Application of Acoustic Variable Density Logging Technology in Petroleum Energy Development

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Abstract. Energy is an important factor restricting the development of national economy, and petroleum energy is the main supplier in the current world energy environment, which promotes the development of agriculture, and various industrial sectors are closely related to petrochemical products. However, with the long-term development of the oilfield, it has experienced the stages of flowing production, water injection development and three times of chemical agent injection development, the production and explorable new reserves have decreased significantly, especially after the oilfield entered the well pattern three times of infilling adjustment, because of the exploitation of thin, poor and off surface reservoirs mixed between the main oil layers. Due to the requirements of oilfield development, not only the channeling between the adjusted thin and poor layers should be prevented, but also the channeling between the adjusted thin and thick layers should be prevented. Therefore, the requirements for cementing quality are higher and higher, and the requirements for testing and evaluation standards of cementing quality are more and more accurate. In this paper, through the application of acoustic variable density logging technology in petroleum energy development, combined with the examples of acoustic amplitude and acoustic variable density logging curve, the cementing accuracy of the first, second and interface of cement sheath after cementing is further improved, so as to meet the new requirements of correctly evaluating the cementing quality in the later stage of oilfield development.

1. Introduction

Energy is an important factor restricting the development of national economy. The petrochemical industry is the main supplier of the current world energy environment, which promotes the development of agriculture. Various industrial sectors are closely related to petrochemical products. Gasoline, kerosene, diesel oil, heavy oil and natural gas produced by petroleum refining are the irreplaceable main energy sources at this stage. At present, oil and natural gas are the main energy sources in the world. However, gas consumption accounts for about 60% of total energy consumption. It is no exaggeration to say that without fuel, there would be no modern transportation industry; metal processing and all kinds of machinery without exception need all kinds of lubricating materials and other supporting materials, which consume a lot of petrochemical products; light industry and textile industry are traditional users of petrochemical products, and the development and promotion of new materials, new technologies and new products all have petrochemical products.

At present, the rapid development of electronic industry and many high-tech industries have put forward new requirements for petrochemical products, especially the fine chemical products produced with petrochemical products as raw materials, and petroleum exploitation is the most important strategic position in the development of petroleum energy. However, with the long-term development
of the oilfield going through the stages of self injection production, water injection development and three times of chemical injection development, the production and explorable new reserves decrease greatly. Especially when the oilfield enters the three times of infilling adjustment of well pattern, the thickness of remaining underground recoverable reserves that can be further tapped becomes smaller and smaller, because the purpose of the three times infilling adjustment of well pattern is to exploit the main reservoir How to correctly evaluate the cementing quality and the requirements for the acceptance of cementing quality in drilling and the perfection of the corresponding perforation scheme also put forward higher requirements.

2. Current Cementing Quality Detection and Evaluation

Cementing is an important process of drilling and completion. The quality of cementing has a direct impact on the quality of logging. Therefore, it is necessary to deeply analyze the factors that affect cementing quality logging. Through the summary and analysis of the oil production stage, the factors affecting the well cementing quality mainly include the following three aspects: first, the influence of micro ring, the cement cementation has the process of volume expansion to shrinkage, thus forming a tiny space with water, called micro ring space. Because the propagation direction of casing wave is parallel to the interface, the micro ring space makes the acoustic coupling worse, which reduces the sensitivity of cementing logging; second, the influence of instrument eccentricity is that the time of reflected wave arriving at the transducer changes and the transducer is too close to the casing wall, resulting in multiple reflections between the transducer and the casing, which is superimposed with the measured wave, The third is the influence of fast formation or double casing. In fast formation or double casing, when the outer boundary of cement sheath is smooth and there is obvious acoustic impedance difference between the media on both sides of the boundary, there will be strong reflection echo on the boundary, which will affect the measurement results.

Acoustic variable density logging inspection of cementing quality mainly includes the following four parts: first, there is no cement outside the casing. Second, the cement is well cemented with the casing and formation. Due to the small difference between casing and consolidated cement, a large number of acoustic waves enter into the formation, so the casing wave is very weak, the formation wave is very strong, and the cementing acoustic amplitude is low; third, the cement is only well cemented with casing, but poor cemented with formation. The acoustic wave is not reflected at the casing interface, but enters the cement sheath. The cement sheath attenuates the acoustic energy greatly, and the acoustic energy transmitted to the formation is very small, so the casing wave and formation wave are very weak, but the cementing acoustic amplitude shows low amplitude. Fourth, the cement and casing are generally cemented. In this case, the casing reflects most of the acoustic energy back, only a small part of the acoustic energy enters the formation, and the casing wave and formation wave have a certain amplitude.

At the end of last century, the cementing quality testing in oilfields has completed the transformation from acoustic amplitude logging (CBL logging) to acoustic amplitude logging and acoustic variable density logging (CBL/VDL logging). The cementing quality evaluation and acceptance criteria have been changed from the relative amplitude of acoustic amplitude logging curve to the cementing quality evaluation and acceptance criteria currently using cement bonding index (BI value) as cementing quality evaluation and acceptance criteria. Quantitative evaluation.

Formulas for calculating BI values:

\[ BI = \frac{\text{Acoustic attenuation rate of target interval}}{\text{Sound attenuation rate of cemented layer}} \]

At present, J55 is widely used in oilfields. The calculation method of reservoir casing is as follows:

\[ BI = -6.64 \times \log(SA) + 13.02 \]

Formula: \( SA \) Casing Wave Amplitude for Measuring Point

MSA Casing Wave Amplitude for Well Section with Good Cementation
When BI is greater than 0.8, it is interpreted as well cemented. When BI is less than 0.4, it is interpreted as poor cementing. 0.4 < BI < 0.8, which is interpreted as moderate cementing.

