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Eddy current testing method for zirconium and zirconium alloy tube

锆及锆合金管材涡流检测方法

（*English Translation*）

（送审稿）

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National Standard of the People’s Republic of China

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H 26

Foreword

This standard is drafted in accordance with rules given in the GB/T 1.1-2009

This standard is proposed by China Nonferrous Metals Industry Association.

This standard is administrated by National Technical Committee for Standardization of Non ferrous Metals

Eddy current testing method for zirconium and zirconium alloy tube

1. **Scope**

This standard specifies the eddy current testing method for zirconium and zirconium alloy tube.

This standard is applicable to testing of zirconium and zirconium alloy tube with outside diameter range from 5mm to 16mm. It is also recommended for the testing of other size of zirconium and zirconium alloy tube.

1. **Normative references**

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

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

GB/T 30565, *Non-destructive testing- Eddy current testing-General Principles*

1. **Testing Principle**

Eddy current testing is the method of detecting the defects produced on or near the surface of conducting specimen by using the eddy current testing according to the principle of electromagnetic induction.

Generally, the testing by using the external probe can be adopted for zirconium and zirconium alloy tube. Also, single frequency or multi frequency detection method may be adopted. When it is necessary, the testing by using the surface probe can be adopted. It is required to conduct spiral scanning of tubes relative to the surface probe to ensure 100% inspection of inspected tubes when the surface probe is employed for testing.

1. **General Requirements**

4.1 **Personnel**

Personnel performing testing shall be qualified in accordance with GB/T 9445 issued by the relevant administration department or awarded with a similar document certified by the equivalent agency. All levels of personnel can only engage in work consistent with the level of qualification certificates.

4.2 **Tube**

Internal and external surfaces of tube shall be clean and free of scale, dirt, grease, debris or other foreign materials. Burrs at the ends of tube are not permitted. The methods used for cleaning and preparation shall not be detrimental to the surface condition of tube. The straightness and the dimensional shall be in accordance with the requirements of technical specification.

4.3 **Environment**

The environment shall be free from magnetic field, vibrations, dust, corrosive gases or others that could impact the performance of device.

4.4 **Device Qualification**

Device qualification shall be conducted periodically as required.

1. **Reference Standard Sample**

5.1 Reference standard sample is the tube with specified artificial defects which is used to adjust or calibrate the device and evaluate the natural defects can satisfy the requirement of standards or not.

5.2 The reference standard shall be identical to the examined tubes in the respect of material, size, surface condition and manufacture process. Also, the reference standard shall be free from the natural defects and acoustical properties which could interfere with interpretation of examination results.

5.3 There are two types of artificial defects: hole artificial defect and notch artificial defect. Hole artificial defect is used in testing with external probe and the notch artificial defect is used in testing with surface probe. Both artificial defects should satisfy the following requirements:

a) Hole artificial defects is radial-direction through hole and its diameter is divided into A and B class (Tablet 1) according to technical specification of eddy current testing. The grade of application shall be specified on the material technical standard or order.

Tablet 1

|  |  |  |
| --- | --- | --- |
| Classes | Outer Diameter of tube（D） | Diameter of hole |
| A | D≤10mm | 0.30mm±0.03mm |
| D＞10mm | 0.35mm±0.03mm |
| B | D≤10mm | 0.50mm±0.05mm |
| D＞10mm | 0.80mm±0.05mm |

b) The notch artificial defect processed on the external surface of the tube is the longitudinal groove parallel to the axial direction. The cross section of the groove can be U, 凵 or V shape. The included angle of V-groove is 60 ° ± 2. U-shape is the standard shape used in arbitration. Longitudinal grooves can be added to the internal surface in the testing with stricter requirements. The depth of the notch artificial defect is 12.5% or 0.1mm of the nominal wall thickness of the examined tube. The larger one is preferred. The allowable deviation of depth is ± 0.03mm. The width of the notch artificial defect should be no more than 0.8mm when the notch length is 3mm-5mm.

5.4 At least 4 identical artificial defects shall be processed along the axial direction of the tube and the distance of one of the artificial defects is ≤ 40mm from the end of tube which is used to measure the length of blind area at the end of tube. The distance between the other three artificial defects shall not be less than 200mm and be distributed at an interval of 120°± 5°along the peripheral direction which are used for calibrating the sensitivity of device. The artificial defects can also be processed at both ends of the tube to determine the location of blind area at the end of tube. See Fig.1 and Fig.2 for the schematic diagram of the reference standard sample.

5.5 The hole artificial defect is processed by mechanical drilling. All through-hole diameters are required to be as uniform as possible. The internal wall shall be smooth without burr and cause no deformation of the tube. The notch artificial defect is generally processed along longitudinal on the external surface of the tube by EDM or other mechanical method. Regular shape, smooth internal wall and bottom without burr are required.



Figure1—schematic diagram of hole artificial defect reference standard sample



Figure2—schematic diagram of the notch artificial defect reference standard sample

1. **Testing devices**

6.1 **Eddy current instrument**

6.1.1 Eddy current instrument include single frequency，dual-frequency or multi-frequency device.

6.1.2 The range of excitation frequency of eddy current instrument should be 30kHz～700kHz for the hole artificial defect and 30kHz～1000kHz for the notch artificial defect at least.

