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Ultrasonic tomography and its applications in oilfield

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Abstract: UTT (Ultrasonic Tomography Tool) is widely used in the oil industry and can be used to inspect corrosion, casing wall damage, casing breakoff, and casing distortion in the well borehole with the maximum environment temperature being 125 °C, and the pressure being 60 MPa. UTT consists of tool head, upper centralization, electronic section, lower centralization, transmitters, and receivers. Its outer diameter is 4.6 cm and length is 320 cm. The measured casing diameter ranges from 60 mm to 254 mm. The tomography resolution is 512×512. The borehole measurement accuracy is 2 mm. It can supply 3D pipe tomography, including horizontal and vertical profile. This paper introduces its specification, measurement principle, and applications in oilfield.

Key words: Ultrasonic tomography, Downhole tool, Casing hole
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INTRODUCTION

Oil and water well is an important basic establishment in oilfields. In many oilfields, there are many different damages in the well's casing walls after its development for a period of time. They will affect the normal production of damaged wells and adversely influence the neighbouring wells and the block, and threaten steady production. There are different kinds of damages due to multiple problems in the casing walls, for example, corrosion, perforation, decreased diameter, distortion, etc. For solving the problem of casing wall damages in most area of the oilfield, tomography technology can be used to inspect the damage level and casing condition, analyze the mechanism, provide the technical basis for preventive measures and extending the life of the oil wells. Ultrasonic tomography technique can be used to estimate the corrosion, perforation, casing breaking off, and casing distortion exactly (Liu and Xie, 2002); it can also be used to inspect the type and the level of the damage clearly and directly. It plays an important role in casing inspection and decision making in oilfield.

ULTRASONIC TOMOGRAPHY TOOL

UTT configuration

UTT consists of tool head, upper centralization, electronic section, lower centralization, pressure balancer, transmitters, and receivers (Fig.1) (Liu, 1999). The tool head connects the signal cable of steel wire, the upper centralization which assures the tool being in the centre and going down successfully. The electronic section controls the motor and is responsible for collection, management and synthesizing of the signal. Lower centralization makes sure that the transducer can lie in the centre of the casing, pressure balancer makes the transducer spin produce the synchronous signal from the motor, and transmits the sound signal and the synchronous signal from the travelling block to the electro-circuit with lower power components. There is a CPU in this section to control and realize the following function: emission of ultrasonic signal, receiving the time, and amplification of the echo, PCM coding, and receiving command from the surface. The special pressure balancer is adopted to pressurise the tool and for encapsulation of the transducer; it makes the tool run well under the high temperature and pressure.

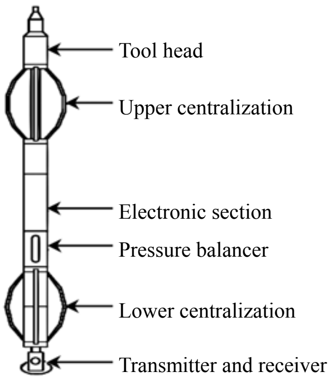


Fig.1 The sketch of UTT

Measuring principle

Utilizing the property of ultrasonic transmission and reflection in the medium, the ultrasonic transducer of the downhole tool sends and receives the ultrasonic pulse to and from the wall. The amplitude and time of the echo are processed and sent to the ground by the cable. The casing condition is studied from the information on time and amplitude. The interpretation software describes the casing wall damages and the distortion position using tomography techniques, including 3D tomography, vertical profile, horizontal profile, time figure and amplitude tomography, etc. drawing production plot with the special equipment (Parilla *et al*., 1991; Sabatini, 1995).

The transducer emits 512 times ultrasonic pulses to the wall in vertical, and has a 6 r/s rotating velocity during well logging with UTT. The receiver picks up echo at 512 points per cycle, and every point takes 325 μs. Information on echo time and amplitude are detected and coded by downhole tools, each information unit consists of 24 bits.

Data acquisition and process

A single chip sends the ultrasonic pulse at 360 μs; this electric signal is sent as sound wave after amplification through the MOS tube and transformer and transmission to the transducer; the sound wave is decreased, reflected and refracted during the travelling from the medium. In the waves emanating from the medium there are many signals that interfere with the first echo, so a band-pass circuit and enlarged circuit are designed before data acquisition to get the ideal echo. Processed echoes are sent to the comparing circuit and integral circuit to get the echo time and echo amplitude. A single chip codes the echo time, echo amplitude, line synchronization, point synchronization (Wang, 1989). Modulated PCM code is transmitted to the ground at 66.67 kbps through seven core cables by power driving.

