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Heavy mechanical general techniques and standards -

Part 15: Non-destructive inspection of forged steel

重型机械通用技术条件

第 15 部分：锻钢件无损检测

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Heavy mechanical general techniques and standards -

Part 15: Non-destructive inspection of forged steel

1 Scope

This Part of the JB/T 5000 specifies the ultrasonic, magnetic-powder and penetration testing methods and quality grades of forged steel.

This Part applies to non-destructive testing of forged steel for heavy machinery.

Non-destructive testing methods as specified in this Part may involve hazardous materials, operations and equipment, so the non-destructive testing personnel shall comply with relevant safety and health regulations.

The method, location, quality grade of the non-destructive testing of forgings shall be indicated in the forging's drawings, technical documents and technical conditions of the ordering.

2 Normative references

The provisions in following documents become the provisions of this Part through reference in this Part of JB/T 5000. For the dated references, the subsequent amendments (excluding corrections) or revisions do not apply to this Part; however, parties who reach an agreement based on this Part are encouraged to study if the latest versions of these documents are applicable. For undated references, the latest version of the referenced document applies.

GB/T 5097 Indirect assessment method for black light source (GB/T 5097-1985, eqv 3059:1974)

GB/T 11259 Standard practice for fabrication and control of steel reference blocks used in ultrasonic inspection (GB/T 11259-1999, eqv ASTM E428:1992)

JB/T 8290 Magnetic-powder flaw detectors

JB/T 9214 Test methods for evaluating performance of A-mode ultrasonic flaw detection using pulse echo technique

JB/T 9216 Methods for controlling the quality of liquid penetrant materials

JB/T 10061 Commonly used specification for A-mode ultrasonic flaw

4 General requirements

4.1 Principles of selection

4.1.1 The selection of testing method and quality acceptance level shall be determined according to the specific use and type of forgings, meet the requirements of the corresponding technical documents.

4.1.2 For ferromagnetic forgings which requires surface testing, it shall give priority to the magnetic-powder testing method. If the magnetic-powder test cannot be used due to structural shape and resource conditions, etc., it selects the penetration testing.

4.2 Documentation of testing

4.2.1 When forgings are tested in accordance with this Part, if necessary, it may follow the provisions of this Part to establish a non-destructive testing procedures which complies with the relevant specifications.

4.2.2 The testing procedures and results shall be correct, complete and signed and approved by the responsible personnel. The period of storage of test records, reports, etc. shall not be less than five years. After five years, if the user needs it, it can be transferred to the user for safekeeping.

4.2.3 In the testing documentation, the corresponding qualification grades and validity period of the testing items undertaken by the testing personnel shall be recorded.

4.2.4 The performance of the instruments and equipment used for the testing shall be periodically calibrated and have calibration records, which can only be used after passing the calibration.

4.3 Testing personnel

4.3.1 Any person engaged in non-destructive testing shall hold the corresponding qualification certificate issued by the relevant state department.

4.3.2 Non-destructive testing personnel's technical grades are divided into high, medium and primary. Personnel of all technical grades who have obtained different non-destructive testing methods can only engage in non-destructive testing corresponding to this grade and bear corresponding technical responsibilities.

defects.

5.3.4 Probe's performance test method is as specified in JB/T 10062.

5.4 Coupling agent

5.4.1 The coupling agent shall have good wettability. It may use the oil, glycerin, paste or water of the full-loss system as a coupling agent. For finished forgings, it is recommended to use the oil L-AN46 of the full-loss system as the coupling agent.

5.4.2 Different coupling agents cannot be compared. Therefore, the coupling agents which are used for the performance test, sensitivity adjustment, calibration of the testing system must be the same as the coupling agent used in the testing.

5.5 Test block

5.5.1 The test block shall be made of the same or approximate acoustic properties as the workpiece being tested. When the material is tested by a straight probe, there shall be no defects greater than the equivalent diameter of the $\Phi 2$ mm flat-bottom hole.

5.5.2 The reflector for calibration use may be flat-bottom hole and V-shaped groove. When calibrating, the main sound-beam of the probe shall be aligned with the reflector, perpendicular to the reflecting surface of the flat-bottom hole, perpendicular to the axis of the V-shaped groove.

