ARMA Geomechanics for Unconventionals Workshop

(Final Agenda)

When: 8:30am to 5:15pm (0830-1715hrs) Saturday, June 25th 2016

Where: Westin Galleria, Houston

Key Features:

- A one-day format before the ARMA 2016 conference in Houston featuring industry experts making keynote-style presentation on critical, geomechanics-related aspects of Unconventional Developments.
- The workshop will consist of seven, one-hour (40 minutes presentation plus 20 minutes facilitated discussion) sessions.

Workshop Schedule:

Workshop Introduction (0845-0900): Marisela Sanchez-Nagel, President & Principal, OilField Geomechanics LLC

Session 1 (0900-1000hrs): "Natural Fractures, 'Pore' Pressure & Variable Formation Stresses: Linkages to Effective Gas & Oil Recovery?" by George King, PE, Distinguished Engineering Advisor, Apache Corporation

In this talk, George E. King, who has over 43 years oilfield experience including basic research on energized fracturing, production and fracturing chemicals, acidizing, asphaltenes, perforating cleanup, well integrity and completions, complex formations (North Sea chalk, San Juan coal, Alaskan and Canadian heavy/viscous oil, US tight gas, GoM Deep Water, and Niobrara shale), unconventional resources (in the Barnett Shale , Horn River Shale, Eagle Ford Shale, Fayetteville Shale, Gothic Shale) sand control, low pressure gas well operations and applications work on coiled tubing, cutoff, formation damage and well repair operations, will provide a geomechanics perspective on: a) Is shale porosity important? b) How is the crack (fracture) development in shales; c) Where is hydrocarbon stored and how does it flow?; d) 'Pore' pressure effects; e) Do all perf clusters or fracs produce?; and f) How are stresses changing along the wellbore?

Session 2 (1000-1100hrs): "Controls Affecting Hydraulic Fracturing and Torsional Stress During Plug Acquisition to Increase the Plugging Efficiency for Best Reservoir Modelling" by Munir Aldin, MetaRock Laboratories, Inc.

Within this talk, the design of a rock mechanics testing program will be presented and the integration with well logs will demonstrated to maximize the value of a geomechanics study. For Unconventional Reservoirs, there have been increasing efforts to develop an understanding of the subsurface complexity, determine the amount of hydrocarbon in place, and develop improved production techniques. One technique to demonstrate the impact of reservoir heterogeneity and anisotropy is to utilize advanced laboratory measurements providing a full understanding of static/dynamic rock mechanical properties as a function of plug orientation, which address significant geomechanics challenges and reduces uncertainties.

Incorrect rock mechanical properties due to damaged core plug can easily multiply overall well costs, influence hydraulic fracture design, drilling operations, and horizontal well landing zone, as well as field development and its economic success. However, shale plays often exhibit poor core recovery, fractured cores, and the presence of micro/macro fractures or bed parting at scale less than one 1.0" along bedding planes. While improvements in coring technologies have led to better core recovery thereby reducing the frequency and magnitude of coring problems, the difficulties in successful plug acquisition remain the same due to the presence of fractures and bed partings

Key controls affecting hydraulic fracturing and torsional stress during plug acquisition are critical factors to increase the process of plugging efficiency leading to a successful core experimental study program. Critical tools to minimize *torsional stress, the utilization of precision bits, and heavy duty milling machines with low runout will be discussed. Significant attention should also be given to optimize the core handling and plug acquisition. Best practices to validate field and laboratory data should be followed to provide the best results in reducing uncertainties, and, it is critical to take the time for a full suite of rock characterization process such as geology, mechanical properties, rock-fluid interaction and flow properties to get the best out of the available core.*

Session 3 (1100-1200hrs): "Exploiting Natural Fractures in Unconventional Reservoir Stimulation & Production: A Geomechanically Integrated Discrete Fracture Network Approach" by Dr. Paul La Pointe, Manager of Upstream Petroleum Service, Golder Associates, Inc.

Understanding the role that natural fractures play in the hydrofracturing process and post-stimulation production offers significant economic benefits through the optimization of the hydrofracturing design to reduce costs and increase production. This session will explore how natural fractures impact hydrofracturing and post-stimulation production, and illustrate workflows for acquiring data, analyzing it, and using it to optimize recovery from both a volumetric and economic perspective. The latter part of this session will illustrate, through field examples, geomechanically integrated Discrete Fracture Network (DFN) modeling approaches to select landing zones, optimize lateral and stage design, pumping rates and make more accurate production forecasts. Topics covered include:

- *Why are natural fractures of concern?*
- *What needs to be known about the natural fractures?*
- *What data should be acquired and how should it be acquired?*
- *How can this data be used to create DFN models to address key questions to optimize stimulation & production?*

Lunch (1200-1300hrs): On your own

Session 4 (1300-1400hrs): "On the Geomechanics of Natural Fractures" by Dr. Neal Nagel, Chief Engineer, OilField Geomechanics LLC

A propagating hydraulic fracture in a formation with natural fractures and weakness planes is affected by (at least): 1) all three principal stress magnitudes; 2) the anisotropy in the stress magnitudes; 3) the orientation of the stress field; 4) in-situ pressure (e.g., pressure within the natural fractures and weakness planes); 5) natural fracture and weakness plane density and connectivity; 6) natural fracture and weakness plane orientation relative to the stress field; 7) natural fracture and weakness plane mechanical properties (elastic properties such as stiffness as well as strength properties such as cohesion and friction coefficient); 8) natural fracture and weakness plane initial aperture; and 9) operational parameters during the hydraulic fracture stimulation (e.g., rate, volume, and viscosity).

