



Advanced Cement Mapping Techniques in Complex Wellbore Environment Aiding Informed Workover Decisions

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Introduction

Cement placement is a critical component of a well's architecture for ensuring mechanical support of the casing, providing protection from fluid corrosion, and, most importantly, isolating permeable zones with different pressure regimes to prevent hydraulic communication. Many cement evaluation techniques based on Sonic and Ultrasonic measurements provide a good understanding of mechanical integrity of casing and cement.

With increasing operational complexities and challenging scenarios like high pore pressure and low fracture pressure formations, application of heavy drilling muds and light cement slurries respectively becomes imperative. Conventional methods of cement evaluation reach their limitations in such environments due to low contrast of acoustic impedance between cement slurry and annular fluids or cement contamination due to heavy muds. Traditional cement bond log (CBL) and ultrasonic pulse-echo techniques are sometimes used together to diagnose zonal isolation but encounter difficulties when attempting to evaluate cements with low density and high contamination of mud. Ambiguity can result because these techniques rely on a significant contrast in acoustic impedance between the cement and displaced fluid to identify solids.

Challenge

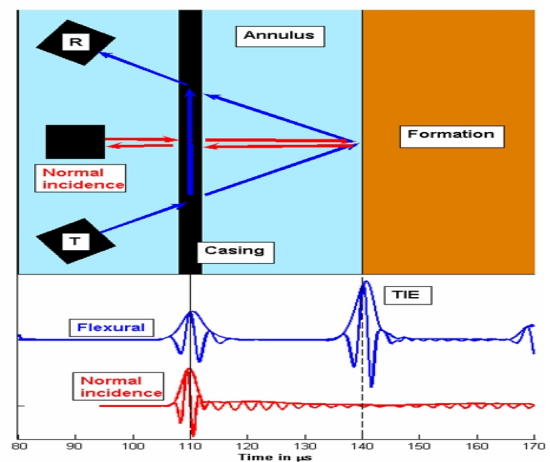
It's quite common to make cement squeeze decisions to ensure hydraulic isolation of formation zones based on CBL-VDL logs acquired after primary cementing operation. More than often it was observed that CBL and VDL logs, however reading medium to high and suggesting poor cement, could not yield a successful slurry squeeze across affected areas with minimal to no Injectivity. Furthermore, unsuccessful attempts are usually made in casing cut and pull operations owing to dubious CBL measurement across sections with barite segregation. Also, during Interpretation of cement quality using ultrasonic technique, there is always uncertainty associated in evaluation and correct classification of microdebonded

material behind casing as liquid or solid from Ultrasonic measurement only.

From cementing operation point of view cement placement in slim hole (5" casing in 6" borehole) is bound to pertain challenges. The annular volume between the casing and borehole to be filled with cement is quite low and this might cause improper removal of mud across certain sections by cement, thereby resulting in casing eccentricity and mud contamination of cement during the cementing job. In order to evaluate the cement bond quality and ascertain the efficiency of casing centralizers for proper cement placement, a complete cement evaluation is much needed.

Flexural wave based Cement mapping

An advanced method of cement evaluation based on Flexural wave propagation was introduced recently. The technique combined the pulse echo measurement with a new ultrasonic technique where an ultrasonic transducer induces flexural wave in the casing and resulting signal is detected at two set of separate transducers acting as receivers. The attenuation calculated between the two receivers provided an independent response that was paired with the pulse echo measurement to distinctly identify material present immediately behind casing.



Advanced Cement Mapping – Flexural Wave

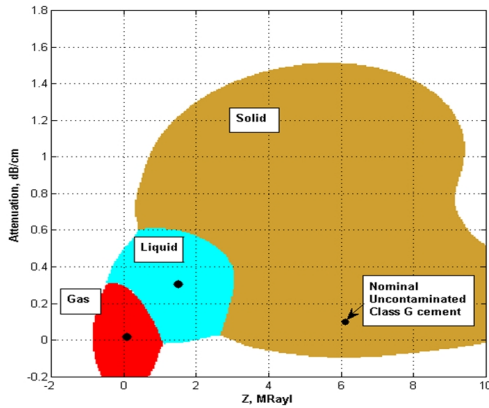


Fig.1: Flexural Wave excitation representation and resonance mode of the casing. Solid-Liquid-Gas Map Showing the correlation of Flexural Attenuation and Acoustic Impedance.

