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Challenges on Sand Control and Completions for Productivity in Ultra-Deep Waters

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OVER VIEW

- Reservoir Conditions at Ultra-Deep Waters
- Challenges in Drilling & Completion
- Completion for Productivity
- Sand Control for Deepwater Viscous Oil
- Conclusion Remarks
Ultra-Deep Waters - Campos Basin

Rio de Janeiro

Cabo Frio

Macaé

Albacora leste

Marlim

Marlim Leste

Caratinga

Marlim Sul

Roncador

Campos

Barracuda

Ultra-Deep Waters - Campos Basin
Reservoir Conditions at Ultra-Deep Waters

- Deep and ultra-deep waters > 1500 m
- Shallow burial sediments < 1000 m
- Fracture gradient < 0.57 psi/ft
- Temperatures 25 – 60 °C
- Viscosities > 20 cP

Source: SPE 98342
Reservoir Conditions at Ultra-Deep Waters

- **Turbidite reservoirs**: internal sub-seismic complexity
- **Non-consolidated sands**: non cemented sands
- **Median to Fine sands**: non uniform, high fines content
- **High porosity and permeability**
Economics X Technology

VOIP (Milhões de m3)

API degree

Non-economic
Technology Dependent
Feasible
Challenges in Drilling & Completion

- Geological uncertainties
- Narrow operational window for drilling
  - Low absorption pressure
  - Elevated pore pressure
- Presence of reactive shales
  - Needs high performance drilling & completion fluids
- Special wells required
  - Improves reservoir drainage
  - Compensates low oil mobility
Challenges in Drilling & Completion

- Mandatory sand control
- Effective control on water injection and production
  - Needs zonal isolation
- Completion reliability and intervention requirements
  - Offshore submarine operations
- Cold sea bed waters → hydrates, thermal fractures for injectors, etc...
Collapsed ESP intake retrieved from the well
Completion for Productivity

- Project considerations for Productivity
  - Well Geometry Selection
  - Oil Production Influx Profile
  - Sand Control System Selection
  - Control on Water Production and Injection
  - Oil Lifting or Sand Control?
Well Geometry Selection

Fishbone multi-laterals

Source: SPE 87966
Well Geometry Selection

Horizontal multi-fractured wells

Source: Schlumberger
Oil Production Influx Profile

Single horizontal well with zonal isolation

Well Segmentation Concept

Original influx profile

Optimized influx profile

Influx control devices into the sand screens

Improved sand screens

Annular Barrier

Source: SPE 98342
Sand Control System Selection

- What are the limits for each sand control method?
  - Installation
  - Operation

- What are the implications if some fine sand production is permitted?
  - Flow lines
  - Surface equipments
  - Sand handling and disposal
Control on Water Production and Injection

• How can well productivity be jeopardized due to the early water breakthrough with fines migration?

• How can water injectivity be maximized?
Oil Lifting or Sand Control?

• Which system will set the rules for the well completion design: sand control or lifting?
Improvements on well construction

- Extensive use of geo-steering technology
- Single-fluid well construction technology
  - Minimization of the fluid damage
- Sand control system
  - Delivering low pressure drop through the screen
- Water injection maximization
  - Well segmentation concept
- Artificial lifting system tolerant to larger amount of fines (bellow 70 micrometers)
Fluid damage removal and return of permeability

• Drilling stability and completion efficiency
  ▪ Highly inhibited drilling fluids
  ▪ Low invasion profile
  ▪ Efficient mud cake easy to remove
Damage removal and return of permeability

Radial Flow Test Cell
- Mud cake efficiency
- Damage due to filtration
- Mud cake removal
- Fines migration
- Plugging effects

Source: SPE 95025
Damage removal and return of permeability

Drill-in Fluid Invasion - bridging agent and polymers

Source: SPE 95025
Damage removal and return of permeability

Typical spectrum for unconsolidated sandstone

Source: SPE 95025
Sand Control for Deepwater Viscous Oil

- **Horizontal Open Hole Gravel Pack**
  - Most used sand control method

- **Stand Alone Screens**
  - Wire Wrapped
  - Meshed (single or multilayer)
  - Expandable

