Study on the application of ultrasonic flaw detection to the monitoring of deep water steel cofferdam

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Abstract. In order to provide a dry operation environment for the construction of high pile cap in water, the steel cofferdam must be completely sealed when working underwater. Therefore, in order to avoid leakage of cofferdam due to welding defects, high requirements are put forward for the splicing weld quality of cofferdam components. Ultrasonic testing is widely used in the detection of cofferdam welds because of its strong environmental adaptability, convenient operation, high automation level and strong data processing ability. This paper introduces the application of ultrasonic detection technology in steel cofferdam, which has achieved good results.

1. Introduction
Ultrasonic flaw detection is a method to check the defects of parts by using the characteristics that ultrasonic can penetrate into the depth of metal materials and reflect at the edge of the interface when entering another section from one section. When the ultrasonic beam passes from the surface of the parts to the inside of the metal from the probe, the reflection waves will occur when the defects and the bottom of the parts are encountered, and the pulse waveform will be formed on the fluorescent screen according to these pulses waveform to determine the defect location and size[1][2].

2. Cofferdam structure
Double-wall steel cofferdam is designed for the steel suspension box, which is divided into baseplate, wallboard, inner support, tension bar and other structures, among which: the baseplate and wallboard are made of 8mm thick steel plate; the keel of baseplate: large keel: hw400 × 300, small keel: HM300 × 300, stiffener: 12.6; the thickness of the bulkhead plate is 16mm, and the inner shell plate is provided with - 12 × 300 reinforcing pad, horizontal reinforcement and vertical reinforcement - 12 × 150, with a horizontal spacing of about 1400 Mm, the spacing between the upper and lower layers is 100cm; C20 concrete is poured into the compartment within the same height range as the cushion cap; box girder is set at the straight line and arc corner, and 16mm steel plate is also used. The horizontal ring plate adopts - 14 × 300, and the spacing between the upper and lower layers is 100cm; the horizontal diagonal brace adopts L100 × 100 × 12 angle steel, and the spacing between the upper and lower layers is the same as that of the horizontal ring plate, which is 100cm; the vertical rib adopts L75 × 75 × 8 angle steel, with the spacing of 400mm; the inner support adopts φ 630 × 10m steel pipe; the tension and compression bar adopts the box section of 2 [] 36a, the lower end is supported at the
intersection of the vertical and horizontal keel of the bottom plate, and the upper end is welded on the casing.

At the intersection of the horizontal ring plate and the compartment plate, the horizontal ring plate is disconnected and the compartment plate is continuous, and it is firmly welded with the whole section of the compartment plate at the disconnection. The double-sided fillet weld is used between the horizontal ring plate and the wall plate and the compartment plate, with the weld height of 6mm. The butt weld shall be fully welded (primary weld).

Fillet weld shall be used for continuous welding between the bulkhead reinforcement plate (300 mm wide and 12 mm thick) and the bulkhead, with the weld height of 6 mm. Double side fillet weld shall be used between the bulkhead and the bulkhead reinforcement plate, with the weld height of 6 mm. All these welds shall ensure that the welding quality meets the impervious requirements. When the vertical and horizontal bars on the bulkhead are welded with the bulkhead, double-sided fillet weld shall be used, with the weld height of 6mm.

The cofferdam structure is divided into four sections (3 × 7.5m, 8.4m). First install the bottom plate of the lifting box, then install the first section (bottom section) and the tension and compression bar. After the first section is installed, carry out the water tightness inspection, and check each joint in detail to ensure the water tightness. After the water tightness test is qualified, lift section 1 to the water, and continue to assemble section 2 on it. After the assembly of section 2 is completed, the water tightness inspection shall also be carried out, and then assemble section 3, section 4 and internal support. After the installation of each section, the water tightness test must be carried out.

In order to verify the accuracy of the inspection effect of ultrasonic testing on the welds, the side wall panels of the cofferdam in this project are tested first by ultrasonic flaw detection method, and then by water tightness test after passing the sampling inspection.

3. Parameter specification
Nantong Youlian pxut-320c full digital intelligent ultrasonic flaw detector consists of screen area, keyboard area, indicator light, R, R / T interface and power switch.