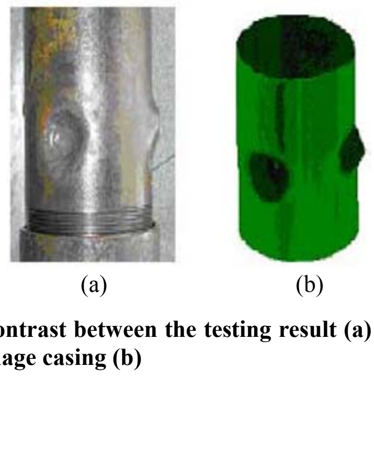
UTT specifications

UTT specifications are: Accuracy: error ±4° (well inclined<70°); Vertical resolution: 2 mm; Hole resolution: 8 mm; Measuring mode: continued; Transmitter frequency: 0.5~2.0 MHz; Transmitter cycle speed: 6~7 r/s; Transmitter work frequency: 1.5 MHz; Transfer speed: 73 kB/s; Horizontal resolution: 512 point/cycle; Logging speed: 60 m/h; Measuring range: 60~254 mm; Environment liquid: 0~1.41 g/cm^3; Weight: 22 kg; Size: ∅46 mm×3200 mm; Temperature: 0~125 °C; Pressure: 60 MPa; Operation environment: Windows OS.

APPLICATION

Calibration test

For visually observing the measure of distortion with UTT, different devices are used, and the real casing is changed to protuberant, concave, breaking off, perforation, for comparing the testing result and actual distortion. Qualitative and quantitative were conducted. Fig.2 is a comparison between the testing result and the real distorted casing.



(a) (b)

Fig.2 Contrast between the testing result (a) and the real damage casing (b)

Damage and caving in the casing wall

Well A is a water injected well in the Daqing oilfield, when adjusting project of injecting water into the well was implemented. An excluder was put on the top oil zone, but much water was discovered when the excluder was set free, and about 28 m^3/d water could be injected into the casing. This indicated abnormality in the casing. For detecting the abnormity, ultrasonic tomography was used. Fig.3 is the inspection result indicating existence of a vertical split in the well wall at depth of 958.7~959.7 m, and a hole on the casing wall at depth of 642.3~642.4 m, clearly shows the abnormity at the beginning. According to the colour tomography data, two excluders should be used, one at the position 600 m above the defect and one at 600 m below the defect, and an excluder should also be used on the level of perforation at 960 m depth and that the connecting part should be used to stop injected water at the lower level of perforation.

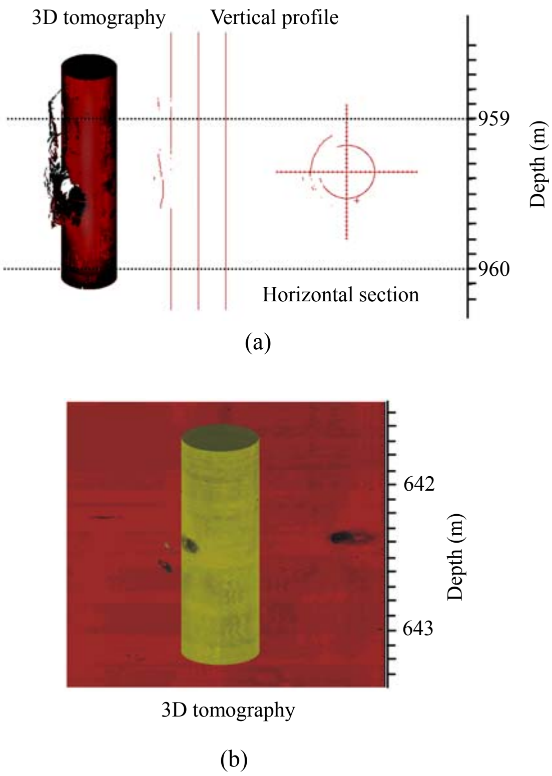


Fig.3 A split (a) and hole (b) on the casing wall in well A

Breakoff in the casing well

Well B plays an important role in the development blocks of Jilin oilfield, its depth is 3200 m and drilling was done in 1991. Because casing damage was found during fixing of the well after drilling in 1991, it has not been used for production. To further find out the real condition in the well, UTT logging was processed in 2001. Fig.4 is the testing result. Logging was at 3120~3150 m, 3D tomography at 3141.8 m revealed that the casing diameter was enlarged, this is box coupling, at this position, the casing was broken off. According to the logging data, oilfield experts figured out that this well was damaged at the box coupling of the casing during drilling, and that the producer will repair it according to these logging data. The depth of it is 3200 m. The high pressure and temperature in it indicated that the UTT is useful in this kind of environment.