By measuring radially beyond traditional cement evaluation boundaries, Flexural based technique confirmed zonal isolation, pinpointed any channels in the cement, and ensured confident squeeze or no-squeeze decision. Furthermore, analysis provided a better insight to casing eccentricity problems and associated cementing challenges.

Case Studies

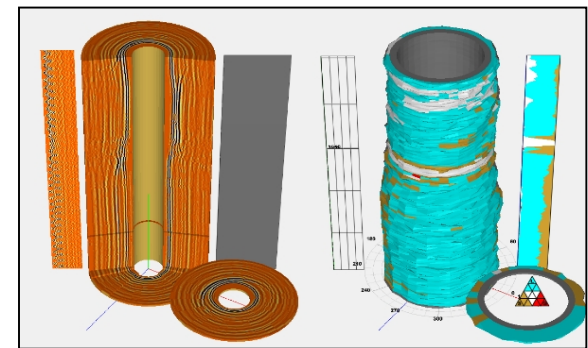
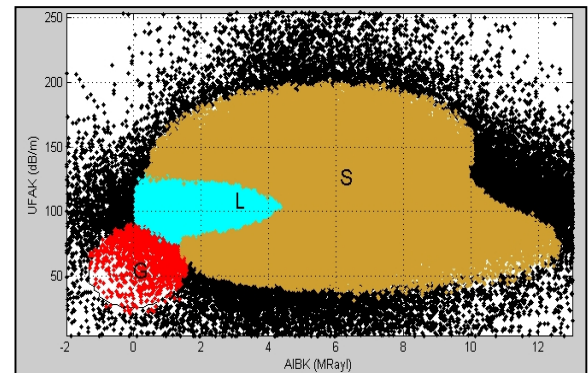
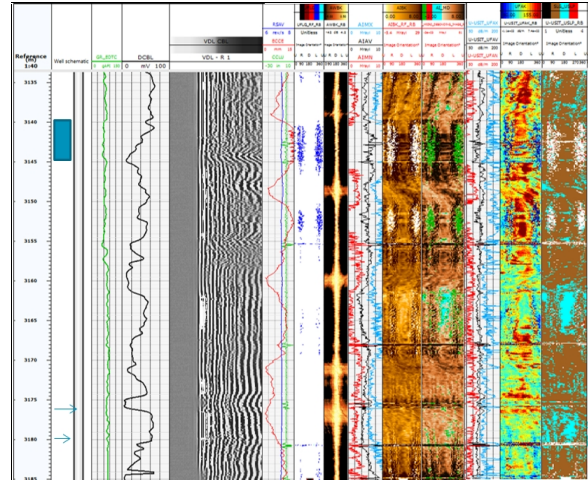
Considering the challenges associated with slim hole cement placement and heavy mud, Cement mapping through flexural measurement was recommended and run for the First time in ONGC, India in field AB and field CD.

CD, ONGC

In this area, wells are generally drilled with heavy mud (~15 ppg or higher) in order to contain the formation pressure and drill as deep as around 4500m. As a general practice, sonic logs apart from basic logs are acquired to evaluate the hole size consistencies and stress regime in the wells in order to produce efficiently after placement of suitable completions and cementation across different hole sections.

Well CD-1 was drilled with 15.7 ppg KCL-PHPA-Polyol mud and completed with 5-1/2", 20 ppg casing. Due to heavy nature of mud within and outside the annulus (MUD AI~2.99 MRayl), it was critical to map and differentiate the liquids from solids in the annulus and also remove the uncertainties related to fluid identification coming from standalone CBL or Ultrasonic measurements. A SLG plot was created in order to locate the flexural and AI data points to characterize the material behind casing. SLG plot clearly identified high density points lying in the solid region with lesser density of liquid filled region, hence

suggesting prominent presence of cement. Hydraulic Communication map indicated no possibility of fluid/solid movement or injectivity behind casing, hence bringing the confidence that injectivity may not be found during any workover operation. However, cement squeeze decision was taken to validate the results from two measurements. No cement injectivity was observed during squeeze across the zone of interest.



Advanced Cement Mapping – Flexural Wave

Fig.2: Flexural and pulse echo technique combination - Solid-Liquid-Gas Map Showing the Distribution of Flexural and Acoustic Impedance Points across the Log Interval. Third Interface and Annulus Material 3-D Visualization is also observed.

