Study on Ultrasonic Evaluation of Cement Bond Quality in Oil Wells

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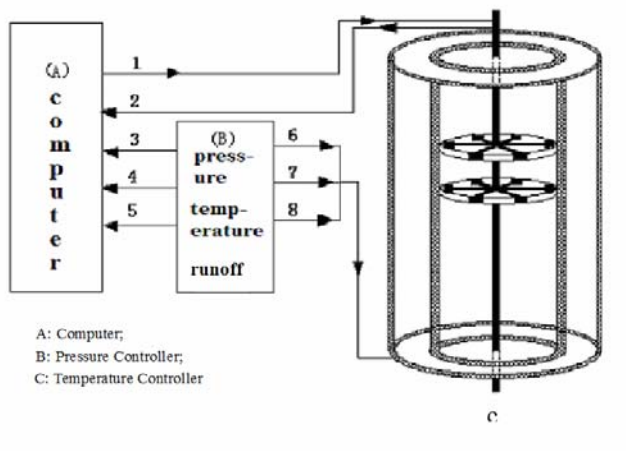
Abstract

During the process of oil production, the cement is used to bond the casing and stratum. At the oil layer, the casing and cement will be perforated. So the oil will flow out through casing and cement to the ground. But when the cement is not bonded to the casing (called I interface), or not bonded to the stratum (called II interface), the oil will flow into other stratum. So it is important to check the quality of cement bonding. At present, the existing methods and technology can't give a correct result on cement bonding.

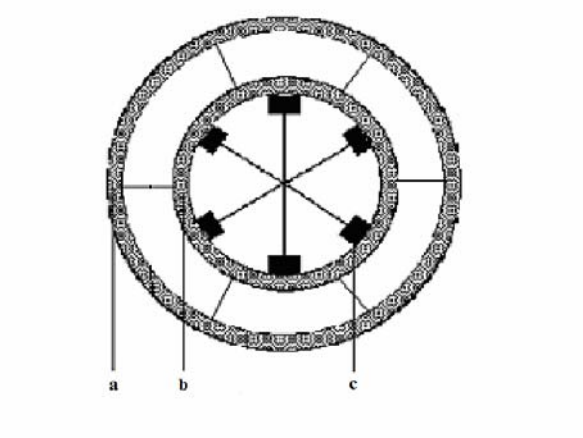
To study the possibility of evaluation of cement bonding quality during the solidification in oil wells, an experimental system by ultrasonic techniques was built and experiments were carried out in the laboratory.

Experimental System



1: Trans the ultrasound;
2: Echo wave of the ultrasound;
3: Feedback of Pressure;
4: Feedback of Temperature
5: Feedback of Runoff
6: Control the Pressure
7: Control the Temperature
8: Control the Runoff