- **Frac & Pack**
  - Not used above 60 degree
Sand Control for Deepwater Viscous Oil

- **Open Hole Gravel Pack**
  - Carrier fluid compatible with the mud cake
  - Pressure at the casing shoe limited by the frac pressure
  - Light propant
  - Gravel impairment

- **Stand Alone and Expandable Screens**
  - Screen performance tests
    - Coupon Tests
    - Tangential tests
    - Full scale tests
Horizontal Open Hole Gravel Pack

Carrier Fluid Circulation

- Work String
- Completion Fluid

- Packer
- Seal bore sub
- Blank pipe
- Screen
- Locator
- Flapper
- Perforated extension
Gravel Pack Impairment Test
Gravel Pack Impairment Test

Some Results

Ceramic 16/20

Sand 12/20
Screen Performance tests

Coupon Test

Selecting the weave apertures
- Slurry test
- Conformance test

Source: SPE 98342
Screen Performance tests

Results for the Coupon test

Pre-Expansion - Time vs Pressure
Old & New PFM125 Screen
KCl & Oil Conformance Tests - Sand put on top of screen with flowrate @100mls/min

Source: SPE 98342
Screen Performance tests

Transversal Flow Test

- Plain Dutch Weave Filtration Layer
- Outer Shroud
- Lower Drainage Mesh Layer
- Support/Drainage Layer
- Base Pipe
Screen Performance tests

Results for the Tangential Flow Test

Time vs Pressure
250cp Mineral Oil with 0.25% Min-U-Sil 30 (<30 µm Fine Silica) @ 10mls/min
Conductivity Cell & Load Press @1000psi

Source: SPE 98342
Screen Performance tests

Full Scale Test
Viscosity Effect on Flow Pressure Drop through a Premium Screen

VISCOSITIES (cP)
- 9
- 46
- 100
- 232
- 270

Multilayer Premium Screen
nominal opening size: 175 \( \mu \)m
3 ft long

Flow Rate (liters/min)
Pressure Drop (psi)
Screen Performance tests
Results for the Full Scale Test

Hydraulic Conductance and Conductivity
OLD and NEW PMF125 expandable screen, 22% Expanded

Conductance OLD
Conductance NEW
Conductivity OLD
Conductivity NEW
Mass of solids OLD
Mass of solids NEW

Initial bridging
Invasion process
Plugging process

Time (min)
Conductance (ml/min/psi/in), Conductivity (mD/cP)
Mass of solids produced (g)
Screen Performance tests

1. **Slurry test** ⇒ **screen conductance**
   - How easily oil flows along a certain path through a porous material
   \[
   G = \frac{Q}{\Delta P}
   \]

2. **Conformance test** ⇒ **sand pack conductivity**
   - How well a porous material accommodates the flux of oil
   \[
   \lambda = \frac{K}{\mu} = 15.34 \left( \frac{G}{l} \right) \ln \left( \frac{Rac}{Rs} \right)
   \]
Sand Control for Deepwater Viscous Oil

Compaction Induced by fluid flow

Seepage forces due to flow leads to increase confining pressure at the sand pack reducing the permeability of the sand layer on the screen surface

from Johan Tronvall
Screen Performance tests

Cell breakdown

Cut screen after test

Screen envelop

Basepipe

Weave surface at the shroud side and internally (10X)
Screen Removed from Well

Shroud cut and opened
Conclusion Remarks

• Improvements on the performance of horizontal wells come from proper well design and completion practices. They also depend on understanding the influence and effects of each productivity factor.

• Where traditional completion solutions have not given good results, special or "designed for" solutions need to be conceived, tested and applied.
Conclusion Remarks

- Viscous Oil exploitation in offshore ultra-deep waters is a challenge that can change the way well construction is done.
- Well geometry, water production control and oil influx profile have high influence on productivity.
- Drilling fluid compatibility, mud cake removal and return of permeability can impact the efficiency of completion.
Conclusion Remarks

- Screen performance is highly affected by its construction, particles size distribution, amount of migrating fines produced and oil viscosity.
Thank you for your attention!

Questions?