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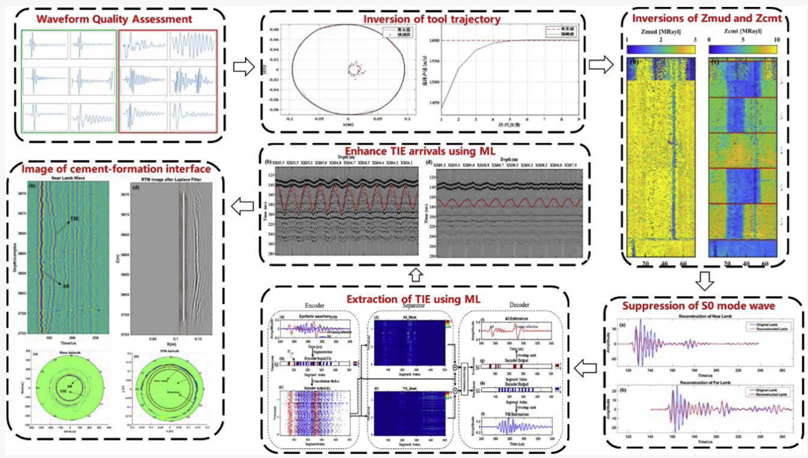
Ultrasonic insights into well integrity: Advances and challenges in cement bond evaluation

GA, UNITED STATES, December 25, 2025 /EINPresswire.com/ -- This study reviews recent advances in ultrasonic cement bond quality evaluation and proposes a unified framework for enhanced signal processing in cased wells, addressing key challenges such as tool eccentricity, lightweight cement discrimination, and weak signal extraction. Validation through synthetic models, laboratory experiments, and field deployments highlights the implications of these developments for machine-learning generalization and real-time well integrity diagnostics.



THE WORKFLOW FOR THE ULTRASONIC ENHANCED SIGNAL PROCESSING TECHNIQUES IN CASED WELLS (UESTC) FOR ULTRASONIC PULSE-ECHO AND PITCH-CATCH MEASUREMENTS INCLUDING.

Ensuring the integrity of wells is fundamental to safe oil and gas production, geothermal energy development, and geological carbon storage. At the heart of well integrity lies cement bonding, which isolates subsurface formations and prevents hazardous fluid migration. Against this backdrop, a team of researchers from China conducted a comprehensive review of recent advancements in cement bond quality assessment based on ultrasonic measurements.

"Ultrasonic logging has become a powerful non-destructive tools for evaluating cement bond quality behind casing, offering high-resolution insight into both the casing–cement and cement–formation interfaces," shares lead author Prof. Hua Wang, a professor at University of Electronic Science and Technology of China. "Over the past decade, ultrasonic pulse-echo and pitch-catch techniques have advanced cement bond evaluation."

Recent advances in ultrasonic well logging include:
1. Automated waveform quality control using variational autoencoders; simultaneous inversion of borehole-fluid and cement acoustic impedance;
2. Suppression of casing reflections via phase-shift interpolation and F–K transforms; joint inversion of tool trajectory and borehole properties under eccentric conditions; separation of A0

and S0 modes using variational mode decomposition;
3. Machine-learning-based enhancement and arrival-time picking for TIE waveforms; and
4. Imaging of the cement annulus–formation interface.

"These approaches have been validated using synthetic simulations, full-scale physical experiments, and field case studies, demonstrating robustness across varied borehole environments and well conditions," says co-author Meng Li, an associate professor at Xi'an Shiyou University. "Machine learning further increases reliability and automation, particularly in complex wavefields and low signal-to-noise settings."

By bridging physics-based modeling with data-driven approaches, this review presents a pathway toward more reliable, scalable, and intelligent ultrasonic cement evaluation—an essential step for meeting increasingly stringent integrity requirements in energy transition applications such as carbon capture and storage.

References
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