New Perspective on Gas-Well Liquid Loading and Unloading

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Outline of Presentation

- Highlight nature and importance of gas well liquid loading and unloading
- Review droplet reversal model
- Introduce film reversal model
- Explore potential impact on deliquification
- Present lab results of tubing wall modification
- Highlight potential of hydrophobic coating
- Summary

See SPE 134483 for details
Nature of Liquid Loading

\( Q_{\text{min}} \) is minimum stable rate
a.k.a. critical rate
a.k.a. liquid loading rate

\( Q_{\text{min}} \approx 200 \times 10^3 \text{ m}^3/\text{d} \)

\( \text{L13FE1.E_FI-01-102.U} \)
194. kNm\(^3\)/d

\( \text{L13FE1.E_PI-29-102.U} \)
25.6 barg

\( \text{L13FE1.E_TI-01-102.U} \)
61.0 degC
Importance of Liquid Unloading

Assumes Vertical Well

Plotted data points show the improvement in inflow (Improving Inflow) and deliquification (Deliquification) for different tubing sizes and fluid heights. The graph illustrates how recovery factors change with permeability (K.H in mD.m) for tight and prolific wells.
Droplet Reversal Model

- Turner, Hubbard and Dukler (JPT, 1963), based on Hinze (AIChE Journal, 1955)
- Liquid loading occurs below critical gas velocity at which friction drag force on largest liquid droplets becomes less than gravity force on droplets
- However, the largest droplet size required to match liquid loading data is much larger than the liquid droplet size typically observed in nature

Fig. 1—Entrained drop movement.
Droplet Size

Assumes FTHP=20 bara

Critical velocity for realistic droplet size is 50% of Turner

8.3 mm

2.2 mm
Film Reversal

- In stable flow regime liquid moves upward in form of droplets and film
- Onset of liquid loading is governed by film flow reversal, both observed and modelled

For illustration only! Film and droplets not drawn to scale!
Gas Well Deliquification

• Revisit existing techniques
  – Foam: How does reduction of surface tension influence film reversal? Is conventional laboratory column test (sufficiently) representative?
  – Vortex: What is critical coherence length?

• Identify and evaluate alternative techniques
  – Reduce droplet size: Must achieve droplet size less than few microns to avoid formation of liquid film!
  – Modify tubing wall: Change geometry or wettability!
Tubing Wall Scenarios

- Change wettability
- Introduce taper
- Introduce orifice

Hydrophilic 30°  Base case SS 60°  Hydrophobic 140°
Lab Setup

- 20 mm ID tubing
- 3 m height
- Atmospheric
- Air-water system
- WGR 0-2000 m³/e6m³
Coated Tubing (WGR=150 m³/e6 m³)

Q\(_{\text{min}}\) is where FBHP reaches minimum

Gravity

Friction

Slug

Churn

Annular

\[ Q_{\text{min}} \text{ is where FBHP reaches minimum} \]
Coated Tubing (WGR=500 m³/e6 m³)

Hydrophobic coating reduces $Q_{\text{min}}$ by 50%
Coated Tubing (WGR=2000 m³/e6 m³)

Hydrophobic coating reduces hydrostatic head by 50%

Hydrophobic coating increases friction!
Compare Against Velocity String

- Hydrophobic coating generates more well capacity than velocity string, assuming same liquid loading gas rate
- Hydrophobic coating generates lower bottom hole pressure than non-coated tubing, at same liquid loading rate
- Both benefits translate into value, especially in case of more prolific gas wells
Benefits of Hydrophobic Tubing

Reduction of hydrostatic head generates value in prolific wells

\[ A = \text{Inflow Resistance: } A = \frac{(P_{\text{res}}^2 - FBHP^2)}{Q} \]
Future of Hydrophobic Tubing

- Demonstrate benefit at more realistic (lab) conditions (tubing size, test height, pressure)
- Develop coating process for field size application
- Field trial(s)

- Synergy with scale and corrosion prevention
Summary

• The droplet reversal model of liquid loading presents a powerful tool for field application but does not describe reality

• The film reversal model of liquid loading is supported by both observations and modelling

• Based on film reversal, existing deliquification techniques can be optimised and alternative techniques can be identified

• A range of tubing wall modification techniques have been evaluated by lab testing

• Hydrophobic coating reduces both the liquid loading gas rate and the hydrostatic head; further testing and development are planned
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