Study on Judgment Methods of Cement Deficiency Position of Non-axisymmetric Well-hole

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***Abstract*—In a series of non-axisymmetric well-hole sound filed, besides judging the channelling type according to characteristics of different sound fields, judgment of cement deficiency position of channelling well-hole is also important. The essay put forward to arrange a series of receivers around the wall of a well, adopt the one-shot eight-receiver device and the three-dimensional finite difference method to simulate various non-axisymmetric well-hole sound fields, select amplitude or travel time of the first wave as the reference and determine the deficiency position of non-axisymmetric sound fields so as to provide theoretical basis for practical well measurement.**

Keywords—channeling; deficiency position; non-axisymmetric; wall of well.

I. INTRODUCTION

With development of the sonic logging technology, new drilling methods like inclined shaft and horizontal well put forward new requirements on well cementation quality test. In big inclined shaft and horizontal well, due to instrument eccentricity caused by centralizer failure because of instrument's gravity, bow missing in horizontal well and section missing in traditional vertical well. It is great significance to judge the deficiency position in a series of non-axisymmetric well-hole besides studying the special sound field to judge the quality of well cementation.

With rapid development of parallel computing technique of computer, the three-dimensional finite difference method started to be widely used in study the well-hole sound fields[1-10]. In respect of boundary convergence, Wang et al [11] put forward NPML, and Song et al [12] adopted NPML to simulate elastic wave propagation problem in porous media. NPML cannot only realize the effects equivalent to that of SPML but it is also simpler in algorithm and will occupy less computing memory.

The essay adopted the three-dimensional finite difference method to simulate the sound field of vertical well section missing, the eccentric source sound field in horizontal well and bow missing sound field in horizontal well. By arranging a series of receivers in wall of well and adopting the one-shot eight-receiver device to receive first waves of sound fields. Study relations between the different cement deficiencies position and the first wave amplitude or travel time so as to provide a judgment method for deficiency position of non-axisymmetric well.

II. MODEL AND PARAMETERS

A. Various Well-hole Models and One-shot Eight-receiver Device

Various well-hole models and one-shot eight-receiver device are as shown in Figure 1.

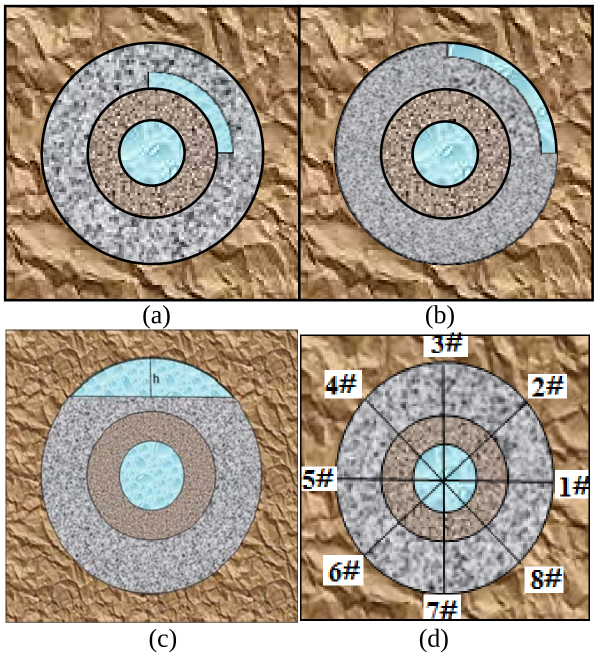

FIGURE I. VARIOUS WELL-HOLE MODELS

B. The Material Parameters

TABLE I. THE MATERIAL PARAMETERS

Media	P - wave velocity (m/s)	S- wave velocity (m/s)	Density (kg/m3)
Well fluid	1580	0	1090
Steel casing	6098	3354	7500
Cement layer	2800	1700	1920
Fast formation	3800	2200	2600

III. SECTOR CEMENT MISSING IN VERTICAL WELL

A. The First Wave Analysis in the I Interface Sector Missing Model

The model of the I interface section missing is as shown in Figure 1(a). To make sure the deficiency position of the cement, arrange receivers around the wall of well with every 45° is as shown in Figure 1(d). Simulate the model with missing angles are 45°, 90°, 135° and 180°. Select the first wave from the 1-8# receivers which have a vertical distance of 1.0m from the sound source, as shown in Figure 2. The curves in Figure 2(a) and Figure 2(b) are relatively similar, and the first wave from 2# receiver is the biggest, followed from 1# and 3# receivers, and the first wave from the other receivers is small. In addition, the curves in Figure 2(c) and Figure 2(d) are also similar, and the first wave from 3# receiver is the biggest, followed by the first wave from 2# and 4#, and the first wave from other positions is small. That's to say, the first wave received by the receivers close to the channelling position is bigger, while the first wave received by receivers which far from the channelling position is smaller. Moreover, the first wave is received along the channelling centre can basically reach to the maximum.

