Research on ultrasonic phased array inspection technology of small diameter tube based on Ultravision simulation technology

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Abstract: —According to the principle of ultrasonic phased array inspection, the ultrasonic phased array inspection simulation experiment is carried out on the butt weld of small diameter tube of power plant boiler by using the Ultravision software, which mainly includes the simulation of acoustic beam coverage and focused beam distribution. From the simulation test results, it can be concluded that: through the simulation of the acoustic beam coverage, the accessibility and coverage of the ultrasonic phased array acoustic beam can be simulated, and the applicability of the detection process can be verified and optimized; Through the simulation of focusing beam distribution, the distribution of the beam focus in the butt weld of the small diameter tube can be determined, which can guide the selection of focusing mode in the detection process and improve the signal-to-noise ratio of defect detection.

1. INTRODUCTION
As a new non-destructive testing technology, ultrasonic phased array technology has the advantages of multi angle scanning and variable focusing mode, which can realize wafer self focusing and intuitive A-scan, B-scan, C-scan and fan scan imaging. It can effectively detect all kinds of area type and volume type defects in the welding joint, improve the detection efficiency and defect detection rate by developing a reasonable detection process. In the application of nondestructive testing, ultrasonic phased array simulation technology can be used to simulate the probe wedge design, detection process parameter configuration, ultrasonic beam coverage, encoder design and defect response effect. It can not only improve the efficiency and save the cost, but also optimize the detection process.\[1\]

2. INTRODUCTION OF ULTRAVISION SIMULATION SOFTWARE
Ultravision simulation software is a powerful and intuitive professional NDT simulation system developed by zetec company in the United States. It has the simulation ability of ultrasonic phased array detection system and traditional pulse ultrasonic detection system. Ultravision software has the function modules of ultrasonic setting simulation, mechanical setting simulation, advanced phased array calculator, workpiece and defect 3D model creation, which can simulate the design of detection system, NDT process setting and defect response. According to the actual detection process configuration parameters, by loading the 3D model of the inspected workpiece with defects, tracking the sound beam detection ability, collecting the reflected acoustic signal, and analyzing the defect echo signal data. In
In this paper, the typical small-diameter tubes are selected for 3D modeling, different detection process parameters are set, and the simulation of acoustic beam coverage and defect response capability is carried out to explore the applicability and reliability of detection process. [2]

In this paper, the simulation test selects the butt weld of the small diameter pipe Φ 51 × 6mm of the thermal power plant boiler as the test object. In the software part setting module, the part parameters are set and the 3D model is generated. The workpiece and weld parameters are set as follows: the outer diameter of sample tube is 51mm, the wall thickness is 4mm, the length is 300mm, the material is 20g, the S-wave sound velocity is 3230m / s, the weld groove type is V-shaped, the groove angle is 30°, the root gap is 1mm, the weld reinforcement height is 1mm, the weld toe height is 0.5mm, the width of the heat affected zone is 2mm (both sides of the weld are symmetrical), and the butt weld model of small diameter tube is shown in Figure 1. The detection surface is the outer surface of small diameter pipe, and the detection direction is axial scanning. [3]

3. SIMULATION TEST OF SOUND BEAM COVERAGE
According to DL / T 1718-2017 “technical specification for phased array ultrasonic testing of welded joints in thermal power plants” recommended table of probe parameters and tested weld structure. In this test, the probe and wedge are set as follows: probe type is linear array probe, probe frequency is 7.5MHz, number of spindle chips is 16, distance between spindles is 0.3mm, spindle chip size is 0.2mm, wedge angle is 31°, wedge length is 12mm, wedge height is 10mm, The wedge is 10mm wide and the center height of the first wafer is 1mm. The mode of acoustic beam excitation is pulse excitation, and the mode of transmitting and receiving wave is shear wave.

The process parameters that affect the coverage of acoustic beam mainly include the angle of acoustic beam, scanning mode, step offset, etc. The technological parameters selected in the experiment are as follows: the scanning mode is sector scanning, the starting angle is 35° to 45°, the ending angle is 60° to 70°, and the step offset is 0mm, 1mm, 2mm, 3mm, 4mm and 5mm respectively. Input the above parameters into the ultravision software for simulation test. See Figure 2 for the coverage effect of acoustic beam under the process parameters.

