PaperID **AU147**
Author **Sachit Saumya, Schlumberger, India**
Co-Authors **Sunil Chowdhary, A.K. Vinod, Juli Singh, Jitesh Vij, Sujit Kumar Sarkar, Preetika Shedde, Bhaswati Das**

GEO India 2018

Showcasing industry's first LWD full range quantitative cement evaluation - A case study from Western Offshore basin: India

Abstract

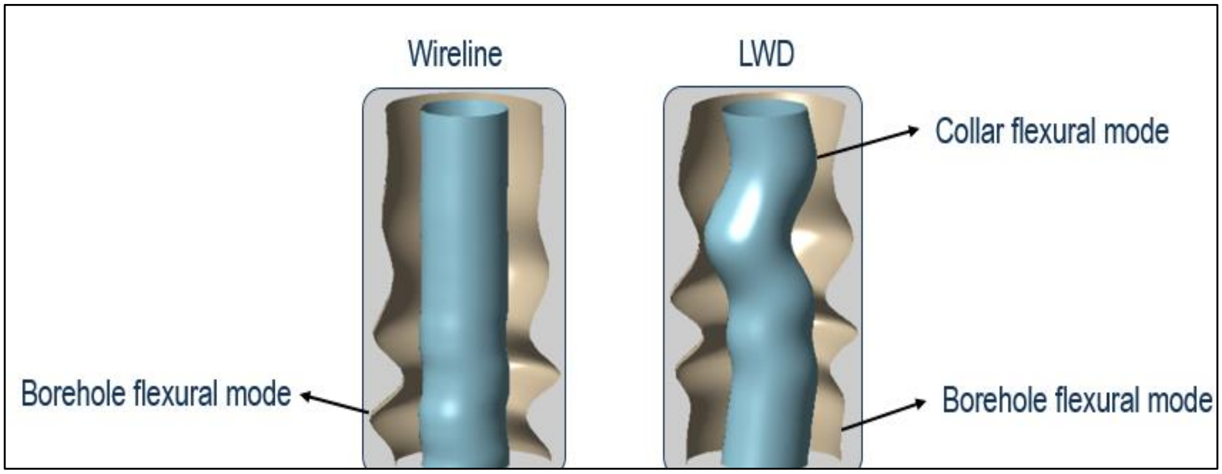
Cementing forms an essential part of well construction as it supports the casing and provides hydraulic sealing. Wireline (WL) sonic tools have been providing the cement evaluation (CBL/VDL) for more than 50 years. Quantitative cement evaluation is becoming increasingly important in the industry to verify well integrity and zonal isolation. There has been a growing interest in providing cement bond quality quantitatively with LWD sonic tools owing to its plethora of benefits over wireline logging, such as, rig time saving, tool conveyance, less tool eccentering effect and time lapse evaluation. However, there is also a LWD specific challenge that has for long hindered the ability to measure quantitative bond index i.e. drill collar contamination which limits the range of cement bond evaluation with the conventional amplitude based approach. Deriving a characteristic correlation of attenuation measurement against the bond index was one of the key components to overcome the limitation of amplitude-based. A new hybrid processing approach combining amplitude and attenuation was established for full-range cement bond evaluation. Schlumberger's LWD multipole sonic Cement Evaluation Service delivers the industry's first quantitative bond index answer product on LWD platform. The quantitative bond index becomes even more critical in offshore and deepwater markets.

This paper discusses in brief the technology and associated challenges in delivering industry's first quantitative bond index and showcases the result for one of the wells in Western Offshore basin in India. A subsequent comparison of LWD multipole sonic cement evaluation results with conventional WL CBL-VDL further corroborates the reliability of the result. The performance of industry's first LWD bond index derived using LWD multipole sonic from around the globe has demonstrated that it can be expected to show abundant success in expanding the LWD utilization globally.

