Application Research on Corrosion Scanning of Coated Pressure Vessel with Ultrasonic Phased Array Inspection Technology

Wei Daoxiang, Wei Daorui*2,b, Si Jun3,c
1Research and development department. Shanghai Institute of Special Equipment Inspection And Technology Research shanghai, China
2Second installation company, China National Chemical Engineering Third Construction Co., Ltd. hefei, China
3Research and development department. Shanghai Institute of Special Equipment Inspection And Technology Research shanghai, China
*a1043130865@qq.com, b2234845202@qq.com

Abstract. Ultrasonic testing is a commonly nondestructive testing method used in the periodic inspection of pressure vessels. The coating on the surface of the vessel should be polished before testing. In order to solve this problem, in this paper, ultrasonic phased array detection is used to detect the coating without removing the coating, and the experimental study is carried out on the painted test plate, the test results are basically the same as the actual size of defects. The results show that the application of ultrasonic phased array detection technology in the corrosion scanning of pressure vessels is feasible. It lays a foundation for the application of ultrasonic phased array detection technology in the corrosion sweep of pressure vessel insulation coating.

1. Introduction
At present, the most widely used corrosion detection still stays on the traditional ultrasonic thickness measurement method, that is, selecting several points in a region to measure the thickness at a fixed point. If you want to obtain the thickness reduction distribution of the whole surface, you need to encrypt the thickness measurement. If the container can not carry out internal macro inspection, it is also necessary to polish the outer surface coating of the container and then test it. After the detection is completed, it is necessary to repair the surface coating of the container, and to complete the detection of a pressure vessel requires a lot of manpower and material resources. At the same time, the conventional ultrasonic detection method has the following limitations:

1. Can not form an effective graphic record.
2. Can not achieve 100% detection in a given area.
3. Can not grasp the overall corrosion condition, it is difficult to obtain thickness reduction and thinning rate.

The ultrasonic phased array corrosion detection system does not need to polish the surface coating, can quickly scan the container through the coating, display the wall thickness of the scanned area in real time on the computer, and distinguish it with different colors. The detection technology has the advantages of strong recordability, fast and efficient detection process, high sensitivity and high result.
The traditional A scanning detection is extended to image detection with A, B, C, D scanning mode. At the same time, the technology makes up for the low accuracy of fixed-point thickness measurement and the difficulty of capturing point corrosion. The traditional manual point-to-point acquisition data is extended to automatic, fast and large amount of detection data, which can easily realize the permanent detection records of annual inspection and re-inspection of specific detection sites. Compared with the traditional ultrasonic thickness meter, it has great advantages.

2. Detection principle and wedge selection of probe

2.1. Detection principle
In electronic linear scanning, the probe is divided into a series of continuous virtual probes, and each virtual probe is excited sequentially. Each virtual probe is launched once at a single Angle, as shown in figure 1. It is mainly used for pipeline corrosion detection, composite lamination defect detection, raw material detection, etc., as shown in figure 2.

![Figure.1 Electron scanning](image)

![Figure.2 Application of linear scanning](image)

2.2. Selection of wedge thickness

Formula (1) is to calculate the wedge thickness. Therefore, the thickness of wedge must meet:

\[ D_1 > \frac{D_2}{V_1} \]

The sound velocity of wedge is 2370m/s. If the sound velocity of the work piece to be inspected is 5900m/s, the thickness to be measured is 47mm. The thickness of the wedge \( D_1 > \frac{47}{5900} \times 2370 = 18.9 \) mm. In consideration of the width of the acoustic pulse, allowance should be set aside to separate the secondary
echo of the wedge from the bottom wave of the work piece to be inspected. Therefore, the thickness of the wedge is selected as 20mm, which is applicable to the work piece to be inspected in the range of 6mm-47mm.

