National standard of the People's Republic of China

GB/T 6402-91
Replace: GB/T 6402-86

Steel Forgings - Method for Ultrasonic Examination

Approved by the State Technical Supervision Bureau on Dec. 13, 1991
Implemented on Oct. 1, 1992

1. Subject Content and Application Scope

The standard specifies the ultrasonic examination method of steel forging, reference block, inspection instrument and facility, examination condition and sensitivity adjustment, deficiency assessment, quality class and inspection report, etc.

The standard is applicable to the general forging ultrasonic examination for carbon steel and low alloy steel with thickness or diameter more than 100mm with impulse reflection type ultrasonic process.

2. Normative References

ZBY 230	A-type impulse reflection type ultrasonic flaw detector general technical specifications
GB 9445	Qualification and certification of nondestructive testing personnel-general principles

3. General Requirements

3.1 The forging is tested by adopting ultrasonic longitudinal wave direct contact method or immersion method. For the annular or hollow forging with ratio of the outer diameter and inner diameter less than 1.4 and axial length exceeding 50mm, if necessary, the multiplicable ultrasonic transverse wave examination shall be noted in the specifications beforehand.

3.2 The forging ultrasonic examination staff shall be trained according to prescription in GB 9445 and obtained the qualification certificate. For the staff signed the inspection report, the staff shall obtain Class 11 or above Class 1 ultrasonic examination qualification certificate, and the forging manufacturing method and deficiency property, cause formation and characteristic shall be known.

4. Reference Block

4.1 The material of reference block shall possess close acoustic property (such as velocity of sound, sound attenuation) and specifications with the

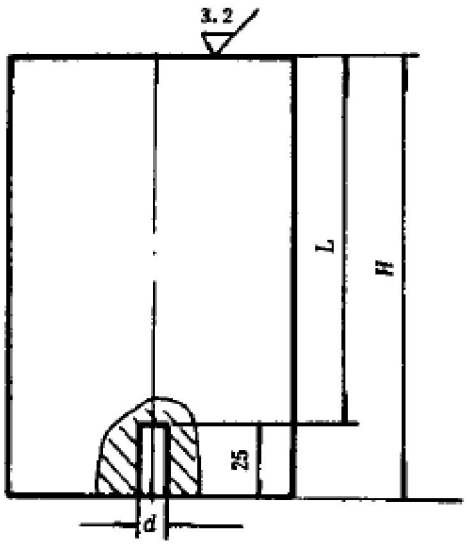
tested forging.

4.2 The reference block using for longitudinal wave examination, its flat bottomed hole diameter shall be 2, 4, 8,16mm respectively. The flat bottomed hole depth is 25mm, the metallic sound distance from detection surface to flat bottomed hole is recommended to 20, 30, 50, 80, 100, 120, 150, 200mm.

4.3 The plane reference block is adopted when the detection surface is plane (such as Figure 1). The curved surface reference block (such as Figure 2) with the approximate radius of curvature of forging shall be selected (0.7-1.1 times radius of curvature) when the detection surface is curved surface.

4.4 The artificial defect of reference block for transverse wave examination can be in the outer and inner surface, it is manufactured into the parallel rectangular tank along axial direction, the axial length of the rectangular tank is 25mm. The depth can adopt 3% or 6mm (adopt the smaller value) of the tested forging wall thickness.

4.5 The miscellaneous reference blocks with the equivalent action of the forementioned reference blocks can be used.



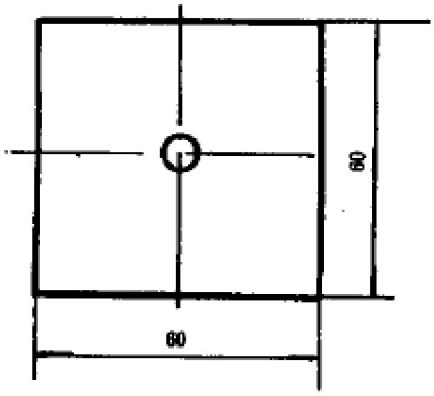


Figure 1 Schematic diagram for plane reference block

H- Block height;