Introduction

Over the past many years, there has been an increased focus on well integrity ranging from operators to regulators. One key element is the cement-to-casing bonding condition, as the cement supports the casing and provides the hydraulic seal. Presently the evaluation of cement integrity behind is limited only to wireline tools such as ultrasonic azimuthal imaging or a sonic cement bond log (CBL). There is, however, an incentive to provide cement integrity information with logging-while-drilling (LWD) tools which can help save rig time. It is important to identify poor cementing conditions as early as possible to be able to consider potential remedial work and to reduce any risk before drilling the next section. They also allow monitoring of the possible changes of the casing-to-cement bonding with time as, while running in and out of hole, LWD tools can evaluate the same cased hole section on multiple passes. In recent years, the service offered by the LWD acoustic tool has been the top of cement (TOC) indication, which has been used only as a qualitative cement presence indicator to confirm or correct the prediction of the depth along the borehole at which the cement has been placed.

There is a technical challenge for quantitative cement evaluation with LWD acoustic tools due to the rigid steel collar of LWD tools. The desired casing signals mix with unwanted signals propagating through the collar at a similar speed. The evaluation of bond index is possible when the casing signal is large enough in comparison to the collar signal. Since the casing signal is a function of numerous factors, such as the



acoustic impedance of the cement and the casing size, then the bond index computed with an LWD tool and its associated limitations also depend on these factors.

Fig 1: This figure shows borehole and collar mode of propagation interference with wireline and LWD tool.

Measurement Physics

The principal behind acoustic cement evaluation with a sonic tool is similar for wireline or LWD tool. A CBL measures the amplitude of the casing plate extensional mode. The amplitude of this mode depends upon the attenuation rate of the mode propagating along the casing. This attenuation rate is a function of the intrinsic attenuation of the casing and the medium around it. The amount of energy loss along the extensional propagation depends upon the thickness of the casing, the acoustic impedance of the cement and the bond index between the casing and the cement.

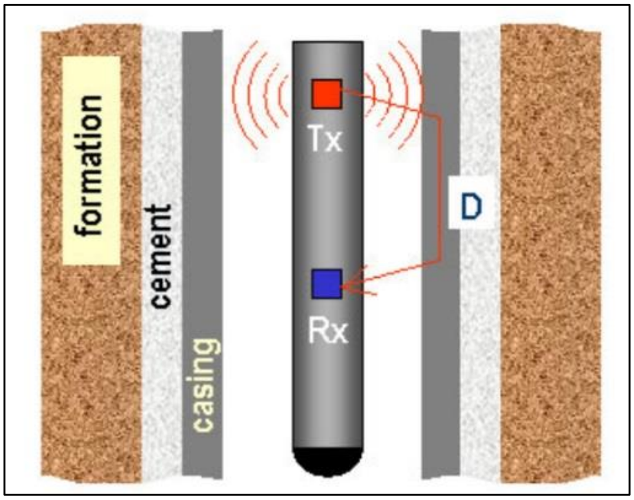


Fig 2: A diagram of a basic cement bond analysis tool showing the arrangement of transmitters and receivers and the signal path length (D) inside the casing

The amplitude of the first peak is measured for measuring the casing amplitude at a given distance from the transmitter within a time window containing the signal propagating in the casing. Peak-to-peak amplitude method is then used to estimate the casing amplitude which is converted to bond index for a given spacing with an established linear relationship for deriving LWD quantitative bond index. The logarithm of amplitude linearly varies between the free pipe value and a value of 100% bond index. In case of LWD sonic, stiff tool structure causes a propagation of acoustic wave on the tool with the similar speed of the casing arrivals. Thus, it is essential to take into account the effect of the tool arrival presence. The effect of tool arrival in amplitude is not significant up to around bond index 0.6. Therefore, amplitude-based method enables to obtain bond index in relatively low bonding conditions. But as the bond index increases beyond 0.6, the quantitative evaluation using signal amplitude is limited by the propagation in the collar such that when there is high attenuation of the casing signal, the collar arrival mixes with it and can even become the dominant acoustic signal.

In a second approach, the measurement of amplitude can be made at various spacing for receivers along the array, and an observed attenuation rate can be computed. The attenuation at each time sample is calculated using linear fitting of amplitudes on envelopes over the receiver array. Using proper modeling (simple summation model) and parameter setting, measured apparent attenuation can be transformed to bond index. At higher bonding index greater than 0.5, attenuation in the modeling decreased with increasing bond index but at lower bond indices the attenuation increased thereby limiting this approach only for higher bond indices.