3. Experimental platform and block

This experiment consists of three test blocks, the thickness and size of which are shown in table 1. First, the three test blocks are directly tested on the surface, and then the surface of the test blocks is coated with a paint layer, the coating thickness is shown in table 1, and then the test is carried out to compare the test results of the test blocks with and without coating. At the other side of the block making Ø 8 mm and Ø16 mm two specifications flat bottom hole, to Ø 8 mm and Ø16 mm made a flat bottom intake of different depth, and numbered respectively and block diagram as shown in figure 3. The size (depth and diameter) of the hole was measured many times with a vernier caliper and averaged.

| The thickness of the block (mm) | Average coating thickness (mm) |
|---------------------------------|-------------------------------|
| 16.3                            | 1.77                          |
| 24.6                            | 1.61                          |
| 46.1                            | 1.69                          |

Table 1: work piece size and coating thickness

4. Testing process

The probe is clamped on the scanning device, and the manual moving scanning device is used to scan the surface of the test block, and the data is collected by the computer in real time. The detection interface is shown in figure 5. There are four display modes of A, B, C and D in the detection interface. The four display modes cooperate with each other to observe defects and conduct quantitative and positioning analysis of defects.
A scan in the detection interface can be used to measure the depth of defects, and C scan can be used to analyze the location of defects, as shown in figure 6 and figure 7.

5. Test results
This experiment is divided into two parts, part 1 is directly on the 3 block surface test, and analysis of laboratory data, part 2 is in the first three block surface were calculated to besmear brushes the paint
coating, coating for many times to make use of coating thickness tester tests and average, part 1 and part 2 experiment using the same testing process and testing equipment. The test results are shown in table 2-4.

| Defect size (mm) | Test depth (without coating)(mm) | error | Test depth (coating)(mm) | error |
|------------------|----------------------------------|-------|--------------------------|-------|
| 1                | 0.52                             | 0.608 | 16.9%                    |       |
| 2                | 1.15                             | 1.251 | 8.9%                     |       |
| 3                | 4.24                             | 4.336 | 2.3%                     |       |
| 4                | 7.36                             | 7.285 | 1.2%                     |       |
| 5                | 0.49                             | 0.643 | 25.1                     |       |
| 6                | 2.08                             | 2.331 | 12.1%                    |       |
| 7                | 5.90                             | 6.105 | 3.5%                     |       |
| 8                | 8.08                             | 8.378 | 3.7%                     |       |

| Defect size (mm) | Test depth (without coating)(mm) | error | Test depth (coating)(mm) | error |
|------------------|----------------------------------|-------|--------------------------|-------|
| 1                | 0.63                             | 0.731 | 16.0%                    |       |
| 2                | 1.20                             | 1.441 | 20.1%                    |       |
| 3                | 3.31                             | 4.595 | 8.8%                     |       |
| 4                | 8.26                             | 8.776 | 6.2%                     |       |
| 5                | 0.60                             | 0.77  | 28.3%                    |       |
| 6                | 2.08                             | 1.92  | 8.3%                     |       |
| 7                | 6.35                             | 6.058 | 4.6%                     |       |
| 8                | 10.20                            | 10.64 | 4.3%                     |       |

Based on testing data analysis shows that under the condition of not brush coating, to a depth of 1 mm the following defects, even if the test results and the actual value is 0.1 mm, detection error can reach 10%, this experiment for defects under 1 mm depth error can be controlled within 0.2 mm, to 1 mm above defects, detection error can be controlled within 5%. For defect positioning, the maximum error is basically within 3mm. The coating will have a certain impact on the detection results and increase the detection error. According to the results of this experiment, the detection error of defects with a depth of more than 2mm is basically less than 10% when the coating is below 1.77mm.
6. Conclusion
Through the analysis of the test results of the experiment, the following conclusions can be drawn:

1. Feasibility of ultrasonic phased array detection technology for work piece with coating.
2. The work piece thickness is above 15mm, and the defect depth is above 1mm with high detection accuracy.
3. The manual moving probe can roughly depict the defect morphology, which is close to the actual defect morphology.
4. The coating will have a certain impact on the detection results, and the detection error will be increased. When the coating is below 1.77mm, the detection error for depth defects above 2mm is basically below 10%.

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