Fig. 1 3D modeling of butt weld of small diameter pipe

Fig. 2 Simulation test results of sound beam coverage
From the simulation test, it can be concluded that the probe scans along the axial direction of butt weld of small diameter pipe. When the probe is 3mm away from the weld center (step offset), the starting angle is 40° and the ending angle is 70°, the secondary and tertiary waves can cover the weld and the heat affected area 100%, which can effectively detect all the defects in the weld.

4. SIMULATION TEST OF FOCUSING BEAM DISTRIBUTION

Ultrasonic array probes are composed of many piezoelectric chips (array elements) arranged in a certain shape, such as linear array, rectangular array and ring array. Each element can transmit and receive ultrasound independently. By controlling the excitation sequence of each chip with electronic signal, the phase of each chip's transmitting signal is different, the phase of each signal reaching the focus is the same, and the intensity of the sound field at the focus is increased, so as to realize the deflection and focus of the sound beam suitable for detection.

There are four kinds of dynamic focusing modes for ultrasonic phased array detection: real depth focusing, half path focusing, projection plane focusing and arbitrary plane focusing. Real depth focus means that all sound beams are focused at the same depth, and the focus is located at the same depth in the test workpiece. The real depth set in the software is the real depth value of the position to be focused in the material; half path focus means that all sound beams are focused on the arc with a single path as the radius. The focusing radius set in the software is the half sound path value of the focus distance from the front of the wedge; the projection focusing is that all sound beams are focused on a given vertical plane. In the software, the start offset is the horizontal distance from the front end of the wedge to the projection plane, and the focus of any plane is that all sound beams are focused on a customized arbitrary plane. The start depth and end depth set in the software are used to set the depth values of the start and end focus faces in any face focus.

Taking the Ф 51 × 6mm small diameter tube as an example, the focusing simulation is carried out. The following four simulation results are obtained by changing the focus mode and step offset distance according to the workpiece, probe and wedge setting parameters above. In the picture, the cross dot is the focus, and the black line is the focus track.

Fig. 3 Real depth 9mm focus simulation results

The real depth is selected as the focus mode. The focus depth is 9mm, and the step offset is 6mm. See Figure 3 for simulation results. It can be seen from the simulation results that the focus of the acoustic beam moves horizontally along the position of 9mm weld depth. The thickness of the workpiece is 6mm, and the focus of the acoustic beam is in the middle of the weld. This process is suitable for detecting the defects in the middle of the weld, and it can also be used as a preliminary scanning process. If you want to detect defects on the weld surface or root, you can set the focus depth to 12mm (weld surface) or 6mm (weld root).

The focusing mode is half path focusing, and the step offset setting is 4.5mm. The simulation results are shown in Figure 4. From the simulation results, it can be seen that the acoustic beam focus track moves along the fusion line on both sides of the root of the weld, and the process is suitable for detecting the root defects of the weld.
The focus mode is projection focus, and the step offset setting is 6mm. See Figure 5 for simulation results. From the simulation results, it can be seen that the focus of the projection focused beam is located in the weld center line, and the focus track moves vertically along the weld center line. The process is suitable for detecting circumferential defects located in the weld center line and parallel to the weld.

Focus mode: select any face to focus, step by step offset 6mm, focus face depth 9mm, offset start 6.95mm, end 3.75mm. The simulation results are shown in Figure 6. It can be seen from the simulation results that, according to the above process parameter settings, the focus of the acoustic beam focused by any focus surface is located on the opposite side of the probe, and the focus track is distributed along the groove surface. This process is suitable for detecting the defects on the groove side of the weld, such as the groove is not fused.

5. CONCLUSIONS
In this paper, ultravisin software is used to simulate the coverage and focused beam distribution of ultrasonic phased array in the detection of butt weld of small diameter tube. Through the simulation test results, it can be concluded that the ultrasonic phased array simulation is an economic and scientific method, which can verify and optimize the applicability of the detection process through the simulation of the acoustic beam coverage; through the focused beam distribution simulation, the distribution of the
acoustic beam focus in the butt weld of the inspected small-diameter tube can be defined, so as to guide the selection of the focusing mode in the detection process. To improve the signal-to-noise ratio of defect detection.

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