In addition, there are a V-shape area with a maximum value as a vertex(the yellow area in the figure). The yellow area is the smallest when the missing angle is 45°. With increase of the missing angle, the yellow area will also increase, and the yellow area will reach to the maximum when the missing angle is 180°. Moreover, as the missing angle of the cement ring increases, the area of the V-shape area increases.

By comparing the four pictures in Figure2, we can determine the deficiency position of the cement ring by finding the maximum value of the first wave amplitude, and determine the missing angle through the V-shape area.

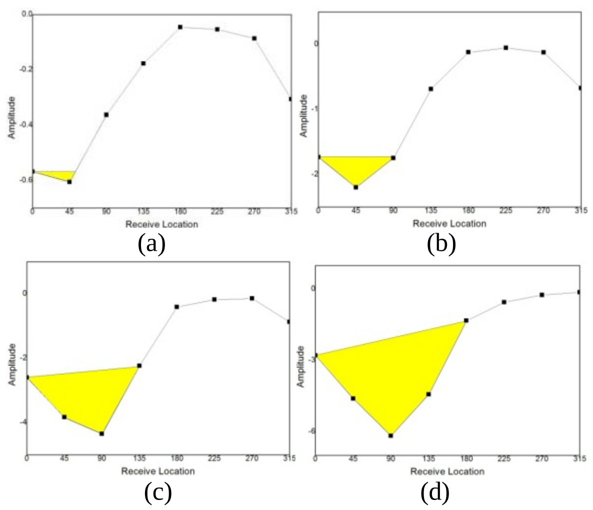

FIGURE II. THE FIRST WAVE AMPLITUDE RECEIVES FROM WALL AROUND WHEN THE I INTERFACE SECTOR MISSING (A) MISSING ANGLE IS 45° (B) MISSING ANGLE IS 90° (C) MISSING ANGLE IS 135° (D) MISSING ANGLE IS 180°

B. The First Wave Analysis in the II Interface Sector Missing Model

The model of the II interface section missing is as shown in Figure 1(b). Simulate the well-hole sound fields, which the missing angles are 45°, 90°, 135° and 180°.

Select the first wave of 1-8# receiver that is 1.0m away from the sound source, which is as shown in Figure 3. Curves of Figure 3(a) and Figure 3(b) have the biggest first wave amplitude received from 2# receiver, followed from 1# and 3# receivers, and the first wave amplitude received from other receivers is small. Moreover, in Figure 3 (c) and Figure 3(d), the first wave amplitude received from 3# is the biggest, followed from 2# and 4# receiver, and the first wave amplitude received from other receivers is small. Similar with the I interface section missing, the first wave amplitude received by receivers close to channelling position are big, while the first wave amplitude is received by receivers far from the channelling position is small. And the first wave amplitude is received along the channelling center can basically reach to the maximum.

Moreover, the change rules of the V-shape area are similar with that of the I interface section missing. Thus, with increase of the channelling angle, the V-shape area will also increase.

At last, we can make sure that no matter the I interface or the II interface section missing, we can determine channelling position through the first wave amplitude maximum, and determine the missing angle through the V-shape area.

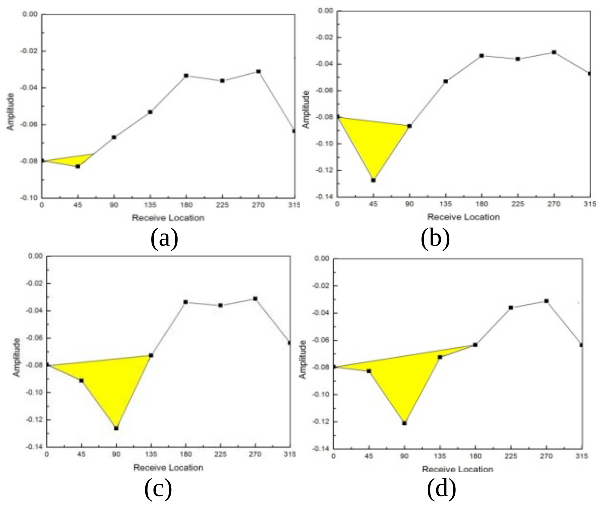

FIGURE III. THE FIRST WAVE AMPLITUDE RECEIVES FROM WALL AROUND WHEN THE II INTERFACE SECTOR MISSING (A) MISSING ANGLE IS 45° (B) MISSING ANGLE IS 90° (C) MISSING ANGLE IS 135° (D) MISSING ANGLE IS 180°

IV. THE FIRST WAVE ANALYSIS IN THE ECCENTRIC SOUND SOURCE OF HORIZONTAL WELL

The sound source and the receivers shift in pairs at the same time and the sound source are not in the center position but in the connection of the 1# and 5# receiver. According to the influence relation between eccentric distance and sound field, we can know that in the model of eccentric sound field, differing from cement channelling, eccentric distance has a small influence on the first wave amplitude but has a big influence on travel time of first wave, so the first wave travel time can be selected as the reference [13, 14].