This presentation will focus on the geomechanical response of naturally fractured formation during hydraulic fracturing with an emphasis on drainage area (SRV), the effect of Stress Shadows, and changes in drainage area with production. This will serve as a foundation for a discussion of frac stage and cluster spacing, well spacing, and the impact of multi-well completion schemes such as Zipper Fracs.

Session 5 (1400-1500hrs): "Practical Hydraulic Fracturing Stimulation Design Models" by Dr. Sau-Wai Wong, Principal Technical Expert on Geomechanics, Shell Oil Company

The technology of multi-stage, multi-frac horizontal wells (MFHW) is arguably the most important technology that unlocks the potential of unconventional shale gas and liquid rich shale oil systems. However, there is still a lack of understanding on how multiple hydraulic fractures would grow and develop in highly heterogeneous rock formations. It is challenging to model the development of these fractures, which are subject to the dynamic process of geomechanical stress changes induced by the fracture stimulation treatment itself, and the interaction with multiple other processes, including wellbore mechanics and fluid mechanics.

The scarcity of adequate fracture stimulation design models has not hindered the successful application of MFHW in exploiting unconventional resources. The technology is typically appraised and continuously improved in the field; however, this field optimization process is not always cost effective, and the present low oil price environment acutely points to the need for competent design models that will aid in the application design and optimization of MFHW. For practical engineering application, we aim to capture key physical processes in computation models, at least in the 'first-order'; apply 'manageable' numerical approach and rely on appropriate model calibration with field data. The talk gives *a brief overview of one such practical computation modelling approach, outlines the coupled processes that are important, and paints the vision to leverage the model and field data (e.g., injection pressures and microseismic data) to gain better understanding and improve the design of multi-fracture stimulation.*

Break (1500-1515hrs)

Session 6 (1515-1615hrs): "ReFracturing In Unconventionals" by Dr. Sid Green, Dr. William Maurer, and Dr. Ali Daneshy

Drain Hole Drilling as a Re-Work Concept (Dr. Maurer): Many thousands of tight shale wells have production that has declined substantially, and, therefore, enhancing production is at present a major consideration. Drain hole drilling is an option that can be highly cost effective to reconnect hydraulic fractures that have reduced conductivity, particularly near the wellbore. Geomechanics drain hole drilling concepts will be discussed as a low-cost re-stimulation method.

Geomechanics Issues Influencing Growth of a Mix of New and Old Fractures (Dr. Daneshy): Re-hydraulic fracturing is an important concept that offers potential for large increases in production of oil and gas from the tens of thousands of current horizontal tight shale wells. However, understanding how a new fracture will interact with the many old fractures is far from clear. Geomechanics is key to better understand the new fracture for refracturing design of horizontal tight shale wells.

Session 7A (1615-1640hrs): "A General Look at Fracture Monitoring" by Ingo M. Geldmacher, Chief Geoscientist, Weatherford

Hydraulic fracturing has become an accepted practice to achieve economic exploitation of so-called unconventional resources (e.g., the North American continental shale basins), and looking at a history of hundreds of thousands of hydraulic stimulations shows that the treatment affects are typically non-uniform (e.g., certain injection entry points are favored over others). There are a number of ways to describe the process (and progress) of a hydraulic stimulation, be it an initial frac, a re-frac, an acid job or a diverter application, and there are a multitude of approaches, prevalent in the industry, to forward model or predict the outcome of a certain treatment. While the details may be different from modeler to modeler, there is, essentially, a common 4d rendering of how the ground changes in time and space due to factors such as stress, fluid, pressures, and so on.

On the other hand, a diagnostic of what actually happens and proof or validation of these pre-job predictions has been lacking behind. The list of potential diagnostic applications is long: from [the most often applied] microseismic monitoring, to future-oriented, field-wide permanent DAS/DTS installations and the use of a number of not-so-common technologies such as noise monitoring, electromagnetic imaging, pressure monitoring (surface and others), and others. This presentation will attempt to provide a brief overview of a variety of diagnostic approaches as they are applied today and described in recent state-of-the-art publications. To illustrate some of the achievements and limitations, selected field cases will be presented.

Session 7B (1640-1705hrs): "Engineering Shale Completions Using Common Drilling Data" by Dale Logan, C&J Energy

Engineered completions are gaining popularity as operators strive to do more with less in todays' challenging environment. To date, there have been a number of roadblocks that have hindered the universal application of engineered completions, most notably the cost and inconvenience of acquiring reservoir evaluation data in horizontal wells. The methodology presented leverages commonly available drilling measurements (rate of penetration, weight on bit, rotational speed, hole diameter, flow rate, differential pressure and standpipe pressure) and mud motor parameters (Kn, Tmax, △Pmax) to derive Mechanical Specific Energy (MSE), using well established algorithms. The MSE parameter is then shown to be a good proxy for Unconfined Compressive Strength, a valuable reservoir parameter commonly used in frac designs. The MSE drives a facies-based answer product that enables the operator to position perforation clusters so that they breakdown at a common treating pressure, resulting in uniform fracture treatment within each frac stage.

Workshop Wrap-up (1705-1715hrs): Marisela Sanchez-Nagel, President & Principal, OilField Geomechanics LLC