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Zirconium and Zirconium Alloy Seamless Tubes

锆及锆合金无缝管材

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Zirconium and Zirconium Alloy Seamless Tubes

1 Scope

This Standard specifies the requirements, test methods, inspection rules, marking, packaging, transportation, storage and contract (or purchase order) content of zirconium and zirconium alloy seamless tubes.

This Standard is applicable to zirconium and zirconium alloy seamless tubes produced by cold rolling (cold drawing) methods.

The Zr-0, Zr-2, and Zr-4 designations of tubes in this Standard are suitable for the nuclear industry; and the Zr-1, Zr-3, and Zr-5 designations of tubes are suitable for general industry; they can be used for heat exchangers and can also be used for the pipeline.

2 Normative References

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

GB/T 228-2002 Metallic Materials - Tensile Testing at Ambient Temperature

GB/T 241 Metal Materials – Tube – Hydrostatic Pressure Test

GB/T 242 Metal Materials – Tube – Drift-Expanding Test

GB/T 4338 Metallic Materials - Tensile Testing at Elevated Temperature

GB/T 6394-2002 Metal - Methods for Estimating the Average Grain Size

GB/T 8180 Wrought Titanium and Titanium Alloy Products Packing, Marking, Transporting and Storing

GB/T 12969.1 Method of Ultrasonic Inspection for Titanium and Titanium Alloy Tubes

GB/T 13747 (all parts) Methods for Chemical Analysis of Zirconium and Zirconium

Where:

p – test pressure, in MPa;

S – allowable stress, taking the corresponding 50% minimum proof strength, non-proportional extension, in MPa;

D – nominal outer diameter of the tube, in mm;

t – nominal wall thickness of the tube, in mm.

When the nominal outer diameter of the tube is no greater than 76mm, the maximum pressure of the hydraulic test shall be no greater than 17.2MPa; when the nominal outer diameter of the tube is greater than 76mm, the maximum pressure of the hydraulic test shall be no greater than 19.3MPa. During the test, the pressure is maintained for 5s, and the tube shall not be distorted or leaked.

3.5.2.3 During the gas pressure test, the pressure of the gas pressure test inside the tube is 1.0 MPa; during the test, the pressure is maintained for 5 s, and the tube shall not leak.

3.6 Ultrasonic testing

The tube shall be inspected by ultrasonic flaw detection. The acceptance of standard flaw (U-shaped) size and flaw detection results shall be in accordance with the relevant requirements of GB/T12969.1.

3.7 Corrosion performance

3.7.1 Zr-2 and Zr-4 tubes shall be subjected to corrosion performance test. The specimen is corroded for 72h or 336h in water vapor at $400^{\circ}\text{C}\pm 5^{\circ}\text{C}$ and $10.3^{+0.7}_{-0.5}$ MPa. After the corrosion test, the inner and outer surfaces of the specimen shall be black, dense, and uniformly glossy oxide film. The weight gain of the specimen for 72h shall not exceed $22\text{mg}/\text{dm}^2$. When the 72h test result is unqualified, the cumulative time (or re-sampling) 336h corrosion test can be continued, and the weight gain shall not exceed $38\text{mg}/\text{dm}^2$.

3.7.2 When required by the purchaser and indicated in the contract (or purchase order), the corrosion performance test of the general industrial zirconium tube shall be negotiated and determined by the supplier and the purchaser.

3.8 Nodular Corrosion

When required by the purchaser and specified in the contract (or purchase order), the nuclear cladding tube can be subjected to nodular corrosion performance test. Nodular corrosion specimens were first treated with pre-oxidized film at $400^{\circ}\text{C}\pm 5^{\circ}\text{C}$ and $10.3^{+0.7}_{-0.5}$ MPa water vapor for 72h. After the test results meet the requirements of 3.7, then

corrosion test is carried out in high temperature water vapor of $500^{\circ}\text{C}\pm 3^{\circ}\text{C}$, $10.3^{+0.7}_{-0.5}$ MPa. The test time and the comparison standard sample for post-test testing shall be negotiated between the supplier and the purchaser.

