Simulation of Short and Normal Logging Measurements in the Presence of Tool Eccentricity Using Fourier Series Expansion in a New System of Coordinates and a Self-Adaptive hp-Finite Element Method

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Overview

1. A Fourier Series Expansion in a New System of Coordinates
2. Short and Long Normal Instruments
3. Numerical Results
4. Conclusions
Eccentered Tool

Cartesian system of coordinates: \((x_1, x_2, x_3)\)

New system of coordinates: \((\zeta_1, \zeta_2, \zeta_3)\)

Subdomain I

\[
\begin{align*}
x_1 &= \rho_0 + \zeta_1 \cos \zeta_2 \\
x_2 &= \zeta_1 \sin \zeta_2 \\
x_3 &= \zeta_3
\end{align*}
\]

Subdomain II

\[
\begin{align*}
x_1 &= \frac{\zeta_1 - \rho_2}{\rho_1 - \rho_2} \rho_0 + \zeta_1 \cos \zeta_2 \\
x_2 &= \zeta_1 \sin \zeta_2 \\
x_3 &= \zeta_3
\end{align*}
\]

Subdomain III

\[
\begin{align*}
x_1 &= \zeta_1 \cos \zeta_2 \\
x_2 &= \zeta_1 \sin \zeta_2 \\
x_3 &= \zeta_3
\end{align*}
\]
Eccentered Tool

Cartesian system of coordinates: \((x_1, x_2, x_3)\)

New system of coordinates: \((\zeta_1, \zeta_2, \zeta_3)\)

Constant material coefficients in the quasi-azimuthal direction \(\zeta_2\)
in the new non-orthogonal system of coordinates!!!
Modeled Tool (that KIGAM has been using)

The vertical dimensions and locations of each electrode:
We followed the vertical tool configuration of a commercial tool

- **M (Long Normal)**
  - Vertical location: 64 Inch (1.6254 m)
  - Ohm-m: $10^6$

- **M (Short Normal)**
  - Vertical location: 16 Inch (0.4064 m)
  - Ohm-m: $10^6$

Radial length of electrodes: 1 cm
Short normal

BH Radius: 0.2 m
BH Resistivity: 10 ohm-m

Largest eccentricity effects on the most conductive layers
Short normal

BH Radius: 0.2 m
BH Resistivity: 1 ohm-m

Smaller eccentricity effects with decreasing BH resistivity
Short normal

BH Radius: 0.2 m
BH Resistivity: 10 ohm-m

Largest eccentricity effects on the most conductive layers
Short normal

BH Radius: 0.1 m
BH Resistivity: 10 ohm-m

Smaller eccentricity effects with decreasing BH radius
Short normal

BH Radius: 0.2 m
BH Resistivity: 10 ohm-m

Largest eccentricity effects on the most conductive layers
**Long normal**

**BH Radius: 0.2 m**

**BH Resistivity: 10 ohm-m**

Smaller eccentricity effects on long normal logging measurements
Eccentered Tool Effects (DC DLL)

Eccentered-tool effects are larger around layer boundaries in resistive layers.

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Conclusions

- We have successfully simulated 3D short and long normal logging measurements by combining the use of a Fourier series expansion in a new system of coordinates with a 2D higher-order self-adaptive hp finite element method.

- Larger eccentricity effects at a more resistive borehole with a larger radius

- Larger eccentricity effects on short normal logging measurements than those on long normal logging measurements
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