The Subsea Sand Management Challenge: “What to do with the sand?”

Hank Rawlins, PhD, P.E.
hrawlins@eprocess-tech.com
Purpose & Outcome

**Purpose**
- Identify drivers for subsea facilities sand management
- Provide a focal point for discussion on subsea processing with focus on “What to do with the sand?”
- Identify and analyze conventional, unconventional, and unique options to reveal technology gaps

**Outcome**
- Approaches include neutralizing effects, improving conventional design, and separation with disposal
- Investigate technology analogues from other industries
- Improve hydrocarbon recovery through inclusionary production (SPE 164645)
12 Years of Progress

Top 5 Technology Needs
1. Seabed separation & disposal
2. Integrated subsurface/surface
3. Sand cleaning
4. More case studies/examples
5. Instrumentation
Produced Solids (Sand)

**Inorganic, Insoluble, Particulate Material**
- Not asphaltene, paraffin, wax, hydrate, or resin (organic)
- Not precipitates or scale (soluble or non-particulate)
- Sand - ISO 14688-1:2002 / ASTM D2487-83 (63-1700 µm)
- Solid particles that are separable in facilities equipment

---

*Onshore Field, Austria*

*Deepwater South China Sea*

*OTC Asia 24705-MS*
Natural Vs. Artificial Solids

Natural Solids
- Indigenous reservoir material
- High angularity, 25-150 μm median size, ~2650 kg/m³
- Low, steady-state, continuous production
- Failure mode – high concentration burst production

Artificial Solids
- From external intervention
- Frac sand, proppant, drill mud, cement fines, corrosion product, gravel pack, injection fines, etc.
- Higher s.g., rounder shape factor, larger avg. particle size
- Often handled as planned event

Sand and coal from Brent Delta 1996
Motivation for Sand Handling

**Erosion**
- Pipe components and valves

**Filling**
- Vessels, tanks, and low velocity zones

**Interference**
- Instruments/valves (plugging or range of motion)

**Oil-in-Water Content**
- May not be critical for subsea
Sand Management Paths

A. Conventional Approach
   • Manage solids production or system configuration using established rules or technology

B. Solids Treatment
   • Modify the solids, in-situ, to reduce or eliminate their deleterious effects

C. Solids Removal/Disposal
   • Separate solids from the well fluids and manage as separate flow stream
Sand Management Paths

CONVENTIONAL
- Downhole mechanical intervention
  - Reduce production below solids level
  - Reduce pipe velocity
- Erosion resistance materials
  - Manage erosion
    - Design
    - Pass through solids

TREAT SOLIDS
- Chemicals
  - Agglomerate
    - Partial/full dissolve
  - Modify shape
  - Coat particles
  - Core laminar flow
  - Modify flow path
    - Pipe in pipe design

REMOVE SOLIDS
- Desander Cyclone
  - Filters
  - Gravity
  - Inertia / Viscous trap
  - Inject into disposal well
    - Mechanical
    - Chemical
  - Clean & Seafloor discharge
  - Compress to puck
  - Containerize
  - Adhesive / cement
  - Grinding attrition
  - Ultrasomics
  - Disintegrate
  - Electrical discharge
  - Chemical dissolution
  - New flow stream
    - Dedicated pipeline
    - Contain / Pig line
    - Float to surface
  - Wellstream
  - Downhole
Technology Gaps

Reliable, known technology

Required to meet subsea demands

http://www.scanadu.com/
Manage solids production or system configuration using established rules or technology

A. CONVENTIONAL APPROACH
Exclusion or Flow/Material Design

**Exclusionary Production**
- Well completion equipment
- Reduce educe well output below sand production level

**Flow Design**
- Lower velocity in piping to minimize erosion
- Increase velocity to prevent solids from settling

**Material Design**
- Design components with manageable erosion or increase MOC for longer erosive life (material type or thickness)

**Separate sand ahead of subsea system and reintroduce downstream**
- Put solids back into production stream
- Put solids into disposed stream (i.e. water injection)
Modify the solids, in-situ, to reduce or eliminate their deleterious effects

**B. SOLIDS TREATMENT**
Effect of Sand Morphology on Erosion


```
<table>
<thead>
<tr>
<th>Description</th>
<th>F_s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharp Corners, Angular</td>
<td>1.0</td>
</tr>
<tr>
<td>Semi-Rounded, Rounded Corners</td>
<td>0.53</td>
</tr>
<tr>
<td>Rounded, Spherical Glass Beads</td>
<td>0.20</td>
</tr>
</tbody>
</table>
```

Effect of Particle Size on Erosion

\[ ER = 1.0 \times 10^{-9} \rho_w E(\theta) \]
\[ E(\theta) = g(\theta)k(H\nu)^{k_1}\left(\frac{V_p}{V}\right)^{k_2}\left(\frac{D_p}{D}\right)^{k_3} \]
\[ h \sim F_r e^{-\left(\frac{1}{d_p}\right)^{0.19}} \]

\( ER = \) erosion ratio (mass of particle/mass loss of target)

Threshold particle size:
20 microns methane and 100 microns water

Rapid decline


Particle Coating

Coat the particles and reintroduce into production stream
Reduce edge sharpness and increase sphericity (0.7-0.9)
Make particle soft/resilient to impact
Reduce net density (impact reduction and easier to carry)
Tech transfer from proppant production
Coating materials: phenolic, polyurethane, epoxy, wax
Inorganic coatings (patent): SbO$_3$, Bi, B$_2$O$_3$, CaBaF, Cu,
Graphite, In, PbO, PbS, MoS$_2$, ZnO

Coating Method (TBD): powder, liquid, reaction, precipitation
Partial/Full Chemical Dissolution