L-metallic sound distance;

d - Diameter of flat bottomed hole

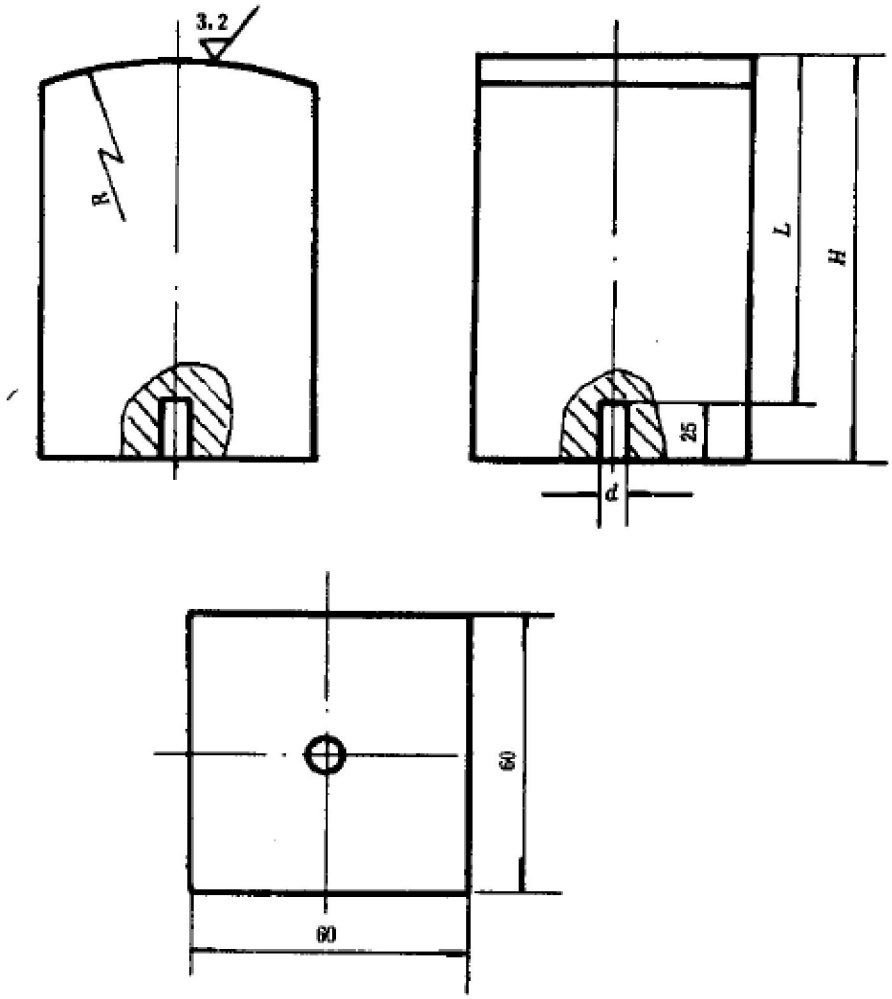


Figure 2 Schematic diagram for curved surface reference block

R- Radius of curvature of block.

5. Inspection Instruments and Facilities

5.1 The performance of flaw detector shall conform to provisions of ZBY 230.
5.1.1 The detection frequency scope is 1- 5MHz.

5.1.2 The horizontal linearity error shall be no more than 1% and the vertical linearity error shall be no more than 4%.

5.1.3 The attenuator shall be possessed and the fine regulation step level of the attenuator shall be no more than 2dB. The maximum decrement of damping shall be no less than 70dB, and the error is no more than 1dB.

5.2 For straight beam probe adopts round wafer, its frequency and diameter are generally prescribed according to Table 1. There is no double peaks and deflection of the probe main acoustic beam.

