Debottlenecking Water-Oil Separation with Increasing Water Flow Rates in Mature Oil Fields

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Outline

• Background and Motivation
• Numerical Model and Test Matrix
• Results and Discussion
• Conclusions
Background

• Maturing fields with increasing water flow rates
• For certain GOSPs, water-oil separator (WOSEP) is the bottleneck
• WOSEPs are reaching capacity to process oily produced water
• Need solution to debottleneck gas-oil separation plant for forecast rates
  - Quantify separation performance
  - Apply enhanced internal technology to improve separation at higher throughputs
Produced Water Forecast

Produced Water Flow Rate

Today

+10 Years

1X

1.5X

Not to scale
Motivation

• Improving oil separation reduces lost production
• Improved produced water quality prevents formation damage on reinjection to maintain reservoir pressure
• Avoid the need to build additional WOSEPs in the GOSP
Objectives

• Use state-of-the-art multiphase CFD to model the oil-water flow in the WOSEP vessel
• Develop debottlenecking solutions to increase water handling capacity
Typical GOSP

Production Header

HPPT

Water

Water

WOSEP

Produced Water Injection

LP Gas

Dehydrator

Dry Oil

HP Gas

Desalter

Gas

Water

Oil
**Water Oil Separation Vessel (WOSEP)**

Approximate dimensions: 180 ft Length; 14 ft diameter

160 MBD Throughput
Multiphase Modeling

Separator CFD Modeling

Eulerian-Lagrangian

Eulerian

Homogeneous

VOF

Explicit (Transient)

Implicit (Steady)

Mixture

N-Phase

Population Balance

Inhomogeneous

N-Phase

Population Balance
Numerical Methodology

• N-Phase Eulerian multiphase model
  - Water - primary phase
  - Oil and gas - secondary phases
• Phase interaction
  - Schiller-Naumann drag model
• Turbulence
  - Standard $k - \varepsilon$ turbulence model with scalable wall functions
• Steady and incompressible
• High-resolution Computational mesh
  - 2 million polyhedral cells/elements
Solution Platform

• ANSYS Workbench for Pre-Processing - Geometry and Mesh
• ANSYS Fluent R18.0 for Solution
  - Simulations run in parallel on an HPC cluster with 216 cores
• ANSYS CFD-Post 18.0 for Post-Processing
## Numerical Test Matrix

<table>
<thead>
<tr>
<th>Run</th>
<th>Flow (MBD)</th>
<th>Oil Droplet Diameter (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>173</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>173</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>265</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>265</td>
<td>50</td>
</tr>
</tbody>
</table>

**Inlet Oil Fraction (OF)** 0.01
Geometry

- Oil Bucket
- Gas nozzle
- Inlet Distributor (Water & Oil)
- Water Weir
- Water Baffle
- Water Outlet
Computational Mesh
WOSEP Flow Field

Streamlines (colored by time)

Run 2
WOSEP Flow Field

Streamlines (colored by time)

Run 1
Run 2
Run 3
Run 4

Front view
Residence Time Distribution

<table>
<thead>
<tr>
<th>Water Flow Rate (MBD)</th>
<th>Mean of RTD [s]</th>
<th>Retention Time (Vc/Q) [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>173</td>
<td>1142</td>
<td>1305</td>
</tr>
<tr>
<td>265</td>
<td>784</td>
<td>851</td>
</tr>
</tbody>
</table>
Residence Time Distribution

[Graph showing Residence Time Distribution with two curves labeled 173 MBD and 265 MBD]
Oil Fraction

Run 2
# Effectiveness of Oil Separation

<table>
<thead>
<tr>
<th>Run</th>
<th>Flow (MBD)</th>
<th>Oil Droplet Diameter (µm)</th>
<th>Oil Removed (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>173</td>
<td>10</td>
<td>&lt;1</td>
</tr>
<tr>
<td>2</td>
<td>173</td>
<td>50</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>265</td>
<td>10</td>
<td>&lt;1</td>
</tr>
<tr>
<td>4</td>
<td>265</td>
<td>50</td>
<td>4</td>
</tr>
</tbody>
</table>

\[
\text{Separation Efficiency} = \frac{\text{Inlet Oil Fraction} - \text{Outlet Oil Fraction}}{\text{Inlet Oil Fraction}} \times 100\% 
\]
Conclusions

- Successful CFD simulations of WOSEP under different conditions
- Flow patterns show adverse vortices induced by the inlet distributor that reduce ability to separate oil from water
- Very low oil separation obtained from separator design for base flow rate
- Increased water throughput further reduces separation performance
- Potential to increase primary stage produced water oil removal through improvements in WOSEP design:
  - Inlet distributor
  - Additional internals (perforated plate baffles or derivatives, coalescing plate packing)
  - Vessel configuration
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