5.5.3 The dimensions of the test block shall be representative of the characteristics of the workpiece to be tested. The thickness of the test block shall correspond to the thickness of the workpiece to be tested. The error does not exceed 10% of the tested thickness.

5.5.4 The manufacturing requirements of the test block shall comply with the provisions of GB/T 11259.

5.5.5 In case of field testing, it may also use other types of equivalent test blocks.

5.6 Test of system's combined performance

The test of the system's combined performance is as specified in JB/T 9214.

in accordance with Appendix A.

5.8.1.8 Whenever the manufacturer or user conducts a review or reassessment, it shall use comparable instruments, probes, and coupling agents whenever possible.

5.8.1.9 Forgings can be tested at rest or in a rotating condition (turning by a lathe or a rotating tire). If the user does not specify, the manufacturer can make selection arbitrarily.

5.8.1.10 When the thickness of forging is more than 400 mm, it shall carry out testing from two opposite planes.

5.8.2 Sensitivity of testing

5.8.2.1 In principle, use the AVG method to determine the testing sensitivity. For forgings which is limited by its geometry and whose testing thickness approaches to the length of near-field, use the test block comparison method.

5.8.2.2 The testing sensitivity shall be based on the initially recorded equivalent value, the reference wave height shall not be less than 40% of the full screen height.

5.8.2.3 When assessing defects, it shall adjust the evaluation sensitivity in the intact part of the forging.

5.8.2.4 Re-verification of testing sensitivity:

a) The detection sensitivity must be re-verified in one of the following cases:

- When the calibrated probe, coupling agent, instrument's knob, etc. are subjected to any changes;
- When the external power supply voltage fluctuates greatly or the operator suspects that the testing sensitivity changes;
- When the it continuously works for 4 hours and at the end of work.

b) When the testing sensitivity is reduced by more than 2 dB, the forgings shall be re-tested completely; when it is increased by more than 2 dB, all recorded signals shall be re-evaluated.

5.8.2.5 Adjustment method of testing sensitivity:

a) For the solid cylindrical forgings and the forgings whose testing surface is parallel to the reflection surface, when the sound-path is more than 3 times the near-field, it shall use the formula (1) to calculate the dB value which needs to increase.

defect's equivalent diameter according to formula (6).

$$\Delta = 40 \lg \frac{\varphi_f \cdot x}{\varphi \cdot x_f} + 2\alpha x - 2\alpha_f x_f \cdots \cdots \cdots (6)$$

Where:

Δ - The dB difference between the defect and the flat-bottom hole of the test block, in dB;

α - Material's attenuation coefficient (comparative test block), in dB/mm;

α_f - Material's attenuation coefficient at the defect's position, in dB/mm;

x - The depth of the flat-bottom hole, in mm.

- b) When the sound-path is less than 3 times near-field, it shall use the test block for direct comparison or otherwise use the measured AVG curve to determine the defect's equivalent diameter.

5.9 Record of defects

5.9.1 Record the defect whose equivalent diameter is not less than the initially recorded equivalent and its coordinate position on the forging.

5.9.2 Record of a cluster of defects:

- a) Record the distribution range of a cluster of defects.
- b) Record the depth of the defect of the maximum equivalent diameter in a cluster of defects, the equivalent, its coordinate position on the forging.

5.9.3 Recording of extended defects:

Record the depth, length range, maximum equivalent, position coordinates of the start and end points of the extended defect.

5.9.4 Record of loss of back reflection caused by defects BG/BF (dB):

Record the difference in dB between the first bottom-wave's amplitude BG in the intact area near the defect and the first bottom-wave's amplitude BF in the defect area when reaching to the same reference wave's height.

5.10 Quality grade

5.10.1 A single, discrete defect in the forging that is less than the initially recorded equivalent is not counted.

sensitivity and adjustment method, instrument model, forging's surface condition, testing period.

5.11.2 Manufacturer's marking number, product's contract number, forging name, drawing number, material, furnace number, card number, etc.

5.11.3 It shall draw a sketch of the workpiece, indicating the actual dimensions of the forging, the size of the untested area and the origin of the defect positioning due to factors such as geometry.