Table 1 Frequency and diameter of straight beam probe wafer

Frequency MHz	Diameter, mm
1-1.25	20-30
2-2.5	14-30
4-5	10-25

5.3 The transverse wave examination uses angle beam probe, the angle beam probe generally adopts square wafer, its frequency range is 1-2.5 MHz, the wafer area is 140 - 400 mm2.

5.3.1 The slide wedge contact surface of angle beam probe shall be in accordance with the detection surface shape.

The angle of refraction of angle beam probe shall generally be 45¡; it is 60¡ -70¡ if necessary.

5.4 The combination sensitivity allowance of probe and instrument shall satisfy examination requirements.

5.5 When the immersion method ultrasonic examination is adopted, its device requires possessing adjuster controlling probe angle and liquid layer distance, when it is rotated; the maximum deviation is able to ensure the need of ultrasonic examination sensitivity.

6. Inspection Condition and Sensitivity Adjustment

6.1 Inspection condition

6.1.1 The forging examination shall be carried out after forging heat treatment and before drilling and fluting processing.

6.1.2 In the contact method examination, the forging surface roughness R shall be less than 3.2¦m. In the immersion method examination, the forging surface shall be level off, there is no adhesive substance (oxide skin, defilement) influencing acoustic coupling and it shall satisfy requirements of examination.

6.1.3 The appropriate coupling agent shall be used between probe and detection surface.

6.1.4 According to forging processing technic, select the detection surface where the defect is easy to find, the examination is generally carried out from the two orthogonal direction (such as Figure 3).