Gain (sensitivity, attenuation), range (sound path), wave gate, zero point, delay and other common parameters are continuously adjustable. When adjusting, a prompt will appear in the upper left corner of the screen, and other parameters will be selected or input in the parameter menu or measured\(^3\).
The main purpose of the gate is to display the echo state data and the alarm peak in the gate. Zero point refers to the fixed acoustic delay of probe and instrument, such as probe wedge or protective film acoustic path. The time delay can make the echo position move to the left and right without changing the distance between the echoes; the echo that does not need to be observed can be adjusted out of the screen to make full use of the effective observation range of the screen. Acoustic range scale refers to the projection value of echo on different coordinate axes, which can be divided into three types: distance (s), horizontal (x) and vertical (y). The probe type is the acoustic emission mode in the probe, which is divided into four types: straight probe, angle probe, double crystal and penetration. The K value is equal to the tangent of the refraction angle. Chip size refers to the area of the probe chip. The angle probe is represented by length * width, and the straight probe is represented by diameter. The front edge of the probe refers to the distance from the incident point of the angle probe to the front end of the probe. The front edge of the probe refers to the distance from the incident point of the angle probe to the front end of the probe. Probe frequency refers to the inherent (resonant) frequency of the wafer in the probe. The sound speed of workpiece refers to the speed of sound propagation in workpiece. Surface compensation refers to the compensation for the sensitivity due to the surface roughness of the workpiece. After compensation, the echo changes, but the DAC / AVG curve does not change, that is, the echo equivalent value changes. Rejection offset refers to the optional offset between rejection line (RL line) and bus in panel curve. Quantitative offset refers to the optional offset between the quantitative line (SL line) and the bus in the panel curve. Evaluation deviation refers to the optional deviation between evaluation line (length measuring line) (EL line) and bus in panel curve.

4. Layout of measuring points
The measuring point is selected at the splicing weld position of each section D, e, a and B, and each section adopts flaw detector to spot check 4 welds, 16 in total. Take the weld along the bridge to the left as the first measuring point, and number clockwise from the first section.

5. test procedure
It is assumed that the flaw detection conditions and requirements are as follows:
① workpiece: 30mm thick steel plate weld
② probe: K2, 2.5p13 × 13, angle probe
③ test block: CSK-IA, CSK - III a
④ DAC method: DAC points: 4 (10, 20, 30, 40);
The offset of waste line is +5 dB; the offset of quantitative line is: -3 dB; the offset of evaluation line is: -9 dB;

![Fig.3 Plan and block diagram of cofferdam](image)

This paper briefly introduces the realization steps of the above functions:

1) boot
   Turn on the power switch of the instrument, connect the probe to the instrument, and the instrument is in normal working state.

2) select channel number
   Press the < channel / setting > key, and then select a channel under the "channel" adjustment state with the add / subtract key.

3) parameter reset
   Press the < function > key and select "1" to clear the current channel.

4) setting parameters
   Press the < channel / setting > key repeatedly, set the probe mode as "angle probe", probe frequency as 2.5MHz, chip size as 13 × 13, and other parameters can be set during or after the test. Press the < OK > key to exit the parameter menu.

5) debugging
   ① press the < adjustment > key, press the < 3 > key to select and make DAC, press the < Y > key to measure the zero point (sound speed) and refraction angle (k value) first. (you can also test 1 and 2 items in < adjustment > and then do DAC).

   ② measurement of zero point sound speed: the sound speed of the workpiece is "3230m / s", the primary sound path of the test block is input for 50mm, and the secondary sound path is 100mm. After confirmation, move the probe on the CSK-IA test block, make sure that the highest echo of R50 appears in the wave gate (if not in the movable gate), hold the probe still, and confirm again when the echo of R100 rises (or falls) to 80%, and measure the horizontal distance from the front end of the probe to R50 Leave and record in the instrument, press the key of < OK > to confirm the stored test value, and enter the K value.
Fig. 4 Diagram of zero point and leading edge of sound velocity measured by test block

③ refraction angle measurement: input 50 mm for reflector diameter, 30 mm for reflector depth, and 2.0 for probe K value. After confirmation, move the probe on CSK-IA test block to make sure the highest echo of Φ 50 hole appears in the wave gate (if not in the movable gate). Press the key < OK > to confirm the stored test value and enter the DAC production.