In order to overcome challenges from both the approaches, the new quantitative bond measurement from LWD multipole sonic waveform, utilizes both amplitude and attenuation of receiver array, so called hybrid method, a full range of bond index determination comes in to picture. Amplitude-based QBI below bond index 0.4 and attenuation-based QBI above bond index 0.5 are spliced for hybrid QBI. Between bond index 0.4 and 0.5, two QBI logs are averaged with a weighting function where in appropriate splicing range is determined from Simple Summation Model to make sure smooth transition in splicing bond index range (Fig 4).

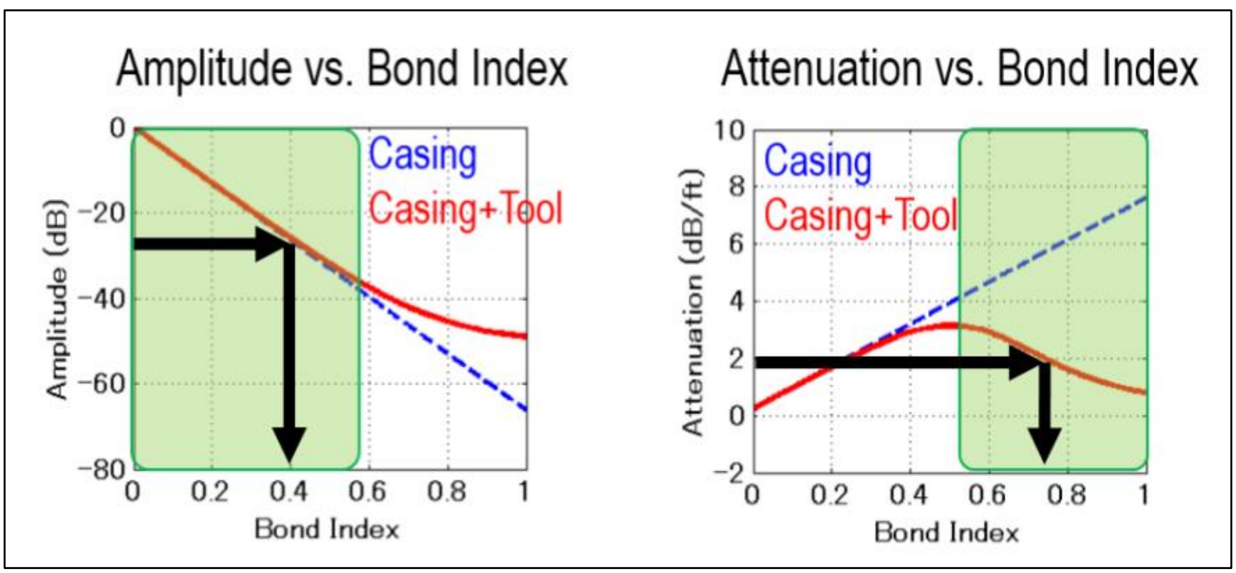


Fig 3: Amplitude/Attenuation versus bond index based on a model considering tool arrival presence

