Role of multiple fracturing of vertical and Horizontal Wells in Maximizing production and extending life of the field

M. Y. Soliman, Ali Rezaei, Fahd Siddiqui, University of Houston

Outline

- Hydraulic fracturing and field development
- Hydraulically-fractured systems: design and arrangement
  - Why multiple fractures
  - Effect on production
  - Geomechanical consequences
- Fracturing and reservoir depletion
  - Low permeability formations
  - Naturally-fractured formations
  - Effect of pore pressure depletion on local stresses
- Re-fracturing and infill well fracturing
  - Is it required?
  - Vertical well: re-fracturing
  - Horizontal well: re-fracturing, infill well fracturing
  - Geomechanical considerations for infill drilling and refracturing
- Summary
Hydraulic Fracturing and Field Development

Horizontal well fracturing

Pad drilling

Fracturing Low Permeability Formation

- High density fracturing is important to maximize fluid flow
- Re-fracturing may be necessary
- Both have Geomechanics consequence
Oil Phase Pressure, Permeability = 1 md

Oil Phase Pressure, Permeability = 0.1 md
Oil Phase Pressure, Permeability = 0.01 md

Oil Phase Pressure, Permeability = 0.001 md
Oil Phase Pressure, Permeability = 0.0005 md

Fracturing Naturally-Fractured Formations

- Model consists of matrix and fracture (other than hydraulic fractures)
- Flow from both matrix and fractures

Kazemi et al, 1992
Oil Phase Pressure, Fracture System

[Diagram showing oil phase pressure distribution with a graph indicating pressure changes over time.]

Oil Phase Pressure, Matrix

[Diagram showing oil phase pressure distribution within a matrix, with a graph illustrating pressure changes over time.]
Cumulative Gas Production

Cumulative Condensate Production
Hydrocarbon Recovery at 10 Years; Permeability vs. Well Type

Fractured Systems
- Design and arrangement
- Effect on production
- Geomechanical consequences
Effect of Fracturing and Refracturing

Multiple Fracturing of Vertical Wells

- Proposed for
  - Low perm formation
  - Declining fracture productivity
- Observed during drill cutting re-injection
Tangential Stress at Wellbore Wall

Wang, et al, SPE 201719
Multiple Fractures in Vertical Wells

Cumulative production comparison for one and two fractures

Multiple Fractures in Horizontal Wells

HGS Applied Geoscience Conference (AGC) “Drilling and Completion Through the Life of the Field” November 2019
Propagation of Multiple Fractures (Clusters) from a Horizontal Well

- Intra-Well fracture Interaction (frac-hits)
  - Interaction between active and passive fractures
- Inter-Well fracture Interactions
  - Interaction between fracture and offsetting wells
- Stress Shadowing
  - Stress alteration caused by deformation due to fracturing

Fracture Interactions in Nature

Propagation of Clusters

Overlapping Zones of Two Interacting Fractures

Rezaei, et al 2015
ARMA-2015-449
Modified Zipper Frac (MZF), Non-Symmetric

Well A

Well B

Modified Zipper Frac, Symmetric

Rezaei, et al 2015
ARMA-2015-449
Six SurgiFrac Waterfracs performed consecutively for an Openhole Chert horizontal wellbore

Re-Fracturing and Infill Fracturing
- Purpose
- Vertical wells: re-fracturing
- Horizontal wells: re-fracturing, infill well fracturing
- Geomechanical considerations
Why is Re-fracturing Needed?

Original

Original + re-fracturing

SPE 134330

Effect of Re-Fracturing on Flow Rate

SPE 136757
Example of a Successful Re-Fracturing

Re-fracturing

- In Early 80’s
- Multiple fractures in different orientations from a vertical well
  - Perpendicular Fractures from late 80’s
  - Testing and refrac of a vertical well
  - Multiple fractures/application to drill cuttings injections
Vertical Well Re-fracturing

- Proposed for
  - Low perm formation
  - Declining fracture productivity
- Improves reservoir access
- Restore production
- Reorientation is desirable
  - Stress reversal helps
- Usually one fracture exist in the wellbore

Figure Source: American Oil and Gas Reporter

Issues with Refrac of Horizontal Wells

- Plug existing fracs
  - Natural loss of conductivity with time
  - Use plugging agent - chemical
  - Multiple proppant sizes
  - Perforate newer areas
- Drill Infill wells (Child Wells)
- Intra-Well Interaction (frac-hits)
- Inter-Well Interactions
- Stress Shadowing and reversal
Pore Pressure Depletion

Rezaei et al (doi: nag.2792)

Changes of Magnitude and Direction of Stresses with Time

Black lines are the $\sigma_{max}$ direction on top of pore pressure depletion

Rezaei et al (doi: nag.2792)
Effect of the Pore Pressure Depletion on Refarc Propagation

Infill Well Fracturing

Parent well attracts the fractures that are initiated in the infill well

Microseismic activity around parent well

SPE-181656-MS

SPE-181767-MS
Infill Well Fracturing Problems

Direct hit

Fracture shadow

Variable pressure hit

Consequences of Frac-Hit

SPE 171628

SPE 189853
Propagation Path for Infill Well Fracture

Rezaei et al, 2019

URTeC 2667433

Safari et al, SPE 178513

Other Factors Affecting Propagation of Infill Well Fracture

Well spacing

Parent well fracture spacing

HGS Applied Geoscience Conference (AGC) “Drilling and Completion Through the Life of the Field” November 2019
Other Factors Affecting Propagation of Infill Well Fracture. Cont.'s

Summary

- Hydraulic fracturing is an integrated part of field development
- Behavior of a hydraulic fractures are affected by:
  - Induced mechanical changes in stress regime (stress shadow)
  - Pore pressure depletion that causes redistribution of stress (stress reversal)
- Stress shadow affects the fracture behavior in multi-fracture systems
- Stress reversal:
  - Helps re-fracturing vertical wells
  - Not desirable for horizontal wells
- Both stress shadow and reversal affect the final recovery from reservoir by influencing hydraulic fractures behavior.
mysoliman@uh.edu