Dispersant Use at Wellhead; Modeling Scenarios

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Acknowledgements

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• Chevron, U.S.A

• Shell International
• **DeepSpill project and field experiment** of oil/gas plumes by SINTEF, Norway (Johansen et al., 2003)

Crude oil and gas release

\[ Q_{\text{oil}} = \frac{1}{60} \, \text{m}^3/\text{s} \]
\[ Q_{\text{gas}} = 0.7 \, \text{Nm}^3/\text{s} \]

Diesel and gas release

\[ Q_{\text{oil}} = \frac{1}{60} \, \text{m}^3/\text{s} \]
\[ Q_{\text{gas}} = 0.6 \, \text{Nm}^3/\text{s} \]
Plume Topology

Observed in Field and Lab Experiments

Predicted from Lab Experiments

\[ u_s = f(\nu, \sigma, d_e) \]
\[ B_0 = \frac{Q_0 \Delta \rho}{\rho_r} \]

\[ N = \sqrt{-\frac{g}{\rho_r} \frac{\partial \rho}{\partial z}} \]
LES Simulations of Stratified Bubble Plume

**Configuration of LES**
- Domain size: \((0.76, 0.76, 0.9)\) m
- Grid number: \((150, 150, 257)\)
- Time step: 0.001 second
- Simulation duration: 140 seconds

**Physical parameters**
- \(Q_{\text{air}} = 0.09\) L/s
- \(\rho_{\text{air}} = 1.4\) kg/m\(^3\)
- \(N = 0.7\) s\(^{-1}\)

Data sampling: every 0.25 seconds.
Movie: 20 frames/s, 400 frames.

Yang, et al. (2016) *JFM.*
DWH Accident

Video image capture from Maxx3 during DWH response activity
DWH Accident

Station B54 on May 30, 2010
By R/V Brooks McCall

DWH Accident

Ryerson, et al. (2011) PNAS
Model Inter-comparison

- **Three test cases without dispersant**

<table>
<thead>
<tr>
<th>Case*</th>
<th>GOR [scf/bbl]</th>
<th>Depth [m]</th>
<th>DOR [%]</th>
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<tr>
<td>1</td>
<td>Deep base case</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>3</td>
<td>Deep, low GOR</td>
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<td>2000</td>
</tr>
<tr>
<td>5</td>
<td>Shallow</td>
<td>2000</td>
<td>200</td>
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</tbody>
</table>

*All cases at 20,000 bbl/day.

- **Three test cases with dispersant**

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<td>2000</td>
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<td>4</td>
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</tr>
<tr>
<td>6</td>
<td>Shallow</td>
<td>2000</td>
<td>200</td>
</tr>
</tbody>
</table>

Socolofsky et al. (2015) *MPB.*
1.) Droplet Size Distribution (DSD)

2.) Nearfield Plume Simulation

3.) Farfield Particle Tracking

Socolofsky et al. (2015) MPB.
Droplet Size Distribution (DSD)

• Equilibrium break-up models

\[ d_{50} = c \left( \frac{\sigma}{\rho} \right)^{3/5} \varepsilon^{-2/5} \]

\[ \epsilon \propto \frac{U_C(z)^3}{b(z)} \propto \frac{U^3}{D} \]

\[ \frac{d_{50}}{D} \propto We^{-3/5} \]

• Resistance of viscosity at low surface-tension

\[ Vi = \frac{\mu_p U}{\sigma} \]

\[ Re = \frac{\rho_p UD}{\mu_p} \]

Socolofsky et al. (2015) MPB.
Model Predictions for DSD

\[ d_{\text{max}} = 4 \sqrt{\frac{\sigma}{g(\rho - \rho_p)}} \]

Socolofsky et al. (2015) MPB.
Population Breakup Models

- Prediction of the DWH size distribution using VDROP-J

![Graph showing droplet diameter distribution](image)

Scenario 1: \( D=0.5 \text{ m}, Q_{\text{oil}}=0.088 \text{ m}^3/\text{s}, Q_{\text{gas}}=0.18 \text{ m}^3/\text{s} \)

Untreated: \( \sigma=20.9 \text{ mN/m} \)

No Dispersant

- Evolution with distance
- Peak value ~ 4 mm

Zhao et al. (2015) MPB.
Population Breakup Models

- Effect of dispersants

Scenario 1: D=0.5 m, Q_{oil}=0.088 m^3/s, Q_{gas}=0.18 m^3/s

100% Dispersant Effectiveness

Peak value ~ 1 mm

15% of mass below 1 mm

Zhao et al. (2015) *MPB.*
Population Break-up Models

- Effect of dispersants

Scenario 1: \( D = 0.5 \text{ m}, Q_{\text{oil}} = 0.088 \text{ m}^3/\text{s}, Q_{\text{gas}} = 0.18 \text{ m}^3/\text{s} \)

With dispersants (50% efficiency): \( \sigma = 2.09 \text{ mN/m} \)

50% Dispersant Effectiveness

Zhao et al. (2015) MPB.
Comparison to Available Data

API Model Intercomparison Cases

Experimental Data

Socolofsky et al. (2015) MPB.
Trap Height Predictions

Intrusion layer depth

Depth (m)

Case number

Far-field Model

Depth (m)
Surfacing Predictions

With Dispersant

Deep Releases

Shallow Releases

- OSCAR
- BLOSUM
- Adams
- CMS
- LTRANS
- MIKE
- OILMAP Deep
Conclusions

- DSD models must **extrapolate from available data** to match field conditions.
- Experiments demonstrate that subsea dispersant addition **reduces the oil droplet size**.
- Dispersant addition is modeled by an assumed reduction in the interfacial tension.
- Available DSD models generally agree within an **order of magnitude**.
- Water column models (near- and farfield) agree that dispersant can move surfacing zone up to **two orders of magnitude downstream** of the no-dispersant location.
Future Needs

• Experimental data for DSD at larger scale
• Expand the observational database of near-field dynamics to constrain model assumptions (e.g., laboratory or LES simulation)
• Experimental data on effectiveness of mixing dispersants into oil at a blowout