5.11.4 The defect record shall contain the coordinate position, equivalent, approximate distribution.

5.11.5 Evaluation of test results.

5.11.6 The date of testing and the signature of the testing personnel.

6 Magnetic-powder testing and its quality grade

6.1 Basis of testing

6.1.1 Relevant requirements of the user or design process department for the magnetic-powder testing for forged steel.

6.1.2 Methods for establishing sensitivity, selection of instruments and equipment, selection of magnetization methods, requirements for magnetic-field's strength shall be consistent with this Part.

6.1.3 Explain whether there is a demagnetization requirement and the degree of demagnetization required.

6.2 Requirements of testing surface

6.2.1 The sensitivity of magnetic-powder testing is highly dependent on the surface condition of the forged part being tested. If the irregular surface condition affects the display or evaluation of the defect, the surface to be tested must be treated by grinding, machining or other means.

6.2.2 There shall be no dirt, grease, cotton fiber, oxide scale or other foreign matter affecting the magnetic-powder testing in the surface of the tested area and in the vicinity of 50 mm.

6.2.3 The removal of foreign matter can be carried out by any method that does not affect the magnetic-powder testing.

6.5.1.2 It may use current directly on the workpiece to magnetize the forgings. It may also use the central conductor or coil to generate an induced magnetic-field to magnetize the forgings. It may use either the AC power or the DC power as the magnetizing power source. In the circumferential magnetization, since the “skin effect” of the alternating current reduces the maximum depth of the tested defect, it shall use direct-current power source for the defects below the main tested surface.

6.5.1.3 It may use one or a combination of the following five magnetization methods:

- a) Contact method;
- b) Longitudinal magnetization;
- c) Circumferential magnetization;
- d) Yoke method;
- e) Multi-directional magnetization.

6.5.2 Magnetic-powder testing method

6.5.2.1 Continuous method

The magnetic-powder or magnetic suspension is applied to the surface of the forged part to be tested while the magnetizing current is not interrupted and the externally-applied magnetic-field acts. In the case of continuous current supply, the shortest duration of energization shall be $1/5 \text{ s} \sim 1/2 \text{ s}$.

6.5.2.2 Fluctuation method

This method is limited to the use of direct-current. Apply a higher magnetizing force first, then lower the magnetizing force to a lower value. Apply magnetic-powder or magnetic suspension while maintaining this lower magnetizing force.

6.5.2.3 Residual magnetic method

After cutting off the magnetizing current and removing the externally-applied magnetic-field, apply the test medium. Use the residual magnetism on the workpiece for testing. This method is generally not used to check forgings. To use it, it must obtain the user's consent.

6.5.3 Magnetization direction

Except for the multi-directional magnetization method, each test part shall be tested at least twice, the magnetization direction shall be substantially vertical. It is not allowed to perform magnetization in two or more directions at the same

- b) When the material's thickness is less than 20 mm, it shall select the magnetization force of 3 A ~ 4 A for each millimeter of contact's spacing; when it is greater than 20 mm, select the magnetization force of 4 A ~ 5 A.
- c) The contact's spacing shall be controlled between 75 mm and 200 mm, the power-on time shall not be too long. To avoid burns to the workpiece, it may use any effective method that does not affect the testing sensitivity to maintain good contact between the contact and the workpiece. The open-circuit's voltage must not exceed 24 V.
- d) There shall be sufficient overlap in the testing, to ensure 100% coverage at the set sensitivity.

6.7.2.7 Yoke method:

- a) The magnetic pole's spacing shall be controlled within 50 mm ~ 200 mm. The lifting force of the yoke shall be at least 45 N for the AC solenoid yoke, or at least 180 N for DC solenoid yoke.
- b) The effective testing zone shall be limited to 1/4 of the maximum pole's spacing on both sides of the connection between two magnetic poles. The pole's spacing shall have an overlap of more than 25 mm each time.