Dissolve to reduced particle shape or size

Inorganic Acid

\[ SiO_2(s) + 6HF(l) \rightarrow H_2SiF_6(aq) + 2H_2O(l) \]

NaOH

\[ SiO_2(s) + 2NaOH(l) \rightarrow Na_2SiO_3(aq) + H_2O(l) \]

Organic acids (citrate, oxalate, and pyruvate) increase dissolution rate 8-10X compared with water


Increasing temperature, and pressure both increase solubility of silica


Increasing cation concentration increases dissolution rate of quartz (\(Ba^{2+} \sim Na^+ \sim Ca^{2+} > Mg^{2+}\) where \(Ba^{2+}\) provides 114X rate compared to DI water)

Separate solids from the well fluids and manage as separate flow stream

C. SOLIDS REMOVAL/ DISPOSAL
Sand Separation Technologies

**Screen/Filter**

**Cyclonic**
- Desander, Inline, Auger

**Rotodynamic**

**Gravity Settling**

**Pipe Trap**

---

Subsea Wellhead Desander

---


Paper SPE 166118 Design of a Cyclonic Solids Jetting Device and Slurry Transport System for Production Systems

Particle Comminution

Grind sand to particle size below critical limit or to modify morphology
  • Ultra-fine grinding, attrition mill, vibratory tumbler
  • Employ methods from mining, ceramic, paint, paper, pharmaceutical, or other fine particle industries

Mechanical comminution
  • Ring & puck mill, disc pulverizer, oscillating mill, micro-powder mill, high-press grinding mill

Media methods
  • Planetary, vibratory, or stirred mill

Non-moving parts methods
  • Jet mill, ultrasonic wet-milling, electric pulse discharge
Comminution Equipment

- Metso Stirred Media Detritor
- Hielscher ultrasonic processor
- Ring & Puck Mill
- Disc Pulverizer
- Sturtevant Micronizer® Jet Mill

Breakage of Rocks by Pulsed Electric Discharge at Elevated Pressures and Temperatures

Y. F. Yazhov\textsuperscript{a}, R. R. Gafarov\textsuperscript{a}, S. Yu. Datskevich\textsuperscript{a}, M. Yu. Zhurkov\textsuperscript{a}, V. V. Lopatin\textsuperscript{a}, V. M. Muratov\textsuperscript{b}, and B. Jefferys\textsuperscript{b}

\textsuperscript{a} High-Voltage Research Institute, Tomsk Polytechnic University, Tomsk, 634028 Russia
\textsuperscript{b} Schlumberger Cambridge Research Center, Cambridge CB3 0EL, United Kingdom
\textsuperscript{*}e-mail: muratov@hvd.ipu.ru
Received November 24, 2010
Particle Consolidation

**Consolidate particles into solid or semi-solid shape, for ease of carrying or “contained” seafloor disposal**

- Compress into puck (mechanical densification)
- Add adhesive polymer an extrude
- Add cement to make brick

[Images of particle consolidation and equipment]

http://www.mechanicalengineeringblog.com/tag/cement-extrusion/
Containerize

Collect into...

- bag/tube/flexible-container
- pig and send up pipeline
- vessel/bin and retrieve by ROV or wireline
- vessel/bin and float to surface

http://freeassociationdesign.wordpress.com/2012/01/24/21st-century-sand-bags/

http://www.subsalve.com/

http://en.wikipedia.org/wiki/Pigging
Sand Cleaning

**Mechanical (agitation)**
- Recirculation loop with cyclones, slop oil slurry cleaning, beach sand cleaning

**Chemical**
- Dispersant, biological, detergent

**Thermal**

[Image of cleaning system for BP Venezuela 1997]

Inlet and sand/water outlet from cleaning loop along with analysis method

[Image of cleaning process]

Slurry Fracture Injection

**Solids injection into disposal reservoir**
- Used significantly for drill cuttings
- OnePetro papers and SPE Monograph
- Typically batch process

Deoiler/desander system with solids disposal via slurry fracture injection for Chevron on Barrow Island (2008)

INSTALLED SYSTEMS SUMMARY AND RECOMMENDATIONS

RPSEA Report 09121-3100-01, 24-Apr-12, RPSEA Ultra Deep Water Disposal of Produced Water &/or Solids at the Seabed
Rated solids handling for subsea at TRL 3
  • Used 100 ppm inlet design at 700 lbs/day

Disposal requirements
  • Selected locations at 1 wt.% oil on dry solids
  • U.S. does not allow solids discharge
  • Water injection quality at <5 ppmv and < 2 microns

Recommendations
  • Put sand into retrievable containers (7.8.3)
  • Add back to oil stream (7.10.2)
  • Manage through velocity
RPSEA: Installed Systems Summary

**Petrobras Marimba, Congro, Malhado, Corvina, Canapu and Shell BC-10, Perdido**
- G/L, sand flows with liquid to surface

**Total Pazflor**
- G/L, sand flows with liquids, backup sand flushing arrangement

**Statoil Troll C**
- Sand flows with injection water

**Statoil Tordis**
- Sand jetting to desander to injection well (after pump), but changed to flowing to surface

**Petrobras Marlim**
- Sand removed pre-separator, sand jetting, produced water desander, sand put back into oil line
Conclusions

**Subsea Processing Requires Sand Management**
- All wells produce sand

**No New Equipment Required for Separation**
- Proven equipment available topsides
- Packaging for deepwater use needed

**Solids Handling Main Concern**
- Erosion, filing, interference, or oil-in-water
- Neutralize, improve conventional design, separate/disposal
- Primarily manage through velocity
- Separation with injection: flow-line, w/water, or discrete reservoir
- Containerize a viable option

**Closing Technology Gaps**
- Coordination between major stakeholders
- Cooperative development approach
- Qualified experienced innovative partners
THANK YOU / QUESTIONS?