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Ultrasonic testing method of copper and copper alloy bars

铜及铜合金棒材超声检测方法

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Ultrasonic testing method of copper and copper alloy bars

1 Scope

This document describes the methods for ultrasonic testing of copper and copper alloy bars. The content includes method principles, general requirements, instruments and equipment, selection of testing types, comparison test blocks, testing steps, defect assessment, quality grades, and testing reports.

This document is applicable to the ultrasonic testing of circular, rectangular, square and regular hexagonal copper and copper alloy bars (hereinafter referred to as "bars") with a diameter of not less than 10 mm by the Type A pulse longitudinal wave reflection method.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

GB/T 9445, *Non-destructive testing -- Qualification and certification of NDT personnel*

GB/T 12604.1-2020, *Non-destructive testing -- Terminology -- Ultrasonic testing*

JB/T 10061, *Commonly used specification for A-mode ultrasonic flaw detector using pulse echo technique*

JB/T 10062, *Testing methods for performance of probes used in ultrasonic flaw detection*

3 Terms and definitions

For the purposes of this document, the terms and definitions defined in GB/T 12604.1-2020 as well as the followings apply.

3.1 contact method

A testing method that uses one or more ultrasonic probes to directly contact the workpiece to be tested for scanning.

3.2 immersion method

A testing method in which both the object under test and the ultrasonic probe are immersed in a liquid used as a couplant or refractive prism.

3.3 6 dB drop method

A method that moves the probe from the position where the maximum echo amplitude is obtained until the echo amplitude is reduced to half of it (a drop of 6 dB), and uses this moving range to evaluate the size of the reflector.

[Source: GB/T 12604.1-2020, 6.8.17, modified]

4 Method principle

The high-frequency electrical pulse generated by the ultrasonic flaw detector is applied to the probe chip, causing the chip to vibrate at high frequencies and produce electroacoustic conversion. The ultrasonic wave generated by the probe chip is transmitted to the workpiece to be tested through the coupling medium. When the ultrasonic wave propagates in the workpiece and encounters the interface of media with different acoustic impedances (such as defects or bottom surfaces), it is reflected and returns to the probe chip. After another electroacoustic conversion by the chip, the sound energy is converted into electrical energy. The signal is received and processed by the instrument. The depth and size of the flaw are displayed on the flaw detector display.

5 General requirements

5.1 Ultrasonic testing personnel shall be trained in accordance with the requirements of GB/T 9445 and obtain an ultrasonic testing technology level qualification certificate issued by the relevant national authorized department. Only those who have obtained the technical qualification certificate of appraisal level II or above (including level II) can be qualified to issue testing reports.

5.2 The surface roughness R_a of the bar being tested shall not be greater than 6.3 μm. There shall be no scale, rust, oil, etc. that would affect the testing.

5.3 Under the specified testing sensitivity conditions, the signal-to-noise ratio of the bar being detected shall not be less than 6 dB.

5.4 To ensure the accuracy and stability of the test results, the test site shall not be located in an environment with strong magnetism, vibration, high frequency, sparks, etc.

5.5 The coupling agent used in the immersion method shall be bubble-free, impurity-free, and clean tap water. The coupling agent used in the contact method shall have good sound transmission, and usually uses engine oil, chemical paste, glycerin, water glass, etc.

6 Instruments and equipment

6.1 Flaw detector

Type A pulse reflection ultrasonic flaw detector shall comply with the requirements of JB/T 10061.

6.2 Probe

6.2.1 The performance test of the probe for ultrasonic testing shall be carried out in accordance with the provisions of JB/T 10062.

6.2.2 The probe used for contact method testing uses a single crystal straight probe or a dual crystal straight probe. The frequency is 0.5 MHz~5 MHz.

6.2.3 The probe used for immersion testing uses a longitudinal wave line focusing probe or a point focusing probe. The frequency is 5 MHz~10 MHz.

6.2.4 The probe element diameter (or diagonal) is 6 mm~25 mm.

6.3 Transmission equipment

6.3.1 The base and probe holder of the immersion probe shall be able to conveniently and reliably adjust the distance of the water layer and the incident angle of the ultrasonic wave, as well as the concentricity between the probe and the transmission equipment. If necessary, floating tracking devices can be used.