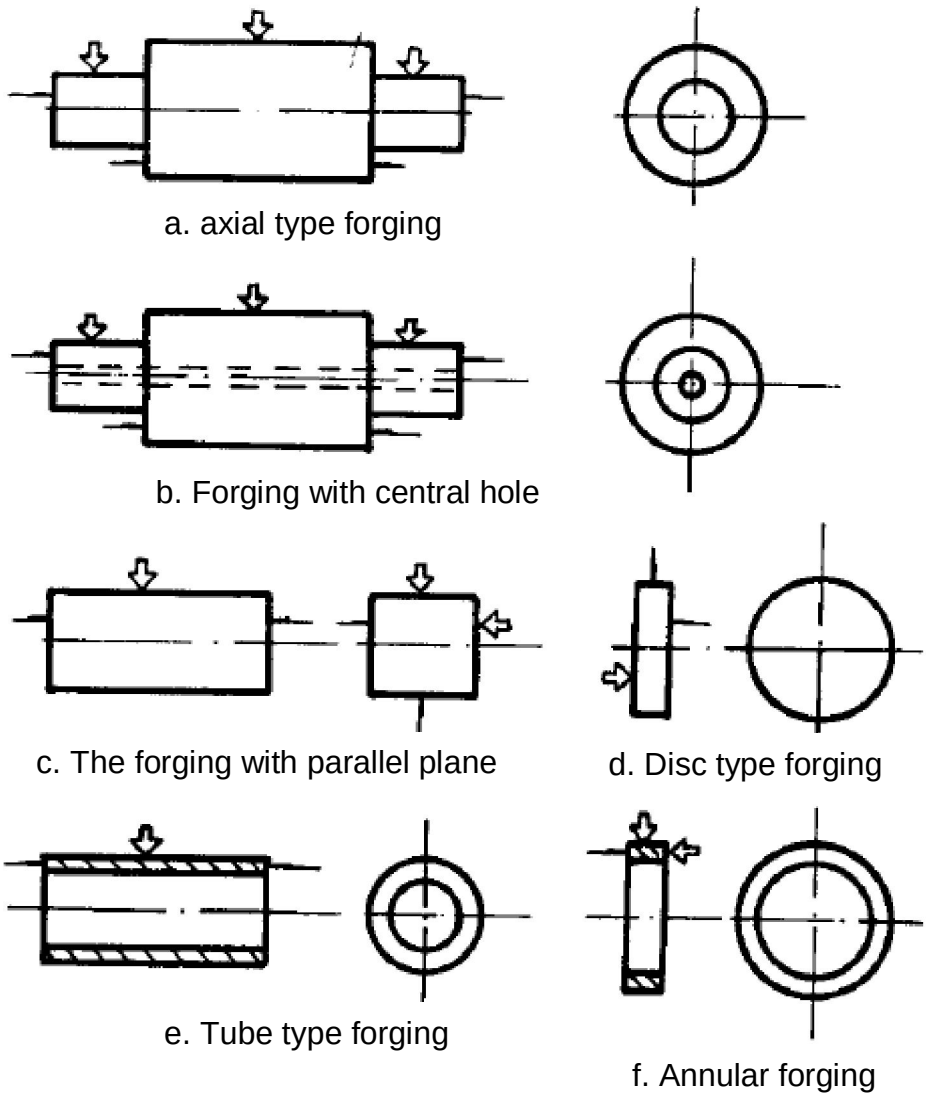


Figure 3 Schematic diagram for detection direction

⇩ Detect direction ↓concerted direction

6.1.5 In transverse wave examination, it is generally inspected the whole according to clockwise and counterclockwise from the outer surface.

6.1.6 The scan inspection mode is divided into manual scan inspection and automatic scan inspection. The scan inspection spacing of the probe on detection surface shall guarantee 15% acoustic beam coverage.

6.1.7 The scan inspection velocity, the translational speed of probe to forging, shall be less than 150 mm/s.

6.2 Sensitivity Adjustment

The sensitivity is adjusted by reference block method or bottom wave

reflection method.

6.2.1 Reference block method

6.2.1.1 The reference block flat bottomed hole diameter shall be correspondence to the specification of related products, and its metallic sound distance shall be equal to or more than forging thickness.

6.2.1.2 The flat bottomed hole echo height in the forementioned reference block is adjusted to the 40%-80% of the full-scale as examination sensitivity.

6.2.1.3 In transverse wave examination, the sensitivity adjustment shall be from the outer circle detecting the artificial defect of inner circle. The maximum echo height of the artificial defect is adjusted to 80% of the full-scale. And the value will be marked on the panel as the examination sensitivity. Moving the artificial defect on probe detection outer circle surface, and marked the maximum echo of artificial defect on panel, then connect the two points with straight line and prolonged, including the whole detection range, then the distance- amplitude curve is drawn.

6.2.1.4 When it is tested from the inner circle surface, the examination method is the same to that in 6.2.1.3, but the used angle beam probe's angular contact surface shall be in accordance with the inner circle curvature of face.

6.2.1.5 So as to be in favor of finding defect, in the initial examination, the higher examination sensitivity than that in 6.2.1.2 is used to examination. When the defect is found, the defect shall be assessed under the prescribed examination sensitivity.

6.2.1.6 When the forging thickness or diameter diameter is large, the examination can be done for the opposite surfaces of the forging. The reference block with metallic sound distance being equal to or more than half thickness (or diameter) can be adopted to adjust examination sensitivity.

6.2.2 Bottom wave reflection method

6.2.2.1 When the detection surface is paralleled to the bottom surface, and its thickness is more than 3 times of the probe near field region, the bottom wave reflection method can be adopted.

6.2.2.2 Find the place on the forging where can represent the state of the intact forging material, the first time bottom surface echo height is adjusted to 40%- 80% of the full-scale as the reference for assessing echoed signal.

6.2.2.3 According to the need of the tested forging, the sensitivity is adjusted according to 6.2.2.4 or 6.2.2.5 as examination sensitivity.

6.2.2.4 When the solid forging is detected, the elevated increment numerical value shall be calculated according to formula (1).

$$A=20\lg\frac{2\lambda T}{\pi d^2} \quad (1)$$

Where, A - elevated increment value, dB.
T - the thickness or diameter of the tested position, mm.
d - Diameter of flat bottomed hole, mm.
λ - wavelength, mm;
π - ratio of the circumference of a circle to the diameter

6.2.2.5 When the forging with hole in center is detected, the elevated increment numerical value shall be calculated according to formula (2).

$$A=20\lg\frac{2\lambda T}{\pi d^2}-10\lg\frac{R}{r} \quad (2)$$

Where, R - the outer diameter of the tested position, mm.
r - Inner diameter of the tested position, mm.