AB, ONGC

The well AB was drilled with 12.8 ppg WBM mud and completed with 5", 18 ppf casing. Due to existing slim hole conditions and heavy nature of mud within and outside the annulus (MUD AI~2.3 MRayl), it was imperative to eliminate the uncertainties associated with correct classification of microbonded material behind casing simultaneously evaluating 5" casing eccentricity if any. High confidence data was acquired against zone of interest to validate and provide information about cement behind casing. Advanced Solid Liquid Gas map showed high solid fraction across the zone of interest while indicating patches of liquid across few sections. Hydraulic communication plot indicates no possibility of liquid channel behind casing. Overcoming Sonic and Ultrasonic limitations, Flexural measurement could clearly distinguish materials behind casing. Third Interface Echo observed at few places helped analyzing casing eccentricity across the dual casing sections.

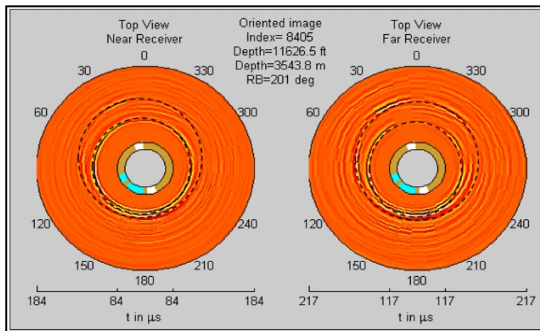


Fig.3: Isolation Scanner* - Borehole Cross-section depicting inner and outer casing and amount of eccentricity observed between two casing

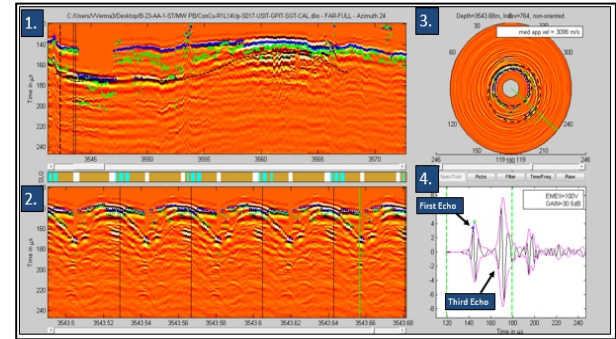
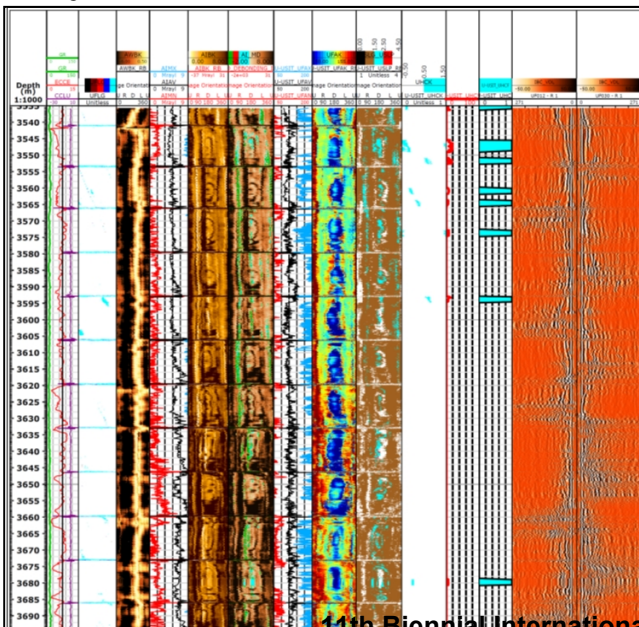


Fig.4: Flexural based -Cement Evaluation Composite Plot (Single Casing) – Microbonded image from Ultrasonic measurement is clearly identified as liquid in the SLG Map. 1: Third interface waveform Along the 30m Log Interval; 2: Waveforms Wrapped Open at a certain azimuth along 5 sampling intervals; 3: Borehole Cross-section depicting inner and outer casing; 4: Echo Waveform showing First and Third Interface Echo

Conclusion

Successful ultrasonic cement imaging and third interface echo analysis was performed in slim hole condition and highly attenuative environments where conventional methods are limited to ambiguous CBL-VDL measurements.

- Advanced cement mapping clearly distinguished microbonded cement as low AI solids or liquids which is a limitation in Ultrasonic measurements. (For all casing sizes).
- Third interface echo analysis provided a better insight to casing eccentricization and cement placement to understand the challenges associated with good cementing job. (Also recommends cut point depth for casing, if any)

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