6.1.3 Eddy current instrument is consist of excitation, signal processing、phase adjustment, filtering and other units together with alarm set, extended analysis function and reliable storage and recording devices.

6.1.4 Impedance plane diagram and time records display shall be used to detect the characteristics of defects such as phase, amplitude and so on.

6.2 **Probe**

6.2.1 Induction current shall be generated on and near surface of the examined tube with combination of the probe and eddy current instrument which can detect the changes of the electrical property.

6.2.2 The shape and dimension of the probe must be matched with the dimension of the examined tube. The applicable test frequency shall satisfy the requirements of excitation frequency and detection sensitivity.

6.2.3 With precondition of adequate detection sensitivity, the clearance between the probe and the examined tube shall be suitable to avoid damaging the probe or scratching the tube.

6.3 **Mechanical Transmission device**

6.3.1 The mechanical transmission device shall ensure that the tubes can be transported at a steady and even speed. The change rate of the feeding speed shall be no more than 5%. The mechanical transmission device shall avoid damaging the tube or generating the vibration that will impact the result.

6.3.2 The mechanical transmission device shall be equipped with adjustment device which can keep the center of probe and the examined tube in line. The recommended range of feeding speed is (10~20)m/min and can be adjusted.

1. **Device commissioning, testing and calibration**

7.1 **Device commissioning**

7.1.1 Before testing, reference standard sample is used to perform the commissioning of ET testing system. ET probe and guiding sleeve in accordance with testing requirements are selected and installed at the request of the specification of the examined tubes.

7.1.2 Checking or adjusting the location of the probe to keep the center of probe and the tube in line.

7.1.3 Commissioning the ET device as the following steps:

a) With the testing speed, adjusting the system in accordance with the equipment specification to make sure that clear and recognizable artificial defect signal can be displayed when the reference standard sample pass through the probe.

b) When commissioning, the display amplitude of the three identical dimension artificial defects on reference standard sample which are used to detect the detection sensitivity should be consistent with each other as far as possible. The gap of the amplitude between the maximum and minimum should be no more than 2dB.

c) The selection of the excitation frequency shall take material, wall thickness, detection sensitivity and length of the examined tube into consideration. The recommended standard depth of penetration of the excitation frequency shall be no less than the wall thickness of the examined tube.

The standard depth of penetration of ET can refer to formula (1):

 ……………………………………（1）

In the formula：

δ—standard depth of penetration，(unit is mm)

σ—electric conductivity, (unit is MS/m)

—excitation frequency,( unit is Hz)

Electric conductivity of alloys is different, refer to annex A for the data.

1. The noise or dither signal in the horizontal orientation of the impedance plane

diagram shall be set up by adjusting the phase position of the device. The phase position angle of the artificial defect signal shall be no less than 30°.

1. A certain standard amplitude of the artificial defect is selected in the range of

50%～80% of the full scale and used to adjust the gain(dB)of the device. The adjustment of the signal amplitude for three artificial defects in the middle of reference standard sample shall be greater than the standard amplitude.

1. If there is no special requirement, take the standard amplitude as the alarm

threshold.

7.1.4 Check up commissioning status

After completion of the commissioning specified in Article 7.1.3, reference standard sample shall be passed through the probe no less than three times. The amplitude of the three artificial defect on the reference standard sample to detect the detection sensitivity shall be no less than the standard amplitude.

7.2 **Testing**

Keep the status of the device and carry out the eddy current test for the tube.

7.3 **Device calibration**

Before and after testing, and during the testing process, check the working condition of the testing device every 2 hours by using the reference standard sample. The signal amplitude of the artificial defect shall be no less than the standard amplitude state stipulated in Article

7.1.3 and the fluctuation value shall be no more than 2dB. Otherwise, it is necessary to commissioning the device again and re-test the examined tubes since the last commissioning.

1. **Evaluation for testing results**

8.1 Evaluation of the testing results is performed according to the responding amplitude of the defect, Comprehensive evaluation is performed with the combination of phase position if necessary.

8.2 After testing, the examined tube is accepted when the responding amplitude of the defect isless thanalarm amplitude.

8.3 After testing, the examined tube is unqualified when the responding amplitude of the defect is no less than alarm amplitude.

8.4 If necessary, the unqualified tube can be processed and re-tested. The evaluation of testing results can refer to Article 8.2 and 8.3.

8.5 The length of the dead zone of tube end shall be recorded.

1. **Testing report**

At least, the report shall include:

1. Product brand, alloy, specification and quantity;
2. Device model, probe type and excitation frequency;
3. Number of this standard;
4. Shape and dimension of the artificial standard defect;
5. The quantity of qualified and unqualified tube;
6. Name and technology level of the issuer of the report;
7. Date of issuance of the report.

ANNEX A

(informative)

Electric conductivity of normal zirconium and zirconium alloy

Informative annex

See Table A.1 for electric conductivity of normal zirconium and zirconium alloy at room temperature.

Table A.1—Electric conductivity of normal zirconium and zirconium Alloy

|  |  |  |  |
| --- | --- | --- | --- |
| Alloy | Electric conductivity（MS/m） | Alloy | Electric conductivity（MS/m） |
| Zr-0 | 2.023 | Zr-Sn | 1.267 |
| Zr-Nb | 1.740 | Zr-Sn-Nb | 1.467 |