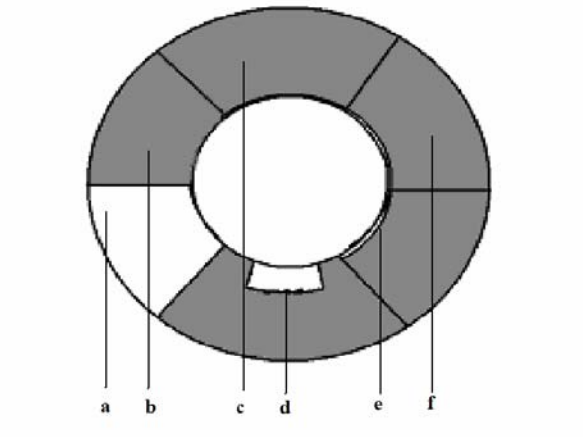
Fig. 1 Sketch of an experimental system



a: Outer Steel Pipe;
b: Inner Steel Pipe;
c: Transducers

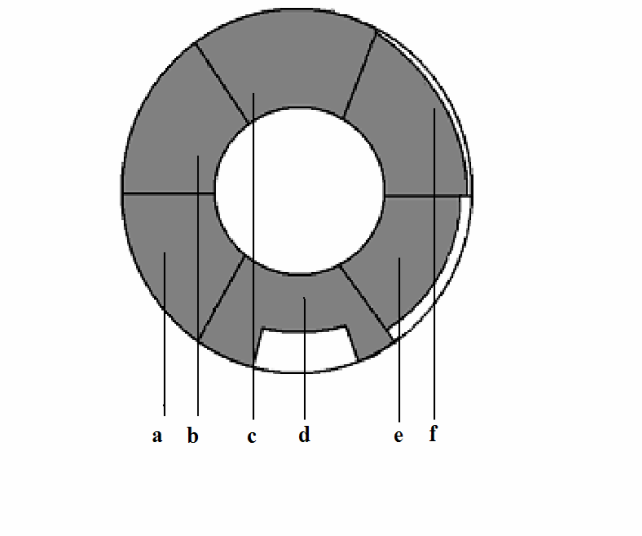
Fig. 2 Transverse Section of Container

The system consists of a 200 MPa high-pressure container with the diameter of 0.6 meter and height of 1 meter. The system can work in the high temperature up to 60°C. In the container, two coaxial steel pipes simulate the pipe and formation in oil wells respectively. Between the two pipes is an annular cement layer of 40mm thickness.



a: Empty Casing; b: Density 2 .1g/cm^3;
c: Density 1 .9g/cm^3; d: Groove on I interface
e: Micro lacuna on I interface;
f: Mud-cake on I interface

Fig. 3 Sketch of man-made flaws - 1



a: Density 1 .7g/cm^3;
b: 25/75 uniformity mix-slurry;
c: 25/75 Asymmetry mix-slurry;
d: Groove on II interface;
e: Micro lacuna on II interface;
f: Mud-cake on I interface

Fig.4 Sketch of man-made flaws - 2

To simulate the different bonding, on the interfaces between the cement layer and two steel pipes there are several different man-made flaws. Inside the inner steel pipe there is several transducers transmit ultrasonic pulses incidenting normally on the inner surface of the pipe.

The pulse penetrates the pipe and cement layer and is reflected back by the interfaces. The transducers in the inner pipe receive the reflected pulses. The received signals contain the information of the bonding quality. In every experiment reflected signals are automatically collected by transducers at different positions for 16 days when the cement layer solidifies from the liquid state to the solid state. The received signals are feed to a computer to be processed. By analyzing the data, it is shown that the flaws on the interface between the cement layer and the inner pipe can be detected effectively.

Experimental Results

Fig.5 shows the waveform and spectrum of one of the transducers. The center frequency is nearly 900Khz and bandwidth is very wide.

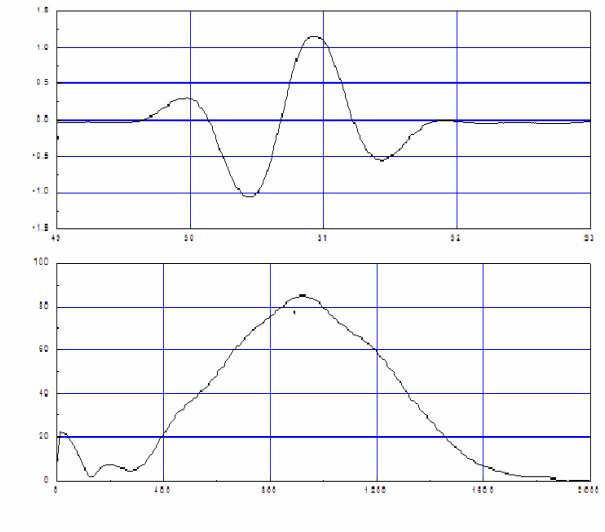
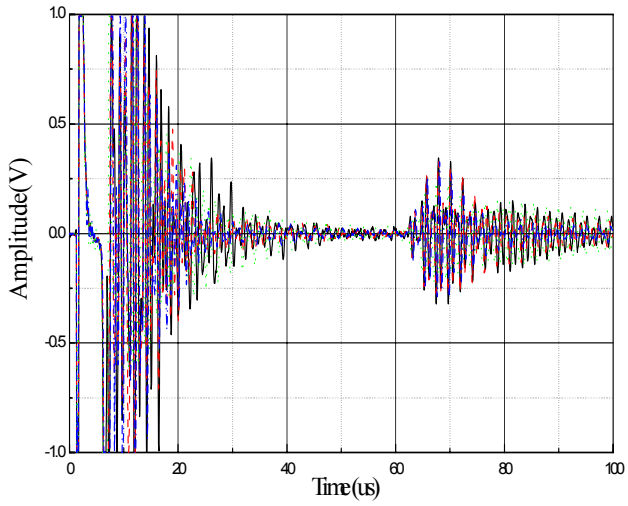