6.3.2 The transmission equipment can be such that the probe rotates and the bar moves forward in a straight line. It can also be that the probe does not move and the bar rotates forward.

6.3.3 The transmission equipment shall run at a constant speed to ensure that the relative displacement speed between the probe and the bar is stable during the testing process.

7 Selection of testing type

The dual crystal straight probe contact method and the single crystal straight probe contact method are generally tested by manual scanning. Immersion method testing shall be carried out automatically on transmission equipment. The selection of testing types is shown in Table 1.

9 Testing steps

9.1 Adjustment of testing sensitivity

9.1.1 When testing by the liquid immersion method, the distance between the water layer and the perpendicularity between the ultrasonic sound beam and the axial direction of the bar must be correctly adjusted so that the ultrasonic sound beam can enter the bar vertically. First, place the probe above the artificial defect in the flat-bottomed hole with a burial depth of 0.5D in the comparison test block shown in Table 1 and Figure 1, which has the same diameter as the bar being tested. Move the probe so that the reflected wave is the highest. At the same time, adjust the instrument gain knob so that the reflected wave height is 80% of the full amplitude. Then move the probe above the artificial defect of the flat-bottomed hole with a burial depth of 0.75D. Also set the reflected wave height to 80% of the full width. The difference between the two attenuator readings is less than 2 dB. At this point, the testing sensitivity has been adjusted.

9.1.2 When testing with the dual crystal straight probe contact method, place the probes above the flat-bottom hole artificial defects with burial depths of 0.5D and 0.75D in the comparison test blocks shown in Table 1 and Figure 1, respectively, with the same diameter as the bar being tested. Adjust the instrument gain knob so that the reflected wave height of the artificial defect in the flat-bottomed hole is 80% of the full amplitude. When the gain reading of the instrument is adjusted to be high, the reflected wave height of the flat-bottomed hole is 80% of the full width as the testing sensitivity.

9.1.3 When testing with the single crystal straight probe contact method, place the probe above the artificial defect in the flat-bottomed hole with a depth of 10 mm in the comparison test block shown in Figure 2, which has the same diameter as the bar to be tested. Adjust the instrument gain knob so that the reflected wave height of the artificial defect in the flat-bottomed hole is 80% of the full amplitude, which is used as the testing sensitivity. When the sound path is greater than 3 times the near-field area, the first bottom wave of the bar can be used to adjust the testing sensitivity. First, adjust the height of the first bottom wave of the bar to 80% of the full width. Then calculate the required gain value A according to formula (1). Increase the instrument gain by A . At this point, the testing sensitivity has been adjusted.

$$A = 20 \lg \frac{2\lambda \cdot d}{\pi \cdot \phi^2} \qquad \cdots\cdots (1)$$

Where,

A - the gain value that needs to be increased, in decibels (dB);

λ - the wavelength, in millimeters (mm);

d - the diameter of the bar to be tested, in millimeters (mm);

π - the circular constant;

ϕ - the diameter of the flat-bottomed hole, in millimeters (mm).

9.2 Scanning sensitivity

During actual testing, an additional 6 dB is added to the above testing sensitivity as the scanning sensitivity. When a defect is found, the sensitivity is reduced by 6 dB to determine the defect.

9.3 Scanning speed

The scanning speed during contact method testing shall not be greater than 150 mm/s. The scanning speed during immersion testing shall be 5 m/min~25 m/min.

9.4 Scanning range

The probe scans 100% along the axial and circumferential directions of the bar. The effective cross-section of the scanning sound beam shall have 15% coverage.

10 Defect assessment

10.1 Defect location

10.1.1 Determination of defect plane location

By moving the probe on the surface of the bar being tested, the position of the highest reflected wave of the defect can be obtained, thereby determining the plane position of the defect.

10.1.2 Determination of defect burial depth

Determine by comparing with a comparison test block, or use the diameter of the bar to determine by the proportion method.

10.2 Assessment of defect equivalent

When the depth of the tested defect is not less than 3 times the length of the near-field area, the DGS method and calculation method are used to determine the defect equivalent. When the depth of the tested defect is less than 3 times the length of the near-field area, the test block comparison method is used to determine the defect equivalent.

NOTE: The DGS method is the distance-gain-size method (DGS) method. It uses a DGS curve to represent the height of the echo from a reflector as a flat-bottomed hole. The equivalent echo is

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