3.9 Hydride orientation

When required by the purchaser and indicated in the contract (or purchase order), Zr-0, Zr-2 and Zr-4 tubes can be inspected for hydride orientation. The hydride orientation factor F_n of the finished tube shall be negotiated and determined by both parties.

3.10 Metallographic structure

The average grain size of the recrystallized and annealed Zr-0, Zr-2 and Zr-4 tubes shall be no coarser than the Level-7 in GB/T 6394-2002.

3.11 Appearance quality

3.11.1 The inner and outer surfaces of the tube shall be clean and free of visual defects such as cracks, folds, peeling, pinholes, etc.

3.11.2 The local defects on the surface of the tube are allowed to be removed, but the outer diameter and wall thickness shall not exceed the allowable deviation after removal.

3.11.3 The surface of the tube is allowed to have scratches, pits, bumps and straightening marks that do not exceed the allowable deviation of the outer diameter and wall thickness. Allow the tube to have different colours after pickling.

3.12 Surface condition

The outer surface roughness R_a of Zr-0, Zr-2 and Zr-4 tubes is no more than $1.6\mu\text{m}$; and the inner surface roughness R_a is no more than $3.2\mu\text{m}$.

4 Test Methods

4.1 Chemical composition analysis method

The chemical composition analysis of the tube is carried out according to GB/T 13747.

4.2 Measurement method of dimension and allowable deviation

The dimension inspection of the tube shall be carried out by the measuring tool with corresponding accuracy.

4.3 Test methods of mechanical properties

The surface condition of the tube is carried out by using the test block comparison method.

5 Inspection Rules

5.1 Inspection and acceptance

5.1.1 The product is inspected by the supplier's quality inspection department to ensure that the product quality meets the requirements of this Standard and the contract (or purchase order); and fill in the quality certificate.

5.1.2 The product received by the purchaser can be inspected and accepted in accordance with the provisions of this Standard. If the inspection result does not conform to the provisions of this Standard and the contract (or purchase order), it shall be submitted to the supplier within three months from the date of receipt of the product, and be solved through negotiation between the supplier and the purchaser. If arbitration is required, the arbitration sampling shall be carried out jointly by the supplier and the purchaser on the purchaser side.

5.2 Batching

Products shall be submitted for acceptance in batches; and each batch shall be composed of products of the same designation, the same melting furnace number, the same specification, the same manufacturing method, the same state, and the same heat treatment furnace batch.

5.3 Inspection items and sampling

Product inspection items and sampling shall comply with the provisions of Table 10.

5.4 Judgment of inspection results

5.4.1 In the chemical composition, mechanical properties, flaring test, corrosion performance, nodular corrosion, hydride orientation, and metallographic inspections, if one specimen fails to pass the inspection result, a double quantity of specimens shall be taken from the batch to re-inspect the unqualified item. If one specimen is still unqualified in the reinspection result, this batch of products shall be judged as unqualified. However, the supplier is allowed to inspect the unqualified items one by one, and the qualified ones shall be delivered.

5.4.2 When the dimension and allowable deviation of the tube, hydraulic test or gas pressure tests, ultrasonic test, appearance quality and surface condition are unqualified, a single piece of the tube is deemed unqualified.

6 Marking, Packaging, Transportation and Storage

6.1 Marking

The following markings shall be marked on the qualified tubes and packaging boxes:

- a) Product designation;
- b) Product name;
- c) Supply status;
- d) Lot number;
- e) The number of this Standard.

6.2 Packaging, transportation and storage

The packaging, transportation and storage of the product are in accordance with the relevant provisions of GB/T 8180.

6.3 Quality certificate

Each batch of tubes shall be accompanied by a quality certificate, indicating the following:

- a) The name of the supplier;
- b) Product name;
- c) Product designation, specification and state;
- d) Smelting furnace number, batch number, batch weight and number of pieces;
- e) Analysis and inspection results, and the seal of the quality inspection department;
- f) Number of this Standard;
- g) Date of packaging.

7 Contents of the Contract (or Purchase Order)

The contract (or purchase order) for ordering the materials listed in this Standard shall include the following:

- a) Product name;

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