Research on Internal Defect Detection of Concrete Structure Based on Ultrasonic Phased Array Technology

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Abstract: Ultrasonic phased array detection technology is an emerging ultrasonic detection technology, which is derived from phased array radar technology. Ultrasonic phased array detection is to control the excitation (or reception) of each element in the ultrasonic transducer array. The time delay of the pulse changes the phase relationship of the time when the sound wave transmitted (or received) from each element reaches (or comes from) a certain point in the target object, so as to achieve the effect of focusing and beam deflection, and realize defect detection. This article introduces the detection principle and characteristics of ultrasonic phased array, this article summarizes its development and research status at home and abroad, and finally takes the internal defect quality inspection of a certain bridge as an example to introduce the application of ultrasonic phased array in practical engineering.

Keywords: ultrasonic phased array; non-destructive testing; research status; practical application

1. Introduction

Ultrasonic testing is an important branch in the field of non-destructive testing. Compared with other testing methods, ultrasonic testing has the advantages of strong applicability, good penetration, portable equipment, and safe operation, and has been the most widely used [1,2]. Ultrasonic phased array technology has been popularized and used because of its fast scanning speed, flexible sound beam control, high detection sensitivity, and wide application range, and has gradually become a research hotspot in the international non-destructive testing field. Ultrasonic phased array detection technology is a phased array technology developed on the basis of conventional ultrasound. Its working mechanism is to use electronic deflection technology to generate electric pulses of different phases according to a certain rule to excite multi-array element wafers to generate focused beams to complete the measurement of the workpiece Location scan detection. This article outlines the development and application of ultrasonic phased array detection technology. First, it briefly introduces the detection principle and characteristics of ultrasonic phased array, then summarizes its development and research status at home and abroad, and summarizes its research hotspots and development trends, and finally introduces a typical engineering application example, that is, a bridge concrete structure Internal defect detection.

The countries where the research and application of ultrasonic phased array are more in-depth are mainly France, Canada, Britain, Germany, and the United States.

In 1959, the first ultrasonic phased array inspection system was born. It was a ring-shaped dynamic focus transducer system developed by Tom Brown. In 1992, the United States General Electric Company (GE) successfully developed a digital ultrasonic phased array real-time imaging system. Realization of fully programmable digital sound beam formation, which can control the sound beam more flexibly; In 2009, the non-destructive evaluation laboratory of Massachusetts Institute of Technology successfully developed a phased array ultrasonic scanning device for concrete evaluation. Detect the position and direction of the steel bars in the concrete. In 2011, the United States, Japan and other countries began to apply ultrasonic phased array detection technology to damage imaging and photometric imaging of complex welded parts [3,4]. In 2013, K. Schabowicz [5] introduced ultrasound imaging technology, studied its testing methods, and designed an experimental program for testing and analysis. In 2016, Pangil Choi [6] et al. applied ultrasonic phase control technology to the detection and identification of cracks and faults in concrete pavements and bridges.

In 2003, the research team of Professor Shi Keren of Tsinghua University and Dr. Xiaoyu Bao designed a 16-channel ultrasonic phased array detection system to improve detection resolution and research on flexible array phased array technology [7,8]; 2007 electronic testing The Key Laboratory of Technology for National Defense Technology has studied the implementation method of a 16-channel phased array launch system based on complex programmable logic devices (CPLD) [9]. In 2008, the acoustics of the Chinese Academy of Sciences used concave linear phased array focusing to scan and image the quality of the pipe [10]. In 2012, Liao Yin and Li Qiufeng proposed a detection method based on linear array probes, combined with synthetic aperture focusing technology, to study high-resolution imaging methods for concrete structure array detection. Wang Ziping [11] studied telescopic piezoelectric orthotropic fiber composite (OPFC) elements and corresponding ultrasonic phased linear array transducers for damage detection of metal and concrete structures. In 2017, Li Juanjuan applied synthetic aperture focusing imaging technology to ultrasonic concrete inspection, which is more conducive to discovering abnormal structures inside concrete. Yao Lijun [12] and others designed and produced 3 reinforced concrete composite slab specimens with different artificial defects in the superimposed surface. The ultrasonic phased array can accurately detect the holes, floating soil and other defects of the new and old concrete junctions by imaging the defects. In 2018, He Shenghua [13] used ultrasonic phased array technology to identify obvious defects such as holes for concrete composite wall specimens, but the ultrasonic transmission method missed the local gap defects of the new and old concrete joints.

2. Engineering Application Examples

Ultrasonic phased array has played an important role in the quality inspection of concrete-filled steel tube compaction. This section takes the steel truss of bridge arch ribs as an example to introduce whether the ultrasonic phased array has voids in the bonding of concrete-filled steel tube and whether there are voids and defects in the concrete. Check for compactness and other conditions. Each rod is selected for detection within 1m of the middle of the rod, and the detection surface is arranged on the upper half of the rod to obtain the compactness of the steel tube concrete in the detection unit, as shown in Fig. 1.

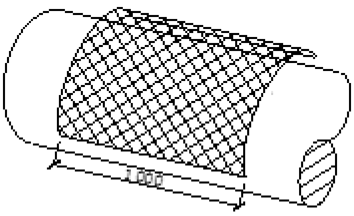


Figure 1. Layout of ultrasonic array detection surface

The test result of a certain rod: there is void on the top and side of the rod, the void area on the top surface is larger, and there is no obvious void on the bottom surface. The overall void area is 15.3% of the total tested area; the center concrete has good density. No obvious defects, as shown in Fig. 2.

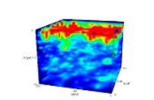
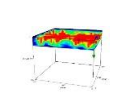
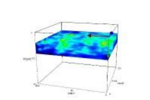
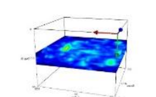
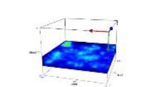
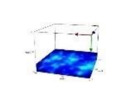
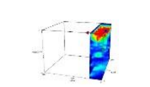
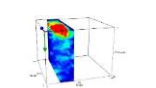
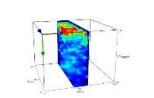
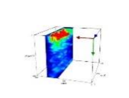
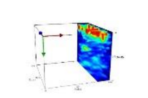
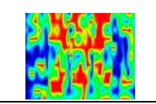
			
(a)Full image of ultrasound array scan	(b)Radial 0-150mm scan	(c)Radial 150-300mm scan	(d)Radial 300-450mm scan
			
(e)Radial 450-600mm scan	(f)Radial 600-720mm scan	(g)Tube axial 0-200mm scan	(h)Tube axial 200-400mm scan
			
(i)Tube axial 400-600mm scan	(j)Tube axial 600-800mm scan	(k)Tube axial 800-1000mm scan	(l)Scanning image of the largest defect

Figure 2. Scanning of ultrasound array under No. 1 internode A of No. 2 arch rib of 1 hole

3. Conclusion

Ultrasonic phased array imaging technology is to control the time delay of the excitation (or receiving) pulse of each element in the transducer array to change the time when the sound wave emitted (or received) by each element reaches (or comes from) a certain point in the object. The phase relationship realizes the change of the focus point and the azimuth of the sound beam to complete the acoustic imaging technology. Since the delay time of the phased array element can be dynamically changed, the ultrasonic phased array probe is mainly used for flaw detection by using its two characteristics: controllable sound beam angle and dynamic focusing. Ultrasonic phased array technology can scan uninterruptedly within the unilateral range of reinforced concrete structures, and the imaging effect is clear; it can accurately identify defects such as poor cementation, internal holes and vertical cracks in the range of the bonding surface of the new and old concrete.

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