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Effect of groove defect State on propagation of SH0 guided wave in flat steel of grounding network

HE Ke-long[1], ZHANG Zhou-quan[2], LIU Zhuan[2], ZHU Hui[1], PENG Guo-da[1], TU Zhan[1]

[1]Nanchang Kechen Electric Power Test And Research Co., Ltd, Nanchang 330096, China

[2]State Grid Jiangxi Electric Power Research Institute, Nanchang 330096, China

E-mail: zhangzq@163.com

Abstract. By studying the depth and length of groove defect, this paper explores its effect on the propagation of SH0 wave in the flat steel of substation grounding network. The results show that the sensitivity of SH0 wave to defect detection in the propagation process depends on the depth of defect, that is, the corrosion cross-sectional area. Reflection waves are difficult to detect when the defect cross-sectional area is less than 18.75%. The smaller the defect depth, the weaker the echo signal.

1. Introduction

The grounding of substation is an important measure to ensure the safe operation of power system. The general method is to lay the grounding net[1]. It can effectively reduce the high pressure on electrical equipment, quickly export large currents generated by lightning strikes or short circuits to prevent damage to electrical equipment, and at the same time protect the personal safety of staff [2]. Due to resources, burial, economy and other reasons, the materials used in grounding network are mainly flat steel with ordinary carbon steel and galvanized carbon steel artists. Poor welding during construction and virtual welding, leakage welding, soil corrosion and other reasons will lead to corrosion, fracture of grounding network materials, electrical conductivity decline[3][4]. At present, the common nondestructive testing methods are ultrasonic method, X-ray method, magnetic powder method and eddy current detection method. Because the ultrasonic detection method has the characteristics of timely and rapid flaw detection, it has great advantages and potential in the corrosion detection of grounding networ[5][6][7]. Grounding mesh flat steel buried in the soil for a long time, by the erosion of water and salinity, will cause serious corrosion, its corrosion form is affected by local soil conditions and differences, in general, the shape of corrosion pits is more common. Laboratory studies usually use simulation tests of typical defects to make it easier to find patterns, and then superimpose typical defects to simulate complex defects. In this paper, the typical Groove type defect is taken as the research object, which provides a reference for the future study of the Guide wave propagation law of the corrosion pit of flat steel. The detection system consists of PRP-4000 pulse function generator, Tektronix oscilloscope, impedance matching instrument at exciting end, impedance matching instrument at receiving end and SH0 magnetostrictive electromagnetic ultrasonic transducer at 310kHZ.

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2. Experimental

Taking carbon steel as an example, a pass with a slope of 90 degrees on flat steel was used as a simulated defect. In Figure 1, the excitation probe of SH0 guided wave is at A and the signal receiving probe of SH0 guided wave is at B. The excitation voltage energy level is 30 and the gain is 70 dB. The flat steel is 4000mm long, 50mm wide and 5mm thick. A groove with a depth of 2 mm and a width of 25 mm was opened at a distance of 1000 mm from the right end of flat steel. The propagation characteristics of SH0 guided wave in conductor were studied as shown in Fig. 1.

