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Method for ultrasonic testing of forged and rolled steel bars

锻轧钢棒超声检测方法

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Method for ultrasonic testing of forged and rolled steel bars

1 Scope

This document specifies the general requirements, instruments and equipment, comparative test blocks, testing procedures, testing program, evaluation of testing results, quality grades, testing records, testing reports, for the ultrasonic testing of forged and rolled steel bars (hereinafter referred to as "steel bars").

This document is applicable to the ultrasonic pulse reflection detection of steel bars, which have a diameter of not less than 6 mm. The forged and rolled bars or non-bars, which have other specifications or materials, may make reference to this standard.

This document does not apply to the testing of austenitic coarse-grained steel bars.

2 Normative references

The provisions in following documents become the provisions of this Standard through reference in this Standard. For the dated references, only the versions with the dates indicated are applicable to this document; for the undated documents, only the latest version (including all the amendments) is applicable to this standard.

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

GB/T 12604.1 Non-destructive testing - Terminology - Ultrasonic testing

GB/T 18694 Non-destructive testing - Ultrasonic inspection - Characterization of search unit and sound field

GB/T 18852 Non-destructive testing - Ultrasonic testing - Reference blocks and test procedures for the characterization of contact probe sound beams

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

JB/T 11731 Non-destructive testing - General specification for ultrasonic phased array probe

JJG 746 Verification regulation for ultrasonic flaw detectors

3 Terms and definitions

Terms and definitions, which are defined in GB/T 12604.1, apply to this document.

4 General requirements

4.1 Personnel qualifications

Personnel, who are engaged in ultrasonic testing of steel bars, shall participate in the training, according to the requirements of GB/T 9445 or corresponding documents, meanwhile obtain the ultrasonic testing qualification certificate. Anyone who issues a test report shall obtain a level 2 or above ultrasonic testing qualification certificate.

4.2 Couplant

4.2.1 The liquid immersion technique usually uses water as a couplant; however, oil can also be used. The couplant shall be free of air bubbles or foreign substances, that affect ultrasonic testing. A suitable rust inhibitor can be added to the couplant, to prevent corrosion of the steel bar. A suitable lubricant can be added to the couplant, to reduce the formation of air bubbles on the steel bar and the probe.

4.2.2 Couplant, such as oil, grease, water, water-soluble gel should be used, for the contact technology. The viscosity and surface wettability of the couplant shall be sufficient, to ensure that the ultrasonic energy is well transmitted to the steel bar.

5 Instruments and equipment

5.1 Ultrasonic detector

5.1.1 Performance test methods and requirements

The performance of the ultrasonic detector is tested, according to the method of JB/T 10061 or JJG 746. Its indicators shall meet the following requirements:

- The vertical linearity is not more than 5%;
- The horizontal linearity is not more than 2%;
- The dynamic range is not less than 30 dB;
- The sensitivity margin is not less than 42 dB;
- The attenuation error does not exceed ± 1.0 dB/12 dB.

5.1.2 Alarms

Optical and/or audible alarms should be used. The triggering of the alarm shall be controlled, by adjusting the amplitude of the ultrasonic signal, which is received on the time baseline; the alarm threshold level is adjustable.

5.2 Probes

5.2.1 The frequency of the probe shall be able to meet the requirements of the ability to penetrate the steel bar to be inspected AND the resolution. It should be 2 MHz ~ 10 MHz. The diameter (side length) of the probe chip should not be greater than 28 mm. The liquid immersion probe should adopt the focusing method. If the testing requirements can be met, other forms of probes can be used for testing, such as phased array probes, that meet the requirements of JB/T 11731.

5.2.2 When the liquid immersion method is used for detection, the angle controller and mechanical control device of the probe shall be easy to adjust.

5.2.3 The parameters of the probe should be tested, according to the methods of GB/T 18694 and GB/T 18852.

5.3 Immersion tank (box) and probe regulator

5.3.1 The size of the liquid immersion tank (box), which is used for liquid immersion testing, shall ensure that the tested parts can be immersed.

5.3.2 The probe regulator shall provide adjustable angle and water layer, in two mutually perpendicular planes; it shall ensure that the probe angle and water layer are stable and reliable, during detection.

5.3.3 When using ultrasonic C-scanning equipment, the motion control of the scanning device shall have sufficient accuracy.

6 Comparative test blocks

6.1 It shall use the materials, which have the same or similar acoustic properties as the tested steel bars. The height difference of the primary bottom wave, between the tested steel bar and the reference test block, shall be within the range of ± 4 dB. Use ultrasonic testing method in advance, to check the material of the comparative test block, under the condition of higher sensitivity; there shall be no echo, that affects the use.

6.2 On the comparative test block, for longitudinal wave testing, it should machine flat-bottomed holes, in the entire circumferential section. When testing steel bars, which have a diameter of 6 mm ~ 26 mm, only one flat-bottomed hole OR two flat-bottomed holes with different depths, as shown in Figure 1, can be processed under the condition of satisfying the resolution. When testing steel bars, which have a diameter of 26 mm ~ 200 mm, it may use the comparative test blocks, which have similar specifications, as shown in Figure 1 and Table 1. When testing steel bars, which have a diameter greater

6.3 The diameter of the flat-bottomed hole of the comparative test block shall be consistent with the diameter of the flat-bottomed hole, which is specified in 9.4.1 for the quality level of longitudinal wave testing. Other requirements for comparative test blocks, for longitudinal wave testing, are as follows.

