Hydraulic Fracture Modeling and the Road to Prediction - A Finite Element Approach*

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Abstract

In unconventional play development programs the concept of a resource or statistical play is used to define production success or failure for a field rather than individual well performance. A complex challenge is the predictability of any single well in the program, with statistical variation of production being an accepted facet in the development program. A potential solution to the problem is to use a combination of a first principles approach in combination with a data driven model. A calibrated model representing all relevant anisotropic reservoir conditions (deformation, stress, strength) and the hydraulic stimulation mechanism is used to test changes to the design of the well and the completion in the virtual environment. This approach attempts to integrate many discrete datasets to eliminate uncertainty. The methodology used, data requirements, pitfalls and successes of this solution are discussed and examples of the predictability of this approach that have recently been published, with the impact on EUR, are examined.
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Uncertain Outcomes

- Oil prices have fallen by ~50%
- Significant number of wells drilled but unprofitable
- Optimal completion uncertainty
- Delineating acreage – where is the sweet spot?

Wolftump, TX – 2014 Horizontal Average Peak Month Production (BOE)

3D Finite Element Approach

- Two component system
  - Mechanics model
  - Hydraulic Flow model
- Rock exhibit anisotropic strength behavior
- Intact rock model incorporate:
  - Layering
  - Natural Joint Systems
- Lakes Heterogeneity:
  - Assumption that bulk rock description can be modelled.
- Vertical permeability
  - Discrete layers described where properties are vertically consistent
- Variables included in model:
  - In situ stress
  - rock strength
  - natural fractures
- The nature of a jointed rock system is a key element to a functional materials model, as this is an important control of the anisotropic strength behavior of the system.

Optimizing the System

- Hydraulic model is based on assumption of laminar flow (Darcy flow) in multiple (parallel) joints
- Incorporates anisotropic hydraulic element
- Hydraulic model mesh is finer than mechanical model – captures pressure gradients.
- Superposition of fluid flow in initial jointed rock mass and fluid flow in up to 4+2 joint sets results in anisotropic hydraulic conductivity matrix
- Only brick elements used in model
- Analysis is non-linear based on multi-surface plasticity material approach
- Domains of fine-mesh and coarse-mesh are defined in the parametric model to balance accuracy and computational efficiency

Calibration

- Goals for optimization are optimal fracture design, well landing, fluid volume, fluid rate as well as optimal wall spacing.
- Output from the Fracture Model is a volume of proppant accepting fractured rock.
- Calibrated to HS, Pump Rate, Pressure, Fluid Volume
- Verification:
  - Incorporate reservoir model data
  - Hydrocarbon quantity
  - Recovery Factor (RF)
- Verification of forecast quality of EUR estimation of the calibrated reservoir model at neighboring wells
- Used to verify model well output
- Additional verification via blind test

Well Cost ($)