Using Wellbore Deformation To Optimize Drilling Performance

By : Juan Tovar
Innovative Engineering Systems Limited

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Content

• Background
• Fundamentals of near wellbore deformation
• Drilling optimisation using near wellbore deformation
  1. Wellbore stability
  2. Hydraulics and hole cleaning
  3. Hole quality
• Zonal isolation and cementing
• Conclusions
• Questions
Near wellbore deformation is an old and well established concept; it is the deformation of the rock at the wellbore wall caused by the drilling process

• Widely used in mining since the 19th century
• Used in civil engineering applications such as tunnelling and dam construction
• Composed of a mechanical, chemical and hydraulic element
• Also known as damaged zone, yield zone or radius of plasticity

For well construction

• Deformation of the near wellbore in well construction can be predicted and verified using current measurements such as calliper logs.
• Modelling is based on geomechanical principles and therefore a geomechanical model needs to be built

• In-situ stresses, pore pressure and rock mechanical properties are required; a temperature element is desired for HP/HT wells

\[ Rp = r_o \left\{ \frac{2q - S_o + p'(k + 1)}{(p + p')(k + 1)} \right\}^{1/k - 1} \] (Sanfillipo et al. 1997)

Where

- **K** Tri-axial stress factor
- **S_o** Unconfined uni-axial strength
- **Q** Hydrostatic stress field
- **Rp** Radius of plasticity
Fundamentals Of Near Wellbore Deformation

![Graph showing stress versus wellbore radii with isotropic stress (5600 psi).](image)

- **Stress (psi)**
  - Radial: Blue diamonds
  - Tangential: Pink squares

- **Wellbore Radii**
  - 0 to 20 units

- **Legend**:
  - Undamaged
  - Yielded

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Fundamentals Of Near Wellbore Deformation

Drilling

Production

Bit Size
Series2

100 DD 500 DD 800 DD 1100 DD 1500 DD
3000 DD 4000 DD 5000 DD 5500 DD Bit Size

IES - Global

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Wellbore size is measured using calliper logs

- 2, 4, 6 arms callipers are used
- Helps to determine stress anisotropy and orientation
- Callipers reflect the mechanical, chemical and hydraulic effects of the drilling process on the finished wellbore
Main areas of application for the drilling processes

• Wellbore stability

• Hydraulics, hole size and wellbore cleaning

• Identification of drilling hazards

• Hole quality and zonal isolation
Drilling Optimisation - Hole Stability
Drilling Optimisation – Hole Stability

Two (2) main stability components; a chemical and a mechanical one

• Deformation can be used to calibrate the OMW, contributes to distinguish the type of collapse mechanism (catastrophic, partial, …)

• Aid in the identification of potential troublesome formations where certain operations/effects (swab & surge, reaming, ...) must be controlled

• Contribute to the identification of the magnitude and location of rock-fluid interaction effects
Cuttings size prediction based on:

- Hole collapse and hole size predictions
- Empirical model (Carles & Bryden 2000) developed from 53 wells sample from NNS
Near wellbore deformation prediction

- Assesses the impact of drilling effects such as swab & surge, changes in ECD and circulation rates
- Allows a more accurate prediction of the drill cuttings sizes and volumes
- Drilling fluid type and properties can be optimised to enhance cuttings transport and hydraulics (e.g. friction…)
- CFD methods can be used if higher accuracy is required for optimisation of the hydraulics
Drilling Optimisation – Hole Quality

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**Wellbore Stability Validation - BaF-5 ST1**

Range (MD) : 631.16m - 1800.01m
Scale : 1:7500

<table>
<thead>
<tr>
<th>Depth [mMD]</th>
<th>Collapse Limit</th>
<th>Fracture Limit</th>
<th>Mud Weight</th>
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<tr>
<td></td>
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<table>
<thead>
<tr>
<th>Plasticity Radius</th>
<th>Bit Size</th>
<th>Caliper</th>
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<tbody>
<tr>
<td>8 inch</td>
<td>20 inch</td>
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**Plasticity Radius - Zechstein Section**

Range (MD) : 2626.00m - 3280.00m
Scale : 1:7500

<table>
<thead>
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<th>Plasticity Radius</th>
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<tr>
<td>16.5 MW</td>
<td>T1 Sandstone</td>
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<tr>
<td>17.0 MW</td>
<td>T1 Sandstone</td>
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<td>T1 Sandstone</td>
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<tr>
<td>19.0 MW</td>
<td>T1 Sandstone</td>
</tr>
<tr>
<td>19.5 MW</td>
<td>T1 Sandstone</td>
</tr>
</tbody>
</table>

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**Drilling Optimisation – Hole Quality**

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• A hole drilled in-gauge does not guarantee near wellbore mechanical integrity

• Deformation is a permanent and irreversible process

• Formation’s porosity and permeability can change as a result of near wellbore deformation
Near Wellbore Deformation – Hole Quality & Zonal Isolation

The diagram illustrates the relationship between Differential Stress and Effective Mean Stress. The graph shows different regions indicating Strong Extension, Moderate Extension, and Onset of Dilation. The Effective Mean Stress ranges from 0 to 450 MPa, while the Differential Stress ranges from 0 to 250 MPa. The diagram helps in understanding the deformation behavior under various stress conditions.
• Zonal isolation might be affected by the impact of deformation on seal’s integrity
• Cement bond might have not failed but annular communication is present
• Deformation might help to overcome invasion and skin
• Other problems such as contamination of other formations, casing collapse or surface pressures might occur
Using near wellbore deformation to optimise drilling operations is a robust and practical approach to enhance performance and reduce operational risk. It can be measured.

- The concept is widely used in other industries such as mining and civil engineering (tunnelling, dam construction)
- The deformation process consist of three (3) main steps: Compression, Dilatancy and Compaction
- It can be very effective in improving the accuracy of wellbore stability predictions, OMW and fluid design
- Identification of problematic zones can be highlighted so drilling procedures and operations can be improved
- Issues such as rock-fluid interaction, BHA manipulation and circulation rates all impact the magnitude and location of the deformation
Conclusions

• Hole quality and zonal isolation can benefit from near wellbore deformation analysis as invasion and changes in petro-physical properties can be identified and their impact on the finish wellbore assessed

• Cementing systems might not be very effective zonal isolation in areas of where near wellbore deformation is present

• The use of 2, 4 or multiple arm callipers allow a accurate measurement of the deformation
Thank you for your attention

Any questions?
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