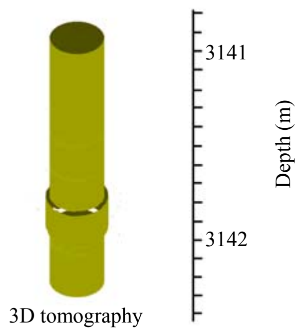


Fig.4 A breakoff in well B

Bend distortion of the casing

Well C was the observed well in the Daqing oilfield. Logging information indicated that the tool works well. The repetition and consistency are all right. Fig.5 is the result of twice testing. The casing bends at depth of 982.4~983.2 m, and is damaged from 45°~135°, so the source direction where this casing was bent 90°.

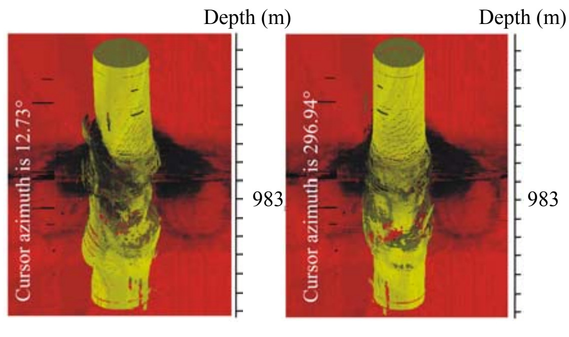


Fig.5 An azimuth-wall thickness tomography in well C

Inspecting the quantity of perforations

Using UTT to inspect 2 wells with these kinds of perforation can confirm the feasibility of the project for azimuth of perforation, and its technical standard. When the direction of the perforation's hole is normal to the least main stress of the zone, the break of waterpower is not serious. There is faultage around the borehole. After the normal perforation, it is easy to connect the fracture with waterpower and faultage. This result shows that the fracture with waterpower is useless and perforation at the back of the faultage is required. Because there are natural cracks in the reservoir, the direction of the perforation's hole should be normal to the direction of cracks and it should be possible to connect them with the natural crack. The azimuth of the perforation was adopted. Error between the direction of perforation and the designed direction can be verified by using UTT. Fig.6 is the profile of inspecting in well D; perforation was finished 2 lines in vertical direction. The azimuths of the first and second lines are NE90° and NE270° respectively. The inspecting result indicated that the hole of the perforation lined on the two areas. The first area is NE86°~NE94°, and the second one is NE264°~NE272°. This result showed that the designing and perforation is correct.

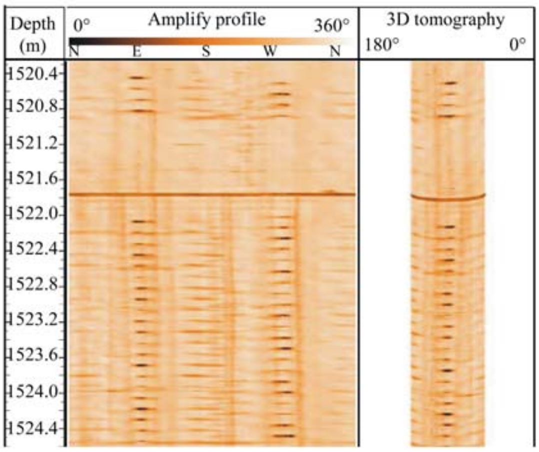


Fig.6 Inspecting the quantity of performances in well D

CONCLUSION

1. Regarding inspecting damage of casing wall, ultrasonic tomography tool (UTT) can exactly detect corrosion, perforation, casing breakoff, and casing distortion. It can show the type and degree of casing damage clearly and directly, and plays an important role in getting proof of well's good condition and making decision on useless well.

2. UTT can inspect the target reservoir for casing damage through oil tube instead of taking out oil tube. Use of UTT saves money and labour, and reduces the possibility of meeting resistance or block from casing distortion.

3. Application proved that UTT can be reasonably designed, has complete function, and is safe in operation. UTT provides a new method for checking casing wall damage in developing oilfield.

4. UTT combined with azimuth can provide directly and visually all directional logging profiles for users. Telling the angle and the direction of the well, especially displaying casing damage, perforation, breaking off and exact direction of casing distortion in different grade and shape helps user to judge the reason of casing damage and provides the exact information.

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