Enhancing CSG well production through FBHP control

Problem definition and aim

Estimation of counter-current two-phase flow pressure profiles is important in a wide range of industrial applications, including coal seam gas (CSG) wells (Figure 1), where prediction of the flowing bottom-hole pressure (FBHP) is key to optimise the well performance. The CSG industry is currently using simulators containing models that were originally developed for conventional wells (co-current flow in pipes) for their CSG developments (counter-current flow in annulii).

This project aims to provide insights into the complex dynamics of gas-liquid counter-current flows, both theoretically and experimentally, under varying operating conditions.

Methodology

UQ’s Transparent Wellbore Flow Simulation Facilities (Figure 2) were designed to replicate as closely as possible the production zone of a typical pumped CSG well in Queensland, Australia:

- 7-in casing and 2¾-in tubing
- air and water used for safety

Experimental results are used to:

- Provide a reliable flow map using signal analysis of the pressure signals
- Validate models developed within the research team
- Investigate flow regimes (bubble, slug, churn, and annular) and their associated holdups and pressure profiles
- Determine the onset of counter-current flow limitation (gas carryover and “slugging”)

Flow regime identification using signal processing

Two-phase flow properties are intrinsically linked to the flow regimes that develop.

Each flow regime was experimentally observed to produce characteristic pressure fluctuation signals (Figure 3) associated with gas-liquid interfacial structures.

Four signal processing techniques (autocorrelation, power spectral density, Shannon entropy and permutation entropy) were applied on pressure signals to objectively identify flow regimes and their transitions. Examples of autocorrelation plots for different flows are shown in Figure 4.

Effect of salinity on flow regimes

Associated water in Queensland, predominantly consists of NaCl with salinity levels typically ranging from 200 ppm to more than 10,000 ppm. Salinity was shown to inhibit bubble coalescence, increasing void fractions and impeding flow regime transitions (Figure 5), for homogeneous and heterogeneous flows.

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Research student

Benjamin Wu
PhD Candidate
p.wu1@uq.edu.au

Research team

Benjamin Wu1, Ayrton Ribeiro2, Mahshid Firouzi1,2, *, Thomas Rufford1,2, Brian Towler1,2
1. UQ School of Chemical Engineering, 2. UQ Centre for Natural Gas,
∗ Lead Chief investigator

Figure 1: Two-phase flow regimes across a well-bore

Figure 2: UQ’s laboratory wellbore flow simulator

Figure 3: Pressure signals reveal flow regime transitions

Figure 4: Autocorrelation functions of pressure signals for different flow regimes

Figure 5: Effect of salinity at constant water rate of 0.018 m/s