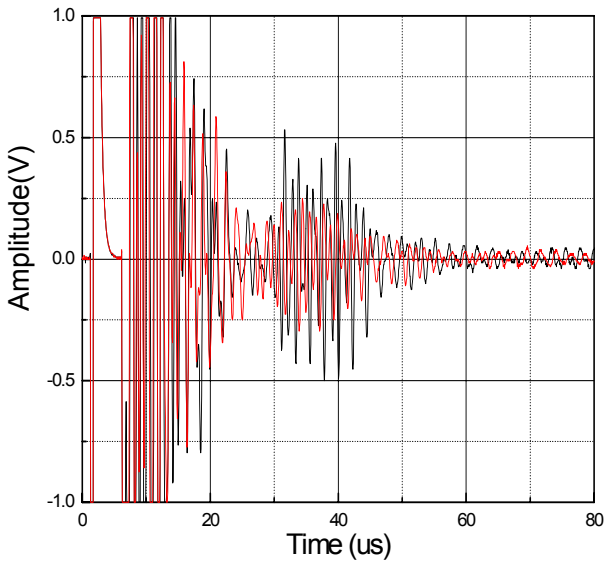
Fig. 5 Waveform and spectrum of one transducer



Black: channel 1; Red: channel 4
Green: channel 8; Blue: channel 12

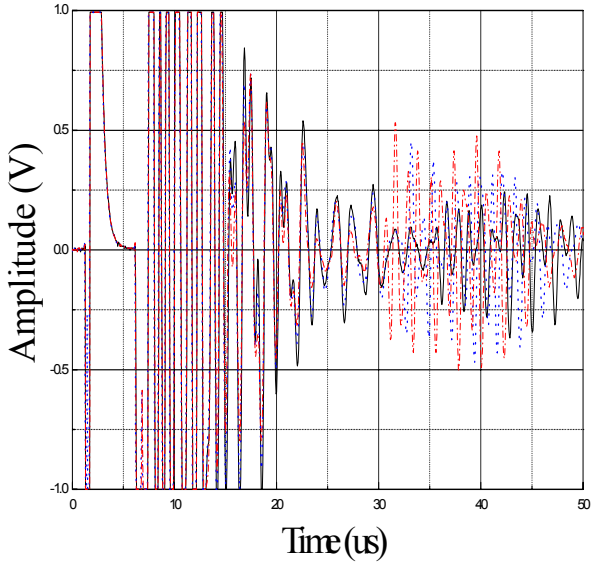
Fig.6 Echo wave of transducers in the empty casing

Fig.6 shows the echo wave of several transducers in the empty casing. In the situation of empty casing, there is full of water between the two pipes. The outer steel pipe reflects the signal. The waveform of each channel is quite same. It illuminates that each transducer is as near as makes no difference. The reflected signals have a fixed time and are easy to detect.