6.8 Application of magnetic-powder and magnetic suspension

6.8.1 When the forging is properly magnetized, it may use one of the following methods to apply the magnetic-powder.

6.8.1.1 When using the dry-powder method, it may use the manual sieve, the mechanical sieve, the powder sprayer or the mechanical blower to apply the magnetic-powder. The sieve can only be used for surfaces that are placed flatly up, the dust sprayer and blower may be used on facades and downward surface. The magnetic-powder shall be uniformly applied to the surface of the forging; the color of the dry-powder shall have an appropriate contrast; the magnetic-powder should not be applied too much; when blowing off the excess magnetic-powder, take care not to damage the magnetic traces.

6.8.1.2 When using the wet method, it shall use the hose to spray the magnetic suspension to the test piece or otherwise use the dipping method to apply the magnetic suspension to the test piece, to make the entire surface to be tested is completely covered.

6.8.1.3 When using the continuous method, the magnetizing current shall be turned on before the application of the magnetic suspension, then magnetize it while applying the magnetic suspension, so that the surface to be tested is covered by the magnetic suspension. The magnetization is repeated at least

application method, magnetization method and specification requirements, verification of testing sensitivity, specification model of test piece.

6.13.3 Manufacturer's logo number, product's contract number, forging name, drawing number, material, furnace number, card number.

6.13.4 Defect record, workpiece's sketch, evaluation of test results.

6.13.5 The date of testing and the signature of the testing personnel.

7 Penetration testing and its quality grades

7.1 Basis of testing

User or design process department's requirements for penetration testing of forged steel.

7.2 Requirements of testing surface

7.2.1 The surface of the testing area and the adjacent 25 mm shall be dry and free of dirt, grease, cotton fiber, oxide scale, oil or other foreign matter which covers the opening defects at surface.

7.2.2 Removal of foreign matter can be carried out by any method that does not affect the penetration test.

7.2.3 The maximum roughness Ra of the machining surface of the forgings is 6.3 μm . If it can be proved that its surface status does not affect the penetration testing, it is not subject to this limit.

7.2.4 The temperature of the testing surface shall be controlled within 15 °C ~ 50 °C.

7.3 Testing materials

7.3.1 Penetration testing materials generally include penetrants, emulsifiers, cleaning agents, imaging agents.

7.3.2 The quality control of the penetration test material shall comply with the requirements of JB/T 9216.

7.3.3 The testing agent must have good testing performance and no corrosion to the workpiece; it is basically non-toxic to the human body.

infiltration, emulsification, removal of excess penetrant, drying, development, drying, observation, post-treatment.

- b) The testing steps of various combinations include: pretreatment, infiltration, removal of excess penetrant, observation, post-treatment.
- c) The post-emulsification type is emulsified after infiltration.
- d) The water-rinsing type and the post-emulsification type are dried before development.
- e) The non-development type has neither imaging nor drying treatment.
- f) Drying is carried out after development by wet-method.

7.5.2 Selection of penetration testing methods

7.5.2.1 The selection of the penetration test method shall be determined according to the surface roughness of the workpiece to be tested, the sensitivity of the penetration test, the size of the tested batch, the test environment, etc.

7.5.2.2 For workpieces with smooth surface and high sensitivity requirements, it should use the post-emulsification coloring method or post-emulsification fluorimetry or solvent-removal fluorimetry.

7.5.2.3 For workpieces with rough surface and low-testing sensitivity requirements or large batch sizes, it should use the water-rinsing coloring method or post-emulsification water-rinsing fluorimetry.

7.5.2.4 It should use the solvent-removal coloring method for the testing of the non-presence of water source and power source on site.

7.5.2.5 For local testing of large workpieces, it should use solvent-removal coloring method or solvent-removal fluorimetry.

7.6 Operating procedures

7.6.1 Pre-cleaning

7.6.1.1 All areas to be tested must be pre-cleaned as required by 7.2 before applying the penetrant.

7.6.1.2 Post-cleaning drying:

The cleaned workpieces shall be dried. Drying methods generally include heating the workpiece in a drying oven, baking it using an infrared lamp, drying it using hot compressed air, or drying it naturally at ambient temperature.

penetrating into the defect from removed, it is prohibited to repeatedly wipe the surface of the workpiece or directly use solvent to rinse the surface of workpiece.

7.6.4 Drying of workpiece

7.6.4.1 The workpiece shall be dried after application of the wet-developer or prior to application of the dry-developer.