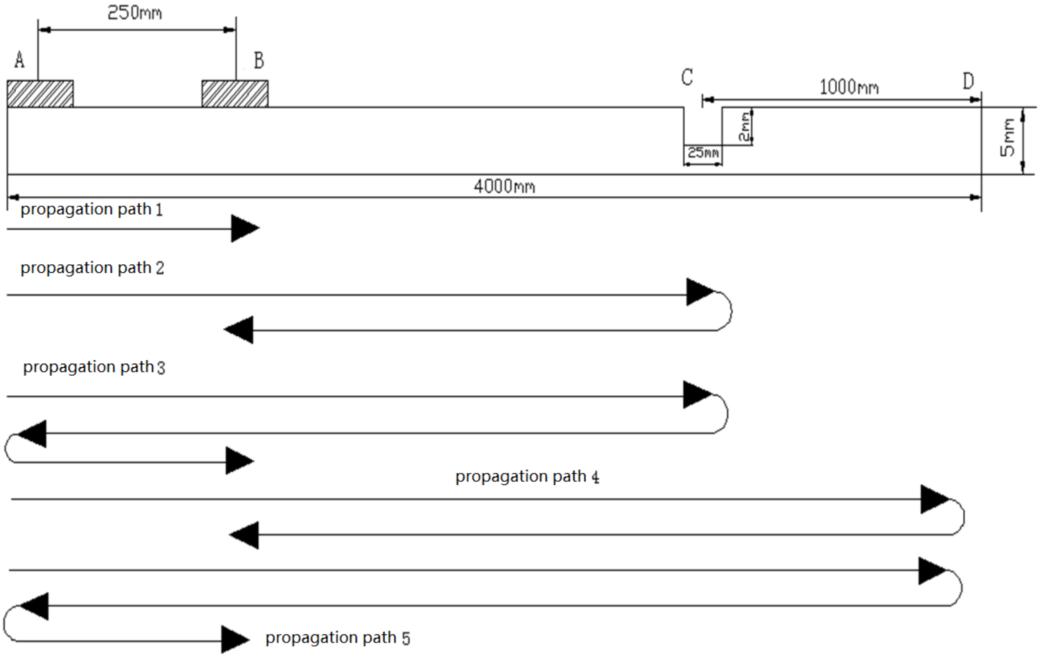


Figure 1. Schematic diagram of propagation path of SH0 guided wave in flat steel

As can be seen from Figure 2, there were 5 wave packets in the defect test, and the time difference between the direct wave A-B and the end echo A-C-B was 1730μs, and the corresponding distance was 550mm, which showed that the actual propagation speed measured in this experiment was 3179m/s, and the relative error with the theoretical value was 2.5%.It was indicated that SH0 wave can be used for defect detection and the positioning is accurate.

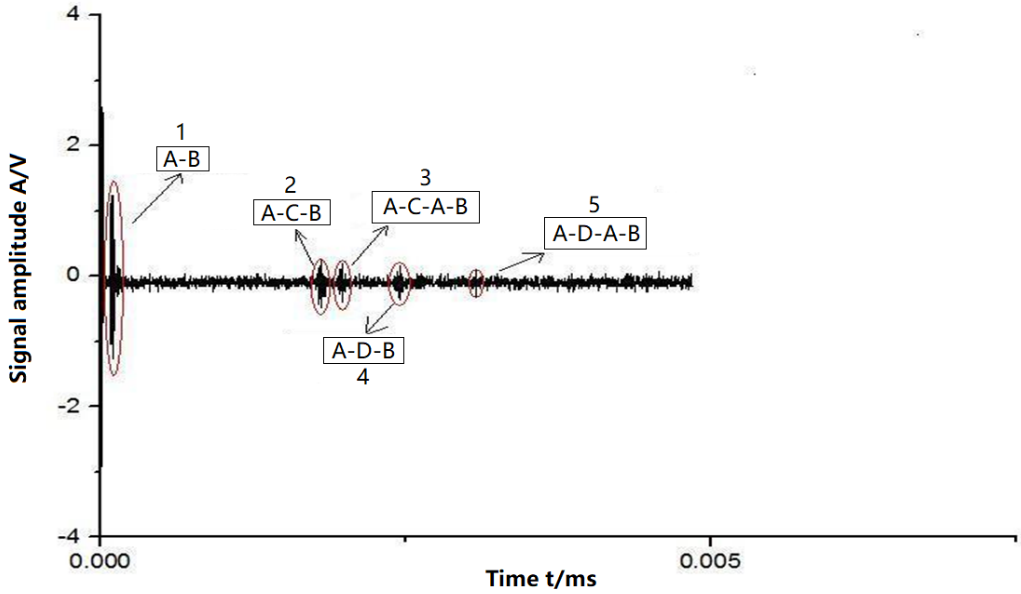
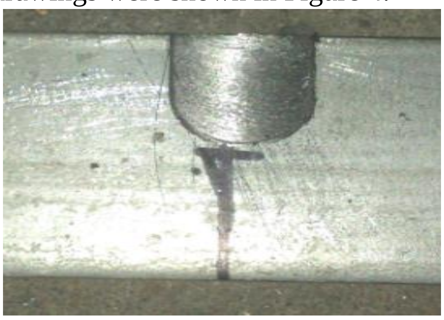


