Phased Array Detection Technology in Artificial Intelligence and Its Application in Power Industry

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Abstract. Modern industry is faced with "four heights" -- high temperature, high pressure, high stress and high speed. Among them, the importance of nondestructive testing is becoming more and more prominent with the process of industrial modernization [1]. Enterprises and society have more and more demanding requirements on product quality and equipment function. How to solve and eliminate this problem has become an important opportunity for the development of NDT industry. The current hot artificial intelligence technology undoubtedly brings the method for NDT, the combination of the two is bound to produce huge energy to promote its progress in the electric power industry [2]. Based on this, this paper explores the phased array detection technology and its application progress in the power industry under the background of artificial intelligence [3].

Keywords: Big Data Technology, Phased Array Detection, Power Industry, Application, Progress

1. Introduction

We live in a world of complex structures, surrounded by large structures, dependent on complex machines. Our lives and livelihoods are inextricably linked to the proper functioning of our infrastructure and machines. In order for this to be safe and feasible, we have to have absolute confidence in the technology we rely on. Nondestructive testing provides this confidence. Nondestructive testing is required by law in many industries around the world. If not, it's still a compelling best practice. Mastering this complex subject takes decades and is the culmination of people who devote their lives to it [4]. It requires a lot of training and practical experience in a variety of situations. Even after 30 years of testing, it's still possible to see something completely new.

2. Principle and characteristics of ultrasonic phased array
2.1. Principle of ultrasonic phased array

Ultrasonic phased array technology is to control each element in the transducer array by electronic system, transmit and receive ultrasonic wave according to certain delay time rule. Thus, the deflection and focusing of ultrasonic beam in workpiece are dynamically controlled to realize nondestructive testing of materials. The transducer is composed of several independent piezoelectric wafers, each of which is called a unit. According to certain rules and time series, each element is excited by electronic system. The ultrasonic wave array emitted by each element in the array is superimposed to form a new wavefront. Also, in the process of receiving the reflected wave, the reception of the receiving unit is controlled according to certain rules and time sequence, and the signal synthesis is carried out, and then the is displayed in an appropriate form [5].

2.2. Characteristics of ultrasonic phased array detection

The combination of different array elements of ultrasonic phased array and different focusing rules forms three unique working methods: linear sweep, sector sweep and dynamic depth focus. The phased array detection system is a high performance digital instrument, which can record the signal of the whole process of detection, and generate and display high quality images projected in different directions after signal processing, such as B sweep, C sweep, D sweep and S sweep view. Ultrasonic phased array technology can detect defects in various directions and different positions [6]. The detection rate of defects is high, the detection range is wide, the quantitative and positioning accuracy is high; the detection data is easy to store, search and call; the scanning device is relatively simple, easy to operate and maintain; and the real-time color image can be formed to facilitate defect evaluation.

3. Application of ultrasonic phased array technology in power industry

3.1. Pipe butt weld inspection

The butt weld of power plant pipeline, especially main steam pipeline, reheat section steam pipeline, main water supply pipeline and reheat cooling section steam pipeline is subjected to higher temperature and pressure during operation. Therefore, it is very important to strengthen the detection of pipe butt weld. The butt weld groove generally has three forms: V type, U type and double V type [7].

When the traditional ultrasonic flaw detection method is used to detect the butt weld of pipeline, the probe should move frequently on both sides of the weld, and the detection process is very complicated. When the butt weld is detected by phased array ultrasonic probe, the whole product scan of butt weld can be realized by scanner and encoder. In the detection process, the key detection parameters are set by the software itself, no need to replace the probe, no need to move the probe back and forth frequently, and no need for complex clamping devices [8]. It should be noted that only by ensuring the distance between the front end of the probe wedge and the welding toe can the sound beam emitted by the probe cover the whole cross section and then move longitudinally along the weld axis to complete the detection.

3.2. Inspection of fillet weld of nozzle

As the key inspection and monitoring part of boiler inspection, the quality of fillet weld of pipe seat directly affects the safety and reliability of boiler operation. In the process of welding, there are often area defects such as weld penetration, fusion and crack. Because ultrasonic detection is very sensitive
to such defects and has high detection sensitivity, conventional ultrasonic detection has become a common internal detection method for fillet welds of pipe seat. However, due to the complex shape and structure of the fillet weld of the nozzle seat, it is easy to be affected by the curvature of the pipe seat, the wall thickness and the form of saddle weld when using ultrasonic wave [9].

Using simulation software, ultrasonic phased array detection technology is applied to the detection of fillet weld of pipe seat, and automatic detection is realized by scanning device. By contrast, the ultrasonic phased array detection technology can ensure the quality of detection.