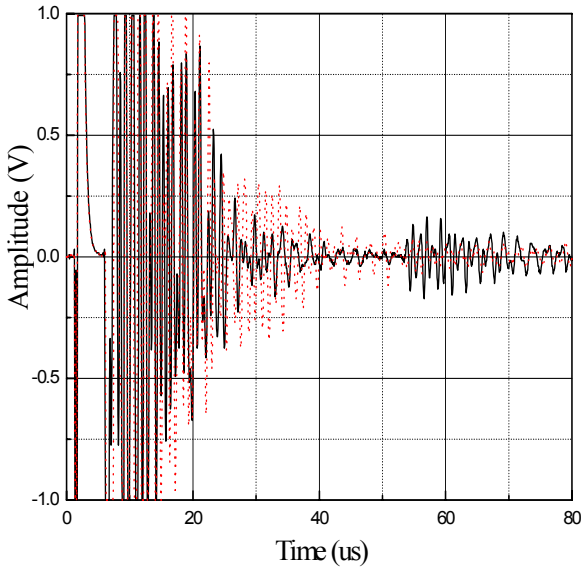
Black: density 1 .9g/cm^3; Red: density 2 .1g/cm^3
Fig.7 Different density of cement

The signals are the echo wave of different density of cement in a well-bonded situation. The difference of amplitude and time of echo wave isn't so much. So it is difficult to distinguish the different density of cement.



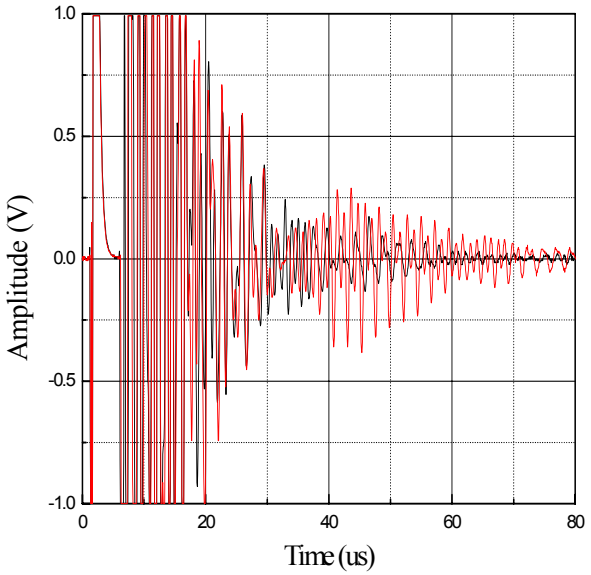
Black: after 2 days; Blue: after 7 days;
Red: after 15 days
Fig.8 Different time during the solidification

Fig.8 shows the difference during the solidification when the cement layer solidifies from the liquid state to the solid state. The black line denotes the signal of echo wave after 2 days from the beginning solidification, the blue line denotes after 7 days and red line denotes after 15 days. It is found that the velocity of sound is faster and faster and the amplitude is greater than the beginning with the time of solidification. The possible cause is that the cement is in the liquid state at the beginning, so the speed of sound is slow. And the granules of cement scatter some ultrasound, so the amplitude is low. After the cement becomes the solid state, the velocity of sound is faster and attenuation of cement is lower.



Red: groove on I interface;
Black: groove on II interface
Fig. 9 Groove on I interface and II interface

Fig.9 shows the echo waves of groove on I interface and on II interface. It illuminates that there is no signal of groove on II interface if the groove on I interface exits; because a large number of energy of ultrasound is reflected by the groove on I interface. So the energy of ultrasound reflected by the II interface is very weak. It is hard to find it.



Red: micro lacuna on I interface;
Black: micro lacuna on II interface;
Fig.10 Micro lacuna on I interface and II interface

Fig.10 shows the echo waves of micro lacuna on I interface and on II interface. From the red line it is found that the system gets the signal of II interface when I interface is not bonded well. But from the black line the system couldn't get the signal of II interface when I interface is bonded well. It is a strange thing. The reason may be that the transducer is not placed well.

Conclusions

Only part of the flaws on the interface between the cement layer and the outer pipe can be detected. The experimental system by ultrasonic techniques needs consummated.

References

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