7.6.4.2 The method and requirements for drying treatment are as specified in 7.6.1.2.

7.6.4.3 When using solvent cleaning, it shall be naturally dried.

7.6.4.4 Drying time is usually 5 min ~ 10 min.

7.6.5 Imaging

7.6.5.1 When using a dry-developer, it must be dried first and then sprayed on the entire surface to be tested evenly by an appropriate method, kept for a certain period of time.

7.6.5.2 When using a wet-developer, after the surface to be tested has been cleaned, it may directly spray or paint the developer on the testing surface, or otherwise dip the workpiece into the developer, then quickly remove the excess developer, then carry out drying treatment.

7.6.5.3 When using a fast-drying developer, after drying, spray or apply the developer onto the surface to be tested and then dry it naturally or blow it dry by the use of low-temperature air.

7.6.5.4 The developer shall be thoroughly stirred before use. The developer shall be applied thin and uniformly. Do not apply the developer repeatedly in the same position.

7.6.5.5 When spraying the developer, the distance between the nozzle and the surface to be tested is 300 mm ~ 400 mm, the spraying direction shall be at an angle of 30° ~ 40° to the surface to be tested.

7.6.5.6 It is forbidden to pour the quick-drying developer on the tested surface to avoid flushing or dissolving the penetrant in the defect.

7.6.5.7 The development time depends on the type of developer, the size of the defect, the surface-temperature of the workpiece to be tested. Generally, it shall not be less than 7 min.

7.6.6 Observation

7.6.6.1 Observation of the displayed traces shall be carried out within 7 min ~

7.7 Classification of liquid-trace

The following rules shall apply (see Figure 13).

- a) When a linear liquid-trace is not lined up with any other linear liquid-traces, or if it is lined up with another linear liquid-trace but the distance between them is greater than 5 times the length of the longer liquid-trace in the two liquid-traces, it shall be regarded as a “single” liquid-trace.
- b) The rows of linear liquid-traces are two (or more) linear liquid-traces arranged in a row. If the distance between the two liquid-traces is less than or equal to 5 times the length of the longer liquid-trace, it shall be regarded as a continuous liquid-trace for evaluation. The length of the row of liquid-trace is the distance between the opposite ends of the two outermost liquid-traces.
- c) The cumulative length of linear liquid-trace is the sum of the lengths of all linear liquid-traces as detected within the evaluation box (i.e., 148 mm x 105 mm, or A6 frame).

Note: Linear liquid-traces are liquid-traces whose length is at least 3 times their width.

- d) The round liquid-trace is a liquid-trace which has a length less than or equal to 3 times its width.
- e) It shall not consider the false liquid-traces due to the geometry of the components (cross-section changes or grooves, etc.) or surface roughness (scarring or machined tool marks).

7.8 Recording limits and acceptance criteria

Five quality grades shall apply to the forging or various parts of the forging.

Appendix A

(Normative)

Transverse-wave testing method and quality acceptance requirements for forging steel

A.1 Scope of application

For cylindrical annular forgings which have an axial length greater than 50 mm and an inner-to-outer diameter ratio not less than 75%, it may select the method as specified in this Appendix, to carry out ultrasonic transverse-wave testing along the circumferential surface of the forging steel.

A.2 Probe

A.2.1 The probe's frequency is mainly 2.5 MHz, it may also use 2 MHz.

A.2.2 The area of probe's wafer is $100\text{ mm}^2 \sim 400\text{ mm}^2$.

A.2.3 In principle, it uses the K_1 probe. However, depending on the geometric diversity of the forging steel, it may also use other K-value probes. The principles of selection shall be such that the entire volume of forging can be tested.

A.3 Test block for verification

A.3.1 It may use the machining margin of the tested forgings in the wall-thickness direction or length direction to make the test block for verification. On the inner surface and outer surface of the forgings, respectively machine parallel V-shaped grooves axially and circumferentially as the standard grooves. The length of the V-shaped groove is 25 mm, the angle is 60° , the depth is 3% of the maximum wall-thickness of the forging or 6 mm (whichever is smaller). The specific production is as shown in Figure A.1.

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