Numerical Model For Optimizing Acoustic Logs With Piezoelectric Transducer Through Production Tubing

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Abstract

At the end of an oil well's useful or economic life, it must be inspected, analyzed, plugged, and subsequently abandoned. This critical operation is known as plugging and abandonment, and it aims to ensure the fluid-tightness of the well and the structural integrity of the wellbore to prevent environmental damage. With the increase in plugging and abandonment campaigns for mature oil wells worldwide, several research centers have invested in acoustic inspection tools and more robust techniques to analyze the integrity of the oil well through the production tubing. Analyses through the production tubing provide significant cost savings during the abandonment phase, although their analysis is complex due to low received energy and potential eccentricities of the production tubing. An important tool to assist specialists and researchers in their analyses is numerical simulations, which apply finite element models to describe the cement layer conditions of the oil well through the production tubing. In this work, concentric and eccentric models of an oil well with production tubing were constructed using the finite element method in the time domain through the commercial software COMSOL Multiphysics®, version 5.6. An omnidirectional pressure source was used, and the results were compared with a piezoelectric transducer source, which is more complex to model. The introduction of the piezoelectric transducer, validated through comparisons with experimental transmission tests, was valuable for approaching results obtained with more realistic cases and configurations. The models utilized the physics of Structural Mechanics, Pressure Acoustics, and Electric Currents. The plane-strain formulation and implicit transient solver generalized alpha with a fixed time step were employed. The analyzed signals have a frequency band from 0 to 50 kHz, and the acquisition points are consistent with commercial acoustic logging tools. The simulations were divided into two main groups: 2D axisymmetric simulations for concentric cases and 3D simulations for eccentric cases. The different models were compared in the frequency domain using the two-dimensional Fourier transform through the velocity dispersion curves for each mode. Overall, it was observed that there was higher received energy and better resolution in the dispersion curves for cases without the production tubing. For cases with the piezoelectric transducer, the most significant mode changes occurred near the transducer's resonance frequency. In eccentric cases with the production tubing, the largest mode changes occurred between 10 and 25 kHz, and a significant decrease in energy was observed.