Figure 2. Waveform of SH0 Guided Wave in Flat Steel

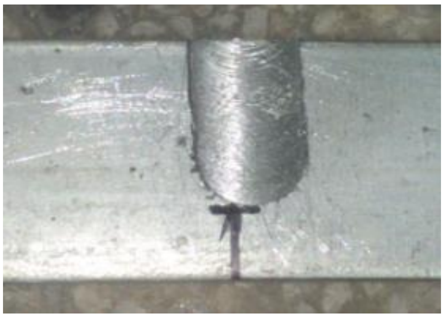
3. Results and discussion

3.1. Effect of groove defect depth and length on SH0 guided wave propagation

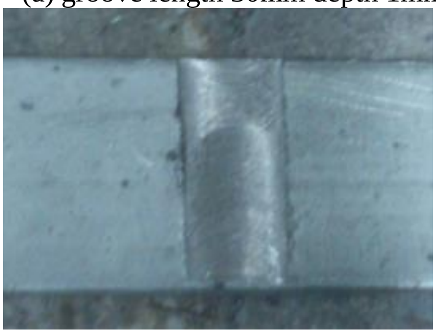
When the groove depth is 2 mm, roughly accurate defect location can be obtained by the detection device. Taking 2000mm long, 60mm wide, 6mm thick, 500 mm from the right end and 20mm width as test objects, the groove depth and length physical drawings were shown in Figure 3, and the detection waveform drawings were shown in Figure 4.



