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Advances in Cement Bond Logging Technology and Issues in Cement Job Quality Evaluation

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Abstract: The Cement Bond Log (CBL) is currently the primary method used in domestic oilfields to evaluate cement job quality. However, its interpretation results are prone to ambiguity, leading to misjudgment and erroneous conclusions. This results in artificially high reported pass rates for cement jobs, which hinders the development of cementing technology. This paper systematically analyzes the limitations of CBL in evaluating cement job quality, discusses in detail ten influencing factors including tool eccentricity, fast formations, micro-annulus, cement sheath thickness, gas-cut drilling fluid, casing parameters, localized channeling, cement slurry properties, logging timing, and acoustic frequency. It also points out inherent shortcomings of CBL in evaluating the second interface, identifying thin beds, locating channels, and providing quantitative interpretation. Research indicates that the consistency rate of CBL in reflecting actual cement job quality is only about 33%. In contrast, the Sector Bond Tool (SBT) offers technical advantages through multi-parameter visual display and cement sheath imaging. It is recommended that SBT be used as a means for detailed evaluation of cement job quality in key or problematic wells.

Keywords: Cement bond logging; Cement Bond Log (CBL); Cement job quality evaluation; Influencing factors; Sector Bond Tool (SBT)

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1. Introduction

Cement bond logging is a key technique for evaluating cement job quality [1]. At present, most domestic oilfields still use the Cement Bond Log (CBL) for this purpose. However, because the CBL is affected by various factors such as micro-annulus, fast formations, and cement sheath thickness, the log data are prone to ambiguous interpretations, often leading to misjudgment of cement job quality [2]. This results in artificially high reported pass rates, which to some extent conceals problems in cementing and restricts both the development of cementing technology and further improvements in cement job quality. Therefore, it is necessary to systematically review the limitations of CBL and the factors that influence it, and to explore technical directions for improvement.

2. Limitations of CBL in cement job quality evaluation

2.1. Oversimplified theoretical assumption

Traditional CBL interpretation assumes that the quality of the casing-cement bond is the only factor affecting the amplitude of the casing wave first arrival. It ignores the effects of cement sheath type (low-density, G-grade with sand, neat G-grade), thickness, water/cement ratio, casing diameter and wall thickness, and the acoustic properties of the external formation. Such oversimplification can lead to two types of misjudgment as follows:

(1) Intervals with poor bonding may be interpreted as moderate or even good bonding;

(2) Intervals with good bonding may be interpreted as moderate or even poor bonding.

2.2. Lack of quantitative interpretation support

Existing interpretation models are overly simplistic and lack theoretical and practical support for quantitative interpretation. This results in vague definitions of bonding quality. Interpretation standards vary not only between different oilfields but also among different interpreters, leading to a lack of consistency and uniformity in cement job quality evaluation.

2.3. Insufficient spatial resolution

CBL cannot accurately distinguish between radial channeling and longitudinal channeling, nor can it accurately locate the azimuth of unbonded intervals. For thin beds whose thickness is less than the vertical resolution of the tool, the bonding condition cannot be accurately assessed. The evaluation of thin cement sheaths has long remained a poorly solved problem.

2.4. Average bond index

CBL only provides an average measurement of the cement sheath. Moreover, its interpretation is based on the assumption of complete cement filling, any cement bond less than 100% is interpreted as channeling or poor bonding. In reality, changes in log response may arise from variations in cement slurry performance rather than from actual changes in the percentage of casing bond.

2.5. Lack of information on the second interface

Cement job quality should be judged by the quality of the bond at both the first interface (casing-cement) and the second interface (cement-formation). However, the CBL curve mainly detects bonding conditions at the first interface and lacks sufficient information to inspect the second interface, this is its greatest shortcoming. The second interface is more concealed, yet it is the pathway for oil, gas, and water migration. A good bond at the first interface does not guarantee a good bond at the second interface.

2.6. Inability to distinguish micro-annulus from channeling

A micro-annulus (a very small annular gap of about 0.1 mm between the casing outer wall and the cement) does not affect hydraulic sealing or cement job quality. In contrast, channeling, incomplete cement filling, fails to provide hydraulic sealing. Under non-pressurized logging conditions, both micro-annulus and channeling intervals appear as poor bonding on the CBL curve and are difficult to distinguish. This often leads to erroneous decisions such as perforating through poor bonding or squeezing cement unnecessarily.

3. Major factors affecting CBL evaluation of cement job quality

3.1. Tool eccentricity

When the eccentricity is 6.35 mm, the amplitude drops by 50% compared with a centered tool; at 25.4 mm eccentricity, the amplitude drops by 75%. This can easily cause intervals with poor bonding to be misjudged as well-bonded. Keeping the tool centered is very important in large-diameter casings and deviated wells.

