Inversion-based Workflow for Oilfield Nested Multi-Casing Evaluation Using Electromagnetic Low Frequency Measurements

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Steel casing corrosion analysis is pivotal in well integrity evaluation for ensuring environment-friendly and efficient hydrocarbon production and for well abandonment at the end of the productive life of the well. Due to their sensitivity to metal loss and depth of investigation, low frequency electromagnetics (EM) based corrosion measurements have long been considered as viable non-destructive diagnostic means [1]. For nested multi-casing evaluation, the quantitative data inversion and analysis requires a thorough understanding and modeling of the underlying measurement physics.

We propose a model-based parametric inversion methodology for quantitative evaluation of multiple nested casings using multi-spacing and multi-frequency induction measurements, to determine effective thicknesses of individual pipes and take into account variations in casing conductivity and permeabilities. Axi-symmetric finite-element forward modeling is used in the inversion loop to match the tool responses allowing us to include the sensor details in the model. The presence of casing collars and ubiquitous eccentering of individual casings affects the tool responses and reduce the effectiveness of elementary interpretation schemes (often based on remote field eddy current concept and aimed primarily at providing the total metal loss). To quantify the effect of casing and measurement tool eccentering, we performed comprehensive 3-D finite-element modeling. The sensitivity and data resolution analysis is used to evaluate individual measurement importance and optimize the inversion based methodology. The workflow is capable of handling arbitrary number of nested casings and raises a QC flag for eccentered casings based on the reconstruction quality of short spacing measurements. Model covariance matrix from the inversion is used to quantify the inverted parameter uncertainty while the extended data resolution matrix [2] concept is applied to extract information about the measurement channel reconstruction. The proposed methodology has been successfully validated on synthetic data and lab measurements.

References:
1. T. M. Brill, C. Demichel, E. A. Nichols and F. Z. Bermudez, "Electromagnetic casing Inspection tool for corrosion evaluation", *International Petroleum Technology Conference*, Feb. 2012.
2. W. Menke, *Geophysical Data Analysis: Discrete Inverse Theory*, Third Edition, Academic Press, 2012.