Optimizing Gas Lift Equipment with CFD Techniques

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**Objective**

**Gas lift valve**

- Model high gas flow rate through the check valve of venturi gas lift valves;
- Establish guidelines to optimize check valve of one of the manufacturers.

**Gas lift mandrel with redirection**

- Evaluate a possible increase in oil production due to the simple change on the direction of the lift gas injection from downwards to upwards.
What is CFD?
Computational Fluid Dynamics - the use of numerical methods for solving fluid flow models, which may include other physical phenomena like: heat and/or mass transfer, phase change, chemical reactions, moving parts, etc.

Why CFD?
- Detailed analysis;
- Objective;
- Time saving;
- Reduction on number of experiments;
- Money saving;
Check Valve Model Proposed by Manufacturer 1
Check Valve Model Proposed by Manufacturer 2
CFD simulation steps:

- Geometry description
- Mesh generation (domain discretization)
- Fluid flow model setup, fluid properties, boundary conditions
- Solve equations system
- Results analysis
Geometry Description
Mathematical Model:

\[ \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{V}) = 0 \]

Mass Conservation Equation

\[ \frac{\partial (\rho \vec{V})}{\partial t} + \nabla \cdot (\rho \vec{V} \vec{V}) = \nabla \cdot \left( -P \delta + \mu \left( \nabla \vec{V} + (\nabla \vec{V})^T \right) \right) + S_M \]

Momentum Equation

\[ \frac{\partial (\rho h_{tot})}{\partial t} - \frac{\partial P}{\partial t} + \nabla \cdot (\rho \vec{V} h_{tot}) = \nabla \cdot \left( \frac{k}{c_p} \nabla T \right) + S_E \]

Energy Equation

\[ \rho = \frac{wP}{R_0 T} \]

Equation of State (methane as ideal gas)
Boundary Conditions

Inlet:
Gas flow rate from 100,000 to 500,000 m$^3$/d at standard conditions

Outlet:
Pressure = 150 bars
Pressure and velocity field in the valve middle section
Gas flow rate: 100,000 m³/d at standard conditions
Partial Validation: During a flow test with gas flow rate of 104,000 m³/d, a difference of 34 psi (2.3 bar) was obtained between a valve with and without check valve.
Pressure loss vs. Flow rate – Manufacturer 2

Pressure loss vs. Flow rate – Manufacturer 2

Gas flow rate @ standard condition [1000 m3/d]
Pressure loss vs. Flow rate – Comparison

Gas flow rate @ standard condition [1000 m3/d]

Manufacturer 1: Original Model
Manufacturer 2
First improvement: enlarging windows
Second improvement: new dart geometry

- Manufacturer 1: Original Model
- Manufacturer 2
- Manufacturer 1: New Gap
- Manufacturer 1: New Dart

Perda de Pressão [bar] vs. Gas flow rate @ standard condition [1000 m3/d]
Check Valve Pressure Loss

- Manufacturer 1: Original Model
- Manufacturer 2
- Manufacturer 1: New Gap
- Manufacturer 1: New Dart
- Manufacturer 1: Gap + Dart

Gas flow rate @ standard condition [1000 m3/d]

Pressure Drop [bar]

- 65 bar
- 11.4 bar
- 7.2 bar
Next steps:

- Simulate entire system including mandrel
- Simulate other types of valves (for example, center body venturi)
Objective:
Evaluate a possible increase in oil production due to the change on the direction of the lift gas injection in the tubing.

Lack of references in the literature

Hard to develop an analytical model
Boundary Conditions

Liquid Inflow:
Water flow rate: 1,500 m³/d;

Gas Inflow:
Methane flow rate: from 100,000 to 500,000 m³/d;

Outlet:
Pressure: 150 bar.
Multiphase model:

- Particle model: water is the continuous phase and methane is the disperse phase (Euler-Euler model);
- Fluids with different properties;
- Each fluid with its own velocity field;
- Interface forces are calculated for particles with defined diameter.
Gas Volume Fraction Fields for Gas Flow Rate of 500,000 m$^3$/d
Pressure Profile in the Tubing Main Axis

500,000 m³/d

$\Delta P = 1.1$ bar
Injecting Upwards

Gas Volume Fraction

Streamlines
Comparing Pressure Profiles

300,000 m³/d

0.85 bar

Pressure [bar]

z [m]

Downward
Upward
Upstream Pressure Difference

Gas flow rate @ standard condition [1000 m³/d]
Simple changes on gas lift valve geometry can increase the production in wells which receive high lift gas flow rates;

In highly productive wells, the change on the direction of the lift gas injection can mean an increase equivalent to 1 PI;

The use of CFD techniques to study and raise improvements in gas lift equipments can be considered a good way because we save time and development cost;
Thanks for your attention