From the above formulas, it can be seen that the BI value is related to the reduction rate of casing wave sound fall in the target interval. When the reduction rate of casing wave sound fall in the target interval is equal to that in the cement bonded interval, the cement bonding index (BI) of the target interval is equal to 1, and the cement bonding is the best.

According to the logging principle of acoustic amplitude and acoustic variable density logging (CBL/VDL logging), it can be concluded that the casing wave (i.e. the head wave of full wave logging) only reflects the cementing quality of one interface between cement sheath and casing, so the BI value can only evaluate the cementing quality of one interface, but can not evaluate the two interfaces correctly.

3. Comprehensive evaluation of cementing quality using acoustic variable density logging (VDL logging)
Acoustic variable density logging is also called full wave train logging. Acoustic variable density logging is a kind of acoustic logging. Acoustic variable density logging is developed from acoustic amplitude logging. This method plays an active role in oilfield exploration and development, and has been widely used in production wells, sidetracking wells, horizontal wells and exploration wells. The principle is: the transmitting transducer is used to transmit a certain energy sound wave to the borehole, and the sound wave passes through the borehole medium, casing, cement sheath and formation and then arrives at the receiving transducer. Due to the different densities of the borehole medium, casing, cement sheath and formation, the receiving transducer receives the drop waves successively, which are casing wave, formation wave and mud wave. The recorded wave train is used to improve the cementing quality comprehensive evaluation was conducted.

Following are several examples of curve analysis:

3.1. Analysis of the situation of free casing, i.e. no cement outside the casing (no cementation at the first and second interfaces)
After the acoustic wave emitted by the transmitting transducer to the borehole is received by the casing, it is impossible to transmit the energy to the formation because there is no cement outside the casing. Except for a small part of the energy propagated to the formation through the mud medium outside the casing, most of the energy is directly propagated to the receiving transducer by the casing. From (fig. 1) it can be seen that the BI value of the curve is above 698 meters, the sound amplitude is above 70 mu, and the first wave of the variable density of the acoustic wave is 0 mu. The receiving time is 156.25 mu(s). Because the sleeve is uniform medium, the reflected wave of the sleeve received by the transducer is straight and the width of the sleeve is uniform. It reflects that the cementing quality of the first and second interfaces is poor, and there is no formation information at the second interface, which shows that the cementing quality of the first and second interfaces is poor.

3.2. Analysis of Curve under Good Bonding of One and Two Interfaces
After the acoustic wave emitted by the transmitting transducer to the borehole is received by the casing, because the cement outside the casing is a steel medium, all the energy is transmitted to the formation, and the energy is transmitted to the receiving transducer through the transmission of the formation. Because the formation is a non-uniform medium, the amplitude of the formation wave received by the transducer varies greatly and the strip width is not uniform. Because of the influence of the non-uniform medium on the energy transmission, the acoustic wave is transmitted by the non-uniform medium. The receiving time of variable density first wave is not fixed, which is between 310 and 330 mu(s).
3.3. Curve analysis under the condition of good bonding at the first interface and poor bonding at the second interface

The acoustic wave emitted by the transmitting transducer to the borehole is received by the casing, and the energy is transmitted to the cement sheath. Because the cement sheath and the formation are not completely cemented and have no steel connection, the energy can not be transmitted to the formation. The energy can only be coupled in the cement sheath. The receiving transducer can neither catch the formation wave nor the reflection wave of the casing, but only receive the direct wave of the mud, the BI value. It is 1. It shows that the cementing quality of the first interface is good and that of the second interface is uncertain.

3.4. Analysis of Special Curve Shape of Acoustic Variable Density Logging

3.4.1. Effect of Mud Impurities on Logging Curves

When the impurities in the mud are more and unevenly distributed in the wellbore, the acoustic wave emitted by the transducer is scattered by the impurities in the mud, which hinders the energy transmission and prolongs the transmission time. The reflected wave of the casing wave is received by the transducer one and a half weeks later than that of the normal mud. At this point, the BI value is 1. It reflects good cementation, but this curve can not really reflect cementing quality.

3.4.2. Effect of Microring on Logging Curve

Since the cement slurry is a square heat process after cementing, the casing will be expanded by heat. When the cement is completely solidified, the casing will resume its original deformation, so it is easy to form micro-loops (micro-gap) at the interface. The acoustic wave emitted by the transducer to the wellbore is affected by micro-loops, which hinders the normal transmission of energy and receives the transducer. When the casing wave is received, the transducer also receives it. A certain intensity of formation wave can be received, and the BI value is generally between 0.6 and 0.8, reflecting the moderate cementation. The influence of mud micro-ring on logging curve is obvious at 942-944 meters.

4. Conclusion and understanding

With the development of domestic oil and gas exploration and development, the requirement of cementing quality evaluation accuracy for oil and energy production wells is higher and higher. After decades of development, acoustic logging technology has become an important application field of geophysical logging. Acoustic variable density is one of the main applications of acoustic logging. It is used to determine the propagation velocity of formation acoustic wave. The source distance is short. The data is used to calculate the formation porosity and determine the gas layer. It can determine the elastic modulus of rock layer. The source distance is long, It is used to calculate the rock strength, check the fracturing effect and cementing quality. This paper will summarize the application of new technology of acoustic variable density logging, which is of great significance to improve the value of comprehensive utilization of data.

(1) There are many factors affecting the acoustic density, such as propagation distance and media, which have an impact on the acoustic reception time. Therefore, the influence of casing wall thickness and casing steel grade on energy transmission should be taken into account in logging.

(2) Cementing quality evaluation should not only consider the size of cementing index (BI value), but also refer to variable density curve to evaluate cementing quality comprehensively, so as to evaluate cementing quality correctly and benefit oilfield development.

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