④ making DAC: input 40mm of maximum detection depth, 1.0mm of reflector diameter and 6mm of reflector length. After confirmation, move the probe on csk-iiiia test block. The instrument automatically adjusts the gain to make the maximum echo of the hole with the depth of 10 mm between 40-80%. When there is "DAC" in the parameter area (for other prompt contents, press the < back > key), press the plus key, and move the cursor to 10 On the echo of mm hole, all parameters of the echo will be displayed synchronously in the parameter area, press the < > key to confirm the echo, and a straight line with the same height as the wave peak will be displayed on the screen; then move the probe to find the highest echo of 20 mm hole, press the plus key to move the cursor to the echo of 20 mm hole, press the < OK > key to confirm, and the DAC bus from 10 mm and 20 mm holes will be displayed on the screen; similarly, confirm After the wave heights of 30 and 40 holes are collected and stored, the DAC generatrix is made.

Fig. 5 Schematic diagram of DAC curve made by csk-iiiia

⑤ other parameter input
Press the < set > key to input the measured leading edge value, press the < Options > key to input 5dB for waste determination offset, - 3dB for quantitative offset, and - 9dB for evaluation (length measurement) offset, and input surface compensation according to the surface roughness of the workpiece to be measured (see 4-6); now that the commissioning is completed, after confirming that the commissioning and setting are correct, the machine can be shut down and brought to the site for flaw detection. After the instrument is shut down, the debugging and setting parameters will not be lost.

6) field flaw detection
Bring the commissioning and set-up instruments to the site. The flaw detection process is the same as usual. By adjusting the gain, sound path and wave gate, the waveform and position parameters of the defect wave can be displayed completely. If it is necessary to record the defect wave, press the < record > key to store the flaw detection result in the instrument memory. Repeat the above flaw detection process, and turn off the instrument until the flaw detection is completed. After the instrument is shut down, the flaw detection data stored in the machine will not be lost.
6. Test result processing

Inclined probe is used for the weld detection of the side wall plate of the cofferdam. The chip size is 13 × 13, the probe K value is k1.97, the refraction angle is 63.10°, the front edge is 11.0 mm, the frequency is 2.5 MHz, the zero point is 6.39 μs, the sensitivity is 40.6 + 0.0 + 0.0 dB, the sound path range is 49.8 (y), and the sound speed is 3230 M/s. The waste offset input is 5 dB, the quantitative offset input is -3 dB, and the evaluation (length measurement) offset input is -9 dB. When it is found that the difference between the reflected wave amplitude of the defect and the reflected wave amplitude of the first screw thread after the defect is greater than or equal to 6 dB, and the indicated length is greater than or equal to 10 mm, it can be determined as a crack.

It can be seen from Fig. 8-10 that the ultrasonic flaw detection results of cofferdam wall plate meet the requirements. After further painting kerosene for inspection on the welds and placing the cofferdam in place for successful bottom sealing, it shows that the cofferdam has good sealing performance.

![Fig.6 Test completion interface](https://example.com/fig6)

![Fig.7 Diagram of horizontal indication length of weld flaw detection of cofferdam wall panel](https://example.com/fig7)
7. Conclusion
The excellent quality of the joint weld of the cofferdam is directly related to whether the structure leaks after the underwater cofferdam is successfully sealed. It is also the premise of providing the dry operation environment for the cushion cap construction, and also determines the safety and stability of the cofferdam work. Based on the construction of a steel cofferdam of a bridge, this paper uses pxut-320c ultrasonic flaw detector to carry out sampling inspection and Analysis on the cofferdam wall plate, and then verifies the accuracy of the application of ultrasonic flaw detection in the detection of steel cofferdam through the later kerosene brushing inspection and the pumping inspection after the successful bottom sealing.

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