- a) B_1 , B_2 , B_3 are 1/4, 1/2, 3/4 of the diameter of the round bar, respectively, which has a tolerance of ± 0.2 mm.
- b) The number and diameter of the flat-bottomed holes are selected, according to the quality level. The diameter tolerance of the flat-bottomed holes is ± 0.01 mm or $\pm 1\%$ of the hole diameter, whichever is greater. The flatness error of the hole bottom shall not exceed ± 0.03 mm. The surface roughness R_a shall not exceed $3.2\text{ }\mu\text{m}$; the center line of each hole shall pass the radius.
- c) If the processing size of the comparative test block is larger, the comparative test block can be made into three separate pieces: one is B_1 size, one is B_2 size, the other is B_3 size; the other dimensions are as shown in Figure 1 and Table 1.
- d) The surface roughness (R_a) of the comparative test block shall be the same as that of the tested steel bar.

6.4 The comparative test block for shear wave testing shall be the same as the nominal diameter of the steel bar to be tested, as shown in Table 2 and Figure 2. When the diameter of the steel bar is less than 20 mm, AND it is impossible to machine the three transverse holes of different depths, as shown in Figure 2, only one transverse hole OR two transverse holes with different buried depths can be machined. According to the distribution rules of the transverse holes on the circumference, as shown in Figure 2, transverse holes with different buried depths can be processed, on different circumferential surfaces. Other requirements for the comparative test block for shear wave testing are as follows:

- a) The deviation of the transverse hole position shall be ± 0.25 mm;
- b) The surface roughness (R_a) of all holes shall not be greater than $3.2\text{ }\mu\text{m}$;
- c) All holes shall prevent water ingress and maintain air-metal interface, permanently plugged;
- d) According to the actual situation, design the number and buried depth of the reference reflectors;
- e) The surface roughness of the comparative test block shall be the same as that of the tested steel bar.

in zones.

8.2.4 During the longitudinal wave testing by the liquid immersion method, the water path shall be adjusted, so that the second interface wave from the tested steel bar does not appear, before the first bottom wave of the steel bar. During the testing, it shall adjust the perpendicularity between the probe and the workpiece, to maximize the reflected signal at the interface. During the sensitivity setting, scanning, evaluation, the difference of the water path shall not exceed ± 3 mm.

8.2.5 When the DAC curve or TCG curve is not used, adjust the ultrasonic detector and equipment, so that the echo heights of the maximum sound path hole and the minimum sound path hole, on the comparative test block, are not lower than 80% of the full amplitude of the phosphor screen. This is taken as the detection sensitivity. When the contact method detects steel bars, whose diameter is greater than three times the near-field area of the probe, the bottom wave calculation method can be used, to adjust the sensitivity. When using the DAC curve or the TCG curve, at least 3 reference reflector echoes, which have different buried depths, shall be taken, in the entire range of the detected metal sound path. For probes and ultrasonic detectors, which are suitable for the DGS method (AVG method), the sensitivity adjustment can be performed, using the DGS method.

8.2.6 During shear wave testing, the probe shall generate shear waves of $35^{\circ} \sim 70^{\circ}$, in the workpiece. The echoes from each reference reflector, on the comparative test block, shall not be lower than 80% of the full amplitude of the phosphor screen.

8.2.7 During automatic scanning, the setting of the gate width shall meet the requirements of the detection range.

8.2.8 The alarm level shall be set, according to the echo amplitude of the flat-bottom hole size of multiple reflectors, which have the corresponding quality level. The echo amplitude of the flat-bottom hole size of a single reflector shall be set for levels C and D.

8.2.9 The scanning spacing shall not exceed 80% of the effective sound beam width of the probe. The effective sound beam width should be determined by the -6 dB method, which is performed by the minimum value, as measured on the reference reflector, within the range of the detected metal sound path.

8.2.10 During manual scanning, the scanning speed should not exceed 150 mm/s. During automatic scanning, when the scanning speed is the maximum, the echoes of the reference reflector, within the detection depth range in the comparative test block, can be found.

8.2.11 The sensitivity of the detection system shall be reviewed, when the following conditions are found:

- a) When the probe, couplant, testing instrument adjustment, equipment status change;
- b) When the scanning sensitivity is abnormal;
- c) Manual scanning for more than 4 hours in a row and at the end;
- d) Automatic scanning at the beginning and end of each shift or batch.

8.2.12 When it is found that the scanning sensitivity is abnormal, within the detection range, all steel bars tested since the last review shall be re-inspected, OR all recorded signals shall be re-evaluated. If it can be proved that the detection system is reproducible, it may extend the sensitivity review interval of 8.2.11 c) and 8.2.11 d).

9 Evaluation of testing results

9.1 Recording of reflected signal

According to the highest sensitivity, which is specified by the quality level, during the scanning process, the reflected signal, which is greater than or equal to this sensitivity level, shall be recorded. The recording method is a coordinate diagram or a C-scan diagram, to indicate the position and size of the reflected signal.

9.2 Evaluation of back wave loss

Use direct wave to measure the bottom wave, at a lower gain; compare it with the bottom wave, in the normal position. If the bottom wave loses more than 50% AND is accompanied by an increase or decrease of the noise signal (at least twice the normal background noise), which is not due to surface state or non-parallelism, it is unqualified.

9.3 Evaluation of noise level

Noise levels above the alarm trigger level are considered unacceptable.

Note: When the tested titanium alloy bar is used as a reference, the alarm level slightly exceeds the noise level, BUT does not exceed 70% of the detection sensitivity level.

9.4 Evaluation of defects

9.4.1 Longitudinal wave testing

9.4.1.1 Single defect

Compare echoes of flat-bottomed holes, which have similar burial depths AND are specified in Table 3, with echoes of defects; the defects exceeding those specified in Table 3 are considered unqualified.

9.4.1.2 Multiple defects

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