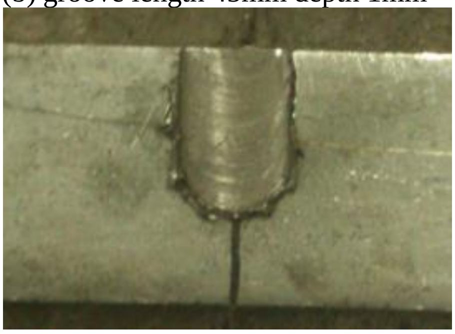
(a) groove length 30mm depth 1mm



(b) groove length 45mm depth 1mm



(c) groove length 60mm depth 1mm



(d) groove length 45mm depth 1.5mm

Figure 3. Physical drawings of different groove depths and shapes

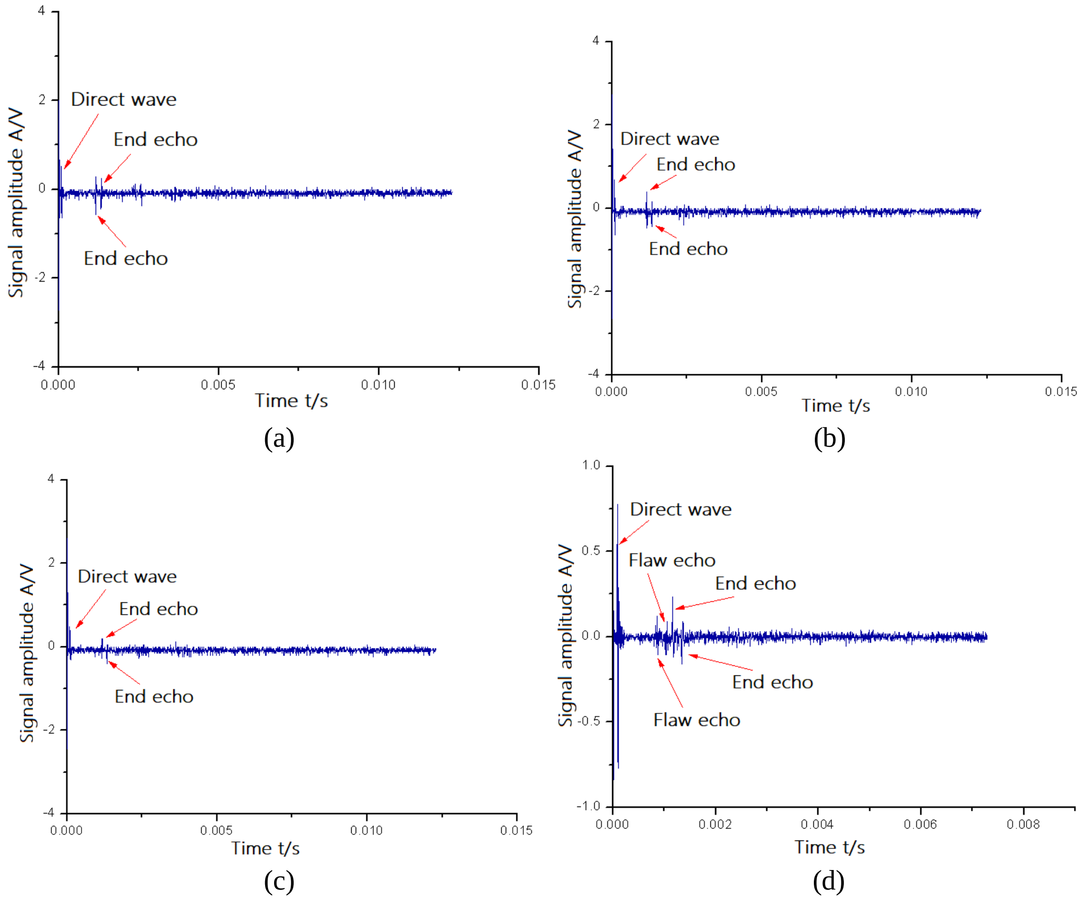


Figure 4. Waveform diagrams of different groove depths and shapes

As can be seen from Figure 4 (a), (b), (c), when the groove defect depth is 1mm, the length is 30mm, 45mm and 60mm, respectively, there was only direct wave and end echo, and no flaw echo was detected. When the Groove defect depth is 1.5mm and the length is 45mm, not only the direct wave and the end echo could be seen, but the defect echo could be located by calculation. That is, if the defect groove is not through the groove, its depth up to 1.5mm can detect the defect echo.

As can be seen from Figure 5, the proportion of defects in the entire cross section was 18.75%.

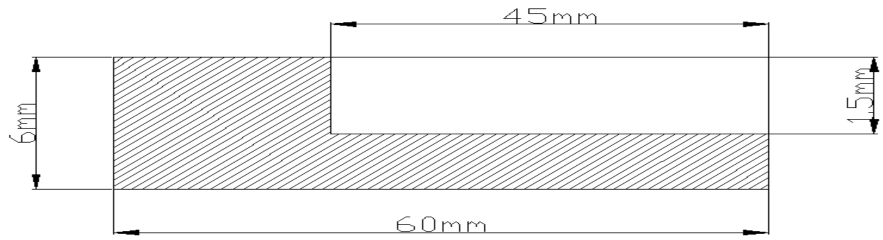


Figure 5. Slot length 45mm deep 1mm defect diagram

3.2. Calculation and analysis of test results

As shown in Figure 6, the SH0 guided wave has only particle motion in the y direction, and the X and Z direction particle displacement is 0.

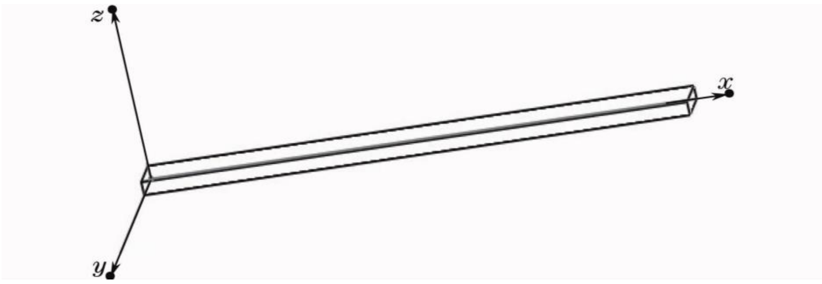


Figure 6. Three-dimensional signal of flat steel

The particle displacement equation of SH0 guided wave is as:

$u_x = 0;$

$u_y = B_H \cos(\omega t - kx)$;

$u_z = 0.$

In formula: u_y is the displacement of the particle in the y direction; B_H is the amplitude; k is the wave number; x is the distance of any point from the wave source; and ω is the angular frequency.

Reflection occurs when the SH0 Guide wave travels to the interface of the defect, the steel and the air. The acoustic pressure reflectivity is:

$$r = \frac{P_r}{P_o} = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$

In the formula: r is the acoustic pressure reflectivity, P_r is the reflective wave sound pressure, P_o is the acoustic pressure of the incident, Z_2 is the acoustic impedance of the air, and Z_1 is the acoustic impedance of the steel. As known from the standard, Z_2=0.00004×10^6 $g/cm^2.s$,Z_1=4.61×10^6 $g/cm^2.s$ .After calculation, r =0.99998≈1.

That is to say, when SH0 guided wave meets the steel-air interface, it almost reflects completely without transmission, that is to say, SH0 guided wave is completely reflected at the defect of 90 degree groove without phase difference, and the height of reflected wave is the sum of defect echoes. The deeper the groove defect is, the more echo superposition is, the higher the effective reflection height is, and the stronger the reflection signal is. When the groove defect area is less than 18.75% of the whole cross-section area, the reflected wave signal is very weak and can not be distinguished from the noise signal.

4. Conclusion

● The sensitivity of SH0 guided wave to defect detection during propagation depends on the depth of the defect, i.e. the corrosion cross section area. The deeper the defect depth is, the more echo superposition is, the higher the effective reflection height is, and the stronger the reflection signal is.

● When the defect area exceeds 18.75% of the whole cross-section area, the echo signal will appear, otherwise it will be difficult to make accurate judgment.

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