6.2.2.6 When the forging examination possessed certain condition, the AVG curve method can be adopted.

7. Defect Assessment

7.1 Defect record and assessment

7.1.1 When the discoverable flaw echo exceeds 6dB of the acceptance reference in the examination, it shall be recorded.

7.1.2 For single and dispersive flaw echo, it shall be assessed with equivalent and semiwave height method.

7.1.2.1 Its equivalent size is measured by using equivalent method or miscellaneous methods and the defect position and quantity shall be recorded.

7.1.2.2 For linear defect and miscellaneous defect more than probe diameter, the defect indicator length is measured and calculated along forging surrounding and axial direction by using semiwave height method.

7.1.3 For density flaw echo, it can be assessed by using the following methods.

7.1.3.1 In the tested pieces, in the cube with 50mm side length, when there are more than 5 flaw echo height exceeds - 6 dB of the product technology condition specified value, it is called density defect and it shall be recorded.

7.1.3.2 The density defect depth range is measured by using the position of flaw echo appearing on scanning line.

7.1.3.3 The density defect plane distribution region is measured by using scanned defect distribution in the course of the probe movement.

7.1.4 In the transverse wave examination, when the discoverable flaw echo height exceeds - 6 dB of the distance- amplitude curve height, it shall be recorded, meanwhile, the defect position and sound course shall be recorded.

7.1.5 In the inspection and defects assessment, the influence of the tested forging surface roughness and material damped amendment shall be taken into consideration.

7.1.6 The defect property assessment shall be analyzed according to static state and dynamic performance of the flaw echo as well as material characteristics and technics factors. It shall be verified by miscellaneous methods if necessary.

7.1.7 According to product technology condition requirements, the forging bottom wave reduction quantity can be assessed.

7.2 Attenuation coefficient (a) measurement

When the forging ultrasonic attenuation coefficient is required to measure, it shall be done as follows:

7.2.1 Select 3 representative positions on the tested forging and measure the

decibels of first bottom surface echo height B1 and the second bottom surface echo height B2.

7.2.2 The attenuation coefficient (a) is calculated according to formula (3)

$$a=\frac{B_1 - B_2 - 6}{2T} \quad (3)$$

Where, a - attenuation coefficient, dB/mm

T - Thickness or diameter of the forging, mm.

B_1, B_2 - the first and the second bottom surface echo height, dB

N - near field length of probe, mm.

8 Quality Class

8.1 The ultrasonic examination quality class of forging, see Table 2.

Table 2 Quality class

Quality class	1	2	3	4
Flat bottomed hole equivalent diameter d, mm	d≤2	2<d≤4	4<d≤8	8<d≤16

8.2 The forging quality allowable class shall conform to corresponding specifications and shall be prescribed in the beforehand agreement.

9 Inspection Report

The forging inspection report shall include following content:

9.1 Forging status

The tested forging title, serial number, trademark, figure number, heat treatment condition, principal position size, weight, surface roughness.

9.2 Inspection condition

The facility and instrument type, probe frequency and size and shape (angle of refraction), inspection standard No., quality class, testing method, test sensitivity, reference block and artificial defect size and position (transverse wave method), coupling agent, inspection staff and name and

technology qualification class of the person who signed the report, date of inspection.

9.3 Inspection result

Defect position, equivalent diameter, flaw distribution sketch, defects assessment and others.

Additional Explanation:

The national standard was proposed by Ministry of Metallurgical Industry of the People's Republic of China.

The national standard was drafted by the Fifth Steel Mill of Shanghai.

The national standard was prepared by Wang Huaixiang, Ji Xiumei and Wang Yongling.