinometers or microseimic mapping), or fracture length from microseisms or possibly surface tilt. Finally, post-frac production analysis and transient testing (also treatment diagnostics) are the only means available to assess the stimulation effectiveness and allow optimization of job size.

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Was the designed fracture length placed? Did the frac clean-up and is the conductivity as expected? Is the well performing as expected? Would a bigger or smaller job be more cost effective? Are all the target zones adequately stimulated? These questions can only be answered through applications of completion diagnostics coupled with consistent reservoir engineering and reservoir characterization. If we can't answer these questions and progressively (or iteratively) improve stimulation response, we are failing in our primary charge as stimulation treatment designers. As a "numerical modeling guy" it may be counterproductive to say that we simply cannot answer these questions through fracture modeling and history-matching alone. Completion diagnostics are required to complete the picture.

Q: ProTechnics
Would you share a real world example of how completion diagnostic technologies have helped one of your clients maximize their completion program?

A: Dr. Barree
Without mentioning a specific operator, well, or field, I can relate one specific example of a frac-pack completion. There was concern about frac growth into water below the producing zone. The concern was initially high enough that the well was completed with a circulating water-pack to avoid fracing into the water. The production results were spectacularly poor compared to offset wells. After re-evaluating the log data I concluded that it should be possible to frac-pack the zone and avoid the water. A traced pre-frac injection test was conducted to determine whether the revised log-derived stress model could actually predict the downward extent of fracture growth. This test, and the subsequent recompletion, required the operator pull the gravel-pack screen and clean-out the water-pack, re-perforate, and ultimately re-treat the well, so this was not a small undertaking.

The traced injection test confirmed the predicted fracture height and provided additional information on leakoff behavior that allowed the frac-pack to be efficiently designed. After matching the injection test with the simulator to calibrate stresses, leakoff, treating pressure, and tracer height, the job was pumped as designed by the calibrated model. The well produced water-free and exceeded expectations for post-frac rate.

Q: ProTechnics
In closing, I want to thank you for graciously allotting your time to this interview. Bob, would you please leave our audience with your assessment of where the future will be for Completion Diagnostic technologies.

A: Dr. Barree
The future of completion diagnostics must be directed toward maximizing stimulation efficiency. That requires being able to "close the loop" from treatment design to production reality. To do this we need to accurately characterize the reservoir pore pressure, stress, and permeability (as well as saturation state) through consistent application of pre-frac injection tests and transient testing, as well as core analysis (when available) and evaluation of all available petrophysical data. With the reservoir characterized, we need to apply direct near-well diagnostics to ensure that perforation placement effectively allows communication to all reserves and that frac height and geometry can be predicted. Accurate numerical simulators can then be employed to design the desired fracture geometry and proppant placement. Models capable of predicting fracture clean-up and in-situ proppant pack conductivity are available and must be employed to select the proper materials (proppants and fluids) and guide the design process toward an optimum stimulation. Finally, a range of post-frac diagnostics including radioactive tracers to confirm frac height, chemical tracers to describe fracture cleanup, and production analysis to determine long-term response to stimulation must all be employed. If the results fail to match predictions then the reason for the discrepancy must be identified and corrected for the process to move forward to stimulation optimization. Leaving out the diagnostics leaves you in a loop going nowhere.

To make this process viable, completion diagnostics must be made more accessible and we, as an industry, need to be able to justify the costs associated with diagnostics so that they become an accepted routine practice. The more consistently and frequently diagnostics are employed the faster will be the growth in our understanding of stimulation processes and our approach to optimization.

ADDITIONAL RESOURCES:

FOR MORE INFORMATION ON BARREE & ASSOCIATES GO TO WWW.BARREE.NET

FOR A COPY OF THIS MANUSCRIPT AND OTHER PAPERS ON COMPLETION DIAGNOSTICS WRITE TO WADE.HUTCHINSON@CORELAB.COM

This interview was previewed in the Spring 2004 / May issue of the ProTechnology newsletter. To download a complete version of this and other interviews, as well as other information on completion diagnostics, please visit our website at **www.corelab.com/protechnics**