3.3. Inspection of blade root of steam turbine

The large-scale steam turbine unit in China has become the main unit, the blade working parameter standard is getting higher and higher, and the safety and reliability are becoming more and more important. The most demanding and workload component of steam turbine is the turbine rotor. The blade root of each blade bears tens or even hundreds of tons of centrifugal force, bending force and torsion in high temperature, high pressure and high speed rotation [10]. The structure of blade root, wheel groove and keyway is complex, so it is difficult to detect the rotor of steam turbine by ultrasonic wave. When the blade root of turbine rotor is detected by phased array transducer, the blade can not be disassembled, which can not only improve the detection efficiency, but also avoid damage during disassembly. The shape of mycorrhizal roots is shown in figure 1.

![Figure 1. Leaf blade mycorrhizal of steam turbine](image)

Bacterial leaf roots have single bacteria, double bacteria and three bacteria. According to the force analysis, it is generally considered that there is a large stress at the first slot, which is easy to produce cracks. Under the influence of the characteristics of conventional ultrasonic detection and the structure of leaf root, the first tooth root can only be detected, that is, the longitudinal wave and shear wave are used to detect the first groove on the detection surface, and the other parts can not be detected. As shown in figure 2.

![Figure 2. Vapor-sealed mycorrhizal test](image)
**Figure 2.** Routine ultrasonic testing of mycorrhizal

Using ultrasonic phased array detection technology, we can use less probe to realize the comprehensive scanning of the detection area in a limited range. The special phased array ultrasonic transducer is shown in figure 3.

![Figure 3. Special ultrasonic phased array transducer](image)

**Figure 3.** Special ultrasonic phased array transducer

Ultrasonic phased array was used to detect mycorrhizal leaf roots, usually the A and B areas of leaf roots. A area refers to the first tooth area, the first slot area, the second slot area; the B area refers to the second slot area, the second tooth area, the third slot area, the third tooth area. A and B representative area locations are shown in Figure 4 [11].

![Figure 4](image)

(a) A schematic map of the coverage of the A area of mycorrhizal roots
Ultrasonic phased array detection technology can identify the artificial defects on the leaf root specimen, and can carry out full coverage detection of the first tooth of the leaf root, which solves the problem of ultrasonic detection of the leaf root of large capacity units, and provides a guarantee for the safe and stable operation of power plants and power grids [12]. The characteristic reflection wave imaging of mycorrhizal fan is shown in figure 5. The characteristic reflection wave imaging of mycorrhizal fan is shown in figure 5.

3.4. Inspection of small diameter tubes

Boiler superheater, economizer, water wall and reheater tube of thermal power plant are called boiler "four tubes ". Under normal circumstances, the heating surface tube is usually called a small diameter tube, the diameter of which is 32~89 mm, and the pipe wall is 4~12 mm. In recent years, the supercritical and ultra-supercritical units are increasing, and the temperature and pressure of the units are increasing, which puts forward higher and higher requirements for the quality of the small diameter...
pipes used. Because the boiler "four pipes" are in high temperature and high pressure environment for a long time, it is easy to produce high temperature creep, inner wall water side corrosion, outer wall to fire side corrosion, outer wall erosion and wear and fatigue.

(a) An artificial groove of mycorrhizal specimens showing (b) an B defect-free detection effect

(c) Area A defect detection effect map (d) Area

**Figure 5.** Image of the characteristic reflection wave swept by mycorrhizal fan

The conventional ultrasonic detection has poor coupling, low acoustic velocity diffusion and low reflectivity, and can only reflect the sound velocity at a fixed angle, and there are certain blind areas. At the same time, because the small diameter pipe row of power station boiler is dense and the space is narrow, it is not suitable for narrow position operation, and the detection efficiency and defect detection effect can not meet the working requirements. Using phased array ultrasonic detection sensor and wedge design, using ultrasonic phased array detection technology to detect the butt weld of boiler small diameter pipeline, can realize multi-angle and blind area scanning of weld crack of boiler heating surface pipeline in power plant, and the detection sensitivity is high, which can effectively eliminate the related hidden trouble. In addition, in the construction and maintenance of electric power industry, ultrasonic phased array can also be used to detect coarse austenitic steel, and the defects of different depths can be detected by ultrasonic phased array technology.

4. Conclusion

Nondestructive testing (NDT) is an essential and effective tool for industrial development. It reflects the level of industrial development of a country to some extent, and its importance has been recognized. Although there is still a big gap between China and the world's advanced countries in the basic theory of NDT and the development of instruments and equipment, especially in the infrared, acoustic emission and other high-tech testing equipment. But artificial intelligence offers new possibilities, and its future prospects are limitless.
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