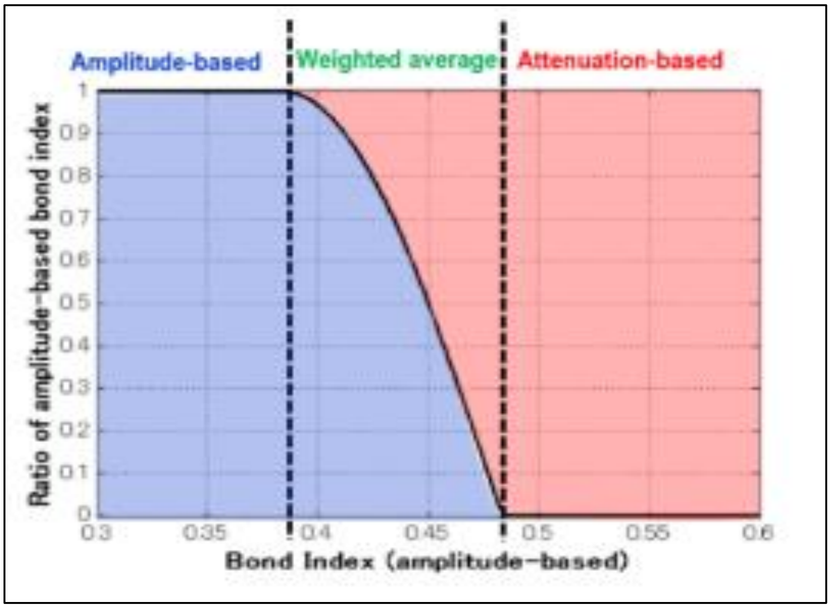


Fig 4: Weight function for splicing range

Result and discussion: Case Study from Western Offshore

A significant advantage of the new LWD QBI offering from LWD Multipole sonic is the fact that in order to derive QBI, no separate run is required to acquire monopole waveform. In a regular LWD multipole service for acquiring waveform while drilling, the monopole waveform can be acquired while running down in hole or while tripping out. The processing quality can be improved by waveform depth stacking if the data can be recorded with tripping speed of 900 ft/hr to have waveform data every 6 in.

LWD sonic monopole waveform was recorded while tripping out at ~1800ft/hr in the Western Offshore basin of India inside the 9.625 in casing with casing ID 8.681 in and weight 47 lbm/ft. In order to evaluate the cement quality, LWD QBI processing was carried out to give India's first LWD quantitative bond index. A subsequent wireline CBL run done inside the casing in the same section followed by a USIT (Ultra sonic imaging tool) run was compared to validate the quality of LWD QBI.

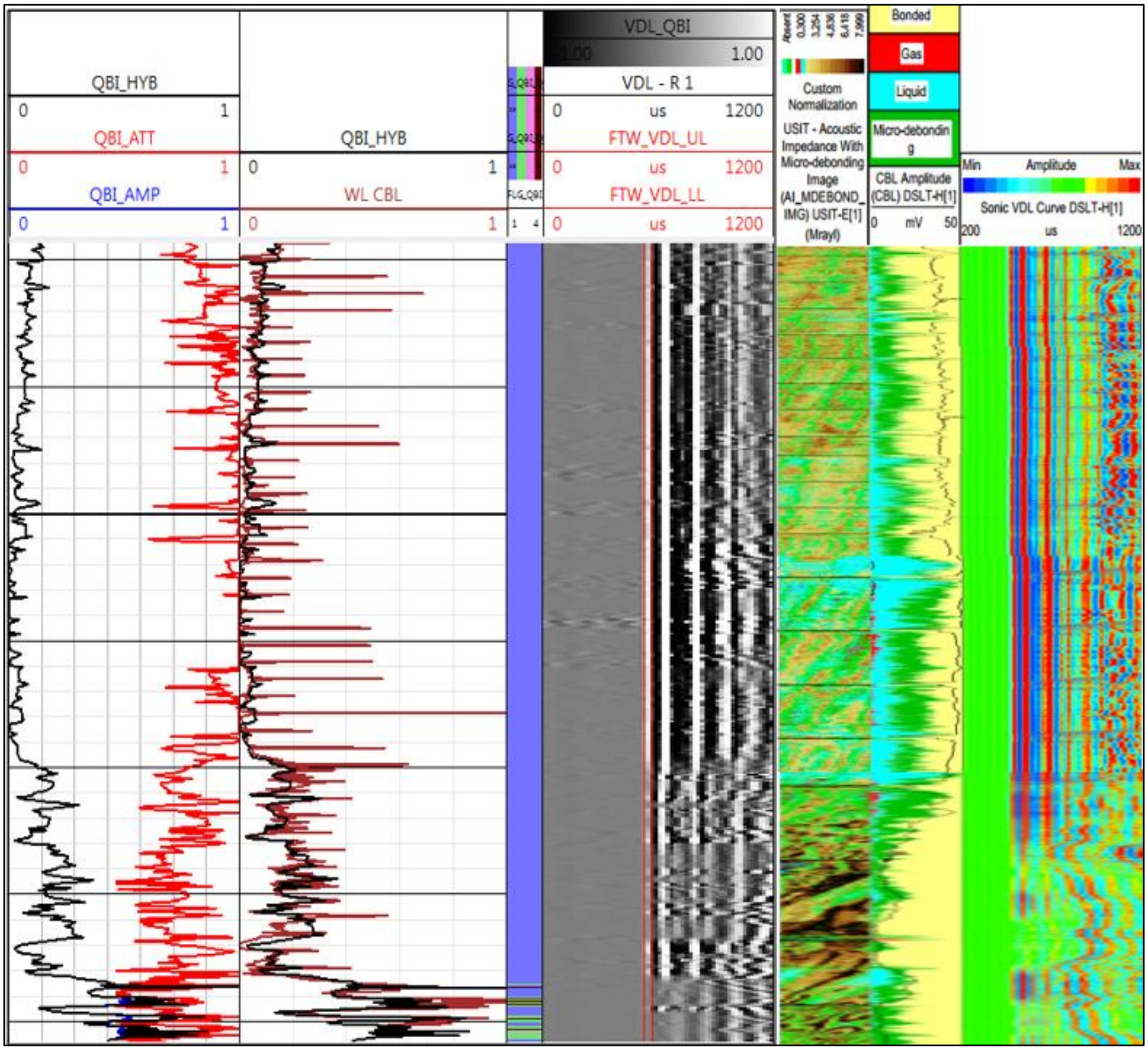


Fig 5: Comparison between LWD QBI and WL CBL and USIT log. Track 1: Derived LWD QBI from hybrid method (QBI_HYB) utilizing attenuation (QBI_ATT) and amplitude method (QBI_AMP), Track 2: LWD QBI and WL CBL comparison, Track 3: QBI Splicing range flag, Track 4: QBI VDL, Track 5: USIT Acoustic Impedance image, Track 6: USIT cement map, Track 7: Sonic VDL DSLT-H

QBI_HYB in the first track is derived by splicing amplitude based bond index, QBI_AMP and attenuation based bond index, QBI_ATT. The LWD QBI shows very poor cementing with low bond index for most of the interval. The QBI_HYB is composed of amplitude based bond index (QBI_AMP) for most part of the interval and as the bonding improves with bond index greater than 0.4 in the bottom depths, a weighted function is used to splice QBI_ATT and QBI_AMP to give QBI_HYB. The blue flag in track 3 also indicates that amplitude based bond index has been utilized primarily owing to the lower cement bonding.

The WL_CBL and LWD QBI depicts an excellent match in almost the entire section indicating that cementing is very poor in most part of the interval. The USIT logs showing liquid and micro-debonding further provides strength to the interpretation from LWD_QBI. The spike in the WL_CBL log is represents the casing collar locator (CCL).

Conclusion

Now with the availability of industry's first quantitative bond index in LWD time, it is possible to evaluate the cement quality very early in the well cycle. With the option to process both running in hole (RIH) and tripping out data, a time lapse analysis of the cement quality provides additional value in analyzing the cementing behavior over time. One of the critical application of LWD QBI is in deepwater wells where recognizing poor cementing as early as possible and taking remedial measures becomes crucial. Based on the interpretation of LWD QBI, further advanced WL logging like USIT and Isolation Scanner (IBC) can be carried out for an advanced cement integrity evaluation.

For large casing sizes, the increased annular space between the transmitter/receiver and the casing due to the relatively small diameter of wireline cement bond logging tools, causes signal reduction which combines with the increased attenuation from the thick casing wall. This means the traditional measurements in large casing strings have low amplitude and are unreliable and very difficult to interpret. Since, evaluation of large casing strings is required by many regulatory agencies, the LWD QBI offers an advantage due to their larger sizes and better centralization in most situations. Similarly, in deviated wells, LWD QBI offers advantage where conveyance can be an issue.

Although the level of sophistication present in the advanced WL cement logging tool like USIT and IBC may not be present, LWD quantitative cement evaluation offers some benefits that are not necessarily achievable with other conveyance methods or that can save time and associated costs. LWD full range quantitative cement evaluation has enormous potential for the enhancing the value utilization of LWD in exploration and development fields

Acknowledgement

Authors take this opportunity to express their gratefulness to the ONGC management for their encouragement and approval to present this work.

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