3.2. Fast formation

If the formation outside the casing is fast (formation velocity higher than that of the casing), the first arrival recorded by CBL is no longer the casing wave but the formation wave. In this case, neither the relative amplitude method nor the bond index method can yield correct conclusions, although qualitative results can be obtained. Typically, when a fast formation is present, the cement job quality is good, and both the casing-cement and cement-formation bonds are of high quality; only then can acoustic energy be transmitted from the casing to the formation and coupled back into the borehole.

3.3. Micro-annulus

A micro-annulus disrupts the shear coupling between the casing and the cement. If the micro-annulus is extremely small and insufficient to cause channeling, the bond should be considered good. However, the acoustic coupling is poor, resulting in little attenuation of the casing wave and creating a false indication of very poor bonding. The high amplitude caused by a micro-annulus can be eliminated by logging with applied surface pressure.

3.4. Cement sheath thickness

When the cement sheath thickness is greater than 2 cm, the attenuation of the casing wave is constant. When the thickness is less than 2 cm, the thinner the cement sheath, the smaller the attenuation and the higher the CBL value. Evaluating thin cement sheaths may lead to misinterpreting well-bonded intervals as poorly bonded. Therefore, it is necessary to refer to the caliper curve during interpretation. The effect of a fast formation is even more pronounced when the cement sheath is thin.

3.5. Gas-cut drilling fluid

Gas-cut drilling fluid attenuates acoustic energy much more strongly than conventional drilling fluid. Consequently, very low CBL values may be recorded in gas-cut intervals, which does not necessarily indicate good cement job quality.

3.6. Casing parameters

The casing can be considered a homogeneous medium with fixed acoustic absorption. The smaller the casing wall thickness, the greater the acoustic attenuation. A thin-walled casing tends to produce low amplitude values.

3.7. Localized channeling

When cement is partially bonded with a channel in a certain azimuth, CBL simply displays a high amplitude value and cannot detect the details of the channel. This is because CBL measures an average cement bond; casing waves arriving at the receiver from different azimuths have different phases and partially cancel each other, producing an effect similar to that of tool eccentricity.

3.8. Cement slurry properties and types

The type of cement slurry, its compressive strength, setting time, and contamination by drilling fluid all affect bond evaluation. Different density cement slurries yield different CBL values. To obtain a reasonable evaluation, the minimum CBL (or attenuation) value indicative of good bonding should be established for each interval.

3.9. Logging timing

After cement placement, the acoustic properties of the cement slurry change with time. Logging should be performed only after the cement has sufficiently set; otherwise, incorrect interpretation may result. This is particularly true for shallow wells, where low downhole temperatures slow the development of cement strength, making early logging even more problematic.

3.10. Acoustic frequency effects

Studies by Chaney *et al.* on the influence of frequency on CBL concluded that "logging systems operating at predominantly high frequencies can lead to pessimistic evaluations of the casing-cement bond. High frequencies generally indicate poorer bonding because high-frequency energy preferentially travels through unbonded paths."

In addition to the factors listed above, other factors such as tool control system, off-centering distance, electrode spacing choice, tool calibration, and logging speed also significantly affect the tool response. Since the introduction of CBL, the validity of its interpretation has been a subject of continuous debate. Foreign data indicate that the consistency rate of CBL in reflecting actual cement job quality is only about 33%.

4. Advantages of SBT logging and recommendations for application

SBT overcomes many of the shortcomings of CBL. Its ability to display multi-parameter information visually, especially cement sheath bond imaging, is a prominent advantage. SBT provides azimuthal information on cement bond around the circumference, effectively distinguishes localized channeling from micro-annulus, and offers improved resolution for thin beds and azimuthal channels.

Although advanced tools like SBT have significant technical advantages, economic considerations suggest that SBT should be used as a means for detailed evaluation of cement job quality, mainly applied to key or problematic wells, to compensate for the deficiencies of conventional CBL.

5. Conclusion

In conclusion, CBL is affected by many interfering factors. Its oversimplified assumptions, lack of quantitative interpretation, insufficient spatial resolution, and inability to obtain information on the second interface result in a low consistency rate. Ten factors, including tool eccentricity, fast formations, micro-annulus, cement sheath thickness, gas-cut drilling fluid, casing parameters, localized channeling, cement slurry properties, logging timing, and acoustic frequency, significantly affect CBL evaluation. All must be considered comprehensively during interpretation. On top of that, SBT is superior to CBL in azimuthal resolution and imaging display. It is suitable for detailed evaluation of cement job quality in key or problematic wells. It is recommended that CBL interpretation standards be improved for routine cement jobs, and that SBT be promoted in critical wells to enhance the reliability of cement job quality evaluation.

Disclosure statement

The authors declare no conflict of interest.

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