By taking the situation when the eccentric distance is 0.03m in the I interface channelling well-hole, select the travel time of first wave received by 1-8# receiver, which is as shown in Figure 4. The travel time of the first wave received by 1# receiver is the smallest, while by 5 # receiver is the biggest. According to the relation between the travel path length and the travel time of first wave, we can see that the sound source is the closest to 1# receiver and the furthest to 5# receiver, and the sound source is in the connection of 1# and 5# receivers and gets close to 1#, which meets the pre-set position of sound position. We can judge shift position of sound source by arranging receivers around wall of the well.

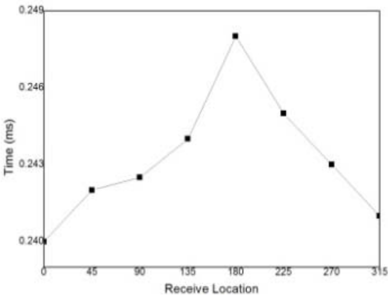

FIGURE IV. THE FIRST WAVE TRAVELLING TIME WHEN THE I INTERFACE CHANNELS

V. THE FIRST WAVE ANALYSIS IN THE BOW MISSING HORIZONTAL WELL

The bow missing horizontal well model is as shown in Figure1(c). Simulating the II interface bow missing model.

Select the first wave amplitude and travel time from the 1-8# receiver which is 1.0m away from the source and has an bow missing height of 20mm, which is as shown in Figure5.

Figure 5(a) is the comparison chart of the first wave amplitude which received from wall around with a distance of 1.0m from the source. Through analysis, we can see that the first wave amplitude received by the1#, 2#, 3# and 4# receivers are smaller than that received by the 5#, 6#, 7# and 8# receivers. That’s to say, the first wave amplitude received close to the deficiency position is small, while the first wave amplitude received far from the deficiency position is big. Figure 5(b) is the comparison chart of the first wave travel time from the 8 receivers. Similar with change rules of the first wave amplitude, the first wave travel time received from the1#, 2#, 3# and 4# receivers is smaller than that received by other receivers. In other words, the first wave travel time received close to the bow missing position is smaller while it received far from the bow missing position is bigger. By arranging receivers around the well wall and analyzing changes of the first wave amplitude and travel time in different positions, we can judge bow missing position accurately.

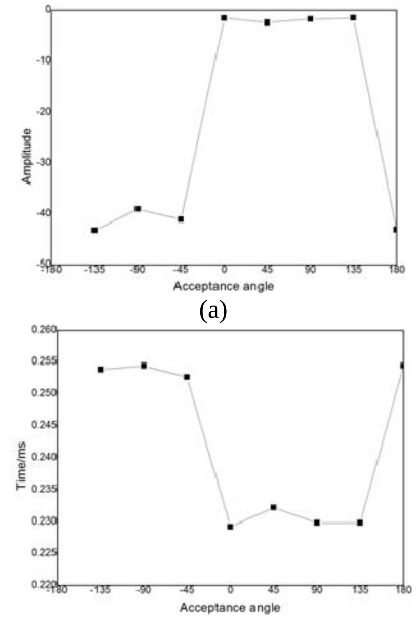

FIGURE V. (A) COMPARISON CHART OF THE FIRST WAVE AMPLITUDE WHICH RECEIVED FROM WALL AROUND (B) COMPARISON CHART OF THE FIRST WAVE TRAVEL TIME WHICH RECEIVED FROM WALL AROUND

VI. CONCLUSION

Use the three-dimensional finite difference method to simulate the three models of cement deficiency which are the I and II interface sections missing of the vertical well, eccentricity sound source of horizontal well and cement bow missing of horizontal well .Extracting the first wave amplitude or travel time, we can judge deficiency position of non-axisymmetric well-hole: for the I or II interface sections missing of the vertical well, the first wave amplitude received close to the deficiency position is big while it received in position far away from the deficiency position is small. And the first wave amplitude received along the deficiency center can basically reach to the maximum. Moreover, the bigger the missing angle, the bigger the V-shape area will be. For eccentric well holes, the first wave travel time close to the sound source is short while it far from the sound source is long. In addition, for the bow missing model, the first wave amplitude received in position close to the deficiency position is small while that far from the sound source is big. Meanwhile, the first wave travel time in position close to the deficiency is small while the first wave travel time in position far from the deficiency is big. It can prove that arranging a series of receivers in the wall of well and extracting the first wave amplitude and travel time can help to judge deficiency position of non-axisymmetric well holes and provide theoretical basis